The unique marine ecosystem surrounding Macquarie Island

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Cover Image: Black-browed Albatross. Photo Jaimie Cleeland

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Foreword

King Penguin. Photo: Tui De Roy.

The internationally significant geoheritage of Macquarie Island and the multitude of undersea features of the Macquarie Ridge are teeming with life in Australia's Sub-Antarctic. While most humans would perceive this environment as hostile and dangerous, here we find a multitude of animals and plants prospering in one of the world's recovering wild places.

This report brings forward the unique properties of the waters of Macquarie Island, in an area of around 478,000 km^2, contained within Australia's Exclusive Economic Zone which is roughly a circle of 200km radius around the island. The exclusive economic zone is an area beyond and adjacent to Australia's territorial sea and our sovereign rights over this area allow us to explore and use resources, but also bestow on us the responsibility to understand, conserve and manage the environment for all humanity.

The marine environment surrounding Macquarie Island is like no other in the world, and as a marine scientist I have been fortunate to visit. I will never forget the exuberance of marine life; silky kelp surging in the waves, seal pups teasing king penguins, and dozens of giant elephant seals lined up in a sleepy row. Ecosystems representing complex webs of interconnection and supporting astounding biodiversity. This report provides a useful summary of the key features and what we know about their influence on the ecology of this precious marine place. Most importantly it examines how well protected are these features within marine reserves, and finds we need to do better if we are to uphold our duty and protect this unique place in the face of a rapidly changing climate.

This report provides a valuable contribution for all Australians to learn a little more of a place that many will never visit but will want to know is kept as the wild and windswept place in the middle of the vast ocean between Tasmania and Antarctica. I commend the five eminent scientists who are the joint authors of this report for bringing together information on this area that is crucial for its conservation and management, and I look forward to the discussions to reinforce the protection of Australia's most remote island and its waters.

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Executive Summary

Macquarie Island lies about 1500 km to the southeast of Tasmania and the Exclusive Economic Zone surrounding it (hereafter referred to as the M-EEZ) constitutes a unique part of Australia's ocean domain. The entire M-EEZ is significant for its geology, oceanography, and ecology. Macquarie Island is the exposed crest of the undersea Macquarie Ridge. Overall, its landscape of steep escarpments, lakes, and Sub-Antarctic vegetation provides an outstanding spectacle of wild, natural beauty complemented by vast congregations of wildlife, including penguins and seals.

Geologically, the area is dominated by the Macquarie Ridge, uplifted at the junction of two oceanic plates, the Indo-Australian Plate and the Pacific Plate. The Macquarie Ridge runs for over 1600 km roughly north to south bisecting the M-EEZ. Macquarie Island is the only place on earth where rocks from the earth's mantle are being actively exposed above sea level. It was on this basis that Macquarie Island and waters around it to 12 nm were designated a World Heritage Area in 1997.

The M-EEZ is also significant oceanographically. The Macquarie Ridge is one of only three such ridges impeding the eastward flow of the Antarctic Circumpolar Circulation (ACC) across the Southern Ocean. This creates significant differences in physical and biological oceanography to the west and east of the ridge. Furthermore, the M-EEZ is divided north to south by two major fronts, the Sub-Antarctic Front and the Polar Front, creating three distinct bodies of water. The M-EEZ is also the point where these two fronts come closest to each other in the entire Southern Ocean.

Ecologically, the M-EEZ is very significant both for its benthic and pelagic ecosystems. The benthic ecology has been best studied along the Macquarie Ridge, including a number of seamounts in the region. There is evidence for changes in community composition north to south, and it is likely that the ridge provides "stepping stones" linking Sub-Antarctic and polar faunas. This bioregion is distinct from others in south-east Australia.

The pelagic ecosystem is also very significant, comprising a high diversity of seabirds and marine mammals. Fifty-seven species of seabirds have been recorded in the M-EEZ of which 25 breed on Macquarie Island, including four species of penguins and four species of albatross. Two species are endemic to Macquarie Island, the royal penguin and the Macquarie Island imperial shag. Of the seabirds recorded in the region, the wandering albatross is listed as vulnerable under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the island is listed as Critical Habitat for this species. This albatross is also listed as Endangered in Tasmania under the *Threatened Species Protection Act 1995*. Eight other species of seabirds are listed as endangered and thirteen are threatened or vulnerable. The M-EEZ is also host to three species of fur seals, southern elephant seals, and thirteen species of cetaceans. Seabirds and marine mammals have been recorded foraging widely across the M-EEZ.

Direct human impacts in the M-EEZ are mostly limited to fishing and marine debris, but in the future could potentially include other extractive industries such as seabed mining. The current Patagonian toothfish fishery targets a deep-water species using bottom longlines mostly in the central zone of the Macquarie Ridge. Its impact is currently relatively low on non-target species assuming that its existing footprint does not increase, and it has minimal impacts on the overall environmental values of the M-EEZ. However, some damage is likely to benthic erect sessile fauna by bottom-set longlines. If new fisheries were allowed to develop targeting pelagic or midwater resources these could directly impact the seabirds and marine mammals that forage in the M-EEZ. Encouragingly, following the cessation of 19th Century exploitation of penguins and seals for oil and fur that resulted in their near extirpation, most of the populations have either recovered or are recovering.

The M-EEZ contains several marine parks and reserves (State and Commonwealth). Waters immediately adjacent to Macquarie Island are Tasmanian state waters to three nautical miles and are fully protected. In addition, a Commonwealth Marine Park covers most of the southeast quadrant of the M-EEZ, including a sanctuary zone and two benthic habitat/ species management zones.

Since the designation of the Commonwealth Marine Park in 1999, our understanding of both the values and the pressures faced in the M-EEZ has advanced. The scheduled review of the Commonwealth Macquarie Island Marine Park in 2023 presents the opportunity to both future-proof for future climate changes, and improve the effectiveness of the marine park through:

- expanding and upgrading its extent and zoning,
- continuing to accommodate the existing, well managed commercial fishery in the waters along the Macquarie Ridge to the north, west and south of the islands.

The Commonwealth Marine Park was incorporated into the regional network of marine protected areas for South-east Australia in 2013, which was established under "CAR" criteria – to be Comprehensive, Adequate and Representative. This report has undertaken further analysis of the Commonwealth Marine Park for the M-EEZ using the CAR criteria, and identified nine Assessment Zones, divided east and west by the Macquarie Ridge and north and south by the ocean fronts. The analysis of the current data available of both the pelagic environment surrounding Macquarie Island as well as the benthic environment, including the known species distributions within these environments, shows the area is not comprehensively or adequately represented by the current marine park. In particular, the entire area west of the Macquarie Ridge is unrepresented, as are most of the northern and southern parts of the Ridge.

The report also considers future threats to the environmental values of the M-EEZ. Ocean warming is expected to result in changes in the South-east Marine Region although the M-EEZ is expected to retain its dynamic oceanography into the future.

The report considers two options to meet the criteria of a CAR reserve system and concludes that the most parsimonious approach would be to declare the whole M-EEZ as a marine park, with increased sanctuary zones as well as a habitat-protection zone over the current fishery area to allow continuation of the sustainable Patagonian toothfish fishery. This provides the simplest, most expeditious reserve design that is relatively easy to implement with no significant impact on the existing fishery, as well as the best protection of the unique geological, oceanographic, and ecological values and importance of the entire Macquarie Island region, and the most resilience to ongoing climate change in the M-EEZ and the South-east Marine Region[1].

Finally, the report notes the potential for future management actions to protect areas of the seafloor and subsoil on Australia's extended continental shelf to the south of the M-EEZ, where Macquarie Ridge extends and features prominent seamounts. A seamount sampled in 2008 was observed to contain a ferro-manganese crust and to support gorgonian deep-sea corals. No prominent seamounts were observed and sampled on the Macquarie Ridge immediately to the north in the M-EEZ. This area of extended continental shelf is eligible for inclusion in the South-east Marine Park Network as part of Australia's obligation under the Convention on Biological Diversity (CBD) and possibly through general obligations under the UN Convention on the Law of the Sea (UNCLOS).

1.0 Introduction

The waters surrounding Australia's World Heritage listed Sub-Antarctic Macquarie Island contain abundant marine life as well as hosting important ecosystem processes and lies some 1500km south-east of Australia (Figure 1). The area has been important as a scientific research and monitoring area for over half a century (McMahon et al. 2020), has supported a Patagonian toothfish fishery for 25 years (Patterson & Steven, 2022) and long-standing marine parks. Since the designation of the marine parks over 20 years ago, our understanding of both the ecological values and human induced pressures has advanced. The scheduled review of the Commonwealth Macquarie Island Marine Park in 2023 presents the opportunity to improve the effectiveness of the marine park to maintain its natural values and enhance its resilience to future threats through expanding and upgrading its extent and zoning, whilst continuing to accommodate the existing, well managed commercial fisheries in the waters of the islands.

The waters surrounding Macquarie Island contain a variety of exceptional pelagic and demersal characteristics, which drive the distribution of species and habitats. In order to best manage these areas for both conservation and sustainable use, this study has sought to understand the differences across the entire region of the EEZ surrounding Macquarie Island, and to make recommendations for their long-term management and protection.

[1] Six Commonwealth Marine Regions were designated within Australian waters for the purpose of regional marine planning and marine bioregional planning under section 176 of the Commonwealth EPBC Act

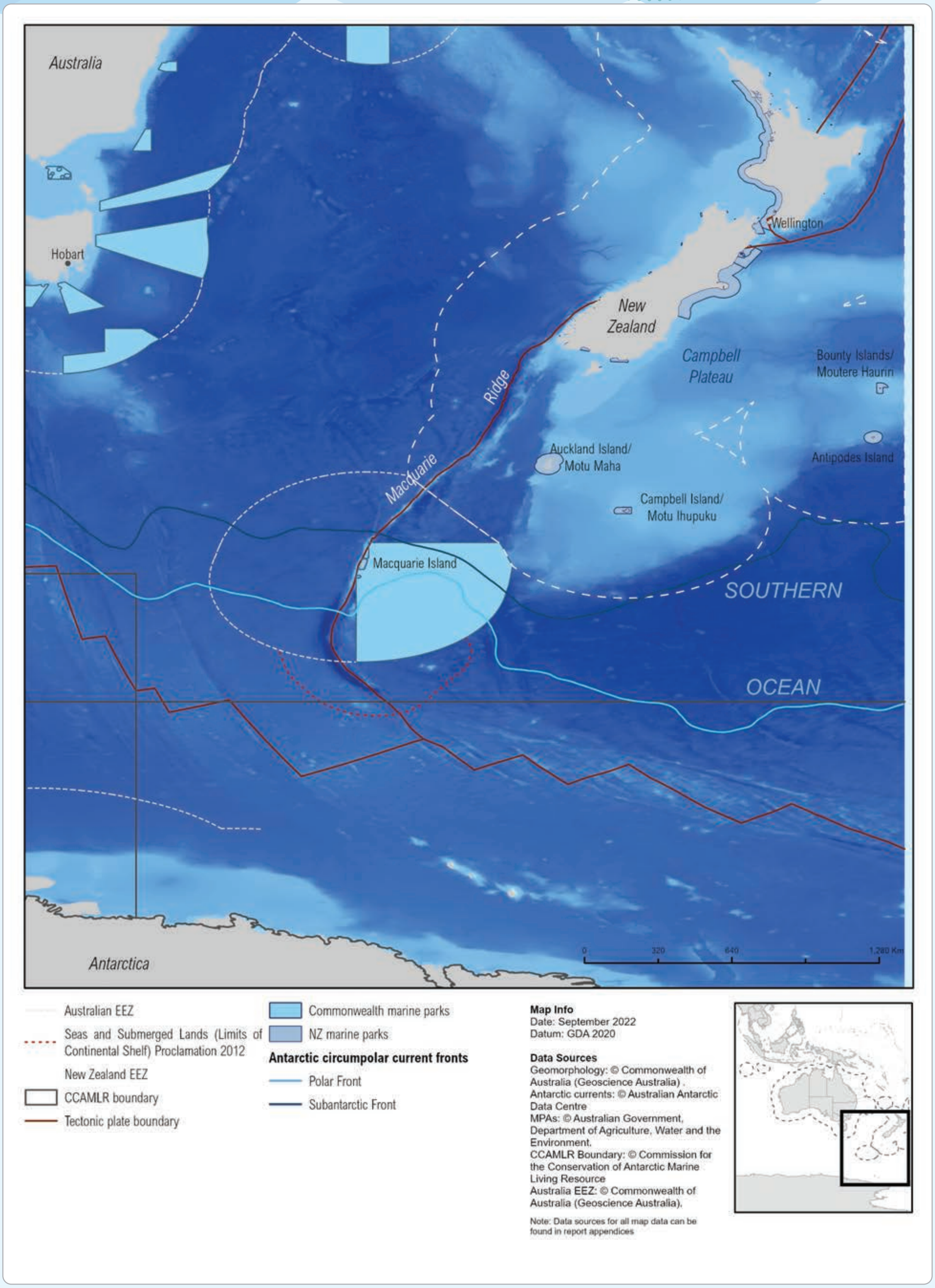


Figure 1: Regional Overview

The waters around Macquarie Island within the limits of the EEZ (M-EEZ) include both state and territorial waters (Figure 2). The M-EEZ is more extensive in covering different ocean and benthic provinces than the area often referred to as "Macquarie Island", which is generally referring to the state and territorial waters near to the island. Within the M-EEZ there is currently a complex set of different management arrangements, including two marine reserves, a World Heritage Area, and an area of fishery management.

Macquarie Island itself is part of the Australian State of Tasmania. It is completely contained within the Tasmanian Macquarie Island Nature Reserve which covers the Island, the adjacent islets of 'Bishop and Clerk' and 'Judge and Clerk' and includes the ocean surrounding the Island and islets to a distance of three nautical miles (Figure 3). It is the only island in the world composed entirely of oceanic crust and rocks from the mantle - deep below the earth's surface (Comfort 2014). The Macquarie Island World Heritage Area encompasses the Macquarie Island Nature Reserve, as well as the surrounding waters to a distance of 12 nautical miles (Figure 3). It was listed as a World Heritage Area in 1997 due to its (i) superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; and (ii) outstanding examples representing major stages of earth's history, including the record of life, and significant on-going geological processes in the development of landforms (Parks and Wildlife Service 2006).

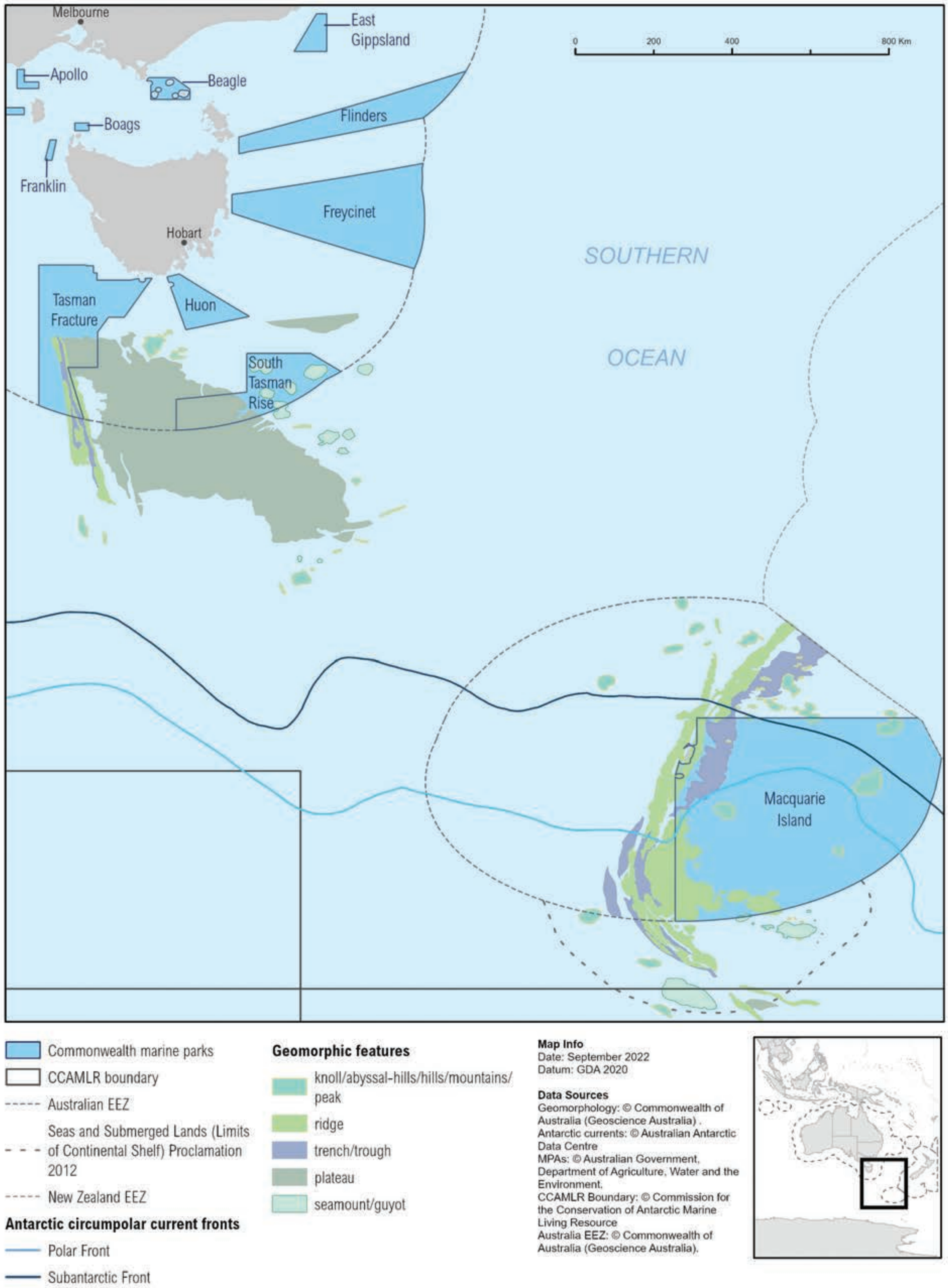


Figure 2: The major administrative boundaries of the South-east Australian marine region

The Macquarie Island Marine Park (formerly known as the Macquarie Island Commonwealth Marine Reserve from 2007 until 2017) was declared by the Australian Government in October 1999. It includes part of the EEZ to the east of the island from 3 nautical miles out to the limit of the EEZ and covers an area of 162,000 km^2. This comprises 58,000 km^2 of Sanctuary Zone and 104,000 km^2 of multiple use Habitat Protection Zone (see Figure 3).

At the time of the Macquarie Island Marine Park declaration its Sanctuary Zone (IUCN Category 1a), where no fishing or mining are permitted, was the largest highly protected (no-take) marine area in the world (Butler et al. 2000). Moreover, there was also a formal commitment to "pursue a second stage of the park", including updating information, public consultation, and possible changes to the Park. (Butler et al. 2000).

> *"Consistent with the Macquarie Island Marine Park Proposal (Environment Australia, 1999), the current Marine Park represents those areas of acknowledged high conservation value in the Macquarie Island Region. Consideration of any further areas in the Region for protection and management will occur in the context of establishing the National Representative System of Marine Protected Areas. "* (Commonwealth of Australia, 2001).

That part of the Macquarie Ridge immediately to the south of the Macquarie Island EEZ (see Figure 2) is one of nine areas of Australia's extended continental shelf agreed by the UN's Commission on the Limits of the Continental Shelf (CLCS) on 9 April 2008.

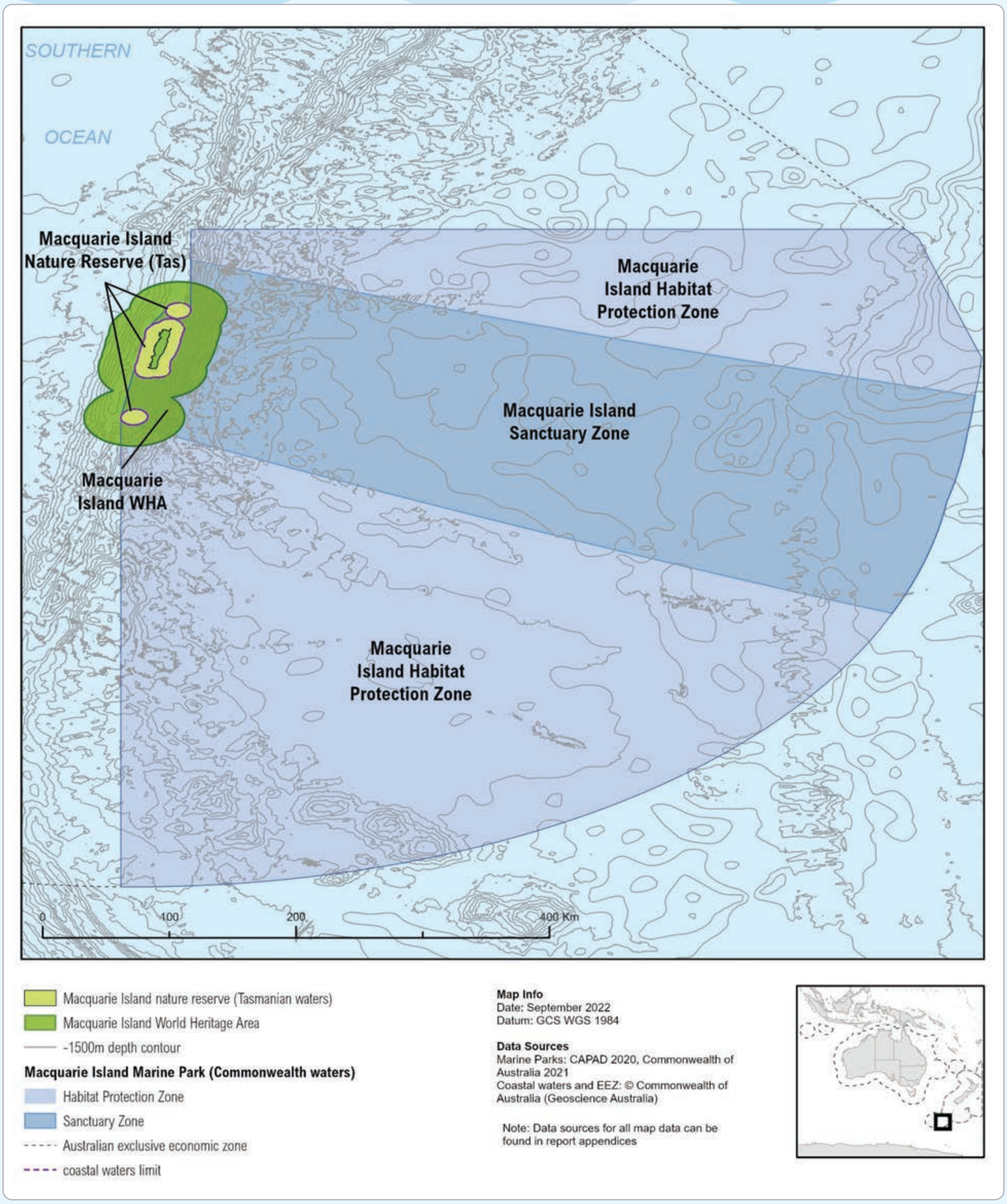


Figure 3: Protected areas within the Macquarie Island EEZ.

2.0 Methods

This report is based on a desktop study of the current scientific literature, existing management plans, and personal communications with managers, stakeholders, scientists, and the fishing industry. It is important to understand that the information on which this study is based is patchy, with most scientific effort centred on the terrestrial environment of Macquarie Island and its role as a habitat for seabirds and mammals. Much of the broader marine area is not well studied, particularly at depth, with many areas having had no biological data collected.

In order to best manage the area for both conservation and sustainable use, it is important to understand the different characteristics across the entire region of the EEZ surrounding Macquarie Island. The aim of the assessment was to determine whether the current reserve system can satisfy the principles of the CAR – comprehensiveness, adequacy and representativeness (ANZECC 1998) and related guidelines for the Australian Commonwealth Representative System of Marine Protected Areas (Environment Australia 2002) and, if insufficient, what might need to be done to achieve those principles and guidelines. An evaluation of the current information available for the M-EEZ in terms of biogeography and ecology, determined it was sufficient for this assessment.

All readily available information on the environmental characteristics of the benthic and pelagic environment (structural features such as seabed topography, ecological function and processes, and oceanographic fronts) were collated. A qualitative analysis using a deductive approach was used to divide the area into a set of relatively discrete assessment zones (hereafter referred to as AZs). These AZs were developed to be consistent with assessing concepts embedded in CAR, which are to identify the full range of ecosystem characteristics at an appropriate scale, including the spatial extent necessary to incorporate ecological processes and important areas for populations, and to identify areas expected to be different in their biodiversity.

Delineating the AZ's used information on both the pelagic and the benthic environments at the scales relevant to the ecological processes in the two systems that drive species distributions. The pelagic system is dominated by the boundaries between large-scale oceanographic features; the location of these boundaries, or fronts, that can vary on relatively shorter time scales is reflected strongly in the patterns of occurrence of many pelagic species. In the benthic environment the patterns of species occurrences are strongly influenced by the depth, topography and substrates of the seafloor which show variation at much finer spatial scales but persist over longer time scales.

Information on the benthic environment of the M-EEZ derive primarily from a CSIRO survey from RV Southern Surveyor January 10-February 4, 1999 (SS0199; Koslow and Kloser 1999) and a joint New Zealand/Australia survey from the RV Tangaroa in March 26 - April 26, 2008, as part of the international Census of Marine Life (TAN0803; Rowden et al. 2008). Taxonomic and genetic information include samples collected on additional surveys not necessarily targeting the benthic environment around Macquarie Island, including TAN0306 targeting two adjacent seamounts.

Data on the spatial distribution of seabirds and marine mammals in the M-EEZ is available from satellite tracking studies of birds and seals breeding on Macquarie Island as well as from opportunistic at-sea observations conducted in association with logistics and resupply of the Macquarie Island research station. Much of the satellite tracking data is available from the Retrospective Analysis of Antarctic Tracking Data (RAATD) repository (Ropert-Coudert et al. 2020). Access to the seabird distribution data from the at-sea observations was provided by the Australasian Seabird Group (ASG/E. Woehler unpubl).

Macquarie Island Marine Park is part of the National Representative System of Marine Protected Areas (NRSMPA), which aims to establish and manage a comprehensive, adequate and representative (CAR) system of marine protected areas (Macquarie Island Marine Park Management Plan 2001-2008, Commonwealth of Australia 2001). A secondary goal is to provide for the special needs of threatened species, migratory species and species vulnerable to disturbance. The 2001-2008 Management Plan includes the following strategic objectives:

- To protect the conservation values of the south-eastern portion of the Macquarie Island Region including protecting:
  - the migratory, feeding and breeding ranges of the marine mammals and seabirds
  - threatened species that depend on the area; and
  - the unique benthic habitat
- To provide an effective conservation framework which will contribute to the integrated and ecologically sustainable use and management of the Macquarie Island Region. (Commonwealth of Australia 2001)

In reviewing pre-existing and new information available for the MI-EEZ we focussed on two main questions:

1. Does the south-eastern portion of the M-EEZ covered by the Marine Park adequately protect the fauna of the M-EEZ in terms of their ecological viability and integrity of populations, species and communities, especially marine mammals, birds and unique benthic habitat?
2. Does the Marine Park as currently proclaimed meet the CAR aims of the NRSMPA?

and one subsidiary question:

3. Does the 'Macquarie Island Region' as defined in the 2001-2008 Management Plan (Commonwealth of Australia 2001) need to be updated to include revision of the Seas and Submerged Lands (Limits of Continental Shelf) Proclamation of 2012?

Building on the 2001-2008 Management Plan, we recognize that there are several distinct large-scale habitats in the MI-EEZ based on substrata and oceanography, including "three main water bodies separated by two oceanic fronts" which interact with the Macquarie Ridge to suggest that there are "portions of at least six different large-scale oceanographic habitats in the Region". We provide further analyses to support this identification of six distinct oceanographic habitats, and in addition provide information to support the north-south zonation of the Macquarie Ridge based on the variations in benthic habitats alluded to in the 2001-2008 Management Plan.

3.0 Current environment of the marine area surrounding Macquarie Island

3.1 Physical characteristics

Geology

Macquarie Ridge is one of the southernmost seamount ridges, extending 1600km southwest from New Zealand halfway to Antarctica (see Figure 1). It represents the oceanic portion of the Australia-Pacific plate boundary between the Alpine fault of New Zealand's South Island and the submarine Australia-Pacific-Antarctic triple junction (Lamarche et al. 1997 and Lebrun et al. 2003 cited by Ahyong et al. 2015) and is perhaps the best-known exposure of well-preserved oceanic crust in the southern hemisphere (Varne 1989 cited by Butler et al. 2000). Its position, north-south direction and scale make it one of the most significant features of the Southern Ocean.

The adjacent New Zealand Sub-Antarctic islands (Auckland Islands, Campbell, Antipodes and Bounty Islands, Figure 1) to the northeast are not geologically associated with the Macquarie Ridge and instead lie on the Campbell Plateau, a large extension of the New Zealand continental shelf.

Macquarie Island is approximately 34 kilometres long and up to 5 kilometres wide, with two small groups of islands, Judge and Clerk Islets and Bishop and Clerk Islets approximately 11 kilometres north and 37 kilometres south, respectively. Macquarie Island has steep coastal slopes dominated by an undulating plateau around 200-300 metres above sea level (ASL) with the highest peaks over 400 metres ASL (Comfort 2014). The cool, wet and windy climate of the island is governed by strong westerlies and the influence of the Antarctic Circumpolar Current. Two distinct rock domains are evident on Macquarie Island: intrusive igneous rocks to the north separated from extrusive volcanic rocks and associated sedimentary rocks to the south by a significant north-west trending fault zone (Varne 1989, cited by Butler et al. 2000).

Topography and currents

Topography, the shape of the seafloor, is an important indicator of the types of benthic habitats that might be found in different locations. Ocean currents also play an important role in determining the nature and extent of marine life. Together the topography and the currents are the key drivers of the abundant sea life that live in the waters of Macquarie Island.

The M-EEZ is almost wholly contained within the Antarctic Circumpolar Current (ACC) of the Southern Ocean (Sokolov and Rintoul 2009a) and the Macquarie Ridge is one of only three south-north topographic features in the Southern Ocean that stand in the flow of the Antarctic Circumpolar Current. The others being the Antarctic Peninsula-Scotia Arc in the Atlantic sector, and the Kerguelen Plateau in the Indian sector. It is one of a limited number of underwater features that may serve as "stepping stones" for the dispersal of larvae around Sub-Antarctic waters.

Ocean fronts in the vicinity of Macquarie Island were assessed over the last two decades using temperature profiles from penguin tracking data by Sokolov et al. (2006) and refined using sea-surface height (Sokolov and Rintoul, 2009a; b; Park et al., 2019). Those analyses greatly improve the understanding of the Antarctic Circumpolar Current in the M-EEZ compared to the frontal positions determined from comparatively sparse hydrographic data (e.g. Orsi et al., 1995). The M-EEZ has three oceanographic zones – the Sub-Antarctic Zone to the north of the Sub-Antarctic Front, Polar Frontal Zone between the Sub-Antarctic and Polar Fronts, and the Antarctic Zone south of the Polar Front (Gordon, 1988). These oceanographic zones have distinct temperature regimes (Figure 4) – greater than 8°C, between 5.5 and 8°C, less than 5.5°C respectively.

Macquarie Island and its accompanying ridge section is one of only two island-plateau complexes located between the Sub-Antarctic and Polar Fronts in the Southern Ocean. The other complex being the Crozet Islands in the Indian Sector, although the Polar Front varies in its location from just to the north of Ilse Kerguelen on the northern Kerguelen Plateau to just to the south of those islands. The Macquarie Ridge forces the two fronts through deep openings in the ridge, the Sub-Antarctic Front to the north of Macquarie Island and the Polar Front to the South. Partly as a result of the interaction of the Macquarie Ridge and the ACC the latitudinal separation of the Sub-Antarctic and Polar Fronts is smaller in the M-EEZ than in any other part of the Southern Ocean.

Altogether, the Macquarie EEZ has a biogeographic importance in connecting north and south along the Macquarie ridge and has globally important connections around the entire Sub-Antarctic through the eastward flow of the Antarctic Circumpolar Current (ACC). The interaction between these different features is reflected in the highly diverse oceanographic and ecological characteristics of the region.

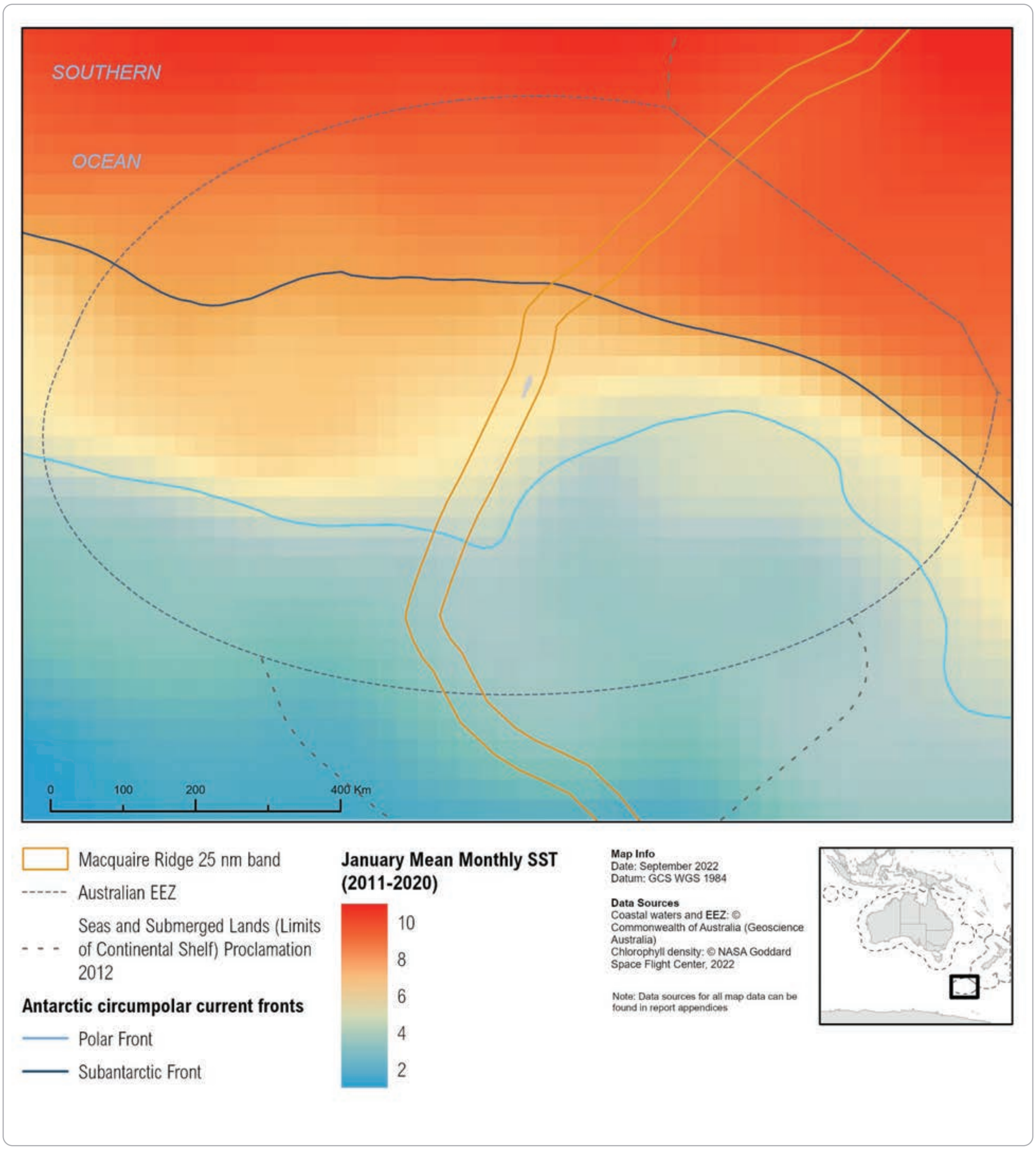


Figure 4: Sea surface temperature: Mean sea surface temperature (°C SST) in January for the decade 2011-2020 (mean of the monthly mean in each year) in the vicinity of the M-EEZ.

Data: NOAA 1/4° spatial resolution, daily Optimal Interpolation Sea Surface Temperature (OISST)(Huang et al., 2021)(subset of analysis for the Marine Ecosystem Assessment for the Southern Ocean e.g. Trebilco et al., 2019 supported by Integrated Digital East Antarctica, Australian Antarctic Division). M-EEZ (black dashed lines), 25 nautical mile band centred on the tectonic plate boundary (yellow line), and the Sub-Antarctic Front (solid blue line) and the Polar Front (solid light blue line). Legend shows the colours at 2°C intervals of the colour ramp plotting individual SSTs in each pixel.

3.2 Biology and ecology

Biogeography

The Australian EEZ surrounding Macquarie Island is one of eleven provincial bioregions described in the South-east Marine Region Profile, following IMCRA v4.0. It is described as follows:

> *"This bioregion surrounds Macquarie Island in the Southern Ocean, southeast of Australia. Macquarie represents an extremely isolated fragment of mid-oceanic ridge (Macquarie Rise) uplifted above sea level in the Miocene. The bioregion has a distinctive Sub-Antarctic flora and fauna with a high proportion of endemic algal and invertebrate species. The deep-water fauna is closely allied biogeographically to the fauna of the New Zealand Sub-Antarctic islands and has probably migrated to the island along the Macquarie Ridge."* (Commonwealth of Australia 2015).

The area of this bioregion is given as 477,430 km2, maximum depth as 6,737m and the proportion in the South-east Marine Region is given as 99.83%. although this appears to be a mapping artefact. Key ecological features have yet to be classified in this bioregion; there are currently no ecological syntheses for the Macquarie Island area. As a consequence there are, as yet, no Biologically Important Areas included in the Conservation Values Atlas (http://www.environment.gov.au/webgisframework/apps/ncva/ncva.jsf, accessed 3/10/2022). The Commonwealth Marine Area is identified as including the continental shelf claim immediately to the south of the EEZ (Figure 2).

Macquarie Island lies within Spalding's et al. (2007) Sub-Antarctic Province situated in the Southern Ocean biogeographic realm, together with Heard and McDonald Islands and southern Atlantic and Indian Ocean islands (e.g. Bouvet, Crozet and Kerguelen Islands). Macquarie Island is the easternmost member of this Province and separated from the Sub-Antarctic New Zealand Province (Bounty and Antipodes Islands, Campbell Islands and Auckland Island) immediately to the east. This classification is based on the continental shelf to 200m depth and included biogeographic data available at the time and pre-existing biogeographic literature. The validity of this classification needs to be revisited based on additional taxonomic work (including genetics). Ahyong et al. (2017) concluded that biogeographic associations between the circumpolar Sub-Antarctic islands vary greatly between taxa.

Productivity

Primary production occurs in the region through phytoplankton in the pelagic realm and through macro-algae in the coastal zone of Macquarie Island. Here, we focus on phytoplankton. Much of what is known on productivity within the M-EEZ is through satellite observations because there are few direct observations in this area (Pinkerton et al., 2021). Ocean colour from satellites is transformed to estimates of Chlorophyll *a* and, depending on knowledge of the assemblages, the amount of primary production and carbon available to the ecosystem is estimated. We used the transformation to Chlorophyll *a* developed specifically for the Southern Ocean (Johnson et al., 2013).

The area between the Sub-Antarctic and Polar Fronts has been documented as a high nutrient - low chlorophyll (HNLC) region of the Southern Ocean (Sokolov and Rintoul, 2007) with greater concentrations to the north of the Sub-Antarctic Front and south of the Polar Front. The Sub-Antarctic Front is the transition from calcifying coccolithophores to the north to diatoms in the south (Deppeler & Davidson, 2017). Productivity is greatest in the November-December period (Sokolov and Rintoul, 2007). Figure 5 shows the mean Chlorophyll *a* density in different parts of the M-EEZ in November over the decade 2010-2019.

The area of the M-EEZ to the west of the ridge is typical of an HNLC environment, limited by the availability of iron and silicic acid (Pinkerton et al., 2021). Silicic acid is generally abundant in spring but depleted by autumn (Deppeler and Davidson, 2017). The Macquarie Ridge, particularly the area around Macquarie Island, is a source of iron, enabling elevated production around the island and ridge and downstream, to the north-east of the island and south of the Sub-Antarctic Front (Sokolov and Rintoul, 2007; Deppeler and Davidson, 2017; Pinkerton et al., 2021). Upstream, the nearest available production in this zone is from the northern Kerguelen Plateau (Sokolov and Rintoul, 2007; Pinkerton et al., 2021).

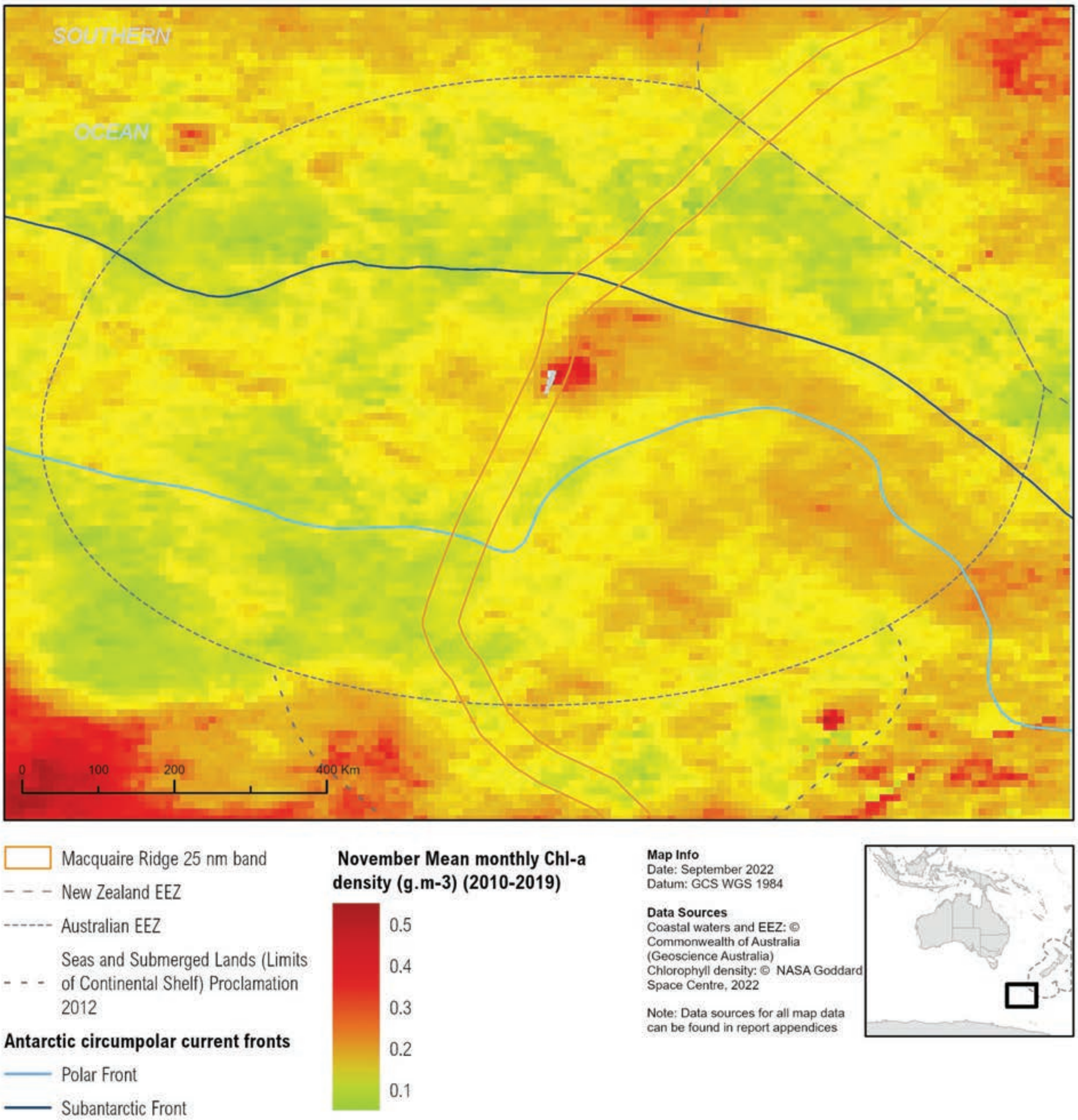


Figure 5: Chlorophyl a: Mean monthly chlorophyll- a (Chl *a*) density (mg.m^{-3}) in November for the decade 2010-2019 (mean across years) in the vicinity of the M-EEZ.

Data: Oceandata MODIS Aqua Level^{-3} mapped monthly 9km Chl-a (NASA Goddard Space Flight Center, 2022) transformed using algorithm of Johnson et al. (2013) (subset of analysis for the Marine Ecosystem Assessment for the Southern Ocean e.g. Trebilco et al., 2019 supported by Integrated Digital East Antarctica, Australian Antarctic Division). M-EEZ (black dashed lines), 25 nautical mile band centred on the tectonic plate boundary (yellow line), and the Sub-Antarctic Front (solid blue line) and the Polar Front (solid light blue line). Legend shows colours at 0.1 mg.m-3 intervals of the colour ramp plotting individual Chl *a* in each pixel. Colours are chosen to show differentiation within the M-EEZ.

Fish

Duhamel et al. (2014) provide an extensive overview of the biogeography of benthic and pelagic fish in the Southern Ocean. Macquarie Island is given its own district (West Pacific) in the Sub-Antarctic Region, which includes all the Sub-Antarctic islands. Importantly, the M-EEZ is distant to the nearest upstream area of the Kerguelen Plateau. In the pelagic realm, the pelagic fish fauna is separated as a temperate sub-group to the north of the Sub-Antarctic Front and the polar subgroup to the south, reinforced by more recent large-scale modelling of acoustic and environmental data (Proud et al., 2017). Duhamel et al. (2014) present recorded observations of many Sub-Antarctic species at Macquarie Island but the data are insufficient for documenting finer scale distributions of species in the M-EEZ. Species distribution modelling included in Duhamel et al. (2014) and Proud (2017) relied in many cases on satellite-derived Chlorophyll *a* data. Data on the occurrence and distribution of benthic fish species taken as bycatch in the fishery for Patagonian toothfish were not made available for this study.

Seabirds

The M-EEZ plays host to a large number of seabirds of national and global conservation importance and has an avifauna that is typical of the Sub-Antarctic, including many species that are also found around Sub-Antarctic islands in the Atlantic and Indian Ocean. Of the 57 species of seabirds that have been recorded in the M-EEZ (see Appendix 2), 25 are species that breed on Macquarie Island and 32 are non-breeding visitors. The breeding species include four species of penguins, four albatrosses, 13 petrels and one species each of cormorant, skua, gull and tern. The non-breeding visitors include 3 species of penguins, 8 albatrosses, 19 petrels, one skua and one tern. There are two species, royal penguin (*Eudyptes schlegeli*) and Macquarie Island imperial shag (*Leucocarbo atriceps purpurascens*) that are endemic to Macquarie Island. Many of the seabirds recorded in the area are of conservation concern including the critically endangered wandering albatross (*Diomedea exulans*), a further eight species, erect-crested penguin (*Eudyptes sclateri*), eastern rockhopper penguin (*Eudyptes chrysocome filholi*), northern royal albatross (*Diomedea sanfordi*), grey-headed albatross (*Thallasarche chrysostoma*), Indian yellow-nosed albatross *(Thalassarche carteri*), sooty albatross (*Phoebetria fusca*), southern fairy prion (*Pachyptila turtur Sub-Antarctica*) and New Zealand Antarctic tern (*Sterna vittata bethunei*) that are listed as endangered and 13 species are listed as either near threatened or vulnerable. All of the species that occur in the M-EEZ are listed as marine species under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and there are 18 species that are listed as threatened species under that Act. Macquarie Island is also listed on the Register of Critical Habitat under the EPBC for both wandering and grey-headed albatross.

Wandering Albatross, Macquarie Island. Photo: J. Cleeland

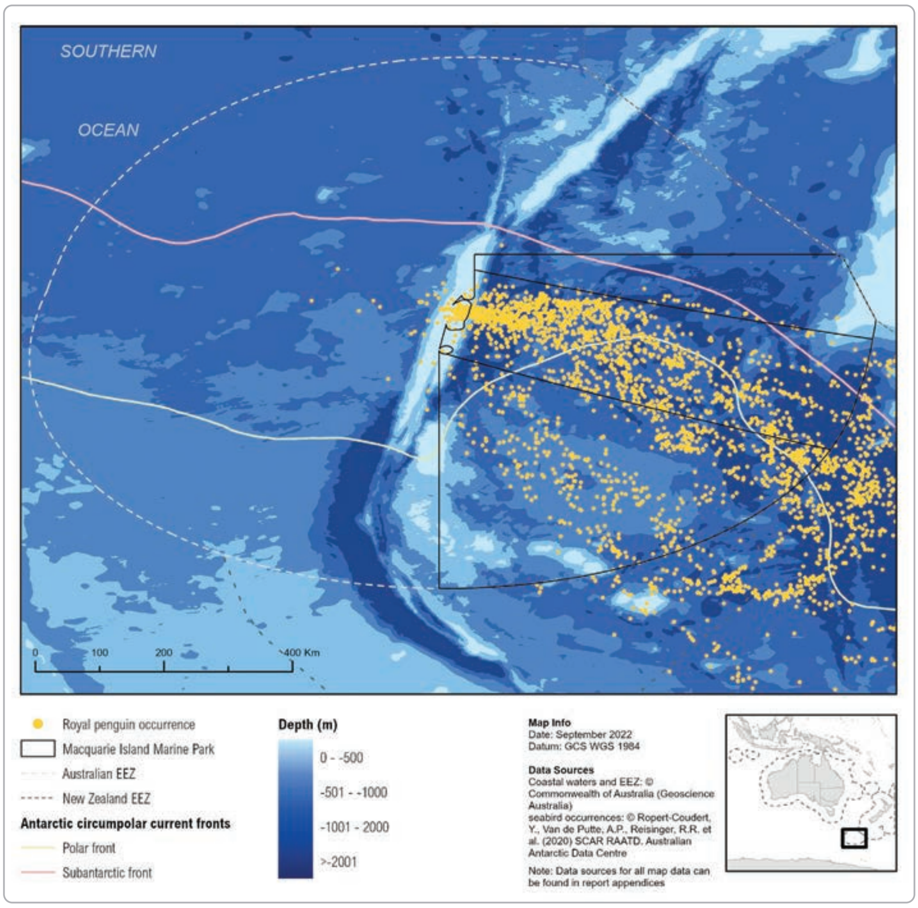
Southern Elephant Seal, Macquarie Island. Photo: J. Cleeland

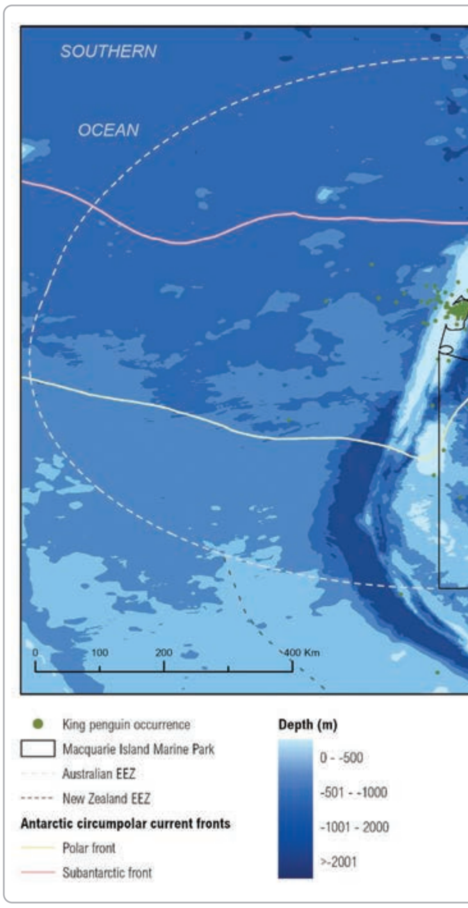
Marine mammals

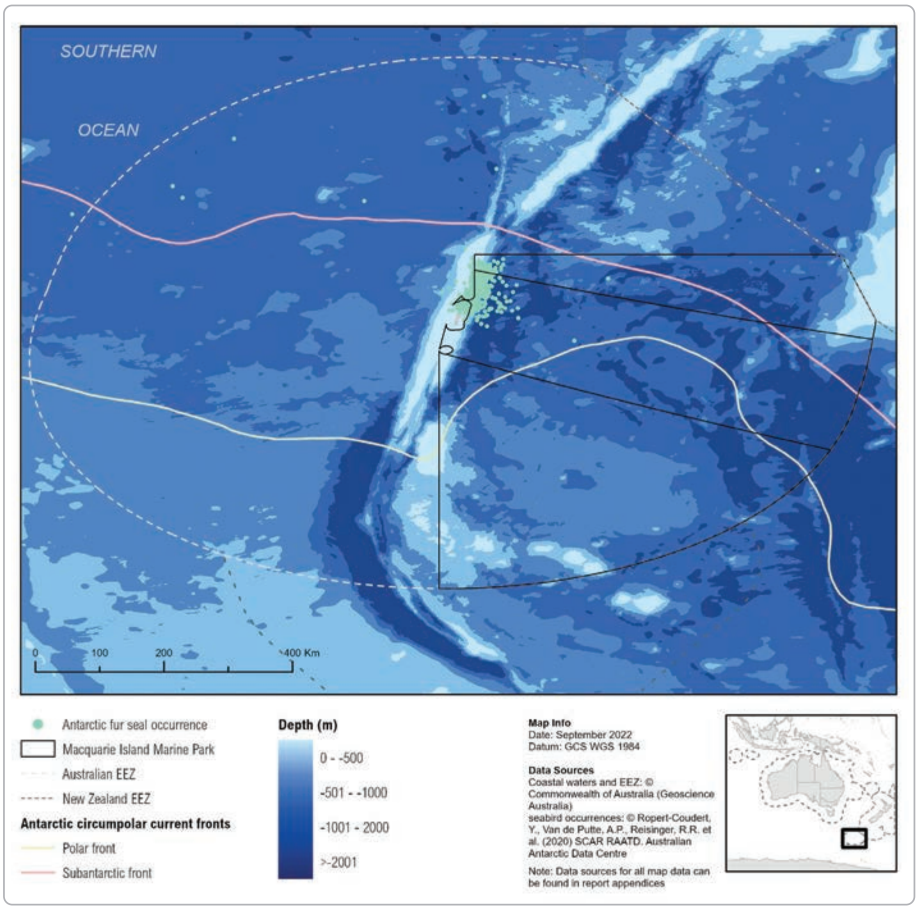
The three species of fur seal breed on Macquarie Island, Antarctic (*Arctocephalus gazella*), Sub-Antarctic (*A. tropicalis*) and New Zealand fur seals (*A. forsteri*) feed extensively in the marine area around the island. The population of southern elephant seals (*Mirounga leonina*) that breed on Macquarie Island represent circa 10% of the global population. Macquarie Island is frequently visited by leopard seals (*Hydruga leptoynx*) and Hooker's sea lions (*Phocarctos hookeri*).

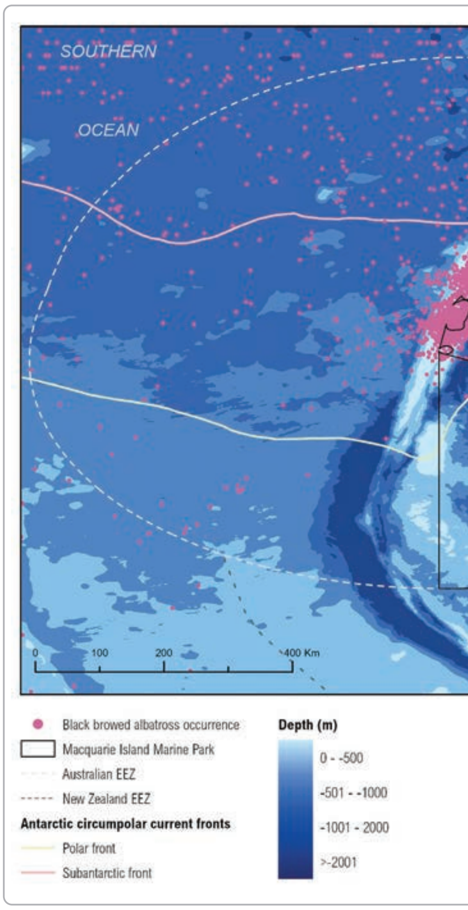
The most frequently reported cetacean species are long-finned pilot whale (*Globicephala melas*) and the killer whale (*Orcinus orca*), the latter are particularly frequently recorded in the period from October to December when they feed on southern elephant seals, fur seals and penguins (Travers et al. 2018). Based on land-based sightings and strandings on Macquarie Island, Clarke et al. (2017) document the occurrence of a further 11 cetacean species (southern right whale *Eubalaena australis*, humpback whale *Megaptera novaeangliae*, sperm whale *Physeter macrocephalus*, Arnoux's beaked whale *Berardius arnuxii*, Andrew's beaked whale *Mesoplodon bowdoini*, Blainville's beaked whale *Mesoplodon densirostris*, strap-toothed beaked whale *Mesoplodon layardii*, Cuvier's beaked whale *Ziphius cavirostris*, southern right-whale dolphin *Lissodelphis peroni*i, hourglass dolphin *Lagenorhynchus cruciger* and spectacled porpoise *Phocoena dioptrica*). Clarke et al. (2017) noted that the presence of very deep water (>1000m) close to Macquarie Island is likely to explain the relatively high diversity of beaked whale species that have been recorded washed ashore on Macquarie Island. These whale species are typically very rarely observed at sea, however, their occurrence as strandings is indicative of their occurrence in the broader marine zone, confirming that the M-EEZ is an area of high marine mammal diversity as reflected in its designation as an Important Marine Mammal Area (https://www.marinemammalhabitat.org/).

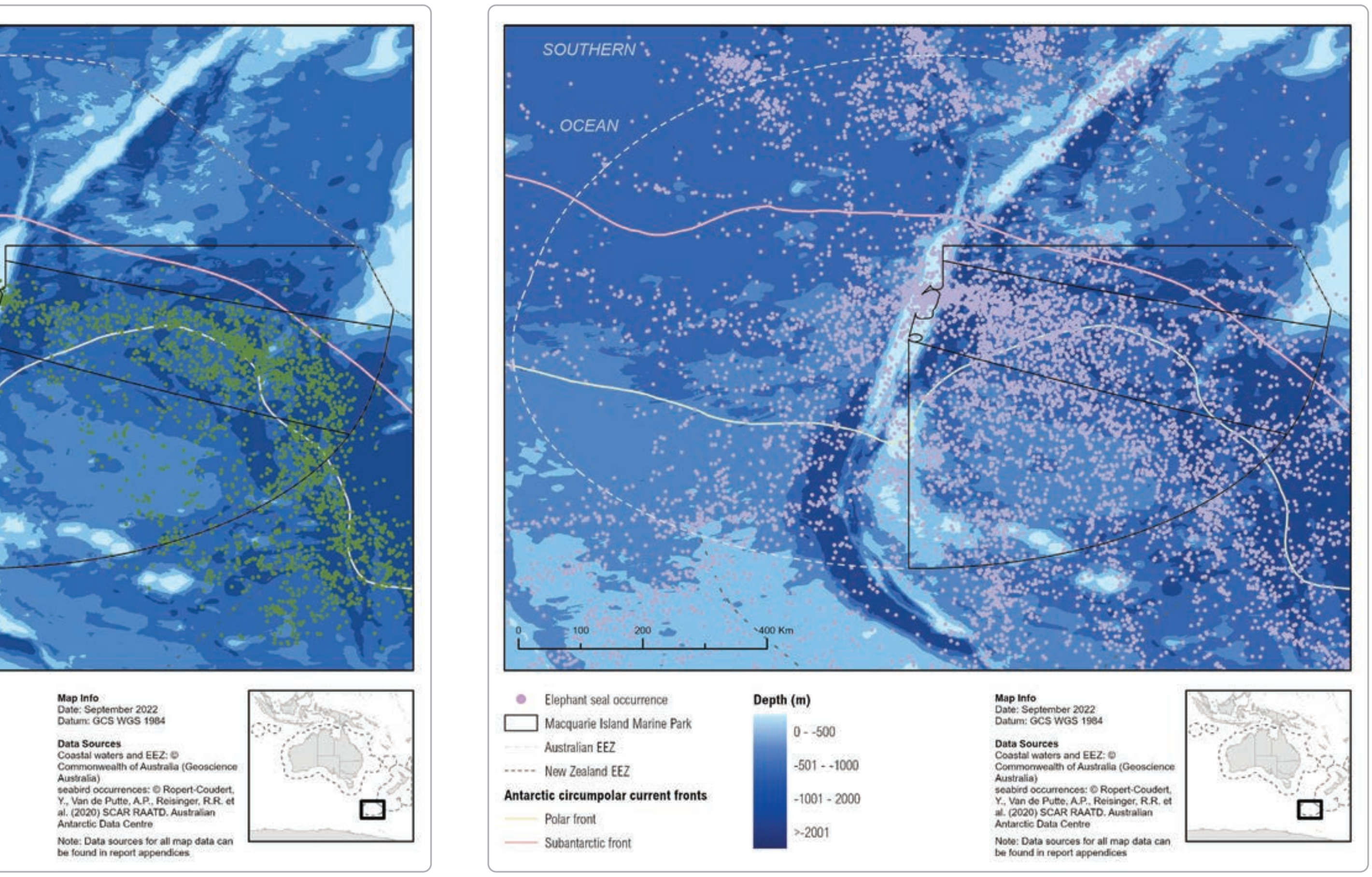
Distribution of seabirds and mammals

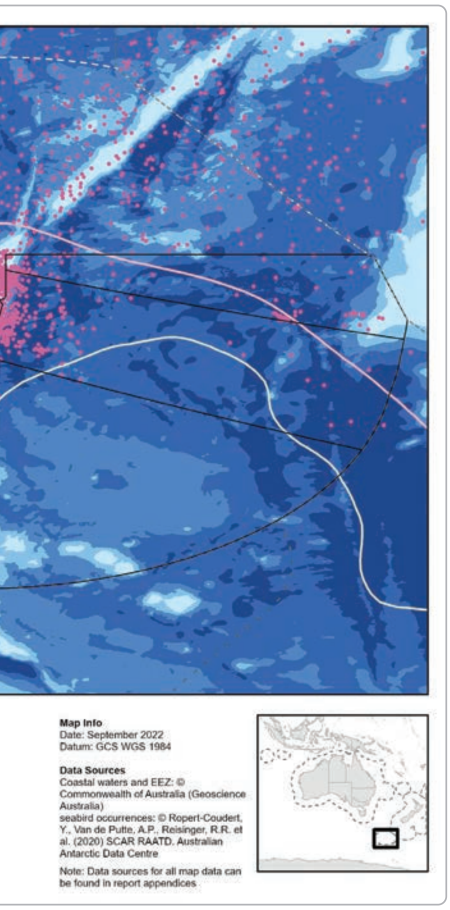












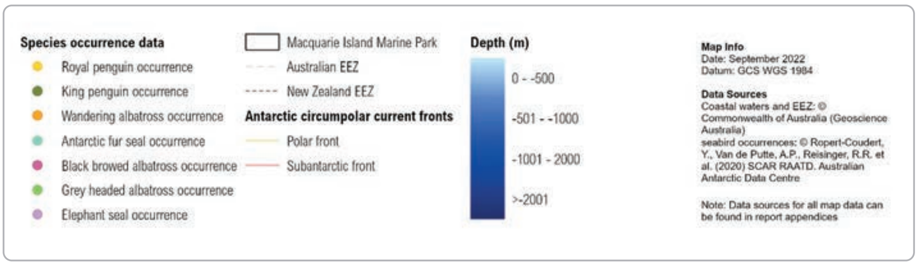
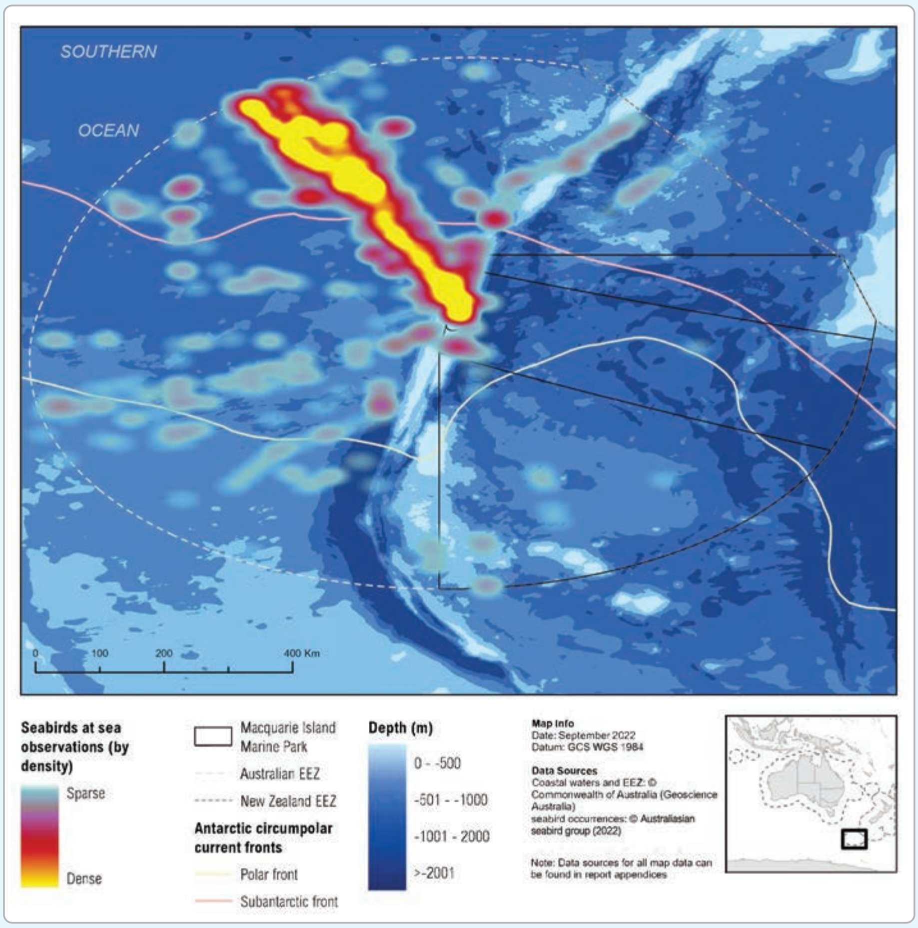


Figure 6: Locations from satellite tracking of king penguin, royal penguin, southern elephant seal, Antarctic fur seal and black-browed albatross from Macquarie Island.

Satellite tracking shows two distinct patterns of movement between different species during the breeding season. There is a relatively well-defined movement to the southeast of the island that is shown by royal and king penguins as well as southern elephant seals, the latter are movements following the breeding season, in contrast both black-browed albatross and Antarctic fur seal foraged in a more concentrated region on the Macquarie Ridge to the north of the island (Figure 6).



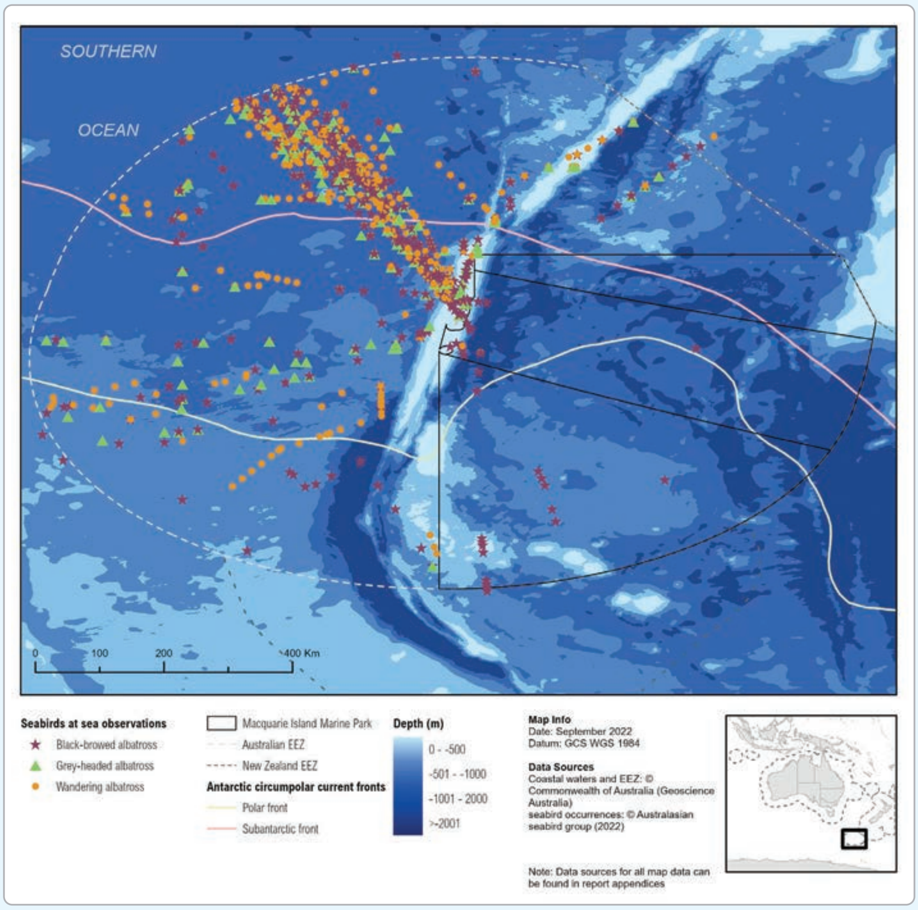


Figure 7: At-sea seabird observations showing the distribution of seabird observations (top panel) and occurrence of black-browed albatross, wandering albatross and grey-headed albatross (bottom panel).

The collection of at-sea observation data is predominantly from the western part of the marine zone. A total of 54 seabird species have been recorded and the location of sightings indicates that as well as foraging close to the island during the season breeding black-browed albatrosses (as well as wandering and grey-headed albatross) are also present across a large area of the marine zone (Figure 7).

In addition to their foraging activity inside the Macquarie Island region many of the seabird species forage over an extensive part of the Southern Ocean including the Pacific, Atlantic and Indian Ocean sectors (Figure 8). While the success of the mitigation measures used in the Macquarie Island longline fishery mean that the risk posed to these species by interactions with those fisheries is low the same cannot be said for the other fisheries that might be encountered across their extensive foraging areas. These large-scale connections are also evident in the tracking of albatrosses from other locations in Atlantic and Indian Oceans that occur as non-breeding visitors to the region, underling the international importance of the waters around Macquarie Island.

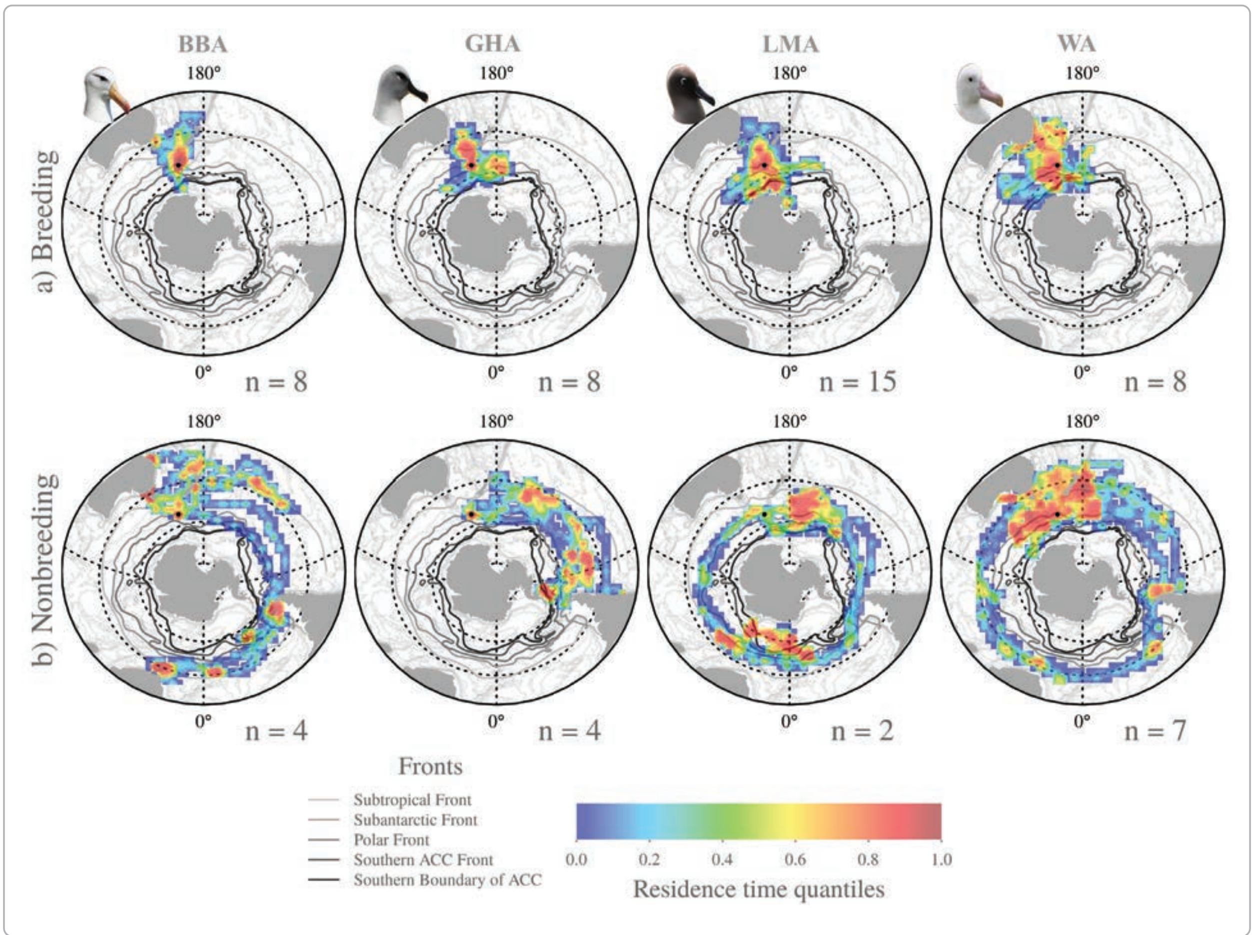


Figure 8: Distribution of black-browed (BBA), grey-headed (GHA), light-mantled (LMA) and wandering albatrosses (WA) tracked from Macquarie Island (shown as black dot) during (a) breeding and (b) nonbreeding periods. Residence time was based on a 100 × 100 km grid.

(Figure from Cleeland et al. 2019 reproduced with kind permission of the Author)

Deep sea benthos including seamounts

Analyses of the benthic communities of the Macquarie Ridge remain preliminary due to uneven sampling effort and incomplete analysis. O'Hara et al. (2002) provided a preliminary assessment of the benthic biogeography of south-east Australia using material collected by BANZARE (1939), NZOI (1959-1965), Eltanin (1965-1968), ANARE (1986) and CSIRO Southern Surveyor (1999, SS0199) cruises to the Macquarie Ridge. There were 58 species of echinoderms (all classes) and pycnogonids in 246 species/station lots for Macquarie Ridge.

Where there were sufficient samples (500-1500m), the authors identified a gradient along the Macquarie Ridge with the fauna separated into three geographic clusters: northern (48-52°S), central (53-54°S) and southern (55-57°S) (see Figure 9). This represents a biogeographic gradient from a New Zealand Sub-Antarctic fauna to an Antarctic fauna, with the central fauna representing a mixed zone with a few endemic species. The far north (48°S) and far south (55-57°S) cells could also be distinguished at the deepest depths analysed (1500-2000m), although the fauna at these depths appeared more widespread although sample sizes were generally smaller.

At shallower depths (0-200, 500-1000 m) the fauna is derived from New Zealand and Sub-Antarctic species that have presumably arrived on kelp holdfasts from islands further west (Edgar 1987). Macquarie Island appears as an outlier, partly due to the inconsistent distribution of shallow habitats along the Ridge but potentially due to the presence of Macquarie Island endemic species (O'Hara et al. 2002).

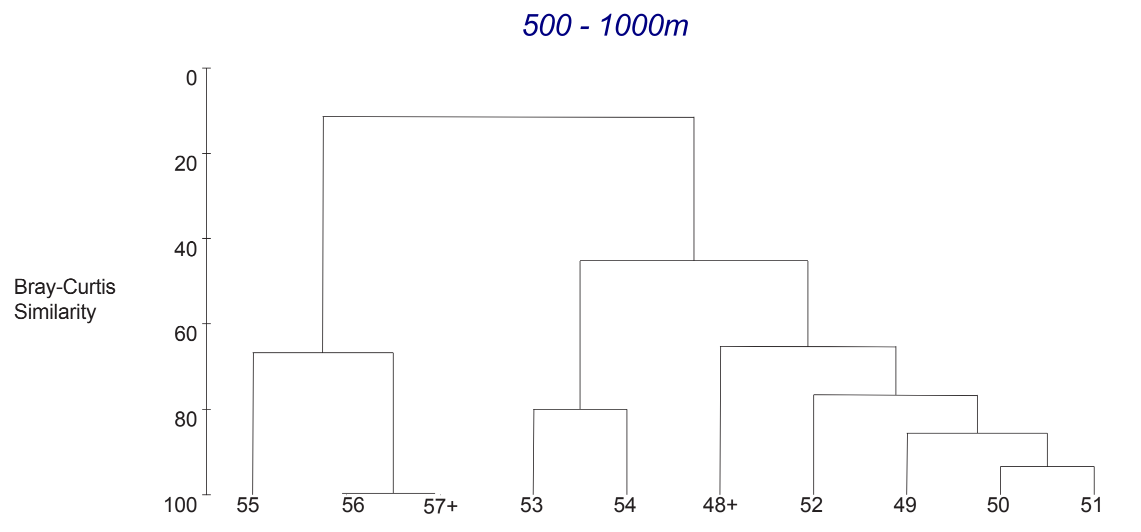


Figure 9: Cluster diagram of species from the Macquarie Ridge, based on presence/absence of each species along the Ridge in cells of one-degree latitude between 500-1000. Macquarie Island is located at 54°S.

(Figure reproduced from O'Hara et al. 2002 with kind permission of the Author).

Considerable heterogeneity in benthic habitat was observed along Macquarie Ridge on CSIRO survey SS0199 with diverse suspension feeders present along the tops of ridges and on ledges and overhangs. Steep areas of the slope were likely unstable with few benthic organisms observed. The flat ground at the base of canyons and troughs where most trawling for Patagonian toothfish occurred was observed to have a typical soft-bottom fauna (Koslow and Kloser 1999).

Habitat forming benthic fauna were present on the ridges north and south of Macquarie Island but restricted to the tops of ridges; very little if any stony corals were collected at deeper sites on the slope or base where more rocks and rubble were present (Koslow and Kloser 1999). Many of the stony corals were dead, perhaps a sampling artefact; gorganacean-type octocorals were at greatest abundance and diversity at the shallowest sites. Stony corals (live and dead) and octocorals were virtually absent from sites directly east or west of Macquarie Island. Brachiopods attached to bivalve shells and two species of solitary ascidians were abundant at these sites. Similar to the ridge, abundance of both live and dead organisms decreased rapidly with depth.

Five benthic communities were described from analysis of the identified components of 16 sled samples collected on CSIRO survey SS0199 structured by depth and latitude:

1. East and west shallow sites (200-500m depth)
2. Three mid-depth sites (400-900) at the beer garden and south ridge
3. Six of the seven deep water sites (1000-1500m)
4. The 'shallow' (400-600m) and mid-depth (600-1000m) sites north of the gap.
5. East and west mid-depth sites (500-1000 m depth) and the deep-water site north of the gap (1000-1500m) (all samples were small so may represent sampling artefact)

Of particular interest is the difference between the mid-depth groups north and south of the gap. Group 4 (north of the gap) was characterized by a suite of sessile taxa in relatively low abundance - colonial stony coral *Enallopsammia* cf *marenzelleri* and *holothurian Psolus neozelanicus* were most abundant and together with the chiton *Placiphorella* sp. and the *carid Merhippolyte* cf chacei were rare or absent at other sites and may have been at the southern limit of their distribution (Butler et al. 2000). Group 2 (south of the gap) was a species-rich community of sponges and octocorals including a very large colony of the octocoral *Primnoa* sp. 1 indicating growth in stable conditions below the wave base for an extended period.

The most extensive survey of the benthic environment around Macquarie Island has been an interdisciplinary New Zealand- Australian research voyage in 2008 (NIWA survey TAN0803) which mapped 10 seamounts along the ridge with peak depths of approximately 90-1200m, base depths of 750-2000m and elevations of 450-1300m (Fig. 10; Rowden et al. 2008). Six of these seamounts (SMT6, SMT7, SMT8, SMT9, SMT10, SMT11) are within the Australian EEZ (Figure 10), with one (SMT10) on Australia's extended continental shelf. Comprehensive analysis of the samples taken on this survey await funding support, but some taxonomic groups have been worked up as part of broader biogeographic work and are reported in subsequent sections. Contour maps of the seamounts and some example images are shown in Figs. 11a and 11b. A summary of the main faunal groups collected is provided (Appendix Table 1).

The most commonly seen fauna on the six seamounts in Commonwealth waters were:

- SMT 6 (90-750m depth) - ophiuroids, plus anemones, sponges, fish and sea stars.
- SMT 7 (750-1250m depth) - ophiuroids, anemones, sponges and gorgonian corals, plus crabs, hydrocorals, black and stony corals.
- SMT 8 (400-850m depth) - bubblegum corals, gorgonians, hydrocorals and sponges, plus crabs, crinoids, black corals and anemones.
- SMT 9 (500-1200m depth) - gorgonian corals, bubblegum corals, sea pens and sponges, plus hydrocorals, sea stars, bryozoans, fish and sea cucumbers.
- SMT 10 (1200-2500m depth) - gorgonian corals (including bamboo corals), plus crinoids, fish and sponges.
- SMT 11 (550-1200m depth) - sponges, plus anemones, crabs and sea pens.

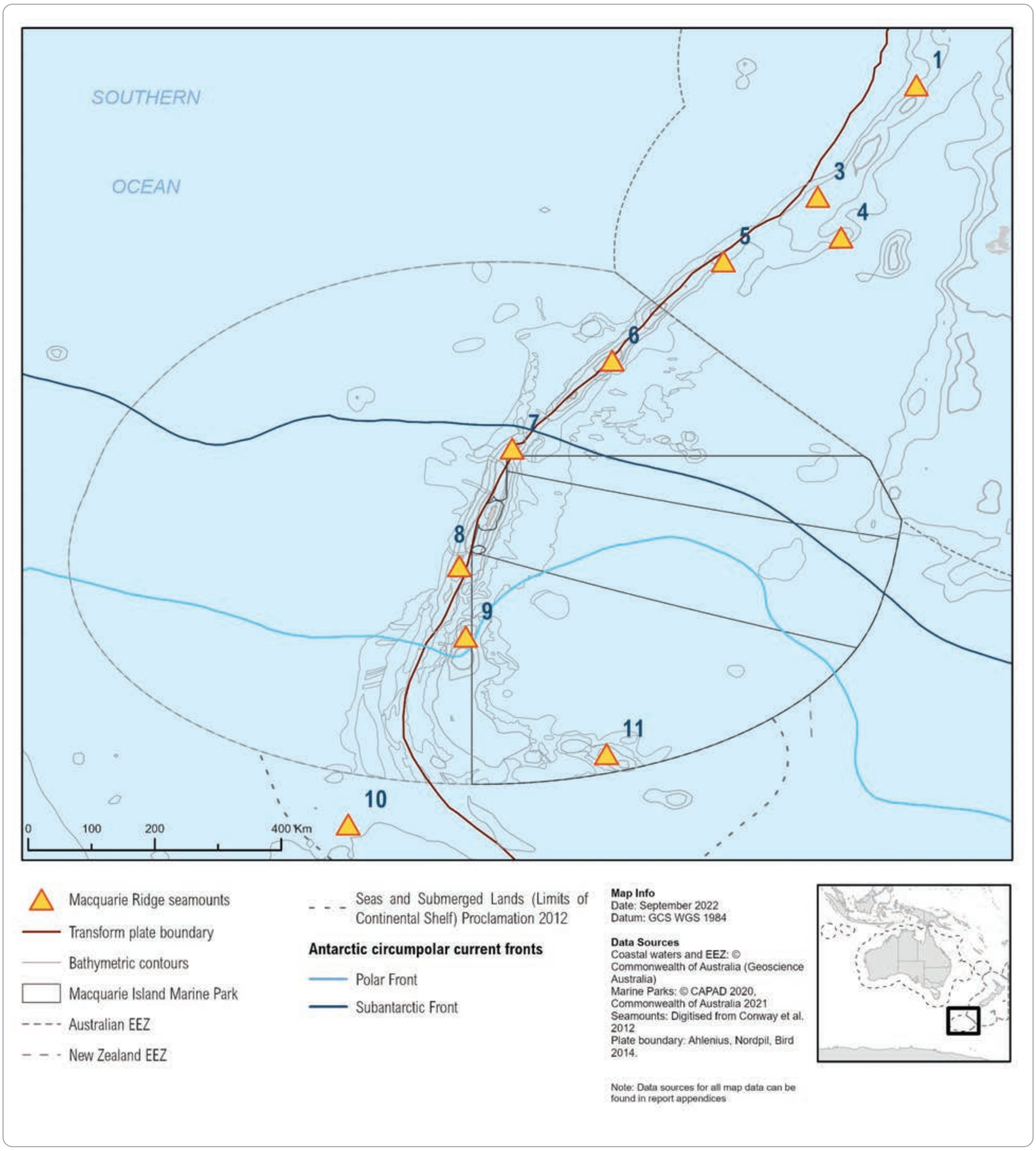


Figure 10: Site and station positions for samples taken on voyage TAN0803, showing sampled seamounts on Macquarie Ridge inside and outside Australia's EEZ.

(Figure reproduced from Rowden et al. (2008) with kind permission of the Author).

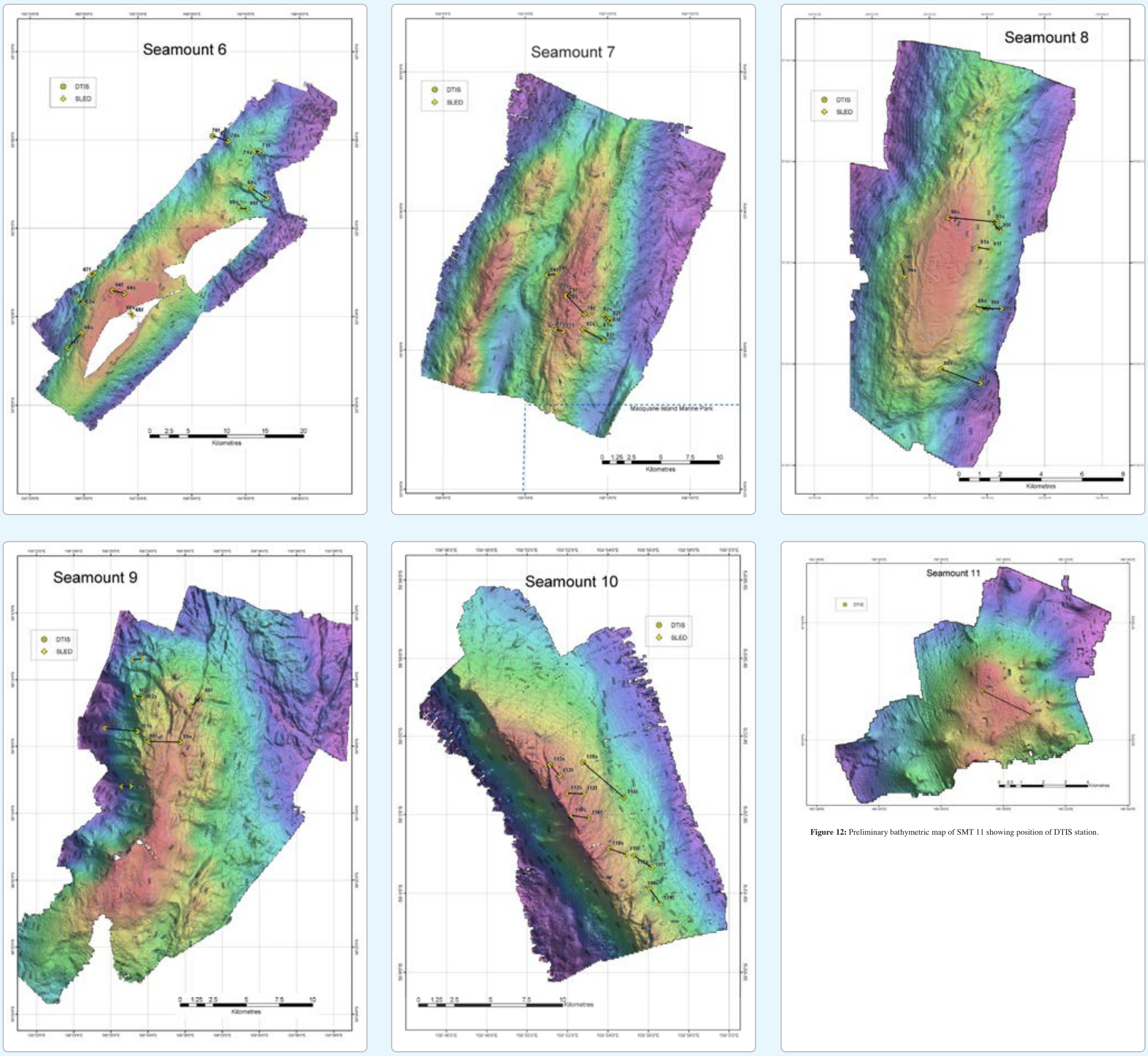


Figure 11a: Preliminary bathymetric maps of Macquarie Ridge seamounts within Australia's EEZ surveyed on TAN0803 showing positions of sled and DTIS stations. See Figure 10 for locations.

(Figure reproduced from Rowden et al. (2008) with kind permission of the Author).

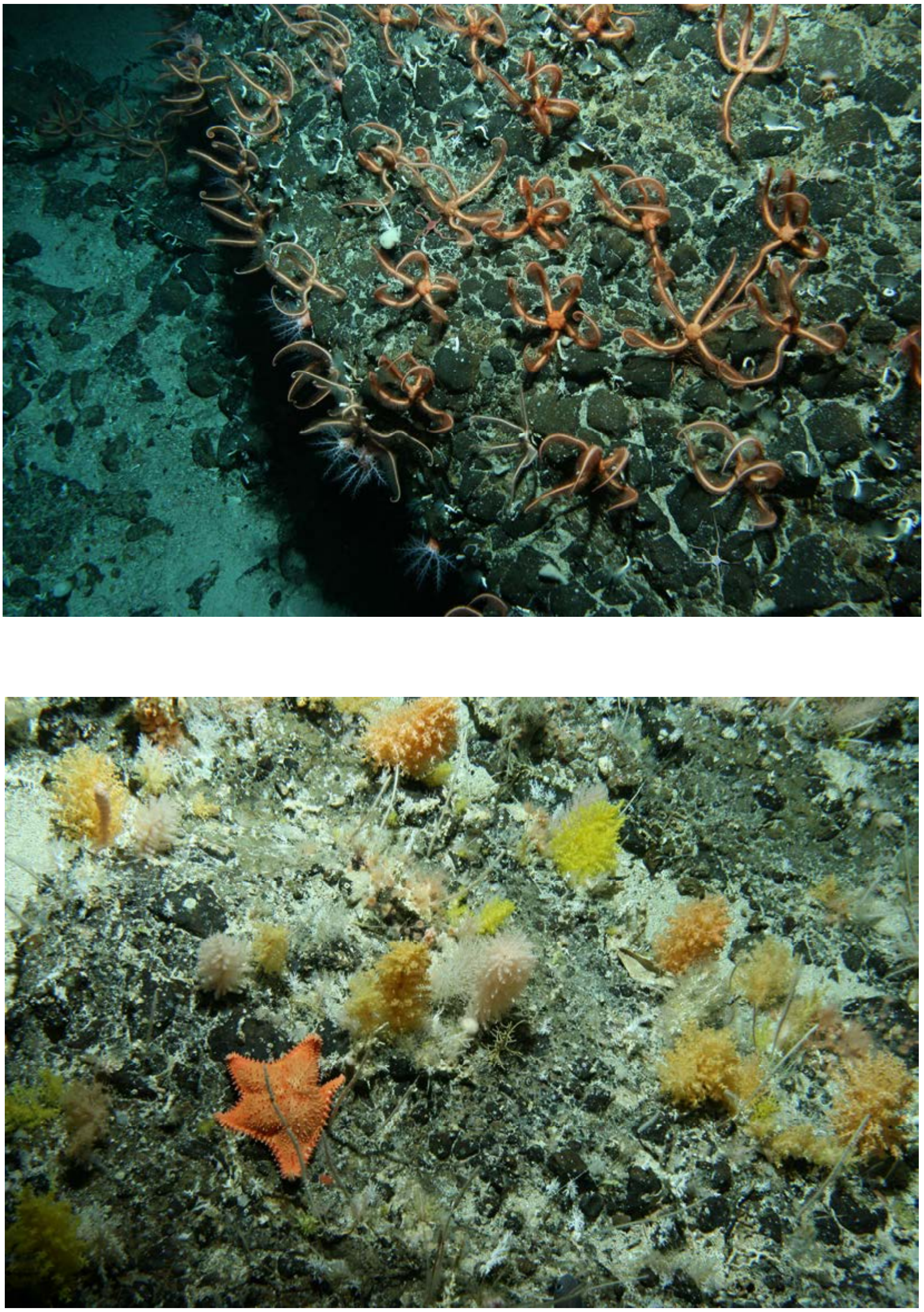


Figure 11b: Example DTIS images showing common fauna seen on study seamounts on Macquarie Ridge within Australia's EEZ: top ophiuroids on SMT 6 (stn 68), bottom - gorgonian corals on SMT 7 (stn 78). See Figure 10 for seamount and station locations.
(Figure reproduced from Rowden et al. (2008) with kind permission of the Author).

Seabed habitat in the Macquarie Island Marine Park

The seafloor to the east and west of the ridge is very deep and mostly unsampled. Three video transects were completed on the CSIRO 1999 survey of the Macquarie Island region and toothfish fishery (SS0199) in the subsequently declared marine park covering depth ranges 100-200m, 457-500m and 450-1230m (Koslow and Kloser 1999). Imagery shows a steep rugged seabed of debris flows, talus deposits (scree) and outcrops of breccia (consolidated pebble/cobble) (Fig. 12, Butler et al. 2000).

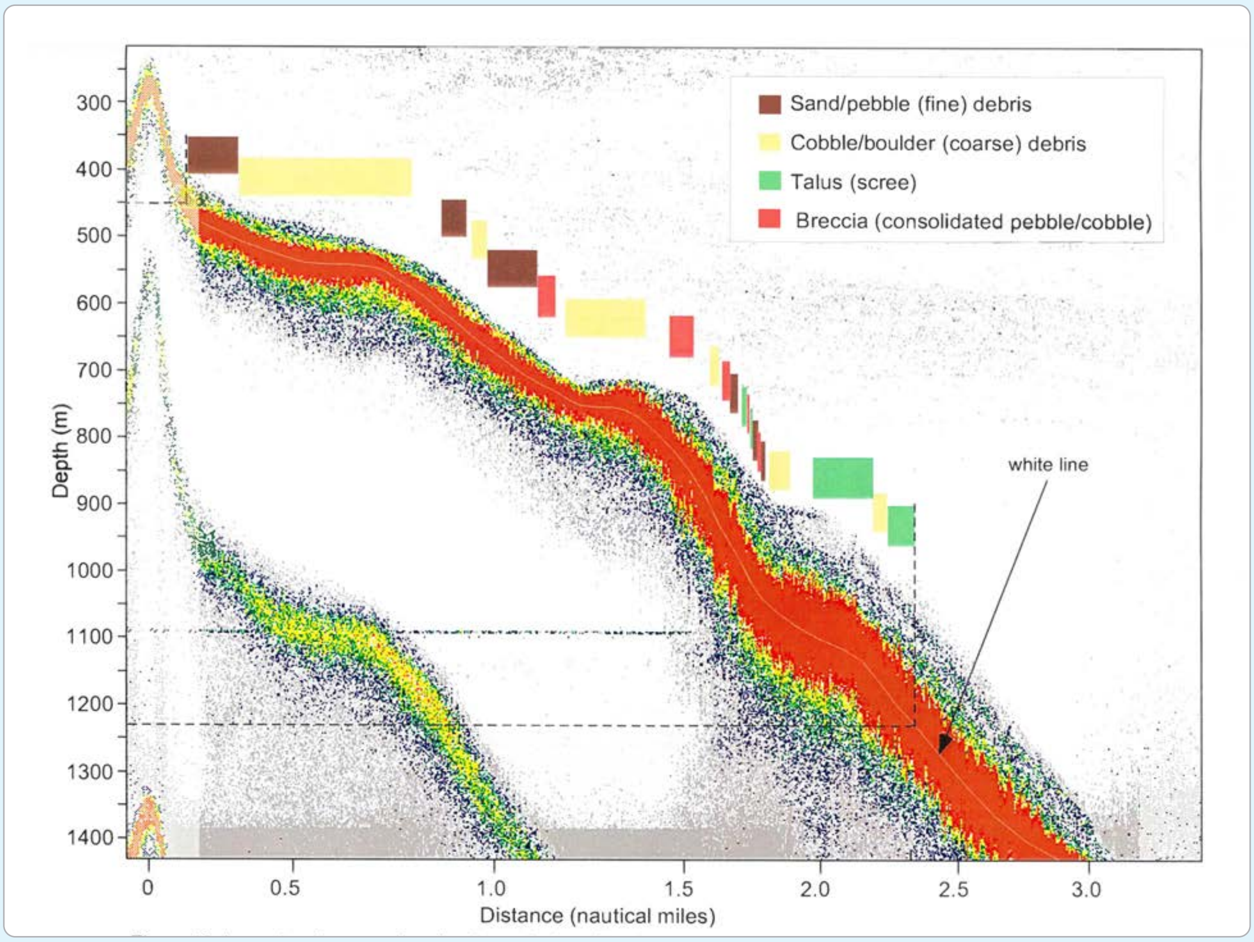


Figure 12: Physical seabed profile through the Macquarie Island Marine Park. (Figure 12 of Butler et al. 2000).

Based on incomplete analysis of 16 benthic sled samples on CSIRO survey SS0199 (some faunal groups remained to be worked up by expert taxonomists), the shallow water community (~200-500m depth) east and west of Macquarie Island formed one of five distinct benthic communities around Macquarie Island, characterised by high abundances of brachiopods, bivalve molluscs and ascidians. Sponges and octocorals were noticeable by their virtual absence (Butler et al. 2000). Seapens were recorded only on the eastern side of the island.

The mid-depth community (600-1000m) in the marine park had similarities to the mid-depth community west of the island and (counter-intuitively) the deep (1000-1500m depth) community of the north Macquarie Ridge, characterised by few species, low biomasses, the absence of sponges and a low abundance of octocorals (Butler et al. 2000). Similar to the shallow water community, the presence of seapens only on the eastern side of the island is consistent with a more sheltered environment, less energetic water movement and greater silt deposition.

The deep-water community (>1000m) in the park had similarities with 6 of the seven deepest samples (>1000m) from around Macquarie Island, characterised by a low-biomass community of primarily small sponges and an absence of the groups characterizing many most of the shallower communities (particularly molluscs, octocorals and echinoderms).

Video transects through the subsequently declared park identified small mixed macrobenthos of encrusting filter-feeders on consolidated seabed from ~100-500m depth. This same community persisted to the maximum depth video-surveyed (1230m) supplemented by some larger erect filter-feeders including large spongers, gorgonian and other octocorals and black corals (Butler et al. 2000).

Connectivity of deep sea benthos including seamounts

Macquarie Ridge is a rare example of an approximately N-S feature in the Southern Ocean that may allow a 'migration path' for a temperate bathyal fauna (e.g. the coral matrix forming *Solenosmilia*) to retreat to the south as the oceans warm, although this may be complicated by aragonite saturation limits shoaling in the south (personal communication Tim O'Hara, Museum Victoria).

While there have been considerable advances in our knowledge of the deep-sea fauna of Macquarie Ridge and adjacent areas in the last two decades, our knowledge remains incomplete due to a lack of comprehensive samples, and the lack of analysis of samples already collected at considerable expense. For example, prior to Henry Resiwig's work on glass sponges (Resiwig 2017) only 3 glass sponge species were known from New Zealand waters. Following his work 26 species are now known from 14 genera, including three species which are new to science.

Ophiuroids

Macquarie Ridge is an area of high species turnover (beta diversity) (O'Hara et al. 2019). These authors assessed 160k distributional records and DNA sequence data from 596 species (267kb) to examine the origins of the latitudinal evolution of the entire class of ophiuroids or brittlestars. Notable latitude changes in phylogenetic diversity included the area around 54oS (Figure 13), the latitude of the Macquarie Ridge where many of the samples at that latitude would have come from. These data plus results of species turnover as a function of depth indicate that five distinct biomes can be described for this class - tropical shallow, temperate shallow, tropical deep sea, temperate deep sea and Antarctica.

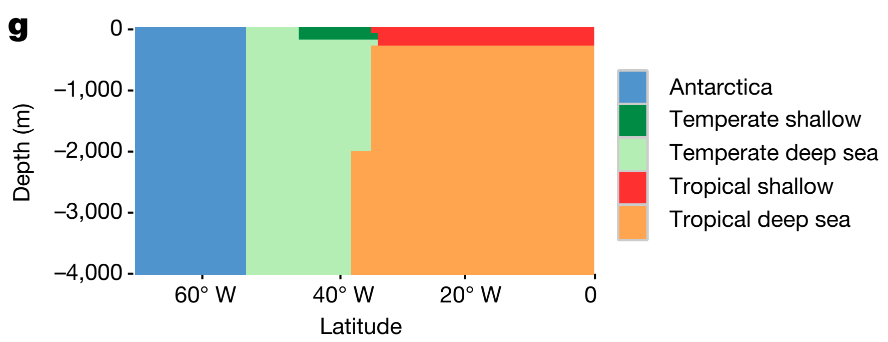


Figure 13: Clusters derived from the latitudinal and depth components of Simpson's beta phylodiversity turnover for 596 species of brittlestar, showing the high turnover (cluster boundary) at the latitude of the Macquarie Ridge.

(Figure reproduced from O'Hara et al. (2019) with kind permission of the Author).

Macquarie Ridge shares many species with southern Australia and New Zealand and a smaller number with Sub-Antarctic and Antarctic locations (O'Hara et al. 2013, Figure 14). Subpolar and polar affinities increase to the south.

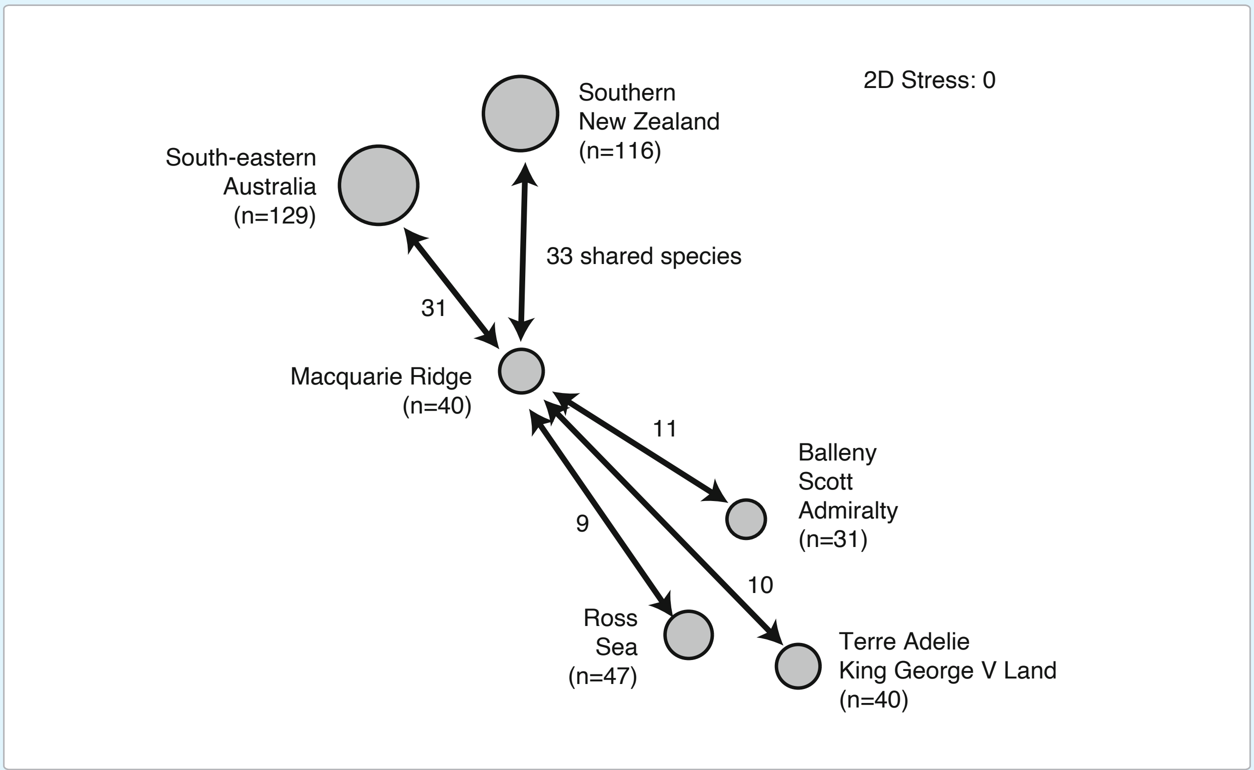


Figure 14: MDS ordination of the presence/absence of morpho-species (MSPs) on Macquarie Ridge and adjacent regions using the Bray-Curtis dissimilarity coefficient.

The size of the ordination symbol is scaled to the number of MSPs in each region. The numbers next to the arrows refer to the number of shared MSPs between regions.

(Figure reproduced from O'Hara et al. (2013) with kind permission of the Author).

Corals

Miller et al. (2010) found evidence of genetic subdivision for three species of deep-sea coral in the Australia/New Zealand region, including the solitary coral *Desmophyllum dianthus. D. dianthus* collected on the Macquarie Ridge differed from those collected on Auckland Island, but no differences were detected with those collected on the northern Chatham Rise. *D. dianthus* collected from Macquarie Ridge, Auckland Island and northern Chatham Rise also differed from those collected from Tasmanian seamounts. Holland et al. (2022) assessed the gene flow of *D. dianthus* in five areas around the New Zealand EEZ, including Macquarie Ridge, and observed pronounced between-region genetic differentiation, high levels of self-recruitment, but also high connectivity between distant sites. Overall, north-central-southern patterns of genetic connectivity were consistent with oceanographic predictions of dispersal routes. The authors concluded that existing spatial closures within the New Zealand EEZ and surrounding high seas do not encompass the extent of genetic diversity and connectivity for *D. dianthus*, a similar result to information available for other deep-sea taxa in the region. *D. dianthus* is one of the indicator species for Vulnerable Marine Ecosystems (VME).

Zeng et al. (2017) also noted evidence of 'pronounced self-recruitment' within geomorphic features around New Zealand for three deep sea coral species – including the reef building coral *Solenosmila variabilis* on Macquarie Ridge. A north-central-south regional differentiation was found in each of the three species. The authors suggested these findings indicated the need for additional protected areas to maintain genetic diversity at features that do not already receive some level of protection. New Zealand established 17 Benthic Protection Areas (BPAs) between 2011 and 2007, exceptions being the Hikurangi Margin, Bounty Trough and the Macquarie Ridge.

Squat lobsters

Early indications of distinct squat lobster species on Macquarie Ridge have not been borne out following further sampling of adjacent areas (Schnabel et al. 2020). There was evidence of limited genetic differentiation for three squat lobster species (*Munida isos* and *M. endeavourae* which typically occur on isolated seamounts, and *M. gracilis* which occurs on more widespread soft sediments) in the southwest Pacific Ocean based on nuclear microsatellite markers (Yan et al. 2020). However, evidence of source (Tasmanian slope *M. isos*) and sink (Kermadec Ridge – all three *Munida* species) populations suggest the importance of considering gene flow at the regional scale for this VME indicator taxa.

Sponges

One of the four deep sea sponges (*Poecillastra laminaris* Sollas 1886) examined by Zeng et al. (2019) showed significant mitochondrial and nuclear differences between provinces, north-central-south regions and geomorphic features. There was no migrant contribution from populations in the northern province to populations in the southern province (Campbell Plateau and Macquarie Ridge); however, the Macquarie Ridge population contributed migrants to the Kermadec Ridge and Challenger Plateau populations, indicating again the importance of Macquarie Ridge as a one of the population sources for deep sea marine taxa around New Zealand. The authors propose that this north-central-south population differentiation, that is also observed in other taxa, is maintained by incident oceanic currents that tend to pass either to the north or south of New Zealand, Chatham Rise and the Subtropical Front. Further, the unique *P. laminaris* haplotypes found in the most southerly samples from Seamount 10 on the NIWA survey TAN0803 (SMT10 labelled S19 in Figure 15) may be isolated by the Antarctic Circumpolar Current and Sub-Antarctic Front.

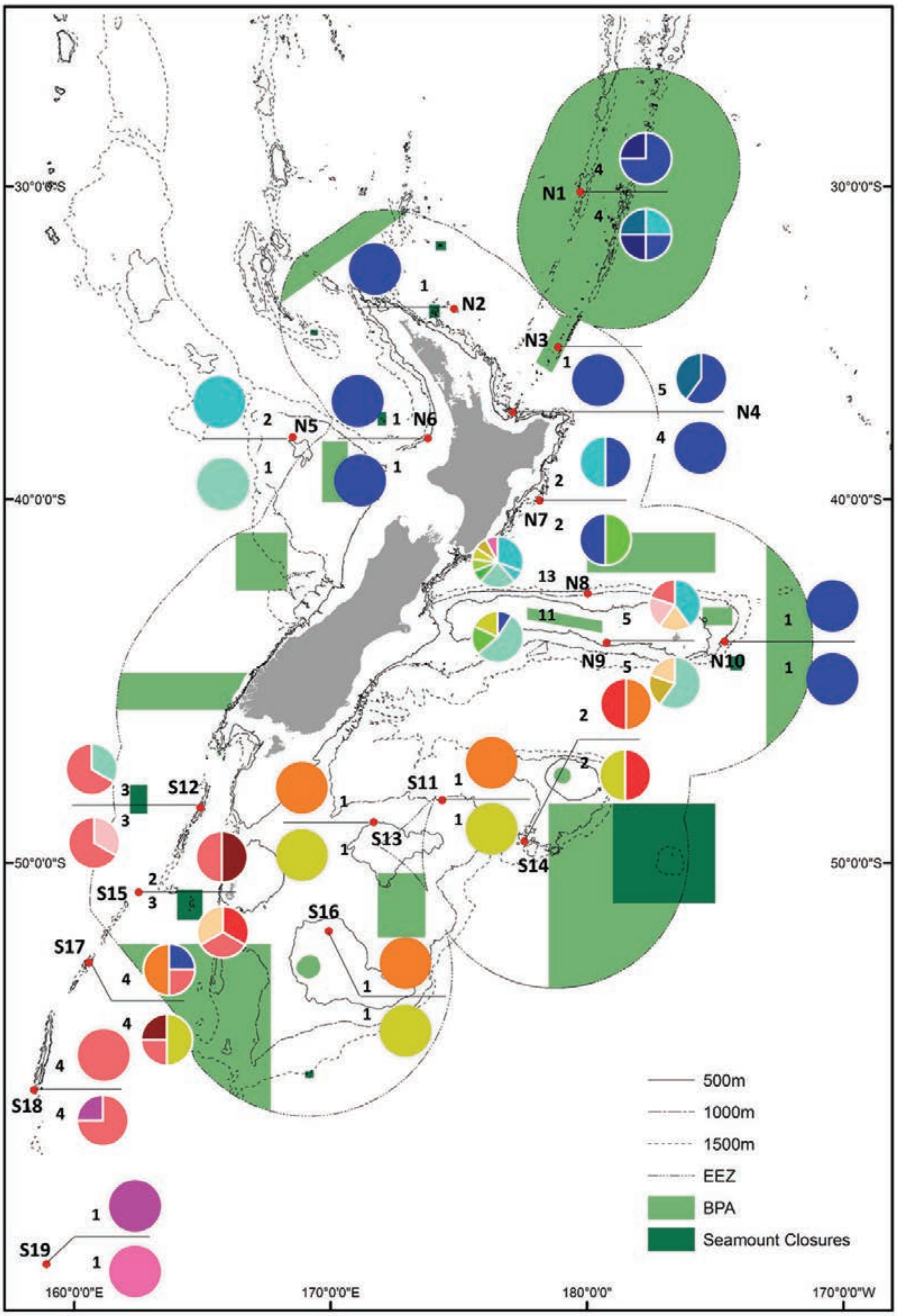


Figure 15: Haplotype map for *Poecillastra laminaris* in the New Zealand EEZ and further south on Macquarie Ridge including the Australian EEZ (S18) and extended continental shelf (S19) (COI above line, A1; *Cytb* below line, A2). Areas shaded green are marine protected areas within the New Zealand EEZ.

(Figure reproduced from Zeng et al. (2019) with kind permission of the Author under Creative Commons Attribution 4.0. http://creativecommons.org/licenses/by/4.0/).

Hydroids

Twenty seven species of deep-water hydroids, including six new and three probably new species (insufficient material for clear identification) were recorded from the 11 sites dredged on CSIRO survey SS0199. No distributional pattern with depth was discerned.

4.0 Pressures on Macquarie Island's marine ecosystem

4.1 Climate change

Anthropogenic impacts on the climate of the Antarctic region come from greenhouse gas emissions and ozone depletion in the stratosphere (Wienecke et al. 2021, IPCC 2013, WMO 2018, IPCC in press-a). The 2016 and 2021 State of the Environment reports reported improvement in Antarctic stratospheric ozone concentrations, with 2019 having the smallest Antarctic ozone hole since 1988, but then a large amount of ozone destruction occurred in 2020 (the severity of ozone depletion varies seasonally). Ozone depletion and increased greenhouse gases have resulted in changes in wind patterns in southern subpolar latitudes, which have influenced the heat content, salinity and dissolved oxygen content of the Southern Ocean (Turner et al. 2014, Rintoul et al. 2018, Swart et al. 2018, Wienecke et al. 2021).

> *"Ocean acidification is likely to have profound impacts on Antarctic marine species and ecosystems if it continues to increase at current rates" (Wienecke et al. 2021, Doney et al. 2009, Hancock et al. 2020). Ocean acidification is already affecting many ocean species, especially organisms such as oysters and corals that make hard shells and skeletons by combining calcium and carbonate from seawater (IPCC in press-a).*

Ocean acidification causes a net decrease in the carbonate ion concentration of ocean waters, which in turn reduces biogenic carbonate production including that needed for coral skeletons. Coral reefs in the deep sea have been identified as particularly vulnerable to this impact of ocean acidification due to low pre-impact carbonate levels (Guinotte et al. 2006) and a potentially limited opportunity for vertical migration where they occur on seamount summits (Thresher et al. 2011). Seamount tops currently supporting deep-sea coral reefs, such as the bioherm-building species *Solenosmila variabilis* observed on the Macquarie Ridge, may become undersaturated with carbonate ions in the next 50-100 years, which has been hypothesized to potentially lead to the loss of this coral-based biogenic habitat that supports biodiverse deep-sea ecosystems (Poloczanska et al. 2007).

(Thresher et al. 2011) examined the distribution and skeletal characteristics of coral taxa along a depth gradient in the Huon and Tasman Fracture Marine Parks and found little evidence of an impact of carbonate ion under-saturation with scleractinian and gorgonian corals growing, "often abundantly" in waters as much as 20-30% under-saturated. Developmental anomalies observed on an isidid gorgonian at nearly 4 km depth, suggest an absolute lower tolerance of about 40% under-saturation (Thresher et al. 2011). They suggest that the corals' live tissue may shield the carbonate skeleton from the under-saturated water. However, they note as a possible exception two scleractinian corals - *Solenosmila variabilis* and *Enallopsammia rostrata* - both of which form important biogenic habitat and both of which were found only above or close to the Aragonite Saturation Horizon (ASH)[2]. This is consistent with earlier reports that globally >95% of bioherm-forming coldwater scleractinian corals are found at or above the ASH (Guinotte et al. 2006), perhaps because the relatively fast-growing, elongate, branching skeletons that make these species so important as biogenic habitat are not as well protected by live tissue as more compact solitary forms (Thresher et al. 2011).

Climate change effects have been described for the terrestrial environment of four Sub-Antarctic islands (Macquarie Island by Adamson et al., 1988; Kerguelen Island by Frenot et al., 1997; Heard Island by Budd, 2000; Marion Island by Smith VR 2002 and le Roux and McGeoch 2008). The climate is oceanic and sits at the boundary between cool temperate and polar, with boundary zones considered susceptible to current and future climates changes. While climate change is considered to have a greater impact on the islands' terrestrial biota, which rely on the cool, humid conditions typical of Sub-Antarctic islands, there are also potential effects in the marine area.

[2] Aragonite is one of two biogenic carbonates found in the skeletons, shells and tests of marine taxa, the other being calcite.

"The projected changes under most mitigation scenarios used by the IPCC are likely to significantly alter the distributions and productivity of marine mammal species globally (Albouy et al. 2020; Learmonth et al. 2006; Schumann et al. 2013; Simmonds 2016). To date, the literature has mainly focused on the marine ecosystem of the Arctic region, which appears particularly vulnerable (e.g., Wassmann et al. 2011; Nunny & Simmonds 2019; Albouy et al. 2020). Recently observed climate variability and climatic shifts have already been implicated in the shifting productivity of several of New Zealand's charismatic marine megafauna species.

Climate change hazards of relevance to marine mammals globally include (but are not limited to): increasing sea temperature, rising sea levels, ocean acidification, decreasing sea-ice cover and changes in ocean circulation patterns (IPCC 2019). Several studies have now reviewed the potential impacts of these changes on marine mammal species and other marine vertebrates (e.g., Learmonth et al. 2006; Schumann et al. 2013; Simmonds 2016; Sydeman et al. 2015)"

Impacts of climate change, including ocean warming, acidification and the increasing volume of areas where oxygen levels are too low to support aerobic life over extended periods are not independent of other anthropogenic impacts on biodiversity, but are likely to act synergistically to amplify the other impacts. For example, increased metabolic rates required to survive in a less environmentally advantageous environment (e.g. animals with carbonate shells, skeletons or tests living in waters that transition to being under-saturated with carbonate ions) may reduce an individual's resilience to concurrent changes in temperature, oxygen, prey availability or predator behaviour.

4.2 Human activities and threats

Macquarie Island Nature Reserve is a restricted area under Tasmanian legislation to protect its unique natural and historic values, with only a small number of commercial educational tourist cruise ships permitted to visit the island each summer to provide an opportunity for people to witness the spectacular wildlife firsthand (NRET 2022). Visits are strictly controlled (see Section 5.2.2 Management approaches for the current limits on entry and the visit restrictions).

All visitors, staff and crew that visit the island must be aware of and observe biosecurity procedures designed to prevent exotic species being taken ashore in landing transport, equipment, materials, or clothing. No animals, live plants or soil may be brought into the reserve, and all reasonable steps must be taken to ensure that any clothing or equipment or materials brought onto the island are free of rodents, soil, seeds, plant material, invertebrates or pathogens. Special attention must be given to ensuring that no soil, seeds or invertebrates are lodged in velcro fixtures or in pockets, cuffs or crevices. Footwear and equipment washdown stations (equipped with scrubbing brushes to remove all dirt and a disinfectant bath using a broad-spectrum disinfectant to kill soil pathogens) must be used by all visitors, staff and crew going ashore prior to, and after, each shore visit. No food (other than the required emergency food) is allowed to be brought ashore, and no food items are to be given to wildlife (NRET 2022).

Pollution in the form of plastic debris is regularly observed and reported on Macquarie Island, and plastic particles have been recorded in marine mammal scats and dead seabirds from Macquarie Island since 1990, with the effects of this type of pollution not fully understood. Some researchers consider the biological accumulation of small plastic pieces through the near-island oceanic foodweb to be a serious concern, similar to that of the accumulation of some pesticides through other marine mammal foodwebs (Eriksson and Burton 2003, Slip and Burton 2009).

Macquarie Island has suffered significant impacts from introduced pests, including the Māori hen (*Gallirallus australis*), cats (*Felis catus*), rabbits (*Oryctolagus cuniculus*) and rodents (*Rattus rattus, Mus musculus*). The Māori hen or weka, was brought to Macquarie Island in the nineteenth century and competed with the native Macquarie Island parakeet and rail, which became extinct in situ. Weka were eradicated from the island by 1988. Feral cats, present since at least 1820, have had a major impact on ground and burrow-nest birds. Cat control measures were first implemented in 1974, and cats were finally eradicated in 2001/2.

Rabbits were brought to the island in the late 1870s for food and quickly colonised the steep, soft-soiled hillsides and the plateau regions, having a massive impact on vegetation and soil stability. An eradication plan for mice, ship rats and rabbits began in 2007, completed in 2011, and after several seasons of monitoring declared a success in 2014 (Terauds et al. 2014).

All vessels visiting the reserve must have a current 'Ship Sanitation Control Exemption Certificate' and provide evidence of ship hull cleanliness demonstrating that the ship is free of marine invasive species. Effective rat guards must be fitted to mooring lines when alongside at any port prior to entering the reserve. Mooring lines or any other lines cannot be run to the shore at any time and ships should anchor at least 1,000m offshore whenever possible, and must be anchored so as to prevent any approach closer than two hundred (200) metres to the shore at any point of the ship's swing. A network of rodent (either poison bait and/or break-back trap) stations must be installed in high-risk areas of the ship (in close proximity to ambient food storage areas, food preparation, serving and dining areas, and passenger cabins). The interior and exterior areas of each vessel must be checked for the presence of any exotic species (such as rodents, invertebrates or birds) or organic material (such as dirt or leaves) prior to entering the reserve. No known incursions of marine invasive pests have been recorded.

While operational discharges from vessels are not defined as 'dumping' under the *1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*, permits are required for any sea dumping of controlled material (including certain wastes and other matter). This is regulated under the Commonwealth *Environment Protection (Sea Dumping) Act 1981*, which gives effect to Australia's obligations under the Protocol, as well as other aspects of Australia's international obligations under the London Dumping Convention 1972. The Macquarie Island Nature Reserve and World Heritage Area Management Plan 2006 regulates the marine environment to 3 nautical miles, and adopts the strategic objectives, policies and actions for the Highly Protected Zone (HPZ) (IUCN Category 1a) of the broader Macquarie Island Marine Park Management Plan. Together these plans regulate that ballast water may not be discharged within any of the marine areas, and preferably not within Australia's EEZ around the reserve.

4.3 Industry (fisheries)

Historically the first recorded use of the island was for the seal industry. In 1810 sealers landed on Macquarie Island and within 18 months more than 120,000 seal skins had been returned to Sydney. Twenty years later the fur seal population had been decimated and the elephant seal population reduced to about 30 percent of its original numbers (Commonwealth of Australia 2015; not clear in report whether these numbers refer only to Macquarie Island or the South-east marine region in total).

The main current extractive use within the waters around Macquarie Island is commercial fishing. The only species targeted is Patagonian toothfish (*Dissostichus eleginoides*) which is widely distributed around the Southern Ocean in waters south of 30-35 degrees. It occurs at a range of depths down to about 1800 m. Around Macquarie Island, its distribution extends to the northeast into New Zealand's EEZ. The population around Macquarie Island is regarded and managed as a separate stock.

The Macquarie Island Toothfish Fishery (MITF) started in the mid-1990s, initially focused on the Aurora Trough immediately to the west of Macquarie Island. Fishing was initially by trawling, with a rapid transition to longlining from 2007 to 2009. Catch levels peaked at over 1700 t in 1996/97 but reduced rapidly thereafter, following initial stock assessment advice. Since 2011, catch levels have fluctuated between 410 and 555t. The area fished has also expanded over time, to both the north and south along the Macquarie Ridge, with some contraction of area fished in recent years. (See Figure 16 from AFMA/MSC). Longline fishing is permitted in the Habitat Protection Zones of the Marine Park, but has not taken place by voluntary agreement of fishers. Only two fishing companies have a right of access to the fishery, and these companies currently pool their quota allocation so that a single longline vessel takes the entire catch for the MITF each fishing season.

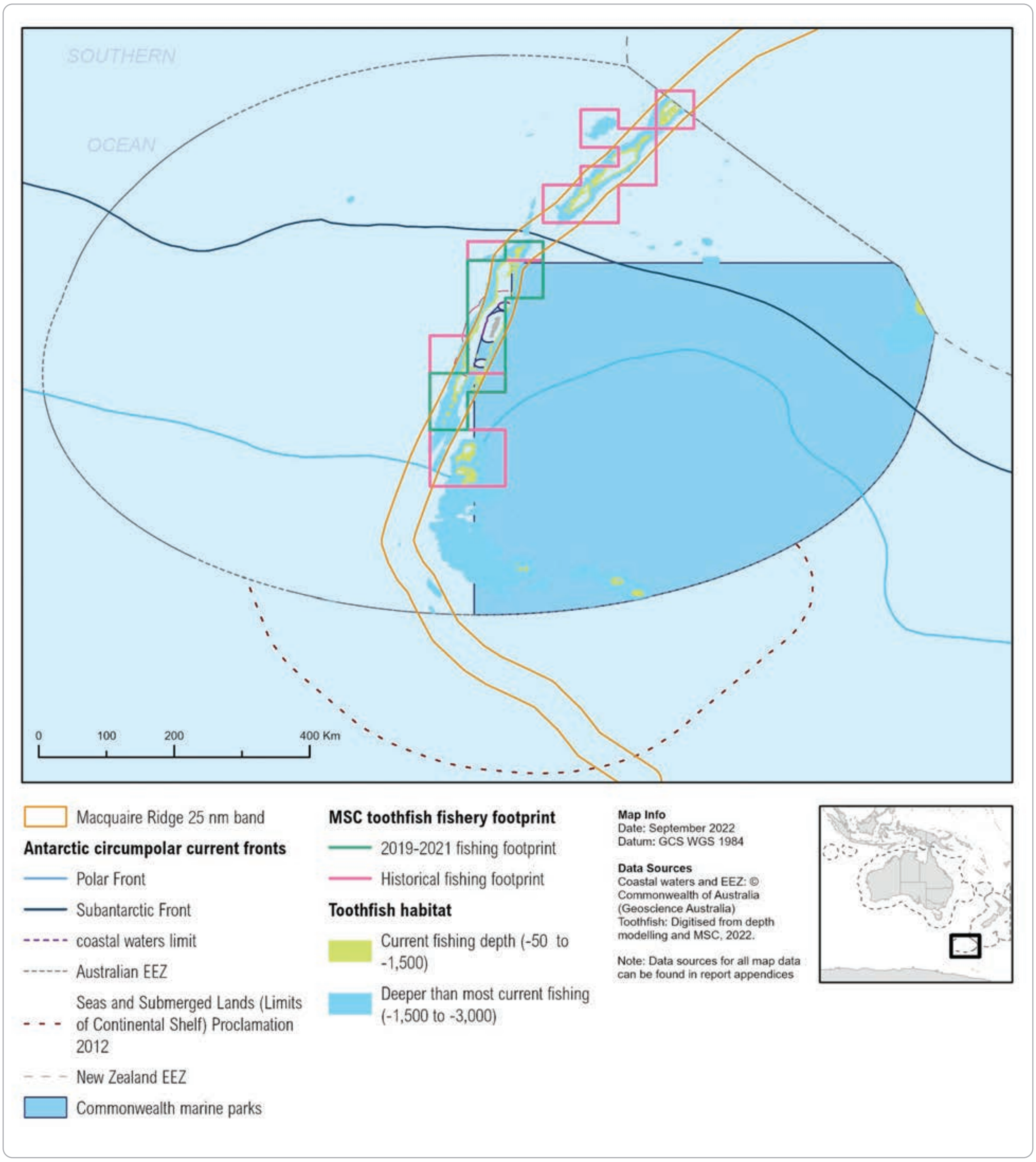


Figure 16: Fishing Footprint (reproduced from MSC 2022).

The MITF has been closely monitored from its inception and has been the focus of considerable research. This research includes extensive tagging of Patagonian toothfish caught in the fishery, with recaptures of tagged fish leading to more robust estimates of stock size and depletion. The very high (100%) level of observer coverage of fishing operations means that bycatch and interactions with protected and threatened species are also well understood. Interactions of fishing gear with benthic habitat and species have also been studied, as has the possible impacts through the food chain of removal of the target species on marine mammals and seabirds.

Given this level of monitoring and research, the ecological impacts of the fishery on the waters around Macquarie Island are relatively well understood. The most recent stock assessment (Hillary and Day 2021) shows a gradual decline in abundance of toothfish since the start of fishing. The model estimates the current median depletion of female spawning biomass at 0.7 (range 0.65 to 0.76) relative to unfished levels. This is well above the longer-term management target of 0.5. There is some spatial variation in the level of depletion north and south.

Since all fishing operations are monitored by independent scientific observers, levels of bycatch, gear loss, and interactions with wildlife are well understood. The fishery only targets toothfish, which comprise 97-99% of the catch. All other species caught are recorded and discarding is tightly controlled to minimise interactions with wildlife. No interactions with seabirds or marine mammals have been recorded in the past five years (MSC 2022).

The effect of fishing gear on benthic habitat and species is monitored and has been assessed. Bottom trawling has a larger impact than demersal longlining but has been discontinued since 2009. Demersal longlining can snag erect benthic species with complex morphology and needs to be considered. Demersal longlines are currently set deeper than 1200 m where Vulnerable Marine Ecosystem species of concern are likely to be less abundant but longlining also targets more complex habitat on steeper slopes than trawling.

An assessment of the benthic impacts from fishing around Macquarie Island up to 2015 has been undertaken (Dell et al. 2016, based on methods developed by Welsford et al. 2014). The Dell study found, using the Welsford model, that the removal of benthic fauna from the combination of trawling and demersal longlining was no more than 3% of biomass, but also noted the uncertainty in this estimate and the paucity of information about benthic assemblages in the area fished. The Welsford study did find evidence for impacts of demersal longlines on erect benthic fauna and noted the as yet undocumented but possible minimum recovery times from such damage of decades to centuries. It also recommended that the field methods developed in the study, including deployment of cameras and assessing the swept area of the lines, could be used to improve information and better validate impacts. The Dell study recommended further research to assess whether the existing marine park provides comprehensive, adequate and representative protection of vulnerable benthos.

The potential for impacts of the MITF on seals and seabirds through trophic interactions has been considered (Goldsworthy et al. 2001) where the authors concluded that the trophic linkages between toothfish and these marine predators was generally weak. Since then, studies elsewhere have indicated the important role that toothfish can play as top predators in food webs. Consideration of food web interactions of the fishery may need to be updated in line with other food web studies (e.g. Subramaniam 2020).

The ecological impact of the MITF has been subject to external review by the international Marine Stewardship Council (MSC) since 2012. The MSC assesses fisheries against three principles with associated standards (https://www.msc.org/en-au/standards-and-certification/fisheries-standard). Principle 1 assesses the status of the target species and the robustness of the harvest strategy used to manage it. Principle 2 considers impacts of the fishery on byproduct, bycatch, threatened and protected species, benthic habitats and ecosystems. Principle 3 assesses the robustness of the overall management system. The fishery was found to be compliant with the MSC standard in 2012 and again in 2017 and is currently undergoing reassessment. A final draft report (MSC 2022) finds the fishery to be still compliant across all three Principles and meeting the MSC standard at a high level of performance.

4.4 Scientific field activities

Macquarie Island's strategic position surrounded by a cold ocean and clean air makes data collected on the island uniquely valuable in weather forecasting and atmospheric monitoring. It is an important site for studies of the ionosphere and upper atmospheric physics, including observations of the ozone layer.

In 1948 the Australian Government built a scientific station at the northern end of the island, and over the past 7 decades of occupation, the footprint of the station has been subject to environmental incidents, including fuel spills associated with bulk fuel storage and use (King et al. 2020). An oil spill in the marine environment also occurred during the grounding of the ice breaker, Nella Dan, during resupply operations in 1987 (King et al. 2020). There are two fuel-contaminated sites within the station footprint, which have a complex history of contamination associated with station activities. Elevated hydrocarbon contamination was documented more than 25years ago (Deprez et al. 1994), and since that time at least 1 other fuel spill event (in 2002) has been reported (Rayner et al. 2007). Since then, remediation was carried out on site from 2009 to 2016. A permeable reactive barrier was installed in 2014 to capture and treat hydrocarbon-contaminated groundwater (Freidman et al. 2017). To date, ecotoxicology research has concentrated on the impacts of fuel contamination in the terrestrial ecosystem (Errington, King, Wilkins et al. 2018).

There has been substantially less assessment of potential risks to adjacent marine communities, apart from studies of the effect of hydrocarbons on marine communities at Macquarie Island following the 1987 grounding of the *Nella Dan* (Smith and Simpson 1995, 1998). Although the marine environment is less directly exposed to significant hydrocarbon sources, groundwater monitoring has identified seepages of fuel-contaminated water discharging via coastal cuts onto the shoreline margins of the contaminated sites (King et al. 2020). Fuel and other contaminants are therefore at risk of migrating from these groundwater seepages to the coastal marine environment. Whether this contamination source poses a risk to the Macquarie Island marine environment is unknown.

King et al. (2020) in a study of groundwater discharges to the natural environment report that concentrations of individual hydrocarbon compounds including toluene, naphthalene, and benzene in test solutions were below current Australian and New Zealand water quality default guideline values for marine waters (ANZG 2018). However, concentrations of N were above laboratory limit of reporting in most test solutions, with elevated ammonia and nitrate concentrations in excess of the current default guidelines. Although the source of higher nutrient concentrations may in part be attributed to input from wildlife (Erskine et al. 1998), a likely contributing source is residual nutrients from additions during the remediation process. King et al. (2020) concluded that the likelihood of these groundwater discharges causing an effect on communities in the receiving environment was low and no further site management was required.

Sampling of the marine benthic environment has been minimal, primarily the two surveys SS0199 and TAN0803. Scientific sampling with dredges and scientific trawls has a much smaller footprint than the cumulative impact of multiple longer tows with larger gear associated with commercial fishing. Scientific impacts would have been undetectable or minimal at the scale of the Park or EEZ, but have provided essential information on the distinct communities, species and genotypes used in this report. This information could not have been obtained from visual surveys alone.

4.5 Cumulative pressures and impacts

Pressures on the M-EEZ stem from direct human activities in the area and from the impact of ocean warming as a consequence of climate change and increased acidification as a consequence of increased concentrations of carbon dioxide in the atmosphere. While individual pressures may arise independently, their impacts are likely to be cumulative, as a consequence of multiple pressures acting simultaneously and also as a result of the same pressures persisting over long time periods. It is also possible in some cases that an increase in one pressure may alleviate an increase in other pressures.

Ocean warming is expected to result in changes in the M-EEZ, although the ability to predict the nature and consequence of such changes is limited. A defining feature of the M-EEZ is the boundary between subtropical and polar water and there is little evidence for historic (or projected) southward movement of these fronts. Furthermore, if ocean warming proceeds at different rates this may intensify the frontal processes (eddies). In this scenario the M-EEZ is likely to remain a region of dynamic oceanographic frontal systems and remain an important area for a range of threatened species.

Changes in the ocean environment, especially warming and acidification, may impact species directly and/or indirectly through increased metabolic demand reducing their resilience to other impacts. Ocean de-oxygenation is less likely to be an issue in this high energy ocean environment.

Direct human impacts in the M-EEZ potentially include fishing and other extractive industries such as seabed mining. At present the longline fishery for Patagonian toothfish is relatively low in terms of its spatial footprint and impact on non-target species. However, future projections of ocean warming suggest the potential for warmer water pelagic species to occur in the M-EEZ potentially resulting in opportunities for new fisheries to develop. If these fisheries operated in the M-EEZ they would present a risk to a number of the threatened seabirds that breed and/or feed in the region.

Seabed mining and bioprospecting are both possible future activities, however there are many more accessible places, closer to existing infrastructure to be targeted before the M-EEZ is likely to become an attractive prospect.

Tourism in the region is focussed on visits to Macquarie Island and its management is essentially a terrestrial process other than generic shipping and vessel safety issues. Small boat use is generally restricted to essential tasks, to minimise atmospheric emissions, wildlife disturbance and the potential for fuel spills. A Macquarie Island Station Oil Spill Contingency Plan is in place and provides policies and procedures for dealing with nearshore oil spills in the waters of Buckles Bay.

Pressure on breeding seabird species in the M-EEZ has been alleviated with the removal of non-native mammalian species from Macquarie Island; this has already had positive outcomes for a number of threatened species.

The M-EEZ represents a distinct province in the South-east Marine Region. It extends the environmental and biological diversity of this region, thereby increasing the resilience of the region to ongoing climate change by providing additional opportunities for adaptation. It may also provide a north-south corridor for temperate bathyal fauna, as suggested by the north-south gradient in temperate to Sub-Antarctic species or genotypes, although this would depend on the interplay between warming water and a shoaling aragonite saturation horizon.

5.0 Management

5.1 Legislation, policy and international obligations

5.1.1 International obligations & treaties

Macquarie Island was first nominated for inclusion on the World Heritage List in 1992 for geological values, but the nomination was declined by the World Heritage Committee, although Australian authorities were asked to consider Macquarie Island in the wider sense of an oceanic island ecosystem representative of the Sub-Antarctic biogeographic realm. Macquarie Island was subsequently inscribed on the World Heritage List by the World Heritage Committee in 1997. A Statement of Outstanding Universal Value was adopted by the World Heritage Committee in 2012.

Macquarie Island is listed for outstanding universal value under two criteria of the World heritage Convention, namely:

> *Criterion (vii) to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; and*
>
> *Criterion (viii) to be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features.*

It provides a unique opportunity to study, in detail, geological features and processes of oceanic crust formation and plate boundary dynamics, as it is the only place on earth where rocks from the earth's mantle (6 kilometres below the ocean floor) are being actively exposed above sea level. These unique exposures include excellent examples of pillow basalts and other extrusive rocks. Macquarie Island is the exposed crest of the undersea Macquarie Ridge, raised to its present position where the Indo-Australian tectonic plate meets the Pacific plate. Overall, its landscape of steep escarpments, lakes, and Sub-Antarctic vegetation provides an outstanding spectacle of wild, natural beauty.

Macquarie Island is world renowned for its wild environment with huge congregations of penguins and seals populating what has been described as a "a speck of green in the vast, windswept sea, it is a haven for many creatures that live above and below the waves" (Lester and Tulloch 2019).

The Macquarie Island World Heritage Area covers the island and all the seas out to the edge of the outer limit of the territorial sea (12 nautical miles from the territorial sea baselines established under the *Seas and Submerged Lands Act 1973*) (see Figure 3) and is managed to protect heritage that is of such outstanding universal value that its conservation is important for current and future generations. The World Heritage area is protected under the legislative protection of the Tasmanian Macquarie Island Nature Reserve to 3 nautical miles, and from 3 to 12 nautical miles under the Commonwealth Macquarie Island Marine Park. Approximately 45% of the Commonwealth waters of the World Heritage Area are currently outside of the Macquarie Island Marine Park.

The land area (contained within the Macquarie Island Nature Reserve) is 128 square kilometres and the total area of the World Heritage Area is 5272 square kilometres. The nomination for World Heritage listing focused on the island's geology and particularly on the sequences from the oceanic lithosphere including the oceanic crust and upper mantle. These elements of the island's geo-conservation significance are summarised below:

> *"It is the only known locality in the world where oceanic lithosphere formed at a normal mid-ocean spreading ridge environment is being exposed above sea-level within a major ocean basin. It provides a unique example of ocean crust uplifted as a result of transpression at a strike-slip plate boundary in an oceanic setting. The exposed rock sequence provides a uniquely complete section through the Earth's oceanic crust to upper mantle rocks. The geological evolution of Macquarie Island began 10 million years ago and continues today with the island experiencing earthquakes and a rapid rate of uplift, all of which are related to active geological processes along the boundary between two plates. The island is unique in that its present geomorphology shows features of the marine erosion (raised beaches and benches) that have progressively affected its whole surface during uplift. This unique feature complements, and is a consequence of, its unique geological attribute of being uplifted sea-floor. It, therefore, has outstanding universal value in that it provides a unique opportunity to study, in detail, geological features and processes of oceanic crust formation and plate boundary dynamics above sea-level." (DEST 1996)*

Australia is a signatory to the Agreement on the Conservation of Albatrosses and Petrels (ACAP) which entered into force in 2004 in order to conserve albatrosses and petrels by coordinating international activities to mitigate threats to their populations. In 2019 ACAP's Advisory Committee declared that a conservation crisis continues to be faced by its 31 listed species, with thousands of albatrosses, petrels and shearwaters dying every year as a result of fisheries operations.

Macquarie Ridge immediately to the south of the Macquarie Island EEZ is one of nine areas of Australian extended continental shelf agreed by the UN's Commission on the Limits of the Continental Shelf (CLCS) on 9 April 2008. This area is addressed in Section 9.1 "Consideration beyond the M-EEZ".

Additional sectoral and regional organisations directly or indirectly relevant to the marine environment of the M-EEZ and the adjacent extended continental shelf include the Convention on Migratory Species (CMS), the South Pacific Regional Fisheries Management Organisation (SPRFMO), the International Maritime Organisation (IMO), the International Seabed Authority (ISA), the UN Fish Stocks Agreement (UNFSA), and general agreements under the CBD, UNCLOS, and the UN Sustainable Development Goals (SDGs). The draft "BBNJ Treaty", also known as the "Treaty of the High Seas" for the conservation and sustainable use of Biodiversity Beyond National Jurisdiction (BBNJ) may also be relevant to management of the extended continental shelf and surrounding areas.

5.1.2 Legislation & policy

National

The Commonwealth Macquarie Island Marine Park includes a section of Australian waters to the east of Macquarie Island from 3 nautical miles to the edge of the EEZ (Figure 3) and is managed as part of the South-east Marine Parks Network (Parks Australia 2022).

Regional

Macquarie Island, the adjacent islets of Judge and Clerk and Bishop and Clerk, and all surrounding waters out to three nautical miles, are managed as the Macquarie Island Nature Reserve by the Tasmanian Parks and Wildlife Service (PWS). Management of the reserve is done in conjunction with the wider World Heritage Area and is guided by the Macquarie Island Nature Reserve and World Heritage Area Management Plan (2006).

5.2 Management approaches

5.2.1. Fisheries

The Macquarie Island Toothfish Fishery (MITF) is managed by the Australian Fisheries Management Authority (AFMA) under the *Fisheries Management Act 1991*. While the fishery is outside the area of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), the ecosystem-based management approach used by CCAMLR has been adopted by AFMA for the MITF. This includes comprehensive observer coverage of the fishery and a precautionary harvest control rule for setting quotas. The fishery is also subject to the spatial constraints imposed by both the closure of Tasmanian state waters out to 3 nautical miles around Macquarie Island, as well as the Commonwealth marine park out to 200 nautical miles to the southeast of Macquarie Island, comprising over 30% of the EEZ around the island.

As with all Commonwealth-managed fisheries, the MITF is subject to a management plan. The AFMA website lists the latest management plan as of 2006, with modifications up to 2016. However, most of the operational aspects of management sit in regulations and processes outside the formal management plan. Advice on management of the fishery is provided by the Sub-Antarctic Management Advisory Committee (SouthMAC) which includes representatives from AFMA, scientific agencies, environmental non-government organisations, and industry. Technical advice is provided by the Sub-Antarctic Resource Assessment Group (SARAG) comprising fishery scientists, fishing industry members, an economist, an AFMA manager, and an environmental non-government organisation representative.

The harvest strategy for the MITF follows the same CCAMLR approach used for other Patagonian toothfish fisheries around the Southern Ocean (Constable et al. 2000). The harvest strategy determines the maximum constant catch level that, applied over a 35 year projection period, satisfies the following two criteria: 1) the probability that the female spawning biomass will fall below 20% of unfished levels is less than 0.1; 2) the median escapement (stock level) for the female spawning biomass shall not be less than 50% over the projection period. Both the long projection period and the requirement for a constant catch level (even though in practice it will change over time in response to updated information) lead to a conservative approach to setting quotas, which are updated every two years.

Management arrangements to minimise bycatch include: 1) a prohibition on targeting any marine life other than Patagonian toothfish; 2) all bycatch and offal must be retained to help minimise interactions with mammals and seabirds; 3) most retained bycatch is minced into offal with the exception of some species like jellyfish, sponges, crabs and coral which are returned to the water as they have low post-release mortality and are unlikely to attract seabirds and mammals; and 4) a precautionary bycatch limit of 50 t for any one bycatch species.

Longline fishing is known to attract seabirds and in some cases cause seabird mortality, for example when they target bait on hooks. A threat abatement plan requires that less than 0.01 seabirds are killed per 1000 hooks set but additional measures protect particularly vulnerable species such as wandering albatross, black-browed albatross, grey headed albatross, grey petrel and soft plumaged petrel. For these species, a single bird killed through interaction with the fishing gear results in immediate suspension of fishing for the vessel involved for the remainder of the fishing season. The 100% level of observer coverage ensures compliance with this requirement. A number of other management measures also help minimise interactions with seabirds, including: 1) a prohibition of dumping of offal; 2) line setting can only occur at night; 3) paired streamer lines are used to scare birds away from gear during line setting; 4) a bird excluder device discourages birds from accessing baited lines during line hauling; 5) a prohibition on use of plastic packaging bands; and 6) reduced lighting to reduce the risk of seabirds colliding with the vessel. All these measures have resulted in no reported interactions with seabirds or mammals over the past five years.

The main measures limiting benthic impacts from fishing are the declaration of Tasmanian state waters out to 3 nautical miles as a nature reserve, and the Commonwealth marine park in the southeast quadrant of the EEZ. The location of fishing is well monitored both through observer coverage and through requirement of vessels to be fitted with a Vessel Monitoring System (VMS). While the footprint of the fishery is limited to areas along the Macquarie ridge (Figure 17), some level of damage to benthic biota does occur within this area, as discussed in section 4.3.

While the Commonwealth marine park has restricted access to some fishable grounds for the Macquarie Island toothfish fishery, this has not prevented the quota being taken in most years. Parts of the historical fishing footprint do abut the boundaries of the park, which according to the fishing companies do make it more difficult to fish in these areas (Figure 16). Some of this historical footprint is for the trawl fishery, which would now be excluded from both the sanctuary zone and the habitat/ species management zones, but the current bottom longline fishery is not excluded from the habitat/ species management zones. However the current fishing companies have not fished in the habitat/species management zones of the Macquarie Island Marine Park to date. It seems more likely that the 3 nm protection of state waters is constraining the footprint of the current fishery, which is almost entirely to the west, north and south of Macquarie Island along the Macquarie Ridge. While it is possible that toothfish have been afforded some protection and benefit from existing marine parks, the strong environmental performance of the fishery, attested to by its longer-term MSC certification, is mainly attributable to sound fisheries management and the responsible approach taken by the fishing industry, and not to any protection afforded by marine parks.

As noted above, past and recent assessments of the MITF under MSC certification requirements have found that the fishery meets all MSC standards, including for management systems under Principle 3. The only condition listed for the latest MSC recertification is that 1) the bycatch and discarding work plan, established in 2013, be updated; and 2) the ecological risk assessment, published in 2010, also be updated.

5.2.2. Protected areas

Generally, conservation efforts focus on the protection of distinctive areas or species because of their unique value to biodiversity, but in the marine environment it is also necessary to understand patterns of species distribution that traverse many different areas of our oceans.

The following section outlines the current set of protections that exist surrounding Macquarie Island, namely the Tasmanian Macquarie Island Nature Reserve (covering the island and surrounding waters out to three nautical miles), the Macquarie Island World Heritage Area (the island and waters out to 12 nautical miles), and the Macquarie Island Commonwealth Marine Park (a marine park to the east of the island from 3 nautical miles to the edge of the EEZ).

5.2.2.1 Macquarie Island Nature Reserve

Day-to-day management of the Macquarie Island Nature Reserve (the island and surrounding waters out to three nautical miles) is the responsibility of the Tasmania PWS within the Department of Natural Resources and the Environment (NRET). Macquarie Island Nature Reserve is a restricted area under Regulation 18 of the *National Parks and Reserves Management Regulations 2019* and all visitors must have an access authority, or be accompanied by an authorised person, in order to enter or remain in the reserve. All commercial educational tourist operators must also obtain a business licence under the *National Parks and Reserves Management Act 2002* from the Tasmanian Director of National Parks and Wildlife before any visits can be authorised.

The following quotas for educational tourist visits to the reserve are expected to apply for the 2022-2023 season, however these may be reduced in response to COVID-19 risk management requirements and/or PWS operational constraints:

- Up to 18 ships, with up to 1,500 visitors in total, can enter the reserve per financial year for the purpose of undertaking commercial shore visits;
- Out of the 18 commercial shore visits, only 12 visits may be made to the Australian Antarctic division scientific station per financial year;
- Up to two ships can enter the reserve per financial year for the purpose of conducting small boat cruising only visits (no shore visits); and
- Up to two yachts can enter the reserve per financial year for the purpose of undertaking shore visits. (NRET 2022).

All visitors, staff and crew must be briefed on the reserve status of the Island and surrounding waters in order to protect the environment and wildlife as a condition of the tourist visit. No collection or disturbance of flora, fauna, historical sites, artefacts, geological specimens or objects is permitted. No fishing is permitted within the reserve.

5.2.2.2 Macquarie Island World Heritage Area

Given the focus of activities that could impact the world heritage values occur on the island and in the state waters around the island the total world heritage area is in effect managed under the Macquarie Island Nature Reserve and World Heritage Area Management Plan (Parks and Wildlife 2006). The waters from 3 to 12 nautical miles are also managed as part of the Commonwealth Macquarie Island Marine Park under the Macquarie Island Marine Park Management Plan (Commonwealth of Australia 2001). Together these two management plans provide overall protection consistent with Australia's World Heritage obligations. The management prescriptions of the Macquarie Island Marine Park Management Plan complement the prescriptions of the Macquarie Island Nature Reserve and World Heritage Area Management Plan (Parks and Wildlife 2006).

In 2013, a report on the state of conservation of the property gave an overview of the implementation of the Macquarie Island Pest Eradication Plan and included new findings on the dieback of the Macquarie cushion plant and impacts of long-line fishing within and outside the Australian Exclusive Economic Zone around Macquarie Island. The Macquarie Island Pest Eradication Plan was aimed at the eradication of introduced rabbits and rodents (mice and rats), and no rabbits or rodents have been detected since 2011. Vegetation has been re-established and seabirds returned to breed in previously affected areas.

In more recent years Australia has reported the progressive dieback of the Macquarie cushion plant which is attributed to climate change. Initially dieback appeared triggered by increased drying due to greater wind speeds and hours of sunshine and disease, however, the dieback remains pervasive, persisting under increasingly wet and warm conditions. The cushion remains healthiest in the southwest of the island where temperatures are coldest, with the highest number of freezing days (Dickson et al. 2021).

5.2.2.3 Macquarie Island Marine Park

The Commonwealth Government is responsible for the management of the 'Macquarie Island Region' which are the Commonwealth waters that extend from the 3 nautical mile zones around each of the exposed outcrops (Macquarie Island, Bishop and Clerk Islets, and Judge and Clerk Islets) to the edge of the EEZ around Macquarie Island and associated islets (Commonwealth of Australia 2001). This same area is referred to as the 'Macquarie Island Province' in the Interim Marine and Coastal Regionalisation for Australia (IMCRA Technical Group, 1998). The Macquarie Island Marine Park (see Figure 3) was proclaimed in October 1999 and includes significant feeding and migratory areas for a number of threatened marine mammals and seabirds, a variety of benthic habitats spanning a wide range of depths and oceanic conditions, and seabed sediments down to 100 metres below the seafloor. The marine park covers an area of approximately 16.2 million hectares and is assigned as IUCN category IV (habitat/species management area), and contains a highly protected zone situated between two highly regulated habitat/species management zones. The management plan divides the marine park into three zones; one highly protected zone (IUCN category Ia — strict nature reserve approximately 5.8 million hectares) at its centre and two habitat/species management zones (IUCN category IV — habitat/species management zone covering an area of approximately 7.7 million hectares), one either side of the highly protected zone (see Figure 2). The highly protected zone is managed primarily for scientific research and environmental monitoring, with no commercial or recreational fishing, mining or commercial tourism activities allowed. Within the habitat/species management zones no mining operations, including petroleum and/or mineral exploration or extraction, are allowed. Commercial fishing is possible in accordance with a fishing concession granted by AFMA but is currently not active in the marine park.

Macquarie Island Marine Park is a representative sample of a much larger area used by a number of broad-ranging species (Commonwealth of Australia 2001). Millions of seabirds and thousands of seals rely on both Macquarie Island and the surrounding waters but they also utilise marine ecosystems throughout the Sub-Antarctic. The Macquarie Island Marine Park provides a vital part of their protection but cooperative management arrangements across international boundaries is also important for their long-term survival.

The Macquarie Island Marine Park includes the only portion of the Campbell Plateau that is part of Australian waters (see Figure 1).

While the Macquarie Island Marine Park lies to the north of the area covered by the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), Australia ensures any conservation actions adjacent to the area covered by CCAMLR are in harmony with CCAMLR measures, particularly to ensure any harvesting is conducted in a responsible manner. This includes adopting the CCAMLR harvest strategy to set quotas, which results in more precautionary catch levels than required under the Commonwealth harvest strategy policy.

5.2.3 Threatened communities and species

The Macquarie Island region provides important habitat during various life stages of five species of seals (see section 3.2) and 38 species of seabirds (see Appendix 2.1). It also provides important feeding and migratory areas for many marine mammals (see Section 3.2), some of which have extremely large migratory or foraging ranges (Scott, 1994). These are all protected species under the EPBC Act (see Appendix 2.2 for the list of all EPBC listed marine mammal species recorded in the M-EEZ).

5.2.4 Cumulative impacts management

The Macquarie Island Nature Reserve and World Heritage Area Management Plan (2006) outlines a number of research priorities and actions that are part of the management approach to dealing with cumulative impacts on the island, and to a lesser extent flow on effects into the marine area. Generally cumulative impacts can be associated with some form of human activity and therefore the plan focus is on the specific human activities that occur on Macquarie Island as the probable place to monitor for any impacts. Furthermore, the Macquarie Island Nature Reserve and World Heritage Area includes Special Management Areas (SMAs) that are designated to further protect natural or historical values for wildlife. The SMAs are determined by species' conservation status, population numbers, breeding activity, vulnerability to human disturbance and cumulative impacts.

The Macquarie Island Nature Reserve and World Heritage Area Management Plan (2006) research priorities includes work to monitor impacts due to the conduct of research programs:

> *"Investigate the cumulative impacts of research programs on threatened species or species that are vulnerable to human disturbance, and their habitats".*

The Macquarie Island Nature Reserve and World Heritage Area Management Plan (2006) outlines a major action to monitor commercial educational tourism activity at the three Tourist Management Areas to determine cumulative impacts on the cultural and natural heritage values of the sites and for the presence of new alien species.

The Macquarie Island Nature Reserve and World Heritage Area Management Plan (2006) also includes an objective in minimise cumulative effects arising from waste management.

5.2.5 Future threats from fishing

Serious threats to the environmental values of the waters around Macquarie Island are unlikely to arise from continuation of the current Patagonian toothfish fishery. The stock itself is sustainably managed, there is minimal bycatch and no mortality of seabirds or marine mammals. There is likely to be some damage caused to benthic erect sessile fauna by bottom-set longlines, but this can be constrained by restricting the fishery to its recent spatial distribution (footprint). Broader trophic impacts of fishing toothfish have been shown to be minor. The fishing companies currently targeting Patagonian toothfish have expressed no interest in expanding fishing to target other benthic fish resources in the M-EEZ.

Future threats from fishing to the environmental values of the water around Macquarie Island could arise if substantial new fisheries were to develop targeting pelagic or midwater resources. Examples might include fisheries for krill or myctophids, or other pelagic species such as mackerel which could possibly expand their range in response to warming sea temperatures under projected climate change. Impacts from commercial fishing of such species could arise in at least two ways. Firstly, there could be mortality to seabirds or marine mammals arising from the fishing operations themselves. Secondly, there could be negative impacts on these same predators from reducing the abundance of their prey (i.e., impacts through the food chain). There is no current evidence that the emergence of such new fisheries targeting low trophic level pelagic or midwater species is likely or imminent.

Marine parks could play a role in limiting impacts from new or emerging pelagic fisheries if such were to develop. This would require that substantial areas be closed to fishing, to limit the impacts on predators from both bycatch and removal of prey (or interruption to prey fields). This would require that large areas would need to be designated as sanctuary zones (IUCN categories I or II), or as habitat/ species management zones (IUCN category IV) that restrict both benthic and pelagic fishing.

Additional forms of marine management and protection, apart from marine parks, would also be valuable if new fisheries are to be considered in the future. Fisheries around Macquarie Island are managed by AFMA under well-developed policies regarding target species management (the Commonwealth Fisheries Harvest Strategy Policy), bycatch (Commonwealth Fisheries Bycatch Policy) and require the assessment of broader aspects of sustainability, including trophic impacts, under fishery-specific environmental management plans. Fisheries management thus embodies the use of a wider set of management tools than just closed areas, though in practice the two can work in concert and have been shown to be effective. In considering the development of new fisheries in the M-EEZ, it would be important to assess the likely impacts on the broader environmental values of the region before any development took place.

6.0 Assessment of Comprehensiveness, Adequacy and Representativeness

The Guidelines for Establishing the National Representative System of Marine Protected Areas (known as the ANZECC Guidelines) (ANZECC 1998) were prepared to assist government agencies to develop and stakeholders to understand NRSMPA, with the primary goal being:

> *to establish and manage a comprehensive, adequate and representative system of MPAs to contribute to the long-term ecological viability of marine and estuarine systems, to maintain ecological processes and systems, and to protect Australia's biological diversity at all levels* (ANZECC 1998).

The ANZECC Guidelines include the CAR principles, as follows:

Comprehensiveness: The NRSMPA will include the full range of ecosystems recognised at an appropriate scale within and across each bioregion.

Adequacy: The NRSMPA will have the required level of reservation to ensure the ecological viability and integrity of populations, species and communities.

Representativeness: Areas that are selected for inclusion in MPAs should reasonably reflect the biotic diversity of the marine ecosystems from which they derive.

The Australian Government published the Goals and Principles for the establishment of the National Representative System of Marine Protected Areas in Commonwealth waters (the Goals and Principles) (DoE 2007), to clarify how the Australian Government would apply the ANZECC Guidelines to meet CAR objectives using biodiversity surrogates (Beeton et al. 2015). Surrogates include provincial bioregions, depth ranges, key ecological features and seafloor features. The expert scientific review of the Commonwealth Marine Reserves CMR network reviews progress of the CMR estate (excluding the South-east marine park network which was designed prior to finalisation of these 20 goals and principles) against the following goals and principles (Beeton et al. 2015):

Goal 1 - Each provincial bioregion occurring in the marine region should be represented at least once in the marine reserve network. Priority will be given to provincial bioregions not already represented in the National Representative System

Goal 2 - The marine reserve network should cover all depth ranges occurring in the region or other gradients in light penetration in waters over the continental shelf.

Goals 3 - The marine reserve network should seek to include examples of benthic/demersal biological features (for example, habitats, communities, sub-regional ecosystems, particularly those with high biodiversity value, species richness and endemism) known to occur in the marine region at a broad sub provincial (greater than hundreds of kilometres) scale.

Goal 4 - The marine reserve network should include all types of seafloor features. There are 21 seafloor types across the entire Exclusive Economic Zone. Some provincial bioregions will be characterized by the presence of a certain subset of features, such as continental slope or seamounts.

Principle 12 - Features should be replicated wherever possible within the system of marine reserves (that is, included more than once).

Principle 18 - The regional marine reserve network will aim to include some highly protected areas (IUCN Categories I and II) in each provincial bioregion.

The expert panel concluded in their 2015 review that for comprehensiveness and representativeness (excluding the South-east marine region which was not included in the review): *"Overall, the proclaimed CMR estate includes the vast majority of the biodiversity surrogates (primary conservation features) on which the design of the networks was based..... Broadly, what is missing or deficient is coverage by CMRs and Marine National Park Zones on the continental shelf, which reflects the greater use and immediate economic value of these waters"* (Beeton et al. 2015, p38); and for adequacy: *"while the CMR estate.... represents the most extensive and comprehensive 'whole-of-ocean' approach to marine conservation by any country, there are some gaps to be addressed in due course."* (Beeton et al. 2015, p40).

6.1 Assessment Zones (AZ)

The South-east marine region is one of six marine regions identified in Commonwealth waters around Australia. Profiles have been prepared for the marine regions to guide conservation management including identifying Australian marine parks for each region. They contain summaries of the conservation values of the region, including key ecological features, species listed under Part 13 of the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), and protected places including marine reserves, historic shipwrecks and heritage places in the Commonwealth marine area.

The South-east marine parks network came into effect in 2013 and was the first network described, prepared under a different process than was used for the subsequent marine regions. While the Macquarie Island marine park is part of the south-east marine parks network the consideration of marine parks within the M-EEZ was undertaken earlier than the remaining south-east region and was proclaimed in 1999. A south-east regional marine plan was established in 2004 which included the M-EEZ (National Oceans Office 2004). A South-east marine region profile (Commonwealth of Australia 2015) was developed subsequent to the declaration of the marine park network for consistency with other marine regions and this included the M-EEZ.

Eleven provincial bioregions were identified in the south-east Marine Region Profile (Commonwealth of Australia 2015). Provincial bioregions can represent provinces or transitions and follow the Integrated Marine and Coastal Regional Assessment (IMCRA v4.0). The Macquarie Island M-EEZ is classed as a provincial bioregion or province under this classification, that is an area of ocean with similar flora, fauna and ocean conditions.

The area of this bioregion is given as 477,430 km^2 and has a maximum depth as 6,737m. The south-east marine region profile did not cover Macquarie Island (as the marine park had been declared earlier) and consequently no key ecological features or biologically important areas were identified at that time. The Commonwealth marine area is identified as including the continental shelf claim immediately to the south of the EEZ.

The guiding goals and principles for establishing the NRSMPA include representing each provincial bioregion at least once (Goal 1), covering all depth ranges (Goal 2) and including multiple examples of all types of benthic/demersal features (Goals 3, 4, 12). The information available for the M-EEZ is not comprehensive. The Macquarie Island Marine Park Management Plan 2001-2008 (Commonwealth of Australia 2001) recognizes "three main water bodies separated by two oceanic fronts" which interact with the Macquarie Ridge to suggest that there are "portions of at least six different large-scale oceanographic habitats in the region". Benthic communities are reported to vary along north-south and east-west gradients. Following this lead, supported by additional review and analysis, we have divided the M-EEZ into nine assessment zones based on the oceanography, topography, and biology, and suggest that conservation planning consider each assessment zone separately.

The combination of the ocean fronts and the Macquarie Ridge divide the M-EEZ into 9 assessment zones (AZ) related to ocean and geomorphic features (Figure 17) (all previous maps can be interpreted in relation to the AZs by simply using the fronts and the ridge as a guide to divide the area). The assessment zones are used to characterise the different pelagic and benthic habitats of the M-EEZ. At present, there is not a consistent set of terms across scientific disciplines relating to the ocean areas between fronts or amongst frontal systems. For this reason, we adopt terms for the assessment zones (AZ) that relate to their relative location within the M-EEZ.

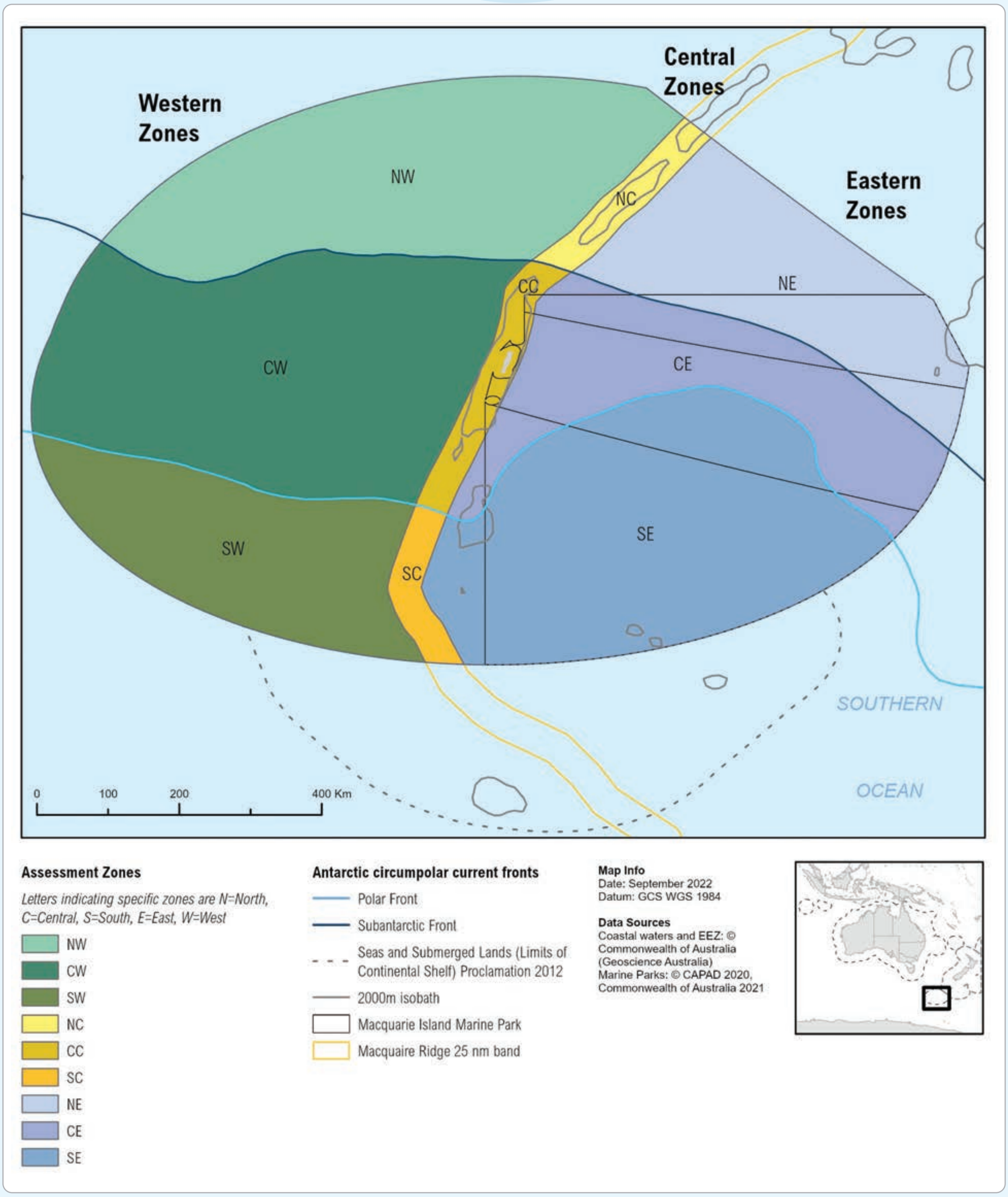


Figure 17: Assessment zones used to assess comprehensiveness, adequacy and representativeness of the existing reserve system within the M-EEZ.

Letters indicating specific zones are N=North, C=Central, S=South, E=East, W=West. Yellow lines indicate a 25 nm band along the Macquarie Ridge, centred on the junction of the geological plates. Solid grey lines indicate the 2000m isobath.

6.2 Attributes of Assessment Zones

The assessment zones can be differentiated based on the sea surface temperature, Chlorophyll *a* density and ocean depth. From north to south, the northern, central and southern zones are clearly different in their temperature regimes. The central and southern zones have marked increases in chlorophyll to the east compared to the west with mid-range chlorophyll on the Macquarie Ridge. Shallow areas are predominantly found in the Macquarie Ridge AZs except for seamounts scattered throughout. The results are summarised in Appendix 3. The categories of ocean depth relate to the combined benthic and pelagic bathomes of Last et al. (2010), which were assessed for different types of benthic and pelagic habitats in Australian waters. The percentage of protection in each combination of bathome and assessment zone is also presented in Appendix 3 in relation to the different conservation areas - the 3nm coastal reserve, and the three parts of the Commonwealth marine park. The defining features of each zone are described below.

Western Assessment Zones

The western AZ are in waters deeper than 3000m, except for a seamount adjacent to the ridge in the North-West AZ.

The seafloor to the west of Macquarie Ridge is mostly unsampled - no samples are recorded in the NIWA invertebrate collection (personal communication Karen Schnabel, NIWA) (very limited incomplete data in the Australian collection, personal communication Tim O'Hara, Museum Victoria) and no samples deeper than 900m (i.e the base of slope of Macquarie Ridge) were taken on CSIRO survey SS0199. These sites immediately adjacent to the western zones, clustered with the mid-depth sites to the east of the island, are characterized by few species and low biomass (Butler et al. 2000). The lack of seapens at shallow and mid-depth sites to the west of Macquarie Ridge was considered consistent with greater water energy and less sediment deposition.

Pelagic seabirds in the western AZ include Antarctic and temperate species reflecting the different water-masses in the three zones. However, as pelagic seabirds often target their foraging on frontal zones and features, the boundaries between the assessment zones are intrinsically important. This is particularly apparent in the M-EEZ where there are three distinct oceanographic zones compressed into a relatively small latitudinal range.

Mesopelagic fish and squid would be expected to be present throughout the western AZ with the species composition likely to be different in North-West AZ compared to the Central-West and South-West AZ given the different water temperatures in those zones.

Central Assessment Zones

The central assessment zones have the greatest diversity of depth regimes of the M-EEZ. These zones are the 25 nautical mile band encompassing the meeting of the tectonic plates, known as the Macquarie Ridge Complex. The ocean frontal systems combined with the topography clearly delineate three different areas in the M-EEZ.

Macquarie Ridge contains the shallowest sites where most samples have been collected. Habitat-forming benthic fauna were observed on ridges and overhangs north and south of Macquarie Island; deeper sites on the slope where rocks or rubble were present were relatively depauperate. Typical soft sediment fauna was observed on flat bottom at the base of troughs and canyons (Butler et al. 2000).

The Macquarie Ridge is a rare example of a roughly N-S feature in the Southern Ocean. It shares many species with southern Australia, New Zealand Sub-Antarctic and Antarctic locations. For example, O'Hara et al. (2013) found 31 morpho-species of ophiuroid shared with south-east Australia, 33 shared with southern New Zealand and 30 with Sub-Antarctic and Antarctic locations.

North-central-south patterns of genetic connectivity in the New Zealand EEZ including Macquarie Ridge were observed for the solitary coral *Desmophyllum dianthus* with high levels of self-recruitment but also high connectivity between distant sites (Holland et al. 2022). High levels of self-recruitment and a north-central-south regional differentiation were also observed for two additional deep-sea coral species including the reef-building coral *Solenosmila variabilis* on Macquarie Ridge (Zeng et al. 2017).

Yan et al. (2020) noted the importance of source and sink populations for three squat lobster species (*Munida* sp.) and the importance of considering gene flow at the regional scale. Macquarie Ridge was identified as a source population for a deep-sea sponge (*Poecillastra laminaris* Sollas 1886), contributing migrants to the Kermadec Ridge and Challenger Plateau populations (Zeng et al. 2019). They also observed the north-central-south differentiation observed in other deep-sea benthos.

O'Hara et al. (2002) identified a gradient of benthic fauna along the ridge itself. Samples collected with 4 bottom trawl surveys and one epibenthic sled survey along the ridge that could be separated into north, central and southern clusters based on their presence/absence. This represents a gradient from a New Zealand to an Antarctic fauna. Butler et al. (2000) also identified latitudinal and depth gradients along the ridge from analysis of epibenthic sled benthic samples collected on CSIRO survey SS0199 (specific groups from this survey were also used in the O'Hara et al. 2002 analysis). No consistent latitudinal variation was detected in the deepest samples (1000-1500m) although sample sizes were small.

Unique genetic haplotypes for *P. laminaris* in the most southerly samples on the extended continental shelf (Seamount 10 on the NIWA survey TAN0803) may indicate isolation of these most southerly areas by the Antarctic Circumpolar Current and Sub-Antarctic front.

North-Central AZ
The North-Central AZ is in the Sub-Antarctic oceanic zone with warmer waters clearly separated from the cooler systems to the south. Habitats primarily range from shallow seamounts less than 200m depth to the abyss at 4000m with some even deeper areas.

Community analyses of benthic invertebrates identified that the northern cluster of available benthic specimens (500-1,000m) is synonymous with this zone (O'Hara et al. 2002). The northern cluster of Butler et al. (2000) - Cluster 4: (400-600m depth) and (600-1000m) sites north of 53.5oS - are also identified with this zone. Cluster 4 was characterized by a suite of sessile taxa in relatively low abundance - colonial stony coral *Enallopsammia* cf *marenzelleri* and holothurian *Psolus neozelanicus* were most abundant and together with the chiton *Placiphorella* sp. and the carid *Merhippolyte* cf *chacei* were rare or absent at other sites and may have been at the southern limit of their distribution.

Seamount 6 on NIWA survey TAN0803 (90-750m depth) sampled by Rowden et al. (2008) peaked at a shallower depth than other seamounts to the south and north. It was distinct from seamounts sampled further south (and some sampled further north) along the ridge by the presence of ophiuroids (shared with Seamount 7) and the lack of corals (shared with Seamount 11) among the commonly seen fauna.

The foraging distribution of both black-browed albatrosses and Antarctic fur seals is concentrated in the Central and North-Central zones during the breeding season.

Central-Central AZ
The Central-Central AZ includes Macquarie Island. Depths range from the surface to the abyss in the Polar Frontal Zone. Sea surface temperatures are lower than the North-Central AZ but are not reflective of the polar waters to the south. Increased production occurs in this AZ compared to the western areas upstream, and the concentration of foraging activity by marine mammals and birds throughout this AZ reflects this increased production and likely presence of increased abundances of prey species, such as myctophid fish.

This AZ included stations from the mid and southern cluster of available benthic specimens (500-1000m) (O'Hara et al. 2002). Cluster 1: East and west shallow sites (200-500m depth); cluster 2: mid-depth (400-900m) sites of Butler et al. (2000) were also associated with this AZ. Cluster 2 was characterised by a species-rich community of sponges and octocorals including a very large colony of the octocoral *Primnoa* sp. 1 indicating growth in stable conditions below the wave base for an extended period.

Seamounts 7 (750-1250m), 8 (400-850m) and 9 (500-1200m) sampled on NIWA survey TAN0803 occur in this AZ and were sampled by Rowden et al. (2008). All peak at a deeper depth than Seamount 6 in the North-Central zone and gorgonian corals and sponges were among the commonly seen fauna.

The foraging distribution of both black-browed albatrosses and Antarctic fur seals is concentrated in the Central and North-Central zones during the breeding season.

South-Central AZ
The South-Central AZ is mostly deeper than 3000m with shallower areas further to the east in the South East AZ (below).

This zone only included stations from the southern cluster of available benthic specimens (55-57oS; 500-1000m) (O'Hara et al. 2002). No samples were collected this far south on CSIRO survey SS0199 for Butler et al. (2000) to analyse.

Seamounts are not as evident in this area and none were sampled on NIWA survey TAN 0803. Seamount 9 is immediately adjacent to the north in the central-central zone, and Seamount 10 is immediately adjacent to the south on the extended continental shelf (Rowden et al. 2008).

Eastern Assessment Zones

The eastern assessment zones downstream from the ridge comprise mostly deep areas with seamounts as part of the ridge complex, particularly in the southeast of the M-EEZ. The deep seafloor to the east of the ridge is mostly unsampled. There are some raised areas in the north-east and south-east zones including Seamount 11.

North-East AZ

The North-East AZ has temperatures of the Sub-Antarctic and is mostly abyssal waters deeper than 3000m. A number of seamounts are present and a small part of the Campbell Plateau deeper than 1000m extends into the eastern area of this AZ. Production in this AZ is similar to productivity to the west of the ridge.

Central-East AZ

The Central-East AZ lies in the Polar Frontal Zone with temperatures elevated above polar temperatures to the south. While it has mostly abyssal depths, the Central-East AZ has the highest productivity of the M-EEZ, fuelled by the supply of iron from the Macquarie Ridge. A large shallow seamount as part of the ridge complex is present in the south-west corner of this AZ. This AZ is occupied by all tracked predators. The distribution of king and royal penguins is concentrated in the Central-East AZ and provides a very good example of the influence of adjacent water masses shaping the distribution of both penguin species.

Imagery from 100m depth (on the Ridge in the central-central zone) to 1230m depth and through the AMP shows a steep rugged seabed of debris flow, talus deposits and outcrops of consolidated pebble/cobble (Butler et al. 2000). Benthic communities were stratified with depth, with the shallow water community (~200-500m depth) east and west of the island appearing distinct from the mid-depth (600-1000m depth) and deep-water (>1,000m depth) communities (Butler et al. 2000). All communities were characterised by the noticeable absence of sponges (only present in low abundance in deep-water community) and octocorals (only present in low abundance in the mid-depth community). Seapens were present in both shallow and mid-depth communities suggesting a more sheltered environment east of the Macquarie Ridge with greater silt deposition than on the west exposed to the predominant easterly current flow. Video transects in the same area identified small mixed macrobenthos of encrusting filter-feeders on areas of consolidated seabed, supplemented by some large sponges, gorgonian and other octocorals and black corals at greater depths down to 1230m depth (Butler et al. 2000).

South-East AZ

The South-East AZ has temperatures at the high end of polar conditions, lying south of the Polar Front. A number of seamounts associated with the Ridge Complex rise from the abyssal plane to depths less than 2000m. Like the Central-East AZ, it also has high productivity and frequented by penguins and seals tracked from Macquarie Island.

Seamount 11 (550-1200m) surveyed on NIWA survey TAN0803 occurs in this zone and unlike other sampled seamounts is not on the Macquarie Ridge and has a very different geomorphology from those seamounts. It is part of a chain of seamounts/volcanoes in this zone and may have been formed by younger volcanic activity (Rowden et al. 2008). With Seamount 6, it differs from other seamounts sampled in the Macquarie Island EEZ and extended continental shelf by the lack of gorgonian corals in the commonly observed fauna (Rowden et al. 2008).

Southern extended continental shelf

Seamount 10 (1200-2500m) surveyed on NIWA survey TAN0803 is an elevated feature on the Macquarie Ridge with ferro-manganese crusts. It sits in the main flow of the Antarctic Circumpolar Current, which is diverted around Macquarie Ridge and prevents sediment accumulation on this seamount. Gorgonian corals (including bamboo corals) were the commonly observed fauna on this seamount (Rowden et al. 2008).

The north-central-south differentiation observed in many deep-sea benthos species, the lack of prominent seamounts along the ridge in the central-south zone to the north, and the increasing influence of the Antarctic Circumpolar Current and Sub-Antarctic front may mean that this zone contains a different mix of species and genotypes from other seamounts along Macquarie Ridge. Few samples exist for this kind of analysis, however, unique genetic haplotypes for the deep-sea sponge (*Poecillastra laminaris* Sollas 1886) were observed in the most southerly samples (Seamount 10 on the extended continental shelf) (Zeng et al. 2019).

This zone is further discussed in section 9.1 "Considerations beyond the M-EEZ".

6.3 Assessment

The combination of topography, ocean fronts and production and the respective associations of benthic and pelagic assemblages provides a good basis for assessing whether the current reserve system satisfactorily achieves the CAR principles.

An overarching feature of the M-EEZ is that it has a very important place in the biogeography and ecology of the circumpolar Sub-Antarctic system with the nearest upstream location being the Kerguelen Plateau and downstream being beyond the Antarctic Peninsula. The comparatively small area of shallow water (less than 2000m depth) locations gives them increased importance from a global CAR perspective.

Within the M-EEZ, we separate the pelagic and benthic realms.

From a pelagic perspective, the northern AZs are different to the central and southern AZs, on the basis of different physical regimes combined with different phytoplankton and fish assemblages. While it is difficult to distinguish between the central and southern AZs based on current information, these combined AZs can be separated from the west to the east on the basis of productivity with the Central-Central AZ as a whole having special importance to the Macquarie Island system.

For the benthic system, the abyssal areas are poorly understood but there is reason to differentiate areas shallower than 2000m between the northern, central and southern AZs.

The use of oceanic fronts is a convenient means to delineate the assessment zones, however, for many seabirds and marine mammals it is very often the ocean boundaries that are particularly important as foraging areas (Chapman et al. 2020). Therefore, when determining how much of a particular zone would need to be included in order to achieve CAR representativeness would need to include an element of the boundary bordering contiguous zones in order to represent the biologically important boundary.

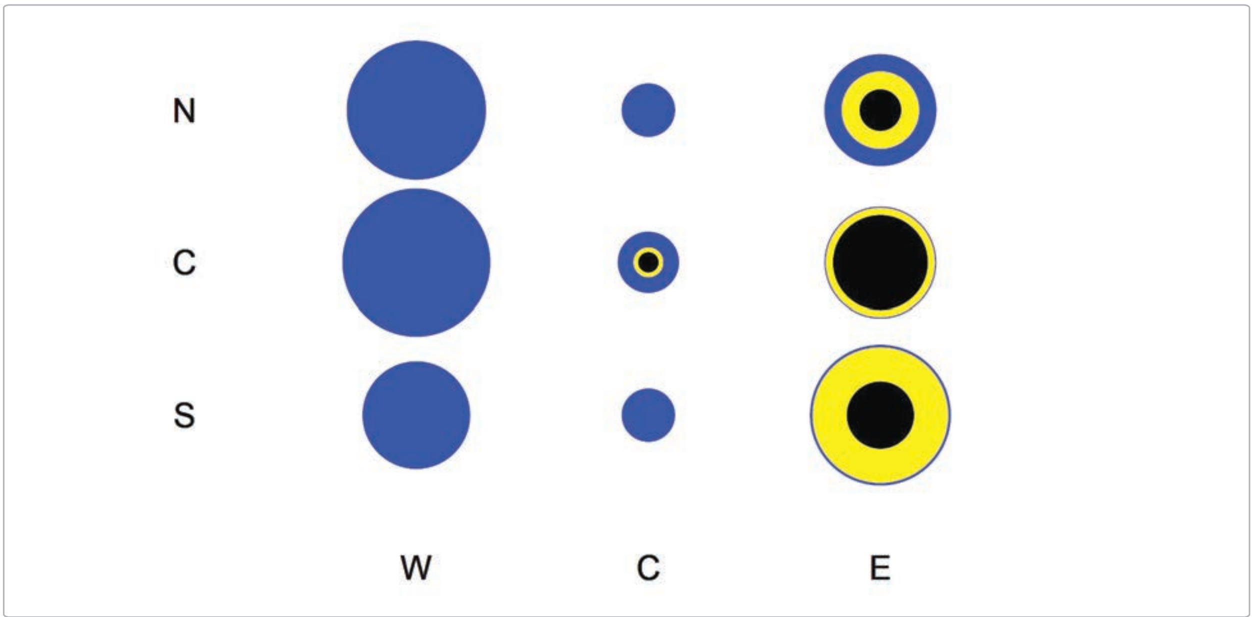


Figure 18: The relative size of the area of protection in the 9 Assessment Zones. The size of the blue circles represents the relative size of each of the assessment zones, the inner yellow circle shows the part of each zone that is in a protected area and the black circle shows the area that is currently in a sanctuary zone.

Assessment against CAR

The reserve system in the M-EEZ is large compared to the size of the M-EEZ but relates to areas of abyssal depths to the east of the Macquarie Ridge south of the Sub-Antarctic Front. In particular, there is no inclusion of shallower areas to the north of the Sub-Antarctic Front or any of the areas to the west of the Macquarie Ridge.

There are two aspects of adequacy that also need to be considered. These relate to the oceanography of the region, the predominant west-east movement of the currents and the scale of ecological processes in the Sub-Antarctic. Given the Antarctic Circumpolar Current, corridors from west to east are important to consider for enabling ecological processes to naturally occur from upstream of the ridge, on the ridge and downstream. This would avoid upstream disturbances and impacts having downstream effects. The second aspect relates to the size of shallow areas (between 200m and 1000m) and the ability for assemblages to be resilient to change into the future. At present, areas shallower than 1000m are poorly represented in the reserve system.

As each of the nine AZs have unique physical and ecological characteristics an effective CAR system of protection would be expected to have an adequate and representative distribution of sanctuary zones in each of the assessment zones. An analysis of the current arrangement show that this is not the case (Figure 18).

Assessment against the goals of the NRSMPA

The Antarctic Circumpolar Current presents special challenges to meeting the goals of the NRSMPA. Unlike coastal waters around continental Australia, the ACC results in the M-EEZ being a large island in the stream. Nevertheless, the M-EEZ encompasses important biogeographic and ecological properties unique in the Southern Ocean. The Goals of the NRSMPA relate more to representation than to resilience and ecological function. Issues of representation are discussed above in the assessment against CAR. In terms of resilience, Goal 3 is pertinent, where areas with high value for sustaining ecosystems and biodiversity are given prominence and that an area needs to be considered at a scale of 100s km. As discussed for CAR, areas shallower than 2000m have high value on a global scale and are unique at the scale of 100s km. They are difficult to subset while keeping adequate replication (Principle 12) to maintain future resilience.

7.0 Options for expanding the Commonwealth marine park

Based on the analysis presented above two options emerge for extending the coverage of marine parks in the M-EEZ to meet the CAR principles.

- **Option 1:** Extend protection of the entire M-EEZ through designation as a sanctuary zone, with the exception of the existing fishing footprint area, which would be managed as a habitat/ species management zone that allowed sustainable fishing under strict management.
- **Option 2:** Extend the current Commonwealth Marine Park (CMP) to include multiple new sanctuary zones to extend coverage along the Macquarie Ridge and on the western side of the M-EEZ.

Both options seek to minimize impacts on the current, sustainable, Patagonian toothfish fishery. Overall option 1 is considered the most parsimonious way forward, as outlined below in the advantages and disadvantages of the two options.

Furthermore, beyond the current area under consideration, we identify in section 9.1 of this report the potential opportunity in the future to extend habitat protection to the benthic environment in Commonwealth waters south of the M-EEZ on Australia's extended continental shelf.

Option 1

Option 1 would extend the marine park coverage to the whole M-EEZ, with zoning as a sanctuary zone or IUCN Ia, apart from the area of the present toothfish fishery (mainly within the Central/Central AZ) which would be designated as an IUCN IV habitat/species management area allowing the specified multiple use activity of the current fishery.

An IUCN Category Ia is defined as a strict nature reserve, that is a protected area managed mainly for science and is an area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring (Environment Australia 2002).

An IUCN Category IV is defined as a habitat/species management area and is a protected area managed mainly for conservation but that allows for multiple uses with active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species. The zone would be managed primarily to ensure the maintenance of habitats and would seek to ensure that exploitation inconsistent with agreed principles does not occur (Environment Australia 2002).

Option 2

Option 2 would seek to provide comprehensive, adequate and representative coverage of protected zones for all nine Assessment Zones (AZ) identified in our analysis, including to all depth zones within each AZ. Adequate in this option would require at least 30% coverage for all AZ/depth zones, including multiple examples of distinct geomorphic or ecological features where possible. The new areas of marine park would be chosen to minimize impacts on the recent footprint of the toothfish fishery.

Advantages and disadvantages of the options

The advantages and disadvantages of each option are discussed in relation to 1) meeting the CAR criteria for marine park design, and 2) protecting the conservation values of the M-EEZ against future developments in fishing and seabed mining.

Option 1 provides the simplest, most expeditious reserve design that is relatively easy to implement and has no significant impact on the existing fishery. Option 1 provides the best protection of the unique geological, oceanographic, and ecological values and importance of the entire Macquarie Island region.

The advantage of option 1 is that it affords comprehensive protection to the entire M-EEZ while allowing continuation of the current fishery. This option is not expected to impact catches of the current fishery because the catch limits are set for the stock residing in the whole of the M-EEZ. Restrictions on future pelagic fisheries would depend on the details of zoning (IUCN level) across the area (sanctuary zones would preclude any fishing, but habitat/ species management zones may not necessarily preclude pelagic fishing). Mining would be precluded under either category of protection.

The disadvantage of option 1 is the potential restriction it would place on future economic development within the region, particularly for fishing and mining, possibly also impacting bioprospecting. It would signal a clear priority for protection over development. Should priorities change over time, it would not necessarily preclude future development entirely, but would provide a strong requirement for orderly and careful future development, including prior consideration of environmental impacts, if such developments were later contemplated. Any consideration of changes to the current fishery management arrangements should ensure that the management changes maintain or enhance conditions for a long-term sustainable fishery.

Option 1 also provides the most protection for an uncertain future driven by ocean warming and acidification, noting the added importance of the Macquarie Island province in increasing the resilience of the South-East marine region and the lack of benthic protected areas along the Macquarie Ridge in the adjacent New Zealand EEZ.

Option 2 can be designed to address the current CAR deficiencies of the existing marine park (identified in section 6 of this report) and would go some way towards protecting against future developments in mining and fishing, particularly the possible expansion of fishing to target pelagic or mid-water resources.

Option 2 more explicitly provides some opportunity for future economic activities. However, option 1 also accommodates the current fishery area (noting the need to specifically manage benthic impacts), and like all marine parks is reviewed every 10 years.

However, a challenge for option 2 would be to select adequate protection zones that were not too spatially complex, while meeting the requirement of CAR principles across AZ, depth range, and multiple feature level. For example, it is not good reserve design to protect many small areas that are not contiguous and are scattered across the M-EEZ. Furthermore, it may be difficult to include sufficient area for protection within the Central/Central AZ given the current spatial footprint of the current fishery (Figure 17).

There will also be a remaining challenge for option 2 to adequately protect key predator foraging ranges for seabirds and marine mammals, given their wide patterns of use of the M-EEZ should future fishery developments include pelagic or midwater fisheries, as discussed earlier in this report. A feature of the M-EEZ is the west-east flow of the Antarctic Circumpolar Current, which under option 2 would require consideration of multiple areas of importance "downstream" of the ACC in the M-EEZ to have sufficient buffering from upstream effects. The potential threat to predators and food chains from future fisheries could potentially be ameliorated by sound fisheries management, including monitoring for any unacceptable ecological impacts, and working in concert with protection offered by the marine parks. The prospects for future seabed mining are unknown at this stage, as are what would be the specific potential areas of interest, adding to the uncertainty of selection of protection zones under option 2.

Consideration of these options highlights the simplistic nature of the IUCN protected area categorization system, and the need to consider marine park management and fisheries management together. The unique nature of the M-EEZ, its conservation values and the current and possible future economy, suggests that the simple categorisation of sanctuary zones and habitat protection zones may not adequately capture all the conservation needs and how these need to be managed in light of the potential for future economic activities, uncertainty around current ecosystem dynamics and the potential for the region to be under pressure from climate change in the future.

Our assessment of historical information/data demonstrates that the M-EEZ has high conservation significance at a global, national and regional scale. Other than the footprint of the current fishery, it is difficult to designate a sanctuary zone as a portion of the M-EEZ to sustainably manage these significant values based on current knowledge. This lack of ability to easily identify areas with lower values indicates the whole M-EEZ warrants protection (option 1).

8.0 Conclusions

The analysis of the current data available of both the pelagic environment surrounding Macquarie Island as well as the benthic environment show the area is a complex system that is not comprehensively or adequately represented by the current MPA system. In particular, the entire area west of the Macquarie Ridge is unrepresented, as are most of the northern and southern parts of the ridge.

In the pelagic environment large-scale oceanographic features influence where species occur. Additionally, these are inherently dynamic, with moving boundaries whose positions change over time. In the M-EEZ frontal systems can be used to mark an overall boundary or transition from one area of the ocean to another. Our analysis has identified key features that have a strong influence on the variety of habitats and species that are found in the area. Similarly in the benthic environment, species distributions are determined by topography, latitude, depth and substrate characteristics and are zoned according to specific depth contours associated with differing species compositions. Bringing both these pelagic and benthic features together we have identified nine zones within the EEZ waters surrounding Macquarie Island that are expected to contain differences in biological assemblages. Currently biological data for most of this area is extremely limited. Information obtained from fishing in the area, particularly bycatch information, was not made available in time for this report, but all known other published sources of biological information were examined.

This study has shown the importance of updating the current knowledge of any region prior to any formal review process. For instance, updates to the regional profiles and the conservation values atlas prior to Australian marine park networks planned reviews could be formalised to include the most up to date data of key ecological features, protected species, important species areas, and geomorphic features. The extended continental shelf should be considered in future reviews of Australia's Marine Park networks.

On the currently available science, it is possible to achieve comprehensive, adequate, and representative protection through an extension of marine parks under two options provided here.

- ***Preferred option:*** OPTION 1 – **to represent the entirety of the significant biological diversity across the extent of the whole M-EEZ, with little additional research effort required.**
- *Alternate option:* OPTION 2 – this is considered the secondary option, because it will require significant further research (possibly including additional surveys) to assemble the required data to prioritise the areas in order to meet the CAR principles

9.0 Future work

9.1 Future updates to support reserve planning and management

Additional work that would be of benefit for future detailed reserve planning:

- Obtain fisheries bycatch data and incorporate that into the understanding of the biology of the region.
- Obtain new tracking data for marine mammals and seabirds to better understand the use of the entire M-EEZ by different species. The current data on marine mammals and seabirds is limited by the availability of the tracking data obtained from a sub-set of colonies on Macquarie Island, and the opportunistic at-sea observation data. The tracking data for some species (royal and king penguins) is over 20 years old. The collection of tracking data for all species from a representative sample of colonies on Macquarie Island, combined with a well-designed at-sea surveys would allow the current CAR deficiencies of the existing marine park to be addressed.
- Further refinement and identification of the key ecological features and biologically important areas of the M-EEZ.
- Further mapping of the depth habitats of the M-EEZ, as has been completed for most of Australia's other marine provinces.
- Update of the Interim Marine and Coastal Regionalisation for Australia to include meso-scale bioregions for the M-EEZ, as has been completed for most of Australia's other marine provinces (the 9 assessment zones could be considered the first draft of these bioregions).
- Complete identification and analysis of benthic samples collected along the ridge on TAN 0803/SS0199 voyages (Rowden et al. 2008, Appendix Table 1; Butler et al. 2000), and currently housed in museum collections, including genetic analyses to improve description of the transition between northern and southern fauna along the ridge within the Australian EEZ and extending to the extended continental shelf.
- Undertake a comparison of the Macquarie Ridge benthic fauna to adjacent regions (e.g. New Zealand, Tasmanian seamounts, Antarctica) to increase our understanding of the importance of Macquarie Ridge regionally and help to determine its importance as a population source for diverse species and its potential as a migration route for climate vagrants
- Update biogeographic distributions of benthic fauna, particularly fish and elasmobranchs, using the high-quality observer data collected from the commercial fishery for Patagonian toothfish over the period since the late 1990s.

9.2 Future conservation options beyond the M-EEZ

Macquarie Ridge extends immediately to the south of the Macquarie Island EEZ and is one of nine areas of Australia’s extended continental shelf agreed by the UN’s Commission on the Limits of the Continental Shelf (CLCS) on 9 April 2008. It includes a seamount (Seamount 10 sampled on TAN 0803), an elevated feature (1200-2500m) with ferro-manganese crusts and gorgonian corals which may contain a different mix of bottom-attached species and genotypes from seamounts further north on the Macquarie Ridge. There is no record of this area of being fished, and there is limited scientific information available on this area.

Under UNCLOS the coastal state has sovereign rights over the resources of the extended continental shelf, while the resources found in the water column are beyond national jurisdiction (Mossop 2017). These resources include both non-living resources such as oil and gas, and living resources that are sedentary species, defined as those organisms "which, at the harvestable stage, either are immobile on or under the seabed or are unable to move except in constant physical contact with the seabed or subsoil." (UNCLOS, art. 78). The limited scope of this definition contrasts significantly with the ecosystem-level definition of biodiversity used by the Convention on Biological Diversity (CBD) which may complicate negotiations for conservation management and potential bioprospecting on the extended continental shelf. Management of any fisheries in these areas is likely to be considered under regional fisheries management bodies, although responsibility for managing seabed impacts of any fisheries remains an active topic of discussion.

Part VI of UNCLOS which addresses the continental shelf imposes no obligation to protect sedentary species, compared to Part V which addresses sustainable use of living resources of the EEZ (Mossop 2017). However, all states, including coastal states have environmental obligations under UNCLOS Part XII. Article 192 of UNCLOS imposes a general obligation on states to protect and preserve the marine environment. In addition, agreements under the CBD apply to areas under national jurisdiction and therefore apply to the extended continental shelf (Mossop 2017). Under the CBD, coastal states must develop strategies for the conservation and sustainable use of biodiversity within their national jurisdiction and this includes Australia's areas of extended continental shelf.

On May 24, 2012 Australia made the Seas and Submerged Lands (Limits of Continental Shelf) Proclamation 2012 which defines the outer limits of the continental shelf over which it can exercise exclusive rights to seabed resources. While the extended continental shelves generated by the Territory of Heard Island and the McDonald Islands, and Macquarie Island lie south of 60°S and are therefore geographically within the Antarctic Treaty area, they do not conflict with that Treaty as they were generated from Australia's unchallenged sovereignty to areas outside the Antarctic Treaty area. These areas of extended continental shelf are eligible to be included in the NRSMPA as part of Australia's obligation under the CBD and through general obligations under UNCLOS. The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") provides a precedent for this.

The network of 333 MPAs recognized under OSPAR includes seven MPAs protecting extended continental shelf areas subject to a submission to the UN CLCS (OSPAR 2013):

- one MPA protects only the water column above the area
- four MPAs protected by a contracting party (Portugal) protect the seabed and subsoil while the water column is protected collectively by all contracting parties following an invitation from Portugal
- two MPAs protected by a contracting party (United Kingdom) protect only the seabed and subsoil, while the water column remains unprotected. One of these MPAs (NorthWest Rockall) straddles the EEZ-ECS boundary.

Protection of these areas represents, at least in the case of Portugal, a recognition of the obligations under UNCLOS Article 192 to protect and preserve the marine environment, as well as the precautionary principle (OSPAR 2013).

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Appendix 1.

Summary of main faunal groups and number of specimen lots from seamounts sampled on Macquarie Ridge March 26- April 28, 2008 from R.V. *Tangaroa*

(Reproduced from Table 6 from Rowden et al. 2008).

Table 6: Summary of the main faunal groups and number of specimen lots per seamount.

Taxa code	Taxonomic determination	SMT 1	SMT 3	SMT 5	SMT 6	SMT 7	SMT 8	SMT 9	SMT 10	Total # of lots for all seamounts
ANT	Actiniaria	4	6	7	22	11	7	3	3	63
ANT	Corallimorpharia								1	1
ANT	Hormathia				1					1
APH	Amphipoda	2	1	2	3	4	7	5	1	25
ASC	Ascidiacea	3	6	1	3	3				16
ASR	Asteroidea	4	8	12	16	5	10	2		57
ASR	*Benthopecten*				1					1
ASR	*Benthopecten pikei*				1					1
ASR	Brisingidae			2						2
ASR	Hippasteria						1			1
ASR	Plutonaster				1					1
ASR	Stegnaster						1			1
BIV	Bivalvia	1		6	7	3		2	2	21
BIV	Hiatella				1					1
BPD	Brachiopoda	1		1	4	2	4	3	1	16
BRN	Calantica	1								1
BRN	Cirripedia	3		2	3	3	6	3		20
BRN	Hexelasma		1							1
CHT	Polyplacophora	2	2	4	3	2				13
COB	Antipatharia	2	1	3	2	7		2	1	18
COR	Errina		3	2	4		1			10
COR	*Stylaster eguchii*			1						1
COR	*Stylasteridae*	3	11	6	16	12	3	4	5	60
COU	Anthozoa			2		1				3
COZ	Bryozoa	3	7	5	20	8	12	8	4	67
CRB	Brachyura	2	4	1						7
CRB	Lithodes						3	1		4
CRI	Crinoidea	1	3		4	7		3	2	20
CRL	Corallina				1					1
CUP	Caryophyllia	2	1		1			3	3	10
CUP	Caryophyllidae		4	1		5			1	11
CUP	*Desmophyllum dianthus*		3	4	2	4	6		2	21
CUP	Flabellum					1		3		4
CUP	*Flabellum apertum*					1				1
CUP	Goniocorella				1					1

Table 6: Summary of the main faunal groups and number of specimen lots per seamount.

Taxa code	Taxonomic determination	SMT 1	SMT 3	SMT 5	SMT 6	SMT 7	SMT 8	SMT 9	SMT 10	Total # of lots for all seamounts
ECN	Araeosoma		1	1						2
ECN	Caenopedina	4								4
ECN	Cidaroida	1			4	1				6
ECN	Echinodermata			1						1
ECN	Echinoidea	2	5	5	7			1		20
ECN	Gracilechinus	1								1
EHI	Echiura	1			2					3
EPZ	Zoanthidea				4			2	2	8
EUP	Euphausiacea		2							2
FIS	Fish					1				1
FTW	Platyhelminthes			1						1
GAL	Galatheidae	3	4	3	2	3	5	1		21
GAS	Gastropoda	9		9	19	7	7	2		53
GOC	*Callogorgia*							3		3
GOC	Chrysogorgiidae	1	4	1	1					7
GOC	*Corallium*					3			1	4
GOC	Gorgonacea	8	15	7	1	23	20	14	12	100
GOC	Isididae	2	7			7	3	6	3	28
GOC	*Keratoisis*								1	1
GOC	Mopseinae		1							1
GOC	*Paragorgia*						2			2
GOC	Primnoidae		1							1
GOC	*Thouarella*	1					2	6		9
HDF	Hydrozoa	1	13	9	17	19	15	10	3	87
HTH	Holothuroidea			2	14	1	8	2		27
HTH	Psolus			4	2					6
INV	Invertebrate	2		2	4	2	2	3	4	19
ISO	Isopoda			1	4	10	16	3		34
ISO	Munnidae							1		1
ISO	Serolidae	1				2	1			4
MOL	Mollusca				1	1				2
MYS	Mysidacea			1						1
NAT	Acanthephyra			1						1
NAT	Caridea	1	2	4	7	9	6	2	2	29
NAT	Crangonidae				1					1
NAT	Glyphocrangon			1						1
NAT	Sergestidae	1								1
NMT	Nemertea			2	1	1	2	1	1	8
NUD	Nudibranchia						1			1
OCP	Benthoctopus	1								1
OCP	Octopoda				2					2
ONG	Cladorhiza		1							1
ONG	Farrea							1		1
ONG	Hexactinellida	1			1					2
ONG	Lithistid Demospongiae		1							1
ONG	Porifera	12	22	8	32	41	33	36	19	203

Table 6: Summary of the main faunal groups and number of specimen lots per seamount.

Taxa code	Taxonomic determination	SMT 1	SMT 3	SMT 5	SMT 6	SMT 7	SMT 8	SMT 9	SMT 10	Total # of lots for all seamounts
OPH	Gorgonocephalus			2						2
OPH	Ophiuroidea	10	11	9	19	5	7	3		64
OST	Ostracoda							1		1
PAG	Paguridae	1		8	5	1	2	1		18
PLY	Polychelidae					1				1
POL	Polychaeta	9	17	23	31	18	13	5	6	122
POL	Polynoidae				4					4
PTU	Pennatulacea		1			4	1			6
PYC	Pycnogonida	1		4	6	2	4	3	1	21
SAL	Thaliacea				1			1		2
SIA	*Enallopsammia*				2					2
SIA	*Enallopsammia marenzelleri*		1							1
SIA	*Enallopsammia rostrata*			2						2
SIA	*Madrepora*					1	5	1		7
SIA	Mammalia					1				1
SIA	Scleractinia			11	7					18
SIA	*Solenosmilia variabilis*		9							9
SIP	Sipuncula	4	2		3	3			1	13
SOC	Alcyonacea	4	10	14	9	4	12	6	2	61
WRM	Annelida			5	1	1	2	4		13
WRM	Nematoda			1						1
WRM	Pogonophora			2						2
ZFR	Foraminifera				1					1
	Total # lots per seamount	**116**	**191**	**206**	**332**	**251**	**230**	**161**	**84**	**1571**
	# of faunal groups	**40**	**36**	**48**	**54**	**44**	**35**	**39**	**26**	

Appendix 2.1

Seabird species recorded in the M-EEZ

The species list is based on a combination of Clarke and Schulz (2005), Bird (2020) and Australasian Seabird Group unpublished data. The Conservation Status and taxonomy for breeding birds follows the Australian breeding population status for those species included in Garnet and Baker (2021), non-breeding species follow the IUCN conservation status https://www.iucnredlist.org/ accessed 27 Sept 2022. All species are listed as Marine species under the EPBC Act, those marked * are also listed a threatened species under that Act.

Species		Conservation Status
Breeding		
King penguin	Aptenodytes patagonicus	Least Concern
Sub-Antarctic gentoo penguin	Pygoscelis papua papua	Vulnerable
Royal penguin	Eudyptes schlegeli	Least Concern
Eastern Rockhopper penguin	Eudyptes chrysocome filholi	Endangered
Light-mantled sooty albatross	Phoebetria palpebrata	Least Concern
Black-browed albatross	Thallasarche melanophris	Least Concern *
Grey-headed albatross	Thallasarche chrysostoma	Endangered *
Wandering albatross	Diomedea exulans	Critically Endangered *
Southern giant petrel	Macronectes giganteus	Least Concern *
Northern giant petrel	Macronectes halli	Least Concern *
Cape petrel	Daption capense	Least Concern
Antarctic prion	Pachyptila desolata	Least Concern
Sooty shearwater	Ardenna griseus	Vulnerable
Grey petrel	Procellaria cinerea	Near Threatened
White-headed Petrel	Pterodroma lessonii	Least Concern
Soft plumaged petrel	Pterodroma mollis	Vulnerable *
Blue petrel	Halobaena caerulea	Least Concern *
Southern fairy prion	Pachyptila turtur Sub-Antarctica	Endangered
Sub-Antarctic Wilson's storm petrel	Oceanites oceanicus oceanicus	Least Concern
Common diving petrel	Pelecanoides urinatrix	Least Concern
South Georgian diving petrel	Pelecanoides georgicus	Least Concern
Macquarie Island imperial shag	Leucocarbo atriceps purpurascens	Least Concern *
Brown skua	Catharacta lonnbergi	Least Concern
Kelp gull	Larus dominicanus	Least Concern
New Zealand Antarctic tern	Sterna vittata bethunei	Endangered *

Species		Conservation Status
Non-Breeding		
Chinstrap penguin	Pygoscelis antarcticus	Least Concern
Erect-crested penguin	Eudyptes sclateri	Endangered
Little penguin	Eudyptula minor	Least Concern
Northern royal albatross	Diomedea sanfordi	Endangered *
Southern royal albatross	Diomedea epomophora	Vulnerable *
Campbell albatross	Thalassarche impavida	Vulnerable *
Shy Albatross	Thalassarche cauta	Near Threatened*
Salvin's albatross	Thalassarche salvini	Vulnerable *
Buller's albatross	Thalassarche bulleri	Near Threatened *
Indian yellow-nosed albatross	Thalassarche carteri	Endangered *
Sooty albatross	Phoebetria fusca	Endangered *
Antarctic fulmar	Fulmarus glacialoides	Least Concern
Antarctic petrel	Thalassoica antarctica	Least Concern
Snow petrel	Pagodroma nivea	Least Concern
Kerguelen petrel	Aphrodroma brevirostris	Least Concern
Great-winged petrel	Pterodroma macroptera	Least Concern
Mottled petrel	Pterodroma inexpectata	Near Threatened
White-chinned petrel	Procellaria aequinoctialis	Vulnerable
Short-tailed shearwater	Ardenna tenuirostris	Least Concern
Great shearwater	Ardenna gravis	Least Concern
Little shearwater	Puffinus assimilis	Least Concern
Slender-billed prion	Pachyptila belcheri	Least Concern
Fulmar prion	Pachyptila crassirostris	Least Concern
Antarctic prion	Pachyptila desolata	Least Concern
Salvin's prion	Pachyptila salvini	Least Concern
Broad-billed prion	Pachyptila vittata	Least Concern
Grey-backed storm petrel	Garrodia nereis	Least Concern
White-faced storm petrel	Pelagodroma marina	Least Concern
Black-bellied storm petrel	Fregetta tropica	Least Concern
White-bellied Storm-Petrel	Fregetta grallaria	Least Concern *
Arctic tern	Sterna paradisaea	Least Concern
South polar skua	Catharacta maccormicki	Least Concern

Appendix 2.2
EPBC Act status of marine mammal species recorded in the M-EEZ.

The species list is based on a combination of Clarke and Schulz (2005), Bird (2020) and Australasian Seabird Group unpublished data. The Conservation Status and taxonomy for breeding birds follows the Australian breeding population status for those species included in Garnet and Baker (2021), non-breeding species follow the IUCN conservation status https://www.iucnredlist.org/ accessed 27 Sept 2022. All species are listed as Marine species under the EPBC Act, those marked * are also listed a threatened species under that Act.

Species	Scientific Name	EPBC Act Status
Southern Right Whale	*Eubalaena australis*	Endangered; Cetacean; Migratory (EPBC Act, Bonn)
Humpback Whale	*Megaptera novaeangliae*	Cetacean; Migratory (EPBC Act, Bonn)
Minke Whale	*Balaenoptera acutorostrata*	Cetacean
Sperm Whale	*Physeter macrocephalus*	Cetacean; Migratory (EPBC Act, Bonn)
Arnoux's Beaked Whale	*Berardius arnuxii*	Cetacean
Andrew's Beaked Whale	*Mesoplodon bowdoini*	Cetacean
Strap-toothed Beaked Whale	*Mesoplodon layardii*	Cetacean
Cuvier's Beaked Whale	*Ziphius cavirostris*	Cetacean
Southern Right Whale Dolphin	*Lissodelphis peronii*	Cetacean
Killer Whale, Orca	*Orcinus orca*	Cetacean; Migratory (EPBC Act, Bonn)
Spectacled Porpoise	*Phocoena dioptrica*	Cetacean; Migratory (EPBC Act, Bonn)
New Zealand Fur-seal	*Arctocephalus forsteri*	Marine
Antarctic Fur-seal	*Arctocephalus gazella*	Marine
Subantarctic Fur-seal	*Arctocephalus tropicalis*	Endangered; Marine
Southern Elephant Seal	*Mirounga leonina*	Vulnerable; Marine

Appendix 3

[M-EEZ areas]: Physical attributes and protection of the Assessment Zones

Differentiation of Assessment Zones

The differentiation of the assessment zones was evaluated using sea-surface temperature (°C, SST) and estimates of the density of Chlorophyll *a* (g.m-3, Chl *a*), presented in Figures 4 and 5 respectively.

Mean SST for January for the decade 2011-2020 (mean of the monthly mean in each year) was calculated for each pixel in the dataset - NOAA 1/4° spatial resolution, daily Optimum Interpolation Sea Surface Temperature (OISST) (Huang et al., 2021). Pixel values were ordered from lowest to highest. The cumulative proportion of the area of the zone was calculated up to each SST value, giving the proportion of the area for which, the SST was less than or equal to that value. The SST corresponding to 0.1, 0.25, 0.5, 0.75 and 0.9 of the area were then determined and plotted in a similar form to box plots in Figure A3-1.

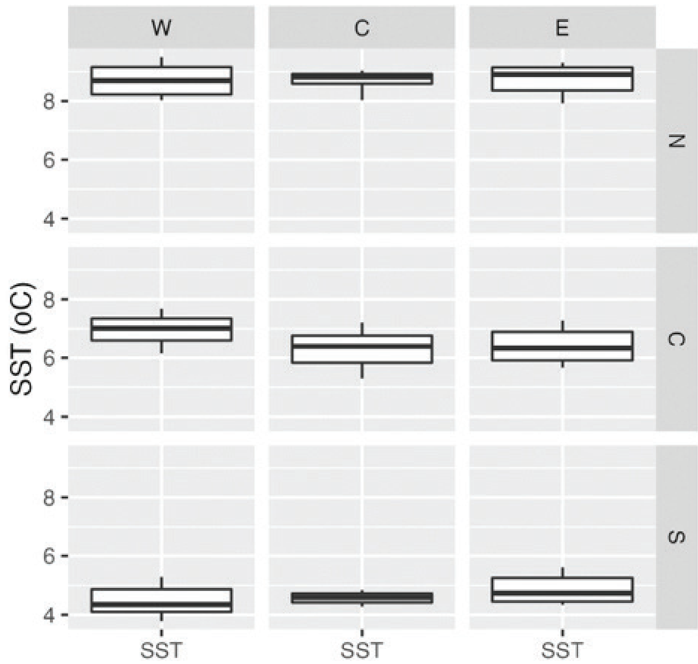

Figure A3-1: Plots for sea surface temperature (°C), SST) in different assessment zones of the M-EEZ showing the proportion of area with SST at or below the respective values – a box displays 0.25 (bottom), 0.5 (middle), and 0.75 (top), and the whiskers display 0.1 (lower) and 0.9 (upper) proportions. Columns of the display show West (W), Ridge (C) and East (E) of the M-EEZ. Rows show the oceanographic zones (Gordon, 1988) of Sub-Antarctic (North, N), Polar Frontal (Central, C) and Antarctic (South, S).

Mean Chl *a* for November for the decade 2010-2019 (mean of the monthly mean in each year) was calculated for each pixel in the dataset - Oceandata MODIS Aqua Level-3 mapped monthly 9km Chl *a* (NASA Goddard Space Flight Center, 2022) transformed using algorithm of Johnson et al. (2013). The same method as for SST was used to determine the Chl *a* for which it was less than or equal to that value for 0.1, 0.25, 0.5, 0.75 and 0.9 of the area and plotted in Figure A3-2.

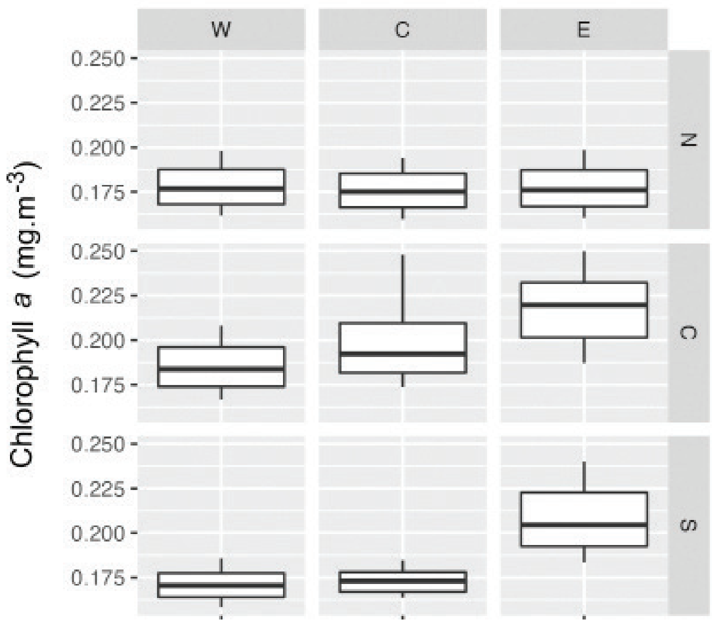

Figure A3-2: Plots for Chlorophyll a in different assessment zones of the M-EEZ showing the proportions of area with Chl *a* at or below the respective values – a box displays 0.25 (bottom), 0.5 (middle), and 0.75 (top), and the whiskers display 0.1 (lower) and 0.9 (upper) proportions. Columns of the display show West (W), Ridge (C) and East (E) of the M-EEZ. Rows show the oceanographic zones (Gordon, 1988) of Sub-Antarctic (North, N), Polar Frontal (Central, C) and Antarctic (South, S).

Areal coverage of different zones and depth strata

Area within each assessment zone of different ocean depths relating to combined benthic and pelagic bathomes of Last et al. (2010). Percentage of protection of bathomes within zones is given for different types of protection: State waters-3nm (St), Northern Habitat Protection (NP), Southern Habitat Protection (SP), Sanctuary (San).

Bathome	Lower Depth (m)	Total (km²)	St (%)	NP (%)	SP(%)	San (%)
		North-West				
Epipelagic	200	0	0	0	0	0
Mesopelagic	1000	0	0	0	0	0
Bathypelagic	2000	82	0	0	0	0
Abyss-1	4000	15773	0	0	0	0
Abyss-2	6000	75758	0	0	0	0
Total		91614	0	0	0	0
		North-Central				
Epipelagic	200	47	0	0	0	0
Mesopelagic	1000	703	0	0	0	0
Bathypelagic	2000	1899	0	0	0	0
Abyss-1	4000	4217	0	0	0	0
Abyss-2	6000	1084	0	0	0	0
Total		7950	0	0	0	0
		North-East				
Epipelagic	200	0	0	0	0	0
Mesopelagic	1000	0	0	0	0	0
Bathypelagic	2000	762	0	**98**	0	0
Abyss-1	4000	19807	0	**19**	0	**9**
Abyss-2	6000	34165	0	**38**	0	**7**
Total		54735	0	**32**	0	**8**
		Central-West				
Epipelagic	200	0	0	0	0	0
Mesopelagic	1000	0	0	0	0	0
Bathypelagic	2000	4	0	0	0	0
Abyss-1	4000	35347	0	0	0	0
Abyss-2	6000	69824	0	0	0	0
Total		105175	0	0	0	0
		Central-Central				
Epipelagic	200	359	**3**	0	0	**12**
Mesopelagic	1000	2081	**2**	**2**	2	**13**
Bathypelagic	2000	2421	**1**	**5**	9	**8**
Abyss-1	4000	5379	0	**2**	0	**7**
Abyss-2	6000	1401	0	0	0	0
Total		11641	**1**	**2**	**2**	**8**

Bathome	Lower Depth (m)	Total (km²)	St (%)	NP (%)	SP(%)	San (%)
		Central-East				
Epipelagic	200	0	0	0	0	0
Mesopelagic	1000	112	0	0	0	0
Bathypelagic	2000	667	0	0	**15**	0
Abyss-1	4000	4546	0	**24**	**16**	**39**
Abyss-2	6000	49015	0	**19**	**8**	**71**
Total		54339	**0**	**19**	**9**	**67**
		South-West				
Epipelagic	200	0	0	0	0	0
Mesopelagic	1000	0	0	0	0	0
Bathypelagic	2000	0	0	0	0	0
Abyss-1	4000	41694	0	0	0	0
Abyss-2	6000	7323	0	0	0	0
Total		49017	0	0	0	0
		South-Central				
Epipelagic	200	0	0	0	0	0
Mesopelagic	1000	0	0	0	0	0
Bathypelagic	2000	0	0	0	0	0
Abyss-1	4000	3173	0	0	0	0
Abyss-2	6000	4624	0	0	0	0
Total		7797	0	0	0	0
		South-East				
Epipelagic	200	0	0	0	0	0
Mesopelagic	1000	17	0	0	**100**	0
Bathypelagic	2000	1175	0	0	**63**	0
Abyss-1	4000	44762	0	0	**86**	0
Abyss-2	6000	47883	0	0	**67**	**31**
Total		93838	0	0	**76**	**16**

		Grand Total
Epipelagic	200	**406**
Mesopelagic	1000	**2913**
Bathypelagic	2000	**7012**
Abyss-1	4000	**174699**
Abyss-2	6000	**291077**
Total		**476107**