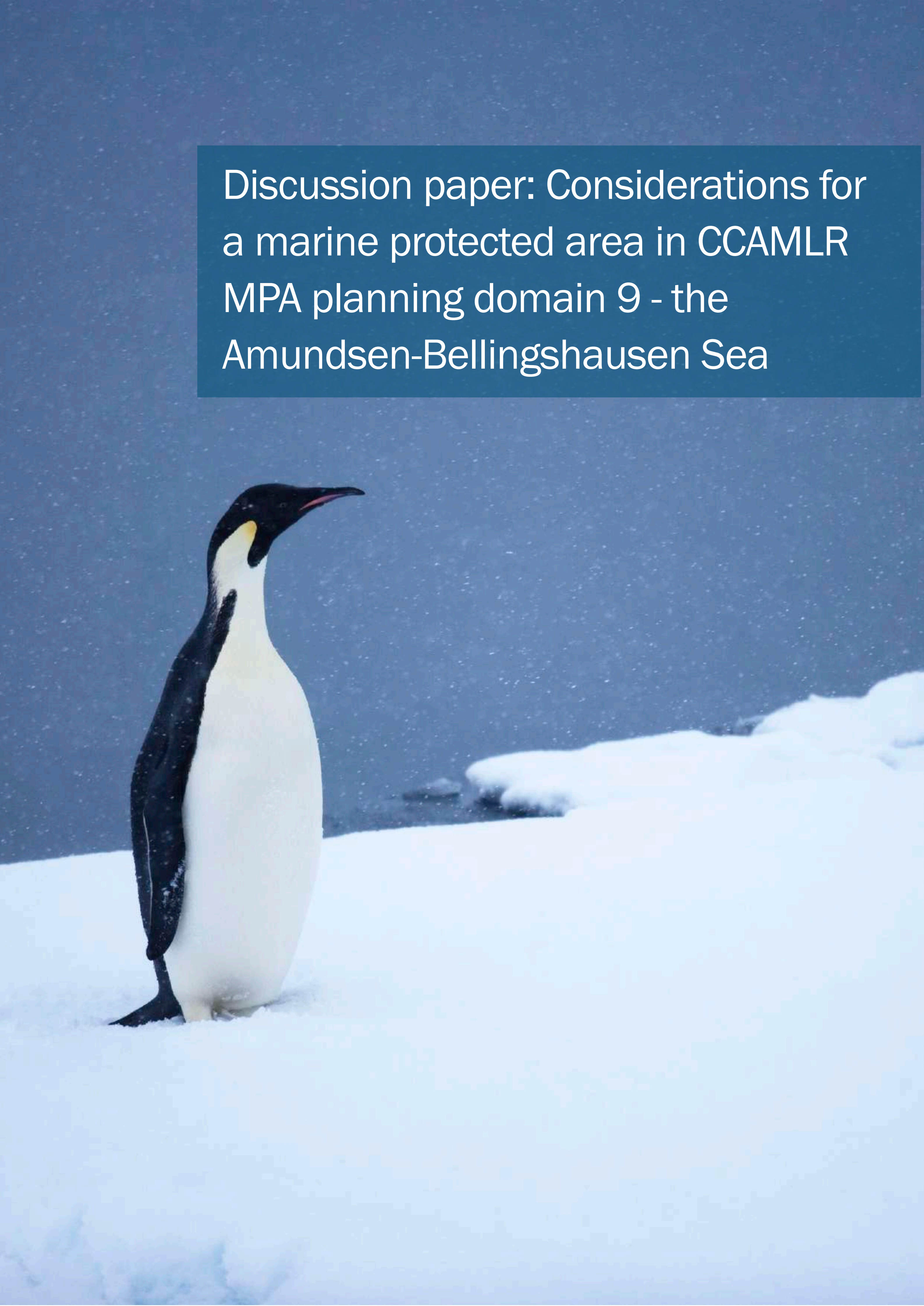
Discussion paper: Considerations for a marine protected area in CCAMLR MPA planning domain 9 - the Amundsen-Bellingshausen Sea



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CENTRE FOR CONSERVATION GEOGRAPHY

The Centre for Conservation Geography is a research group established in 2011 to provide expert technical support and advice to government and non-government stakeholders. The Centre's primary focus is providing world's-best-practice decision support to planning for nature conservation. Based in Australia, we are a multidisciplinary team with expertise in marine and terrestrial protected area planning. Our skills include scientific research, biogeography, GIS analyses and mapping, science communications and advocacy, and evidence-based policy development. We can support conservation decision-making across the world's ecoregions, and currently have projects in Australia, Canada and Antarctica.

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ACRONYMS AND ABBREVIATIONS

ATS Antarctic Treaty System

CAR Comprehensive, Adequate, Representative (protected area system)

CCAMLR Commission for the Conservation of Antarctic Marine Living Resources

CCG Centre for Conservation Geography

CEP Committee for Environmental Protection

CEMP CCAMLR Ecosystem Monitoring Program

IUCN International Union for the Conservation of NatureMPA Marine Protected Area

NGO Non-Government Organisation

SASS Special Area for Scientific Study

SC-CAMLR Scientific Committee for the Conservation of Antarctic Marine Living Resources

SSRU Small Scale Research Unit

TAC Total Allowable Catch

VME Vulnerable Marine Ecosystem

WG-EMM Working Group for Ecosystem Monitoring and Management

WG-FSA Working group for Fish Stock Assessment

WG-FSA-SAM Working group for Fish Stock Assessment, Subgroup on Assessment Methods

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1. EXECUTIVE SUMMARY

The Southern Ocean is an area of marine wilderness containing some of the Earth's most remote and intact marine ecosystems. Southern Ocean ecosystems support biodiversity, provide resources for commercial fisheries, and drive global climate patterns essential for human existence. However, these ecosystems are increasingly threatened by expanding resource exploitation and intensifying climate change impacts.

In 2019 the 'Post-2020 Global Biodiversity Framework' was developed and includes an objective to protect at least 30 percent of all land and seas by 2030. In May 2021, the Conference of Parties to the Convention on Biodiversity (CBD) is set to discuss this new target [1,2]. An area of 30 percent strict reserve within a MPA is beneficial not only to conservation outcomes, but will also ensure fisheries benefits, displayed in multiple case studies across varying marine ecosystems [3].

Currently only 12 percent of the Southern Ocean is protected through MPAs, and many ecosystems and important features in the Southern Ocean are not currently included in existing protected areas. Many of these ecosystems and features exist within the Domain 9 MPA planning region. **Domain 9 is the third largest CCAMLR MPA planning region, spanning 4.3 million km^2 and remains the only domain without an existing MPA or an active process to develop one.** This leaves a critical area of the Southern Ocean unprotected, as well as a gap in the network of Marine Protected Areas in the Southern Ocean.

Domain 9 is a relatively remote portion of the Southern Ocean and also an important but poorly understood climate-sensitive marine ecosystem. It contains the Amundsen and Pacific Basin benthic ecoregions, neither of which are represented in current marine protected area systems. Twenty-six environmental types present in Domain 9 currently have no formal protection, with less than 0.1 percent of the region managed as Vulnerable Marine Ecosystems. Currently 5 percent of the region is subject to fishing, with these areas concentrated in environment types that are desirable for fishing such that more than half the total representation of some environment types is fished.

Within Domain 9 there are unique and globally significant conservation values that warrant protection within a MPA.

Seamounts - Some of the deepest seamounts in the whole of Southern Ocean – highly productive and high levels of endemism of sea mount fauna [4].

Polynas - The Amundsen Sea Polynya is, on average, the most productive polynya (per unit area) in the Antarctic with the highest interannual variation [5,6].

Targeted protection via a MPA network is required to support the continued existence of these rare environments and associated species assemblages and their contribution to global species diversity [7].

The region is also experiencing some of the most significant changes in the ice shelf, driving major ecosystem changes. It includes the Pine Island Glacier, the fastest melting glacier in the Antarctica that is responsible for about 25 percent of Antarctica's ice loss. Along with the Thwaites Glacier, Pine Island Glacier has been described as part of the "weak underbelly" of the West Antarctic Ice Sheet, due to its apparent vulnerability to significant retreat. Ecosystems in these areas are subject to some of the most rapid warming in Antarctica and increased fishing pressure. As the region is relatively untouched compared to other parts of the Southern Ocean, it is also of immense value as a scientific reference area to monitor these climate impacts to ecosystems without the confounding factors of intensive fishing or other human activities. A MPA for Domain 9 would improve the resilience and adaptive capacity for ecosystems in these areas and allow scientists to gain a better understanding of the impact of climate changes on these increasingly vulnerable ecosystems.

A MPA in Domain 9 is thus a critical component of agreed strategies to ensure resilience of this vulnerable and rapidly changing ecosystem, and the Southern Ocean marine environment generally.

The available data and existing conservation planning approaches to MPA development in the Southern Oceans provide a foundation for commencing MPA planning in Domain 9. While further information is useful, MPA planning can be undertaken without the need for any additional research.

There is a timely and rational opportunity for a country/countries to make a critically important contribution to Southern Ocean marine protected area systems through the establishment of a Domain 9 MPA.

Current and proposed Southern Ocean MPAs are not yet representative of the full range of biodiversity or the unique ecoregions present in the CCAMLR area. This paper is the first iteration of what is intended as an up-to-date collation of relevant information and necessary considerations to assist the development of a marine protected area plan in Domain 9. The authors are continuing to expand upon the information contained in this document through further research, analysis and workshop outputs and welcome engagement from interested parties in support of CCAMLR's goal of an ecologically representative MPA system that safeguards Southern Ocean values [7].

2. BACKGROUND

2.1. Introduction

Antarctica and its surrounding waters are remarkable. The frozen continent is key to the regulation of the Earth's climate and ocean systems, while possessing outstanding universal values and hugely productive seas. It is also an exemplary model of consensus based international management of a region, with the world's most successful international agreement in action with the Antarctic Treaty System (ATS), and the world's first intergovernmental commitment to a marine protected area network.

While the region is considered one of the world's last great wildernesses and has been altered less by human pressures than most other parts of the world [8], exploitation has still occurred across all its major marine ecosystems [9]. The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) responds to this need to conserve the region's biodiversity and universal values while sustainably managing exploitation of marine living resources in the region [9,10]. In recognition of the region's critical importance on a global scale, and its vulnerability to both human pressures such as industrial fishing and unprecedented climate change induced ecosystem changes, emphasis has recently been placed on the planning and designation of marine protected areas.

Current and proposed Southern Ocean MPAs are not yet representative of the full range of biodiversity or the unique ecoregions present in the CCAMLR area. Only 12% of the Southern Ocean is protected in MPAs, with 4.6% encompassed in no-take areas [7]. As such greater protection is needed if CCAMLR is to achieve the CBD commitment in the 'Post-2020 Global Biodiversity Framework' to protect at least 30% of the ocean by 2030 [1,2]. This document is intended to initiate the development of a marine protected area plan in Domain 9. In this background chapter we first introduce the overall context of marine protected areas in the Southern Ocean, specifically the relevant political and governance contexts. We then present a range of conservation objectives as they relate to Domain 9 and outline the known conservation values, socioeconomic values, and threats as they relate to each objective. Next, we review current progress in conserving these values through existing special measures – namely Vulnerable Marine Ecosystems (VMEs) – and highlight remaining conservation gaps. Lastly, we outline the next steps in a conservation planning process.

2.2. CCAMLR MPA policy and practice

In the following sections of this chapter we describe the policy and practice including decision-making process for MPA design and implementation under the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and provide a brief history of MPA planning in the CCAMLR area.

ABOUT CCAMLR

The Convention on the Conservation of Antarctic Marine Living Resources (CAMLR Convention) established under the Antarctic Treaty System (ATS) governs the protection and management of marine living resources in the CCAMLR area. Many consider the CAMLR Convention as the most successful multilateral governance system for marine living resources due to its success in implementing precautionary, ecosystem and best-available-science based management and collaborative action to reduce illegal, unreported and unregulated fishing [11].

The Convention is enacted by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) which comprises 25 member states plus the European Union. CCAMLR's central objective is "to conserve Antarctic marine life while managing its rational use" [12]. The commission is the decision-making body and will reach a decision only by consensus [11].

CCAMLR conducts an annual meeting each year in Hobart, Australia (the location of the CCAMLR Secretariat), where member countries consider and request advice from sub-committees and working groups, to develop and ultimately adopt management rules. The Scientific Committee of CCAMLR (SC-CAMLR) advises CCAMLR using the best available scientific advice collated from CCAMLR working groups and sub-committees. Member states take turns to host working groups that meet throughout the year and include the working group on krill, Fish Stock Assessment (WG-FSA-SAM), Ecosystem Monitoring and Management (WG-EMM) and the CCAMLR Ecosystem Monitoring Program (CEMP). Special workshops, such as those to progress MPA planning, also occur as needed.

CCAMLR MPA POLICY

The Southern Ocean contains some of the most remote and intact marine ecosystems on Earth while also supporting globally significant commercial fishing industries [11]. CCAMLR has a unique role as an international convention spanning both conservation and "rational use" of the living marine resources of the region- in particular sustainable fisheries management. MPAs are key to this dual function in that they are central to achieve both objectives.

CCAMLR Marine Protected Areas aim to encompass the full range of biodiversity present in the Convention Area, which covers the Southern Ocean, contribute to conserving ecosystem structure and function, including in areas outside the Marine Protected Areas, and reduce the potential for invasion by alien species, as a result of human activity [13].

CCAMLR has long recognised the value of MPAs as management tools to achieve both biodiversity conservation and resource management. MPAs are a key strategy utilised by CCAMLR to achieve the Convention's primary objective under Article II of "conservation of Antarctic marine living resources" [12]. Article II of the Convention explicitly defines conservation as including the rational use of the region's living marine resources and requires that any harvesting follows a series of principles of conservation that includes precautionary approaches [12]. CCAMLR has included no-take areas in management practices for the past four decades and uses MPAs to complement other management tools including catch limits, gear restrictions, and closures [14]. In recent years CCAMLR and its member states have invested substantial efforts into the planning and declaration of a systematic network of MPAs [14,15].

MPA PLANNING DOMAINS

In committing to develop a representative system of marine protected areas (MPAs) for the Southern Ocean, the CCAMLR divided the Southern Ocean into nine marine planning regions or "domains". The planning domains are intended to reflect the scale and location of current and planned research efforts to be helpful as reporting and auditing units [16]. Marine conservation planning is ongoing and MPAs have been designated in almost all of these planning regions (Figure 1).

Domain 9 in the Amundsen-Bellingshausen Sea is the only planning region without any designated MPA or process underway and thus remains a critical gap in the network.

The full range of biodiversity and ecoregions present in the CCAMLR area are not yet represented in the current and proposed CCAMLR MPA network. The continued development of the MPA system, especially in currently unrepresented areas such as Domain 9, allows CCAMLR to achieve the goals of an ecologically representative MPA system with adequate protection and optimal persistence [7].

In addition to conservation objectives, it is also acknowledged that current CCAMLR fisheries management strategies could be improved by incorporating additional closed areas within MPAs to improve accuracy of biomass estimates and subsequent harvest strategies (see section 2.3).

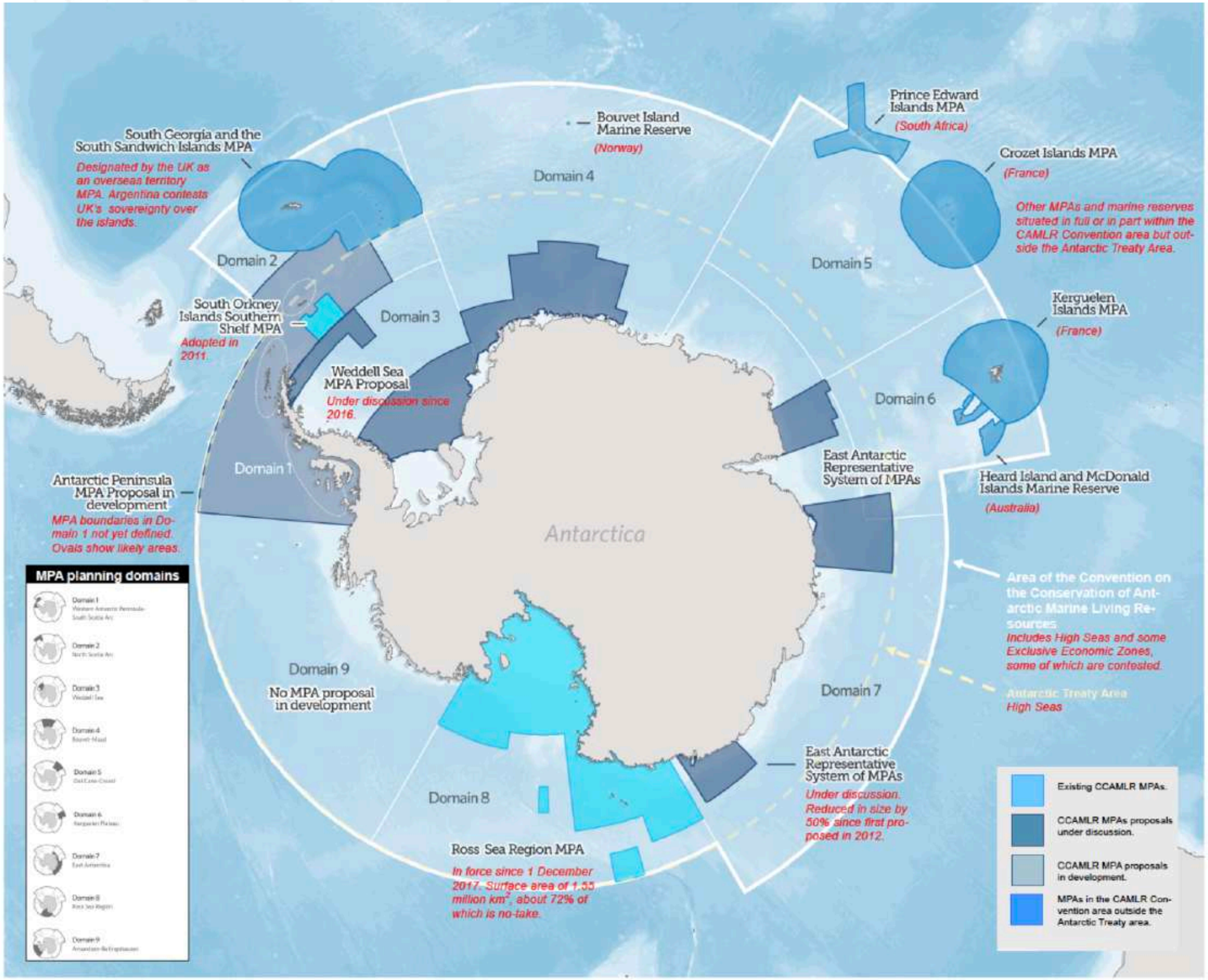

Figure 1. Existing and proposed marine protected areas in the Southern Ocean. Source: Bourseiller [17]

PRECAUTIONARY APPROACHES IN CAMMLR MPA PLANNING

As CCAMLR's approach to conservation and management of the region's living marine resources has evolved, agreement was reached and decisions made to act in a precautionary way [18]. Applying a precautionary approach to management decisions has become central to the setting of catch limits, developing exploratory fisheries, addressing bycatch and protecting vulnerable marine ecosystems [19,20]. For example, current stock assessments for toothfish in Subareas 88.2 and 88.3 are single-area assessments, data-limited, include a number of assumptions and as such demonstrate a high degree of uncertainty [21]. This is recognised by CCAMLR within the approach for estimating biomass in data-limited areas, the *CCAMLR's approach to data-limited exploratory toothfish fisheries: the trend analysis* which defines a precautionary approach to set catch limits [21].

Work is also currently underway in CCAMLR to develop stock assessment methods for use in integrated stock assessment models with improved certainty of outputs. However, improving traditional fisheries management, data and modelling cannot always ensure the long-term sustainability of marine life. Scientists note that "MPAs can serve to hedge against inevitable uncertainties, errors and biases in fisheries management. Marine Protected Areas may well be the simplest and best approach to implementing the precautionary principle" [19].

The precautionary principle was enshrined in International Law through Principle 15 of the 1992 Rio Declaration on Environment and Development. In its essence the precautionary principle requires taking action in the form of protective conservation and management actions to avoid the risk of serious and/or irreversible harm from an activity before negative consequences become apparent [20]. This approach also requires that limits in data do not prevent the establishment of MPAs as a precautionary measure. The use of the precautionary principle in ecosystem management is especially important in the case of the marine environment where scientific uncertainties abound [20]. Repeated failures of management highlighted by the collapse of northern cod off Canada, the Californian sardine fishery, and herring, sandeel, blue whiting, and capelin stocks in the North Sea have demonstrated the need for this approach to help address scientific uncertainty [20]. In data poor areas such as the Southern Ocean this approach has particular saliency.

MPA DESIGNATION AT CCAMLR

The process of designating a MPA at CCAMLR includes both a scientific and policy process.

A member state first proposes to CCAMLR to be the proponent for a MPA, and subsequently proposals are submitted by the proponent member state (otherwise referred to as the lead country) to WG-EMM and potentially other working groups for consideration. The member state would then take the proposals to SC-CAMLR for evaluation and endorsement, and to CCAMLR for designation (Figure 2). The progress from initial proposal to presenting a MPA designation takes at least 3 years or longer and is iterative in nature.

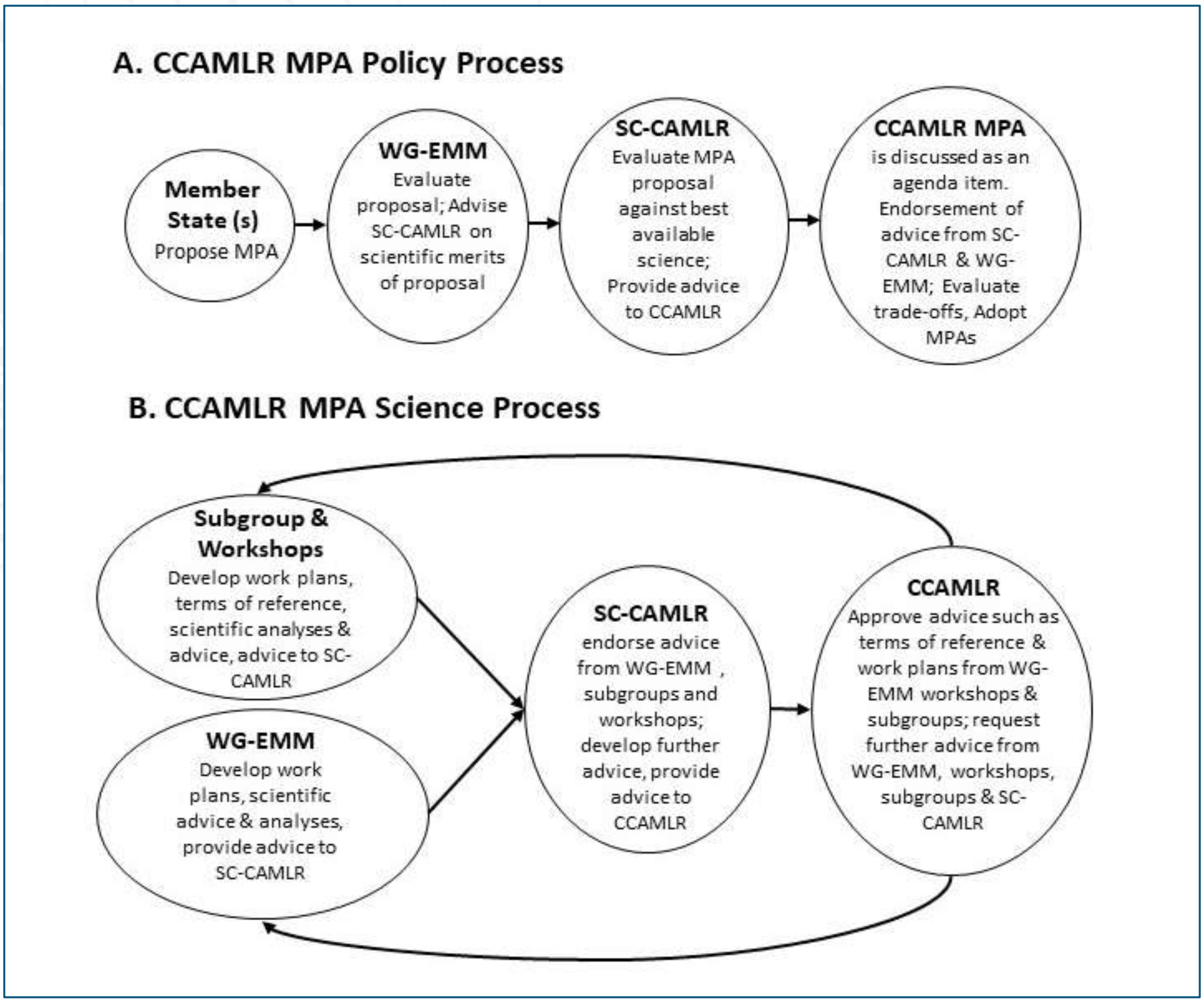

Figure 2. CCAMLR's marine protected area policy (A) and science (B) process. Adapted from Brooks [11].

A CCAMLR MPA designation must have the following components [15]

- specific objectives
- spatial boundaries
- list of activities that are restricted, prohibited, or managed
- management plan, including administrative arrangements
- research and monitoring plan, and research and monitoring arrangements
- period of designation.

Member states also agree that CCAMLR MPAs shall be established on the basis of the best available science according to Resolution 31/XXVIII [22] to achieve the **following objectives:**

> "(i) the protection of representative examples of marine ecosystems, biodiversity and habitats at an appropriate scale to maintain their viability and integrity in the long term;
>
> (ii) the protection of key ecosystem processes, habitats and species, including populations and life-history stages;
>
> (iii) the establishment of scientific reference areas for monitoring natural variability and long-term change or for monitoring the effects of harvesting and other human activities on Antarctic marine living resources and on the ecosystems of which they form part;

(iv) the protection of areas vulnerable to impact by human activities, including unique, rare or highly biodiverse habitats and features;

(v) the protection of features critical to the function of local ecosystems;

(vi) the protection of areas to maintain resilience or the ability to adapt to the effects of climate change"[15].

HISTORY OF MPA DEVELOPMENT AT CCAMLR

Since 2002, CCAMLR has recognised the value of formally designated MPAs as management tools to ensure the long-term persistence of both conservation and fisheries values [7]. CCAMLR committed to establish a MPA system across the CCAMLR region aligned with international MPA design objectives agreed under the Convention on Biological Diversity and developed by the International Union for the Conservation of Nature (IUCN).

In 2005, CCAMLR conducted the first MPA planning workshop, and following the initial workshop, numerous additional MPA workshops and regionalisation research have been conducted. In 2011 CCAMLR committed to the establishment of a system of protected areas in the Southern Ocean in accordance with agreements under the Convention on Biological Diversity[1] [23] and adopted the General Framework for CCAMLR MPAs (Conservation Measure 91-04)[15] to guide future MPA development. Under this framework, CCAMLR adopted 9 planning domains to plan for and assess progress towards a representative system of MPAs.

At the recent 2020 CCAMLR annual meeting, all but two delegations pledged broad support for the further development of the Southern Ocean's marine protected areas and adoption of MPA proposals as part of recognising the urgent need to establish a representative system of protected areas in the CCAMLR area. At this meeting Australia and Uruguay became new co-sponsors for the Weddell Sea MPA, joining the EU, Germany, and Norway. Likewise, Norway and Uruguay became new co-sponsors of the East Antarctica MPA, joining the EU, France, and Australia. Most recently the United States and New Zealand became co-sponsors of the Weddell Sea and East Antarctic MPA proposals [24] (Figure 3).

[1] This includes the decision at the World Summit on Sustainable Development in 2002 to achieve a representative system of MPAs by 2012, and the 2010 Aichi target 11 aiming to protect at least 10% of coastal and marine areas by 2020.

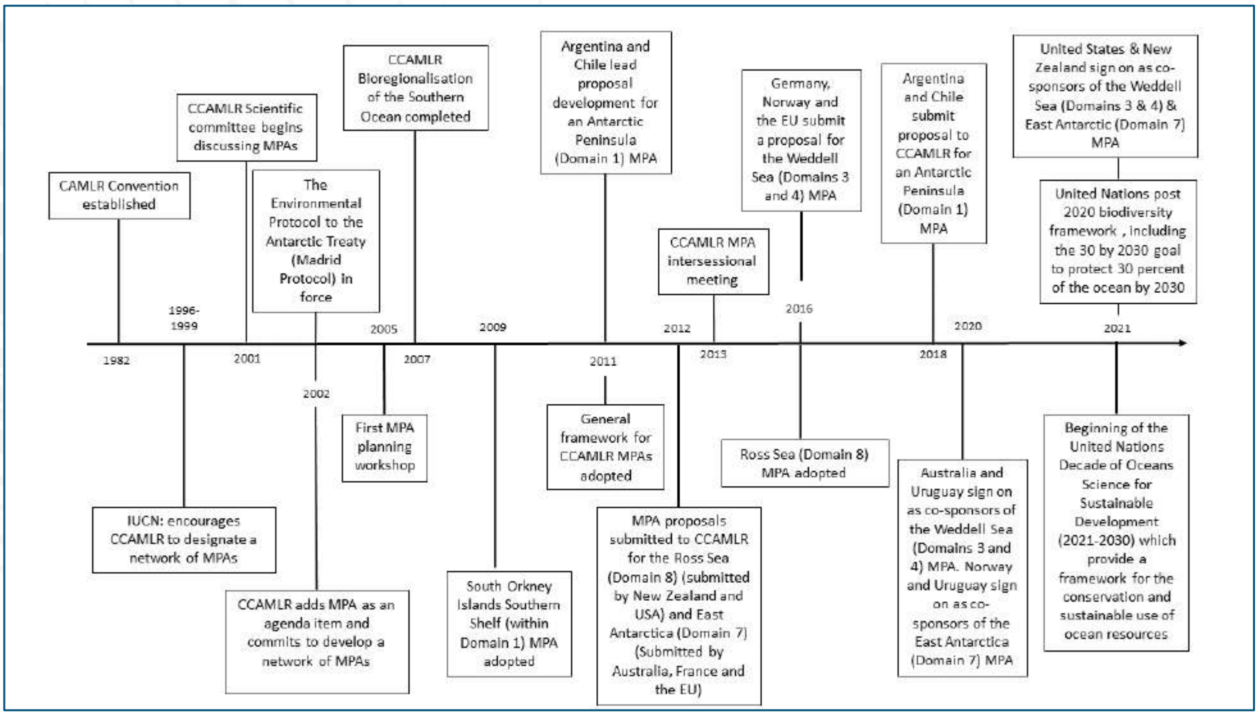

Figure 3. Timeline of key milestones in CCAMLR's MPA development process. Adapted from Brooks [11].

2.3. Key benefits of marine protected areas

MPAs are spatially designed and designated areas of the marine environment where human activities are managed to meet a range of environmental, social, cultural and economic objectives. Initially perceived as a conservation tool, the utility of MPAs has expanded beyond traditional concepts of 'locking away' an area for conservation. They are now accepted globally as essential for healthy ocean ecosystems, beneficial to tourism and a powerful tool for sustainable fisheries [25–29].

MPAs are proven to be powerful management tools to ensure the conservation of nature and the sustainability of marine resources in a time of global anthropogenic climate change [30]. In particular, MPAs are recognised as achieving the protection of biodiversity, avoiding species collapse and ensuring sustainable fisheries [3,31].

While MPAs can prohibit direct threats to a region, such as fishing, shipping, or mining [32], there is also mounting evidence that protected areas provide a range of holistic benefits to the ecosystem beyond these abatable threats. This includes increased climate change resilience, fisheries benefits for the surrounding waters, and increased recovery after damaging storm events [33]. When designed, implemented, monitored, and enforced correctly, marine protected areas can provide a multitude of social, environmental, and economic benefits, both within the MPA and beyond its spatial boundaries.

THE SPECIFIC ROLE OF NO TAKE ZONES WITHIN MPAS

Scientific studies on the effects of no take zones as a component of MPAs highlight the significant positive benefits which include:

- increases in the abundance, individual sizes, diversity and overall biomass of sea life
- increased ability of local marine life to reproduce
- spill-over of larvae and/or adults into unprotected areas
- improvements in ecosystems and habitats, that is, healthy natural balances are restored [34].

BENEFITS OF MPAS TO FISHERIES

Aside from their primary purpose as a conservation tool focused on protecting vulnerable ecosystems, the critical role MPAs play in ensuring sustainable fishery industries is recognised globally. A well designed MPA can deliver both ecosystem conservation and sustainable benefits to existing fisheries [35]. One of the most widely documented benefits of highly protected areas is in the recovery of depleted fisheries, as in many cases these lead to the spill-over of fish and larvae into nearby waters open to fishing [3,26,32,35–39]. Syntheses of measured MPA, or no-take area impacts both inside and outside borders commonly show benefits including increases in the abundance, individual sizes, diversity and overall biomass of sea life within borders and spillover effects outside no-take areas (including increased larval production and egg recruitment to the fishery, as well as mature fish biomass) [3,40].

When used in addition to other fisheries management tools, such as catch limits and fishing licenses, effective MPAs can contribute significantly to improved biomass, catch rates, and economic outcomes [41]. Additionally, MPAs can ensure sufficient stocks for safeguarding against unexpected population fluctuations, provide reference areas to assess stock impacts in the absence of fishing, and increase the resilience of the fishery to environmental change [33].

A review of studies of 124 marine reserves in 29 countries found that on average and within a decade highly protected areas achieve 21 percent higher species richness, 28 percent bigger organisms and 6.7 times the fish biomass compared to nearby unprotected areas [3]. Partially protected marine protected areas offer smaller benefits with fish biomass reaching an average of being 1.8 times greater than in unprotected areas [38].

Bigger fish produce disproportionately more eggs than smaller fish. As a result, one hectare of a highly protected reserve produces on average at least 5 times as many fish offspring as an equivalent unprotected hectare [38]. **For this reason, marine protected areas can be seen as ‘fish banks’ – “an investment in future prosperity rather than a foregone economic opportunity” [39].**

3. SITUATION ANALYSIS FOR DOMAIN 9 – CONSERVATION VALUES AND THREATS

3.1. Overview

CCAMLR MPA Planning Domain 9 is the third largest CCAMLR planning domain, spanning 4.3 million km^2. Domain 9 is located within the Pacific Ocean sector of the CCAMLR Area and contains the Amundsen Sea and the western section of the Bellingshausen Sea.

Domain 9 is a relatively remote portion of the Southern Ocean and an important but poorly understood climate-sensitive marine ecosystem. The Amundsen and Bellingshausen Seas were once characterised by persistently lower temperatures than other parts of Antarctica, and sea ice cover and distance from ports prevented researchers and fishing vessels from accessing the area [8]. However, with warming temperatures, the region is experiencing some of the most significant shifts in the ice shelf, driving major ecosystem changes, and is becoming increasingly accessible to researchers and fishing vessels. The domain includes the Pine Island Glacier, the fastest melting glacier in the Antarctica that is responsible for about 25 percent of Antarctica's ice loss. Along with the Thwaites Glacier, Pine Island Glacier has been described as part of the "weak underbelly" of the West Antarctic Ice Sheet, due to its apparent vulnerability to significant retreat.

In addition to ecologically significant and climate-sensitive ecosystems, Domain 9 is characterized by stakeholder interests and activities in rational uses such as exploratory and research fishing of Antarctic toothfish (*Dissostichus mawsoni*). There is exploratory toothfish fishing in the Amundsen Sea by a range of countries (including Australia, Korea, Russia, Ukraine, the United Kingdom and Uruguay in recent years) and research fishing for toothfish in the Bellingshausen Sea by Korea, New Zealand and Ukraine. In 2019 Russia initiated a research fishery for craboids *(Anomura, Decapoda)* in the region.

This intersection of values makes Domain 9 an important area for MPA planning and design. Furthermore, the domain is almost completely unprotected and meets the full range of criteria identified by the Convention on Biological Diversity for designating marine protected areas [42] (Appendix 1

In the following sections, we discuss key aspects of Domain 9 relevant for MPA planning and design. For each conservation objective we then describe relevant environmental values and socio-economic values as well as threats. Lastly, we describe potential next steps in compiling the data as it relates to these objectives.

3.2. Overarching conservation objectives

Domain 9 contains ecoregions of significant conservation value that are a high priority for protection due to their ecological significance as well as risk from rapid environmental change. Domain 9 contains the Amundsen and Pacific Basin benthic ecoregions [43], neither of which are represented in marine protected area systems [7]. The Amundsen ecoregion comprises the productive shelf and polynyas of the Amundsen and Bellingshausen Seas, and the oceanic shallow environments of Peter I Island, De Gerlache Seamounts and the Marie Byrd Seamount group [44]. The Pacific Basin ecoregion is characterised by the very deep, rugose ocean floor and abyssal plains of the South Pacific Ocean Basin which are warmer than other deep ocean basin regions in the Southern Ocean [44]. Domain 9 is also exhibiting signs of rapid change due to climate change and the related impacts. All ecoregions within the Southern Ocean must contain adequate protection to achieve a representative system of MPAs.

A conservation planning process requires defining operational conservation objectives to ensure all key conservation values are included in reserve design. Conservation objectives should encompass identified conservation values. Once conservation objectives are defined, spatial data is analysed to ensure representation of broad objectives and/or individual conservation values.

Conservation values within D9 can be broadly assigned to one of the following 6 overarching conservation objectives that have been utilised in other CCAMLR planning processes including the Ross Sea [45] and Weddell Sea [46].

1) **Protect benthic marine environments** (including representative habitats as well as rare and vulnerable habitats) and processes
2) **Protect pelagic marine environments** (including representative habitats as well as rare and vulnerable habitats) and processes
3) **Protect areas of importance in the life cycle of fish** (in particular, but not limited to, Antarctic toothfish and krill)
4) **Protection of essential habitats for top predators such as marine mammals and seabirds**
5) **Protect other rare or unique features not captured in objectives 1 and 2**
6) **Establishment of scientific reference areas** to monitor the effects of climate change, fishing and other human activities and to study, in particular, representative, rare, unique and/or endemic examples of marine ecosystems, as well as biodiversity and habitats.

3.3. Conservation values

This section describes the known data and available analysis of conservation values in Domain 9 for each of the six overarching MPA conservation objectives listed above in section 3.2.

BENTHIC MARINE ENVIRONMENTS AND PROCESSES

Key benthic features in Domain 9 are shown in Figure 4. Benthic marine environments – the seabed habitats and associated biodiversity – are a fundamental component of marine planning.

In data limited regions, such as Domain 9, bioregionalisations provide a method of mapping habitats as a surrogate for species and biodiversity protection. Bioregionalisation is a process that aims to partition a broad spatial area into distinct spatial regions, using a range of environmental and biological information. The regionalisation analyses may indicate separations between different species assemblages, in particular areas where endemic or restricted-range species may occur and can also identify areas of ecological separation (poor connectivity) [44]. The data summarised includes the environmental drivers that influence the distribution of biota, biological data and previous regionalisation and environmental classifications.

There have been 3 circum-Antarctic scale bioregional analyses which can inform MPA planning in the CCAMLR area. The 2006 CCAMLR Workshop on Bioregionalisation of the Southern Ocean [47] demonstrated a suitable method for a circumpolar pelagic regionalisation, which has since been revisited as new data becomes available [48]. A hierarchical classification of benthic biodiversity was first developed in 2011 and published in 2014 to inform an assessment of protected areas in the Southern Ocean [48]. Existing bioregionalisation data of the Southern Ocean has been used to analyse the representativeness of environmental classes within planning regions [44] and at a circumpolar scale [7]. This data can be integrated into planning for Domain 9 to simultaneously plan for representativeness at a Domain level and circumpolar scale.

Based on the analysis presented by Douglass et al. 2014 [43], Domain 9 contains a diversity of benthic environments and includes 14 of the 30 geomorphic feature types found in the CCAMLR area. These features span the abyssal (68 percent of domain), slope (22 percent of domain), shelf (8 percent of domain) and oceanic shallow (2 percent of domain) geomorphic classes.

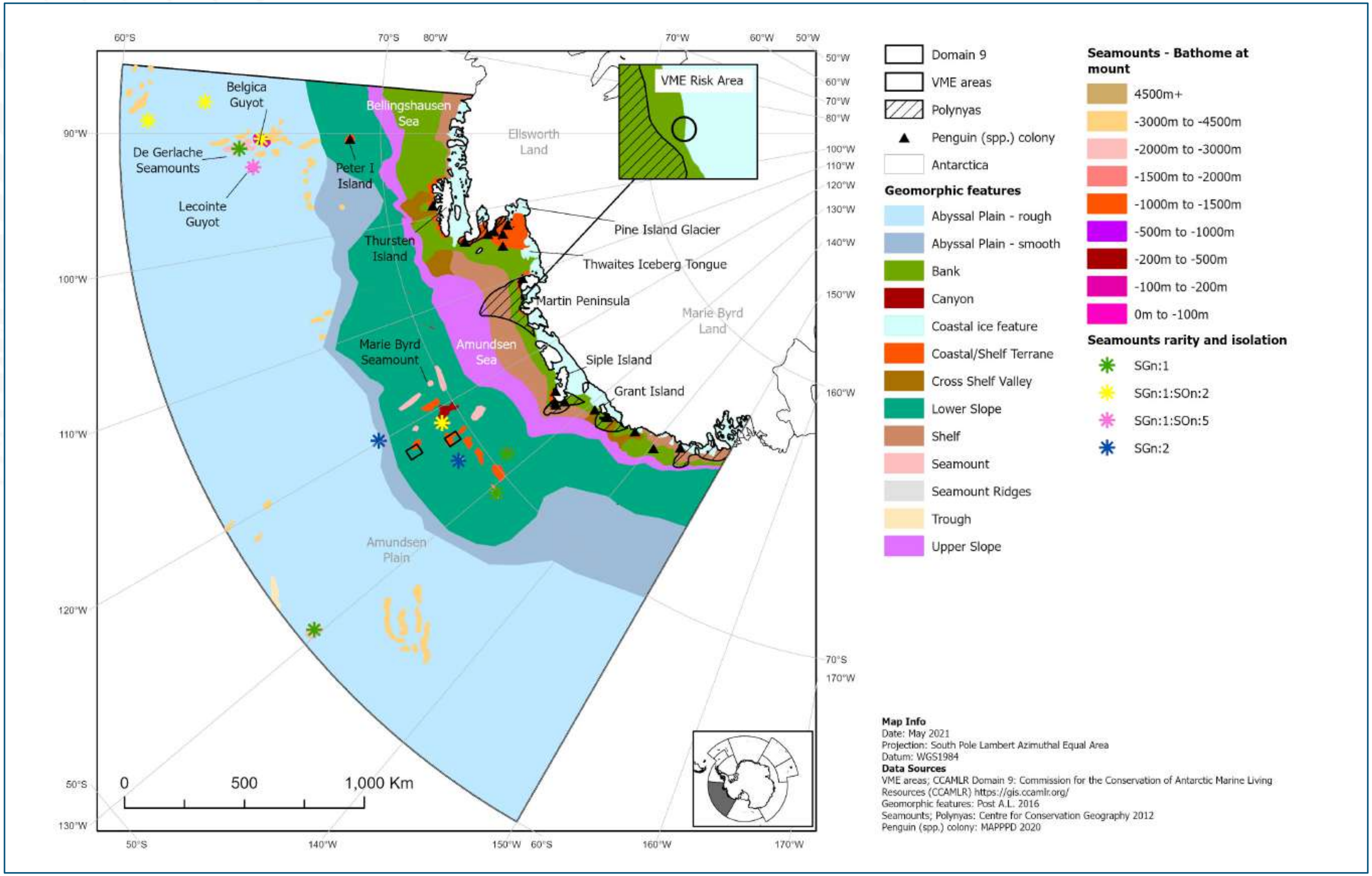

Figure 4. Benthic features of Domain 9.
The number beside 'SGn' is the number of seamounts or seamounts ridges with a specific bathome located within the seamount group. The number beside 'SOn' is the number within the CCAMLR Southern Ocean region. For instance, for SGn:2:SOn:5, there are two seamounts with the same bathome in the seamount group (i.e within 200km) and five seamounts with this bathome in the Southern Ocean

In addition to protecting habitats, conservation plans typically include goals of protecting environmental drivers or processes that set habitat conditions, influence distribution and abundance of taxa, and ultimately can drive evolution of taxa [43]. Benthic processes of relevance are depth, geomorphology, and seabed temperatures. The deep ocean and shelf environment seabed temperatures within Domain 9 are some of the warmest within the CCAMLR area. There are data gaps within the seabed temperature dataset across much of the shelf, however, where data exists, it shows the eastern section of the shelf to have very warm seabed temperatures and indicates that the whole shelf area is likely to be warm relative to many other shelf regions of the Antarctic continent. This rugged terrain with its diversity of depths, shallow areas in the photic zone and temperatures provides an array of habitats and is therefore likely to contain a diversity of biota [44].

UNIQUE OR RARE BENTHIC FEATURES

Seamounts are underwater mountains that rise hundreds or thousands of feet from the seafloor. Seamounts are typically formed from extinct volcanoes that, while active, create piles of lava that sometimes break the ocean surface. Because seamounts rapidly rise from the seafloor they often shape ocean currents and direct deep, nutrient-rich waters up the sloping sides of seamounts to the surface. Seamounts are often fertile habitats for diverse communities of marine life but are also vulnerable to impacts [4,49–51].

Domain 9 contains fifty-five known seamounts and seamounts ridges, of which seventeen have a rare or isolated distribution. Some of the deepest and shallowest seamounts in the CCAMLR area are located within Domain 9. The Belgica guyot is one of only two seamounts in the CCAMLR area with a mount in the 100-200m bathome, and the Lecointe guyot, one of only five seamounts with a mount in the 0-100m bathome within the CCAMLR Area [44]. These guyots are located within the Bellingshausen Sea and belong to a seamount group that interacts with the Polar Front. Nearby, the Der Gerlache Seamount group also interacts with the Polar Front.

North of Peter I Island is one of the deepest seamounts in the CCAMLR area with a mount in the 4,500m bathome, and belongs to a seamount group that corresponds with the southern region of the Sub-Antarctic Front. Another seamount group in the Amundsen Sea which includes the Marie Byrd Seamount interacts with the Southern Antarctic Circumpolar Front, and an isolated seamount group north of the Amundsen Plain sits between the Southern Antarctic Circumpolar Front and Polar Frontal Zone. These features, and their relationships to frontal systems, correspond with higher species richness and are likely to support unique species assemblages.

Peter I Island and surroundings was formed through ancient volcanic activity, creating rugged bathymetry and guyots (flat-topped seamounts formed by extinct volcanoes), and represents the only location of deep island coastal terrane and coastal terrane geomorphic feature types deeper than 1000m in the CCAMLR area. Seafloor studies surrounding Peter I Island reveal areas rich in abundance and diversity of invertebrates, with some of the highest mollusc abundance within the Bellingshausen Sea [52]. Stone crabs were also found in coastal areas of Peter I Island [53].

PELAGIC MARINE ENVIRONMENTS AND PROCESSES

Key pelagic features in Domain 9 are shown in Figure 5. Just as habitat data is fundamental when planning for benthic environments, similar information is required for pelagic habitats. Data-driven pelagic habitat classifications are important when planning for habitat protection in the absence of sufficient in-situ data. A pelagic regionalisation for the Southern Ocean has been completed using similar clustering methods to the benthic regionalisation and based on depth, water mass characteristics, and dynamic ice behaviour [48]. The regionalisation identified twenty distinct pelagic regions (Appendix 3

Domain 9 represents sixteen of the pelagic regions in the CCAMLR area, primarily pelagic region 15 (41 percent), pelagic region 9 (17 percent), pelagic region 10 and pelagic region 11 (both 12 percent) [48] (Figure 5). The remaining twelve pelagic regions each span less than 5 percent of the domain. Domain 9 contains 19 percent of the distribution of the deeper pelagic region 14 (~500–2000m) in the Pacific Ocean Basin. Pelagic region 14 corresponds with the area surrounding Peter I Island, which contains Belgica guyot and Lecointe guyot (Figure 5). Domain 9 is important in representing 72 percent of the distribution of pelagic region 2 in the Pacific Ocean sector. Pelagic region 2 corresponds with polynyas in shallow areas (<1000m depth) with sea ice cover between 0-20 percent of the year have cold sea surface temperatures of <2° Celsius.

The Lecointe Guyot corresponds with the only location of pelagic region 13 in the Pacific Ocean sector of the CCAMLR Area. Other locations of this pelagic region include the shallow areas of approximately 200-1000m depth of the northern Kerguelen, Crozet and South Georgia plateau areas [44]. The deeper (~500–2000m) pelagic region 14 is also located upon these plateau areas [44]. Within the Pacific Ocean basin, pelagic region 14 is mostly located within the Ross Sea domain (80 percent) and the Amundsen-Bellingshausen domain (19 percent) where it occurs over both the Lecointe and nearby Belgica guyots. These guyots are within the Bellingshausen Sea and belong to a seamount group that interacts with the polar front [44]. The deeper seamount group to their north corresponds with the southern region of the Sub-Antarctic front. The seamount group within the Amundsen Sea which includes the Marie Byrd seamount interacts with the Southern Antarctic Circumpolar Current Front (Figure 5).

Pelagic processes relevant for conservation planning are captured with sea ice concentration and areas of high chlorophyll, as these two factors drive pelagic productivity and species aggregations. The shelf area near to the coast has high ice cover for most of the year with patches of polynyas and highly persistent summer productivity [44]. The pelagic regions 1 and 2 north-west of both Grant and Siple Islands and west of the Thwaites Iceberg Tongue correspond with polynyas with persistently high productivity [44] (Figure 5).

UNIQUE OR RARE PELAGIC FEATURES

Some of the rarer distributions of pelagic regions in Domain 9 correspond with important pelagic features - polynyas. Polynyas are defined as recurring seasonally open stretches of open water surrounded by ice. Polynyas are important for wildlife for a variety of reasons – overturning ocean water brings nutrients to the surface making them highly productive. Furthermore, as holes in the sea ice they provide access between the ocean and atmosphere for a variety of animals, including seals and penguins [5].

The polynya off the coast of Martin Peninsula and west of the Thwaites Iceberg Tongue has the most persistently high summer productivity in the CCAMLR Area [44]. This is reflected in the pelagic region mapping of this area which is primarily pelagic region 1 and 2. Pelagic region 2 represents polynya margins upon shallow areas (approximately <1000m depth) with high sea ice cover for 0-20 percent of the year and cold sea surface temperatures of <2°C [44]. Pelagic region 1 is similar to region 2, however with higher sea ice cover of 20-50 percent of the year. The domain also contains year-round ice-free region of open ocean [44].

The inner shelf of the Amundsen Sea lies under influence of two highly productive polynyas – Pine Island Bay Polynya and Amundsen Sea Polynya. Among the 37 known coastal polynyas around Antarctica the Amundsen Sea Polynya is the most productive Antarctic polynya per square meter, exhibiting consistently higher chlorophyll levels during peak bloom as well as the greatest interannual variability [6,54–56].

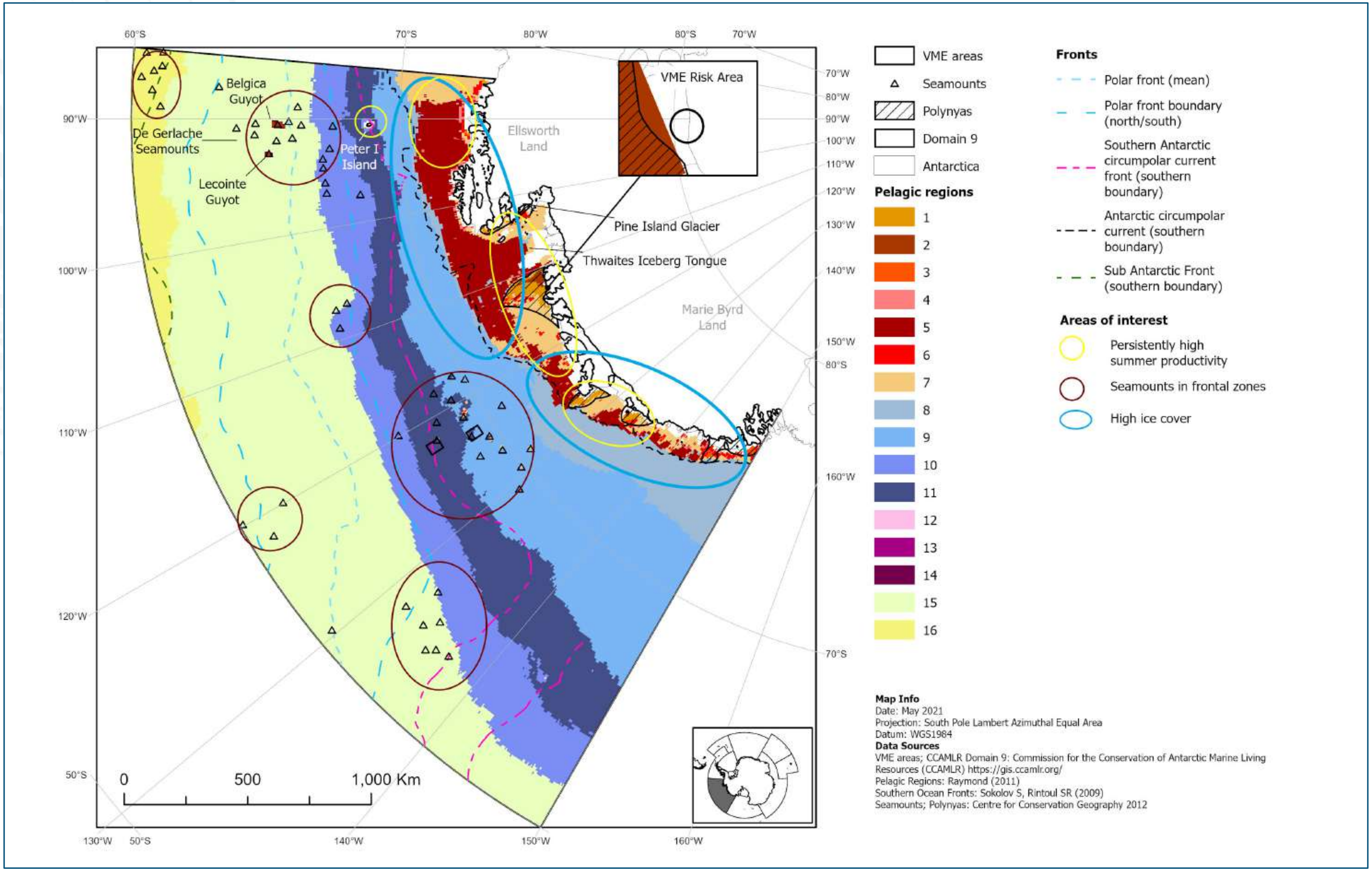

Figure 5. Pelagic features of Domain 9.

PROTECT AREAS OF IMPORTANCE IN THE LIFE CYCLE OF FISH (IN PARTICULAR, BUT NOT LIMITED TO, ANTARCTIC TOOTHFISH) AND KRILL

Antarctic toothfish and krill are important species for conservation not only because of their economic value as fisheries targets but also due to their role within ecosystems. Thus, a key objective in MPA plans is to protect the full life cycle of these species.

Initial surveys of fish species within Domain 9 suggest that the majority of species assemblages resemble those of the Eastern Antarctic [8]. Eelpout and cod icefish families represent the majority of species. In the waters surrounding Peter I Island, surveys of fish species suggest that assemblages are dominated by the notothenioid fish family, such as the painted notie. Species usually only found in the subantarctic were also present such as the emerald rockcod and Charcot's dragonfish. The commercially important Antarctic toothfish are also found here.

Antarctic toothfish utilise a range of habitats throughout their lifetime, spawning on ridges and banks, with larvae and small juveniles (up to 12cm) living in the epipelagic zone and moving into increasingly deeper waters as they mature [57,58]. Fishery-dependent data suggests that older juveniles and sub-adults typically live close to the seabed on the continental slope (800-1500m depth) and larger, older adults (>120cm) are mainly caught on banks, ridges and hills at depths of 1000-1800m [58]. Very little is known of Antarctic toothfish life cycles for the Domain 9 area. A hypothesis of Antarctic toothfish life cycle for the adjacent Ross Sea region based on aspects of reproduction, size distribution and movement suggest that the Ross Sea stock is relatively independent from the adjacent Amundsen Sea stock, with limited movement between these stocks [58]. The Ross Sea hypothetical life cycle suggests that toothfish spawn on ridges and banks during winter and spring, eggs and larvae travel via current movements to grow in shallower waters on the continental slope and shelf before travelling into deeper waters once mature.

PROTECTION OF ESSENTIAL HABITATS FOR TOP PREDATORS SUCH AS MARINE MAMMALS AND SEABIRDS

The protection of top predators has essential flow on benefits through hierarchal ecosystems conserving not only individual species but also the roles these species play in the ecosystem. Areas that provide essential habitats for top predators such as marine mammals and seabirds relate to areas of productivity such as polynyas. In Domain 9, these areas occur across the shelf, within the highly productive polynyas, and at Peter I Island and the Belgica guyot and Lecointe guyots. These same places have been mapped as areas of high species richness (Figure 6).

Limited research in the area provides some data for species distributions and essential habitats. Recent circum-polar analysis of marine predator tracking data identified parts of the Amundsen and Bellingshausen Seas as Areas of Ecological Significance (AES) of high importance for species [59].

Important species occurrences in Domain 9 are described in the following three subsections.

Penguins (Spheniscidae)

Four colonies of the ice breeding emperor penguins *(Aptenodytes forsteri)* have been located within the domain using remote sensing to identify fecal stains. Colonies have been confirmed on the Thurston Glacier off Siple Island, at Ledda Bay of Grant Island, Noville Peninsula of Thursten Island and the Bear Peninsula. Apart from the Thursten Island colony, these colonies correspond with polynyas that may be important for foraging. Adélie penguins *(Pygoscelis adeliae)* have also been observed in Domain 9 [44].

Other seabirds – petrels, prions (Procellariidae) and terns (Sternidae)

In addition to emperor penguins and Adélie penguins, the main seabirds to have been observed in Domain 9 are Antarctic petrels *(Thalassoica antarctica),* blue petrels *(Halobaena caerulea)* and Antarctic prions *(Pachyptila desolata)* [60]. Peter I Island has nesting habitats for southern fulmars *(Fulmarus glacialoides),* Wilson's storm petrels *(Oceanites oceanicus),* cape petrels *(Daption capense),* and Arctic terns *(Sterna paradisaea),* and good foraging areas for seabirds occur near ocean fronts and at continental shelf breaks.

Whales (Cetacea) and seals (Pinnipedia)

Peter I Island hosts colonies of crabeater *(Lobodon carcinophagus),* leopard *(Hydrurga leptonyx)* and southern elephant seals *(Mirounga leonine),* and the waters surrounding the island are highly productive, with whale surveys in the area indicating that orcas *(Orcinus orca)* and minke whales *(Balaenoptera acutorostrata)* and *(Balaenoptera bonaerensis)* are the most common cetaceans. Sperm whales *(Physeter macrocephalus),* blue whales *(Balaenoptera musculus)* and fin whales *(Balaenoptera physalus)* are also likely to frequent the area. Minke whales *(Balaenoptera acutorostrata)* and *(Balaenoptera bonaerensis)* are also prevalent in the pack ice in the southern Bellingshausen Sea [8]. The region is also a known feeding ground for the only endangered population of humpback whales in the world, the Oceania Humpback (*Megaptera novaeangliae*), a migratory species that breed in the Pacific territories of New Zealand and France and in Tonga before travelling to the Amundsen and Bellingshausen Seas to feed [61,62].

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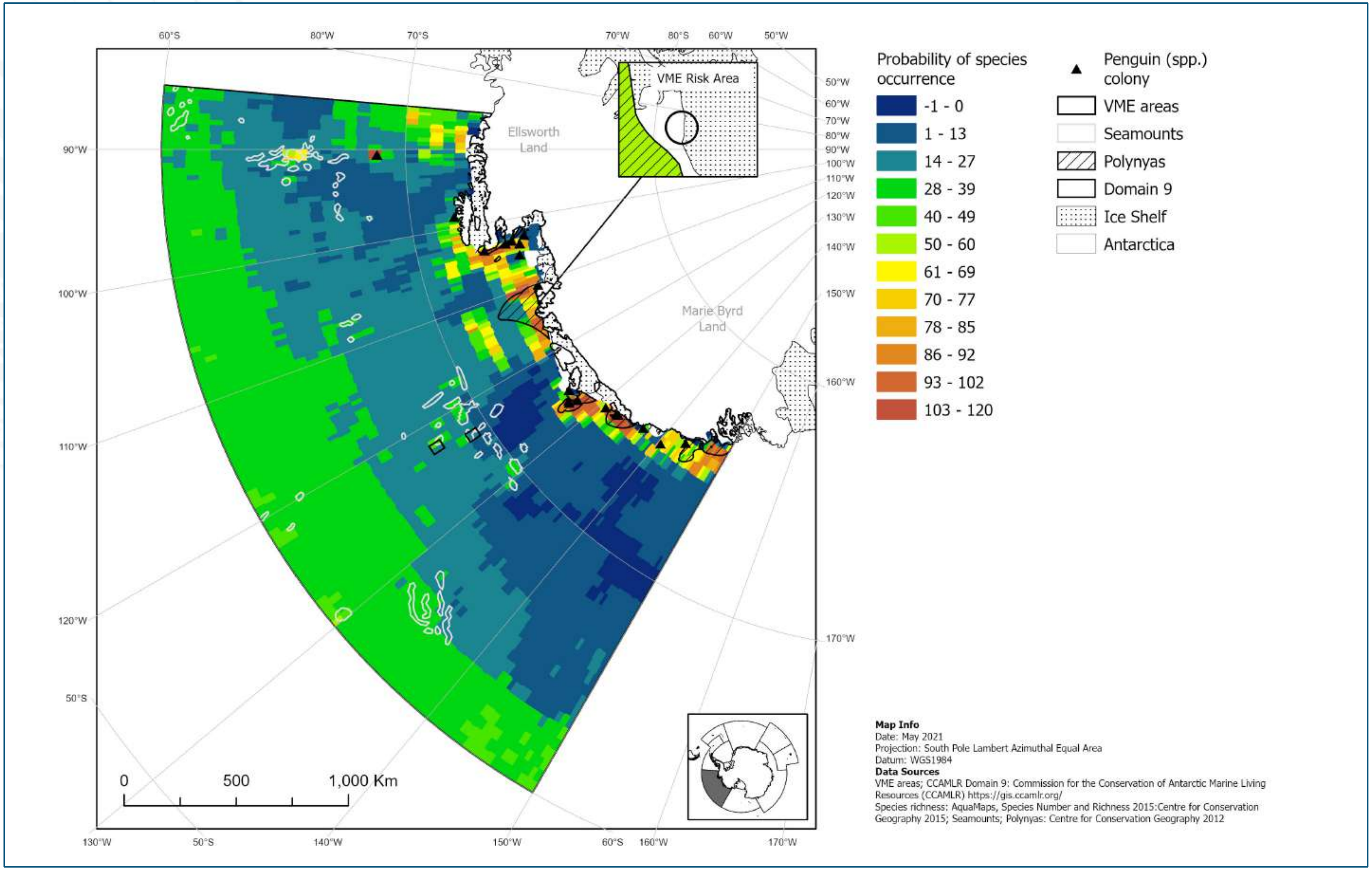

Figure 6.Species richness in Domain 9. Data will be updated when available. Probability of occurrence represents the summed probability of occurrence for all species divided by the total number of species where only species with a probability greater than 60% are included.

PROTECT OTHER RARE OR UNIQUE FEATURES NOT CAPTURED IN BENTHIC AND PELAGIC OBJECTIVES

Unique, rare or sensitive conservation values are often afforded higher levels of protection (e.g. 50-100 percent protection targets) due to their intrinsic rarity or sensitivity to threats. While many of Domain 9's unique or rare conservation values have already been described and captured in the previous objectives we note additional ones here.

Areas of ecological significance

Recent circumpolar analysis of marine predator tracking data was conducted to determine Areas of Ecological Significance (AES) [63], which found some areas of the Amundsen and Bellingshausen Seas of high importance for representation of biological diversity [59]. AES represent the aggregated distribution and demographics of marine predators which indicate the locations of regions of high biodiversity, biological productivity and importance for certain stages within a species life-history. There is a window of opportunity to protect these high value areas within MPAs.

Unique island coastal terrane

The island coastal terrane around Peter I Island and the coastal terrane within Pine Island Bay are the deepest coastal terrane environmental types within the CCAMLR Area [44]. This rugged terrain with its diversity of depths and shallow areas in the photic zone provides an array of habitats and contains a diversity of biota. While it shows some similarity to that of the adjacent continental slope, they are not a subset of the continental slope fauna but have their own unique species composition [64]. The Amundsen Sea fauna shows similarity to neighbouring regions of the Ross and Southern Bellingshausen Seas, but with higher species richness in bryozoans, echinoids and ophiuroids and with a taxonomic composition distinctly different to that of the Dumont D'Urville, Weddell and Ross Seas, and islands in the Scotia Sea [64].

ESTABLISHMENT OF SCIENTIFIC REFERENCE AREAS TO MONITOR THE EFFECTS OF THREATS

When considering where to establish reference areas for monitoring, an understanding of historic and ongoing threats is needed. This is critical as specific research objectives often relate to the establishment of reference areas to monitor long term variability and long-term changes on the environment from threats such as climate change and human activities. Climate change and its associated impacts on the marine environment, is the overarching threat to the region resulting in changing sea ice regime, glacial melt, and ocean acidification (each detailed below) [65]. Historic fishing and stock depletion also threatens sensitive fish populations [8]. Both the trends and specific locations of threats should be considered when establishing scientific reference areas.

Changing Sea Ice Regime and Glacial melt

The Amundsen and Bellingshausen Seas are adjacent to the West Antarctic Ice Sheet which is the most rapidly melting ice sheet in Antarctica [8]. The collapse of the ice sheet allows the Pine Island Glacier to melt at a more rapid rate into the Amundsen Sea. This will have local impacts for biodiversity and environmental values in Domain 9, as ice-shelf collapse opens up new habitats for biological colonisation and ecological succession [65]. Ice sheet and glacial melt is predicted to influence sea level and cause salinity changes with potentially devastating consequences for global environments. Western Antarctica has experienced the highest recorded temperature increase on Earth as a result of global climate change, with an average 2.8° Celsius increase in temperature between 1950 and 2005.

Warming in Western Antarctica has also caused the sea ice in the Bellingshausen Sea and around the Antarctic Peninsula to retreat and the cold season to decrease by three months [8]. The annual advance and retreat of sea ice around Antarctica determines primary productivity, regulates ecosystem processes and provides habitats for species at different life stages. In other areas of the CCAMLR Area such as the Scotia Sea, decline in sea ice has reduced krill population numbers, as krill rely on microorganisms under the ice for food. Krill are essential in the diets of many marine species and reduction in krill would cause cascading impacts throughout the ecosystem. The influence of a changing sea ice regime in the marine environment is not well-understood, and areas with rapid sea ice retreat such as the Antarctic Peninsula and Bellingshausen Sea provide a critical opportunity for scientists to study ecosystem impacts in the absence of large-scale human interference.

Ocean acidification

Over the last two-hundred years, the world's oceans have become thirty percent more acidic, as the oceans absorb carbon from the atmosphere [8]. Increased acidity impacts calcifying organisms, which rely on the availability of carbonate ions to form skeletons and build shells. The colder Southern Ocean is naturally lower in carbonate ions than other world oceans and as such calcifying organisms will experience the adverse effects of ocean acidification sooner than those in warmer waters. The effects will cascade through the Southern Ocean ecosystem.

Fish stock depletion

Many species in the Southern Ocean have suffered from direct and indirect over-exploitation, which led to CCAMLR adopting the ecosystem approach to fisheries management and implementing approaches to reduce illegal, unregulated or unreported fishing. Whilst CCAMLR's precautionary approach is widely considered to be one of the best examples of fisheries management globally, there remains a need to further develop management practices that are robust against a broad range of uncertainties present in the Antarctic ecosystem [66]. For example, current single-area stock assessment models ignore the spatial structures of the population and the fishery. Whilst CCAMLR Decision Rules [21] aim to capture these uncertainties and biases within a precautionary management approach, single-area models risk over-exploitation of those stocks [67] and don't capture concentrated fishing effort potentially risking localised depletions.

Within Domain 9 there are research blocks for research fishing. Estimates of biomass across the research blocks in Subareas 88.2 and 88.3 use CCAMLR's approach to data-limited exploratory toothfish fisheries [21]. The trend analysis for these subareas indicate that blocks predominantly have a status of increasing, stable or unclear (ISU), however three research blocks (88.2_1, 88.3_1 and 88.3_2) have been assessed based on the CCAMLR trend analysis method as declining (D) [21] (Figure 7). A precautionary approach to managing research within Domain 9 might consider closing research fishing within blocks that are declining, or using non-extractive methods of research in these areas, while focusing research fishing in other areas where stocks have been assessed as increasing or stable.

3.4. Socio-economic values

Particular species, such as Antarctic toothfish and krill, are important conservation values both for their relative importance in the ecosystem as well as their fisheries values. A key component of a MPA planning process is to identify and incorporate socio-economic values within the process. This can be through inclusion of additional conservation objectives aimed at protecting socio-economic values in their own right, inclusion of spatially relevant areas as locked in areas to maintain uses, and/or as measures of costs to minimize impacts to users.

Tourism

Domain 9 is currently less accessible for Antarctic tourism than other parts of the Southern Ocean, such as the Antarctic Peninsula. However, the region is an important feeding ground for migratory species such as whales, including the endangered Oceania Humpback (*Megaptera novaeangliae*), which travel to breeding areas in Australia, New Zealand and the Pacific where they are an important economic resource for tourism [68]. The economic significance of whale watching tourism industries in Australia, New Zealand and the Pacific has been a key driver of implementing national sanctuaries and MPAs in these nations [69]. Protecting feeding ground for migratory species across their full range ensures that the industries they support, such as tourism, can persist across all locations.

Fisheries

Domain 9 spans sections of the Amundsen Sea region toothfish fishery for Antarctic toothfish (*Dissostichus mawsoni).* Antarctic toothfish (*Dissostichus mawsoni*) are a large nothotenoid (can survive in very cold waters through an anti-freeze protein) fish of circumpolar distribution. Antarctic toothfish have been targeted by fisheries in the CCAMLR area since 1996/97 [18]. The fishery currently operates as an Exploratory fishery and current research fishing aims within Domain 9 focus on the development of a commercial fishery, indicating that fisheries are highly valued within Domain 9 (Figure 7).

A possible conservation objective for Domain 9 that acknowledges the importance of the toothfish fishery for users could be to protect areas of importance to support further fisheries research to develop and test stock hypothesis for the long-term objective of opening sustainable commercial fishing of Antarctic Toothfish. This objective would allow the identification and inclusion of areas important for research fishing in order to develop a stock hypothesis (where do fish spawn, recruit, move), to complete a stock assessment, and lastly if stock assessment supports it to open commercial fishing.

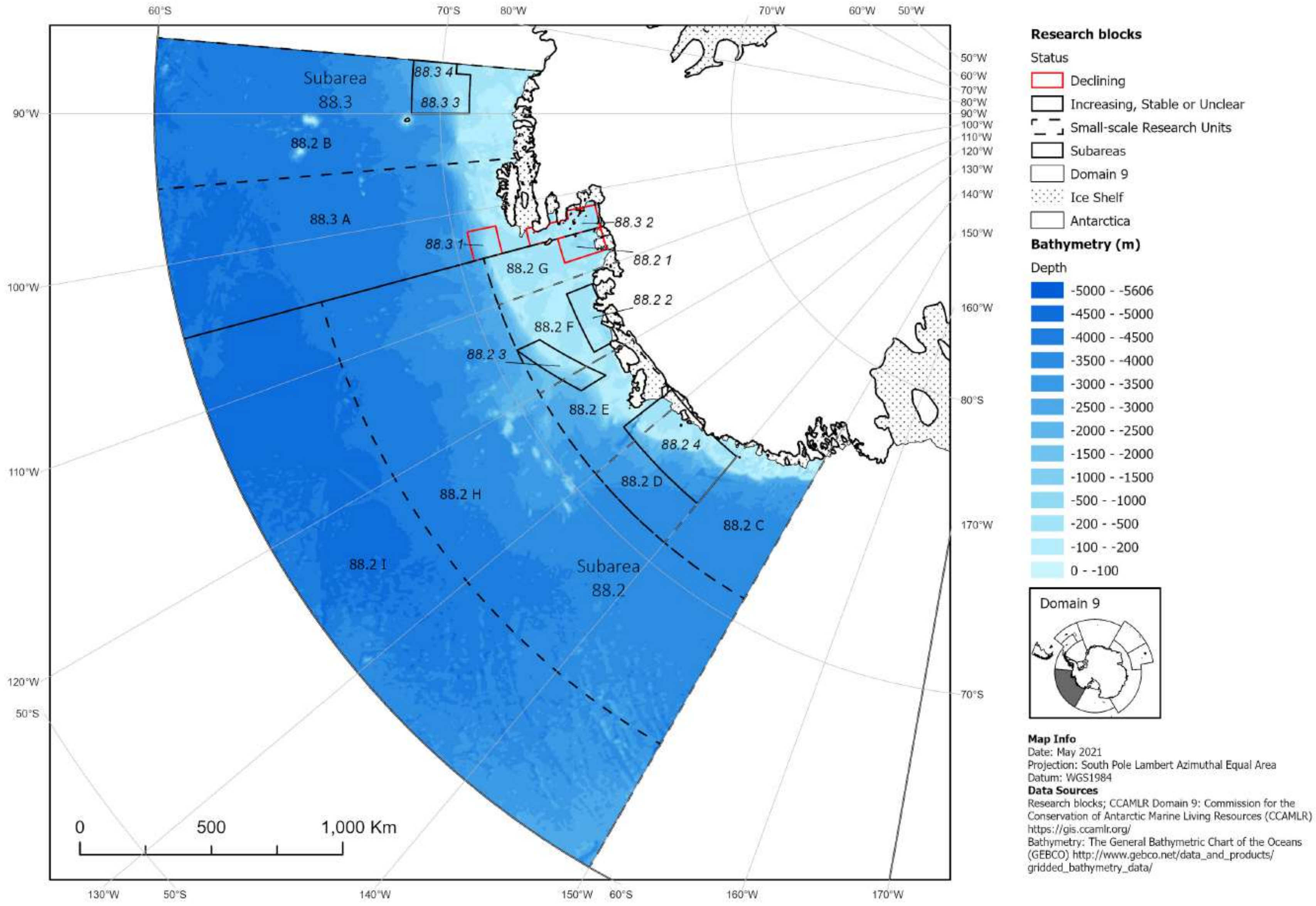

Figure 7. Status of and depth within research blocks within Domain 9 according to the Trend Analysis [21].

3.1. Data availability for the planning process

While existing data needs to be collated and analysed to determine the best scenario for marine protection in Domain 9, no new data acquisition or field work would be needed for MPA planning to progress. The data that exists now, while less than some other regions, is rigorous and sufficient to support a robust scientific decision-making process.

STATUS OF DATA COLLECTION

Appendix 4 provides a table listing conservation values grouped by overarching conservation objective and the available spatial data sourced for the purpose of conservation planning in Domain 9. The data collated in the table builds on previous collections of data relevant for conservation planning in the Southern Ocean must of which has been used in other CCAMLR MPA planning processes [43,44]. Our collation of relevant data has been sourced from publicly accessible sources and by request to specific researchers.

Our current database includes recent data for bathymetry [70], geomorphology [71], environmental variables including seabed temperature, sea ice cover, and chlorophyl [72], krill [73], demersal fish [74], myctophids [75], cephalopods [76], important bird areas [77], echinoderms [78], and areas of ecological significance [63]. Data in our collection which has been used in other CCAMLR MPA planning includes the benthic and pelagic regionalisations [43,48], canyons and polynyas [79].

Additional useful data sources of relevance may be available in private collections, including CCAMLR Toothfish and Craboids catch and effort data, the results of CCAMLR Research Fishing proposals for Toothfish and Craboids, and CCAMLR's updated toothfish stock assessment model. There is also a focus of research, for example by British and Korean led expeditions, to Pine Island Glacier and there is likely to be additional data for this important area available from relevant countries undertaking research. We encourage the input of additional data not listed here.

This known data outlined here and listed in Appendix 4 is the basis of the summary of conservation values in the following section.

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4. DOMAIN 9 – GAP ANALYSIS

4.1. Existing forms of spatial protection

There are some limited spatial protection measures in Domain 9. Analysing current forms of spatial protection for the identified conservation values (as outlined in Chapter 3) is a critical first step in any future planning process as it indicates what is currently managed for conservation and what is left to protect in a marine protected area system. We outline spatial management measures including the percentage of the domain area covered by each measure and calculate the percentage of benthic marine environments covered by each as an indication of what habitats are under spatial management measures.

REGISTERED VULNERABLE MARINE ECOSYSTEMS (VMES)

CCAMLR provides limited spatial protection for some Vulnerable Marine Ecosystems (VMEs), such as cold-water coral and sponge fields, seamounts, and hydrothermal vents where they are registered under relevant conservation measures. Only a very small proportion of known VMEs in Domain 9 are provided temporary protection under these measures.

Under Conservation Measure 22-7, vessels are required to notify the Secretariat of VME bycatch at the notifiable level of indicator organisms [80]. A VME Risk Area is declared when ten or more VME indicator units are recovered within a single fishing line segment. These VME Risk Areas provide temporary protection through spatial closures to bottom fishing activities of one nautical mile surrounding the location of the VME. Other VME "Fine Scale Rectangle areas", are registered by CCAMLR when frequent VME indicator notifications (i.e. five separate notifications of between five and nine indicator units) are reported, but do not result in closures. Fishing in these areas is permissible subject to additional reporting requirements to monitor bycatch thresholds, and the area will be closed to fishing if a certain bycatch threshold is reached. Fishing for toothfish *Dissostichus spp)* is also prohibited in depths shallower than 550m in exploratory fisheries to protect benthic communities [81].

These management actions implement the United Nations General Assembly resolution 61/105 for Regional Fisheries Management Organisations or Arrangements to close areas with vulnerable ecosystems to bottom-fishing activities [82].

The permanent closure or adoption of alternative management measures for VME Risk Areas currently requires further assessment from the Scientific Committee, and as yet no VME Risk Areas have been assessed for permanent closure.

An alternative form of protection for VMEs is through MPAs, as in other areas of the Southern Ocean such as the Ross Sea, where identified VME Risk Areas have been encompassed within MPA areas to provide long-term protection of these vulnerable ecosystems.

Less than 0.1 percent of Domain 9 has been registered as VMEs and afforded some temporary precautionary management or monitoring. Of the benthic environment types, VME Fine Scale Rectangles include 0.5 percent of lower slope environments at -3000 to -4500m in the domain (Figure 8). Lower slope environments at -3000 to -4500m comprise the preferred habitat range for isopod species, a unique area for Echinoid species *Echinosigra amphora* and *Pourtalesia debilis* as well as six bryozoan species, and habitat for the bivalve family Malletiidae and a species of Kelliidae [44]. The deeper lower slope environments of >-4500m comprise only 0.02 percent of the domain; however thirty-five percent of this environment type is included within registered VMEs. The importance of lower slope >-4500m habitats is largely unknown due to very limited samples from this depth, however it is known that Isopod and Polychaete species richness drops rapidly at this depth. Registered VMEs also include seventeen percent of seamount environments between the -1000m to -1500m depth range. This environment type is important for Isopod species and bivalve families Arcidae *(Bathyarca sinuate)* and Vesicomyidae *(Vessicomya sirenkoi)* [44]. This is also important habitat for toothfish [57].

The VME risk area close to the coast includes shallow habitats between -667m and -945m. This is an important depth range for many benthic species, such as many echinoid and bryozoan species, which are restricted to depths less than -1000m [44]. Offshore VMEs include an average depth range between -2922m and -4224m. Depth ranges shallower than -667m, between -945m and greater than -4224m have limited formal protection. The average depth of all VMEs in Domain 9 is -2646m (Figure 9).

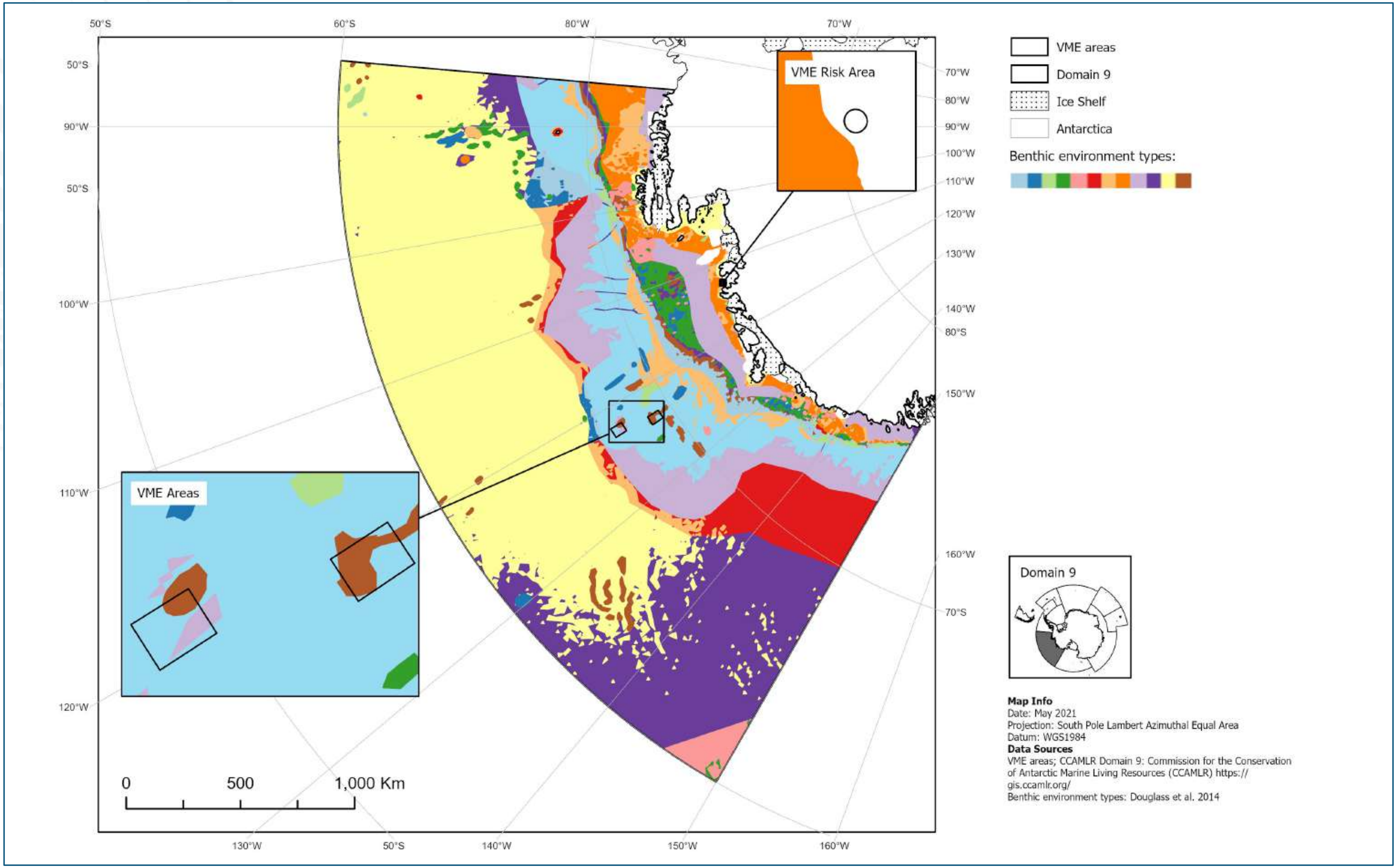

Figure 8. Registered VME locations and underlying benthic environment types.

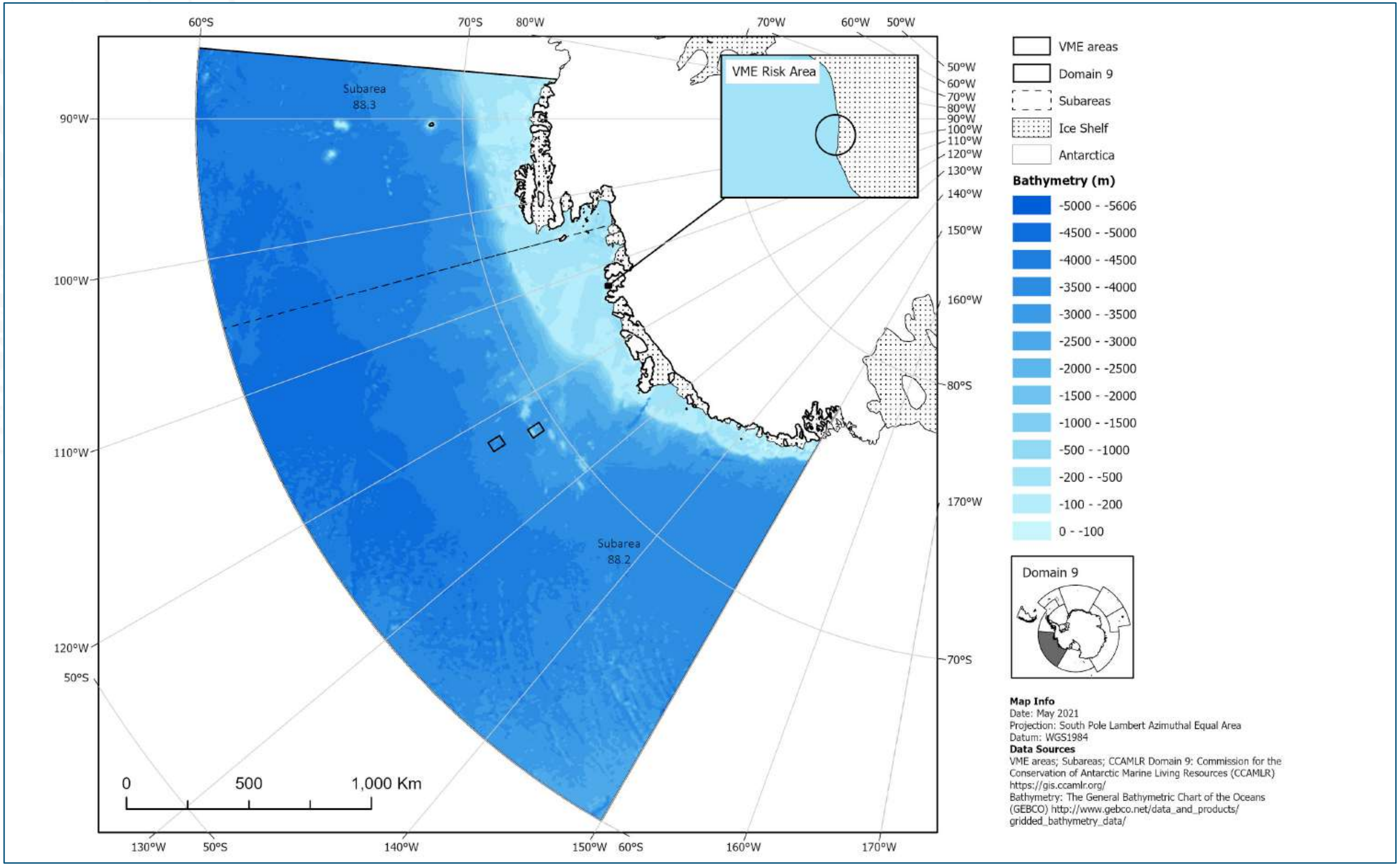

Figure 9. Registered VME location and underlying depth ranges.

PROPOSED SPECIAL AREA FOR SCIENTIFIC STUDY

With advancing technologies and changes in the sea ice regime, Domain 9 is becoming increasingly accessible for fisheries and research [8]. The Pine Island Glacier is the fastest melting glacier in Antarctica, making it critically important to understand climate change impacts, as well as exposing new habitats. In 2019, CCAMLR received a proposal from the United Kingdom to designate a newly exposed marine area adjacent to the Pine Island Glacier in the Amundsen Sea as a Special Area for Scientific Study (SASS) [83] (Figure 10), on the basis that “the implications for biological systems remain poorly understood, above all, for how rapidly physical changes might cascade through marine food webs. It is therefore important that long-term reference areas are established to facilitate scientific study of the effects of such changes, primarily in the absence of any effects caused by other human activities. In this respect, ice-shelf collapse is of special importance as it opens up new habitats for biological colonisation and ecological succession” [65]. Under a proposal to freeze fishing in areas that experience ice-calving events of more than 15 percent in size, the Pine Island Glacier region has been in automatic closure to fishing (stage 1 closure) for two years, due to expire in May 2021. In 2020 the Commission could not reach agreement on the proposal to advance the recognition to a Stage 2 SASS, nor on the suggestion to extend the period of Stage 1 for an additional year and encouraged proponents to submit a proposal for redesignation of a Stage 1 SASS.

The Stage 1 designation will expire before the Commission meets again in October 2021 leaving the area without protection or recognition of its significant scientific value [84]. However, it is understood that, due to incredibly rapid rate of change in the region, the United Kingdom will resubmit a Stage 1 protection SASS at the upcoming CCAMLR meeting in 2021, with new boundaries to replace the expiring stage 1 protection (Pers. Comms. UK Delegation).

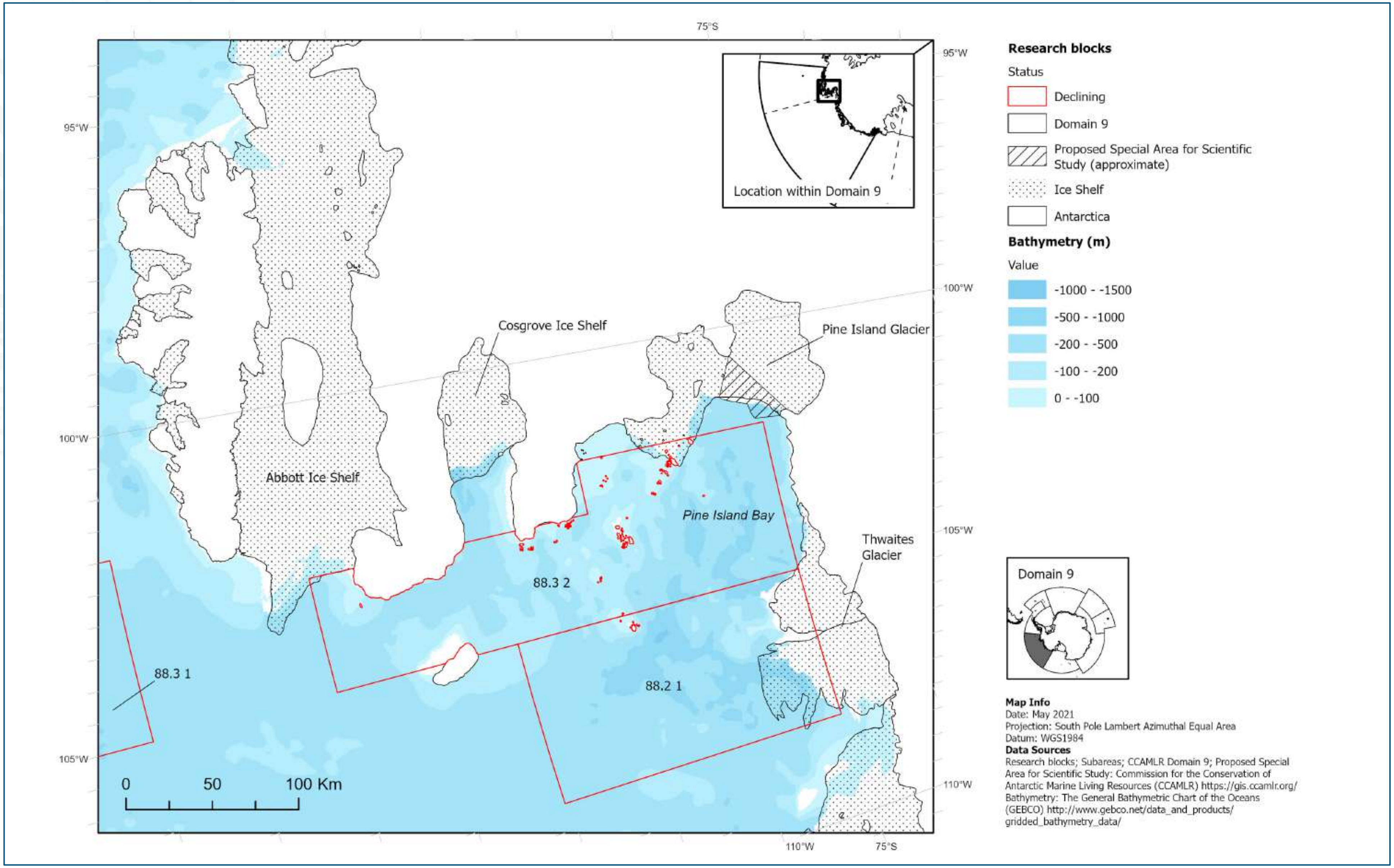

Figure 10. Location of research blocks in relation to the Pine Island Glacier, Proposed Special Area for Scientific Study and Thwaites Iceberg Tongue

4.2. Additional spatial management

FISHERIES MANAGEMENT IN D9

Domain 9 spans sections of the Amundsen Sea region toothfish fishery for Antarctic toothfish (Dissostichus mawsoni). The fishery operates in the CCAMLR statistical areas Subareas 88.2 and 88.3. Subareas are further divided into Small Scale Research Units (SSRUs) for data collection/reporting purposes. Domain 9 spans SSRUs 88.2 C-H and 88.3. A-B. The Total Allowable Catch (TAC) varies for each of the statistical areas. In area 88.2, exploratory fishing occurs over 3 main seamounts in area 88.2H (TAC 128 tonnes) and in four research blocks, 88.2 1 (TAC 192 tonnes), 88.2 2 (TAC 186 tonnes), 88.2 3 (TAC 190 tonnes), and 88.2 4 (TAC 192 tonnes). Area 88.2 I is closed to fishing. Research blocks comprise 5 percent of the total area of Domain 9. Research blocks are located within the optimal fishable depth range of -600 - -1800m (the average depth of research blocks is -1255m) (Table 1, Figure 11).

Table 1. Mean depth and depth range of research blocks within Domain 9.

Research block	Mean depth	Depth range
Research Block 88.2_1	-805m	0m to -1618m
Research Block 88.2_2	-627m	0 – 1524m
Research Block 88.2_3	-1284m	-306m to -2934m
Research Block 88.2_4	-1923m	0 to -4182
Research Block 88.3_1	-1605m	-431m to -3496m
Research Block 88.3_2	-564m	0 to -1469m
Research Block 88.3_3	-1982m	-389m to -3869m
Average depth all research blocks	-1255m	0 to -3869m

Benthic environment types underlying research blocks

Some benthic environment types within Domain 9 are mostly contained within current research blocks, meaning there is less of the environment type available outside of the research blocks to meet protection targets. 76.59 percent of the environment type Cross Shelf Valley -100 to -200m is contained within current research blocks. Other environment types with over 50 percent of the total environment type within Domain 9 within research blocks are Upper Slope -100m to -200m (63.58

percent), Cross Shelf Valley -200m to -500m (63.46 percent), Coastal Terrane (62.97 percent), Bank -2000m to -3000m (58.54 percent) and Upper slope -1500m to -2000m (50.90 percent) (Appendix 3

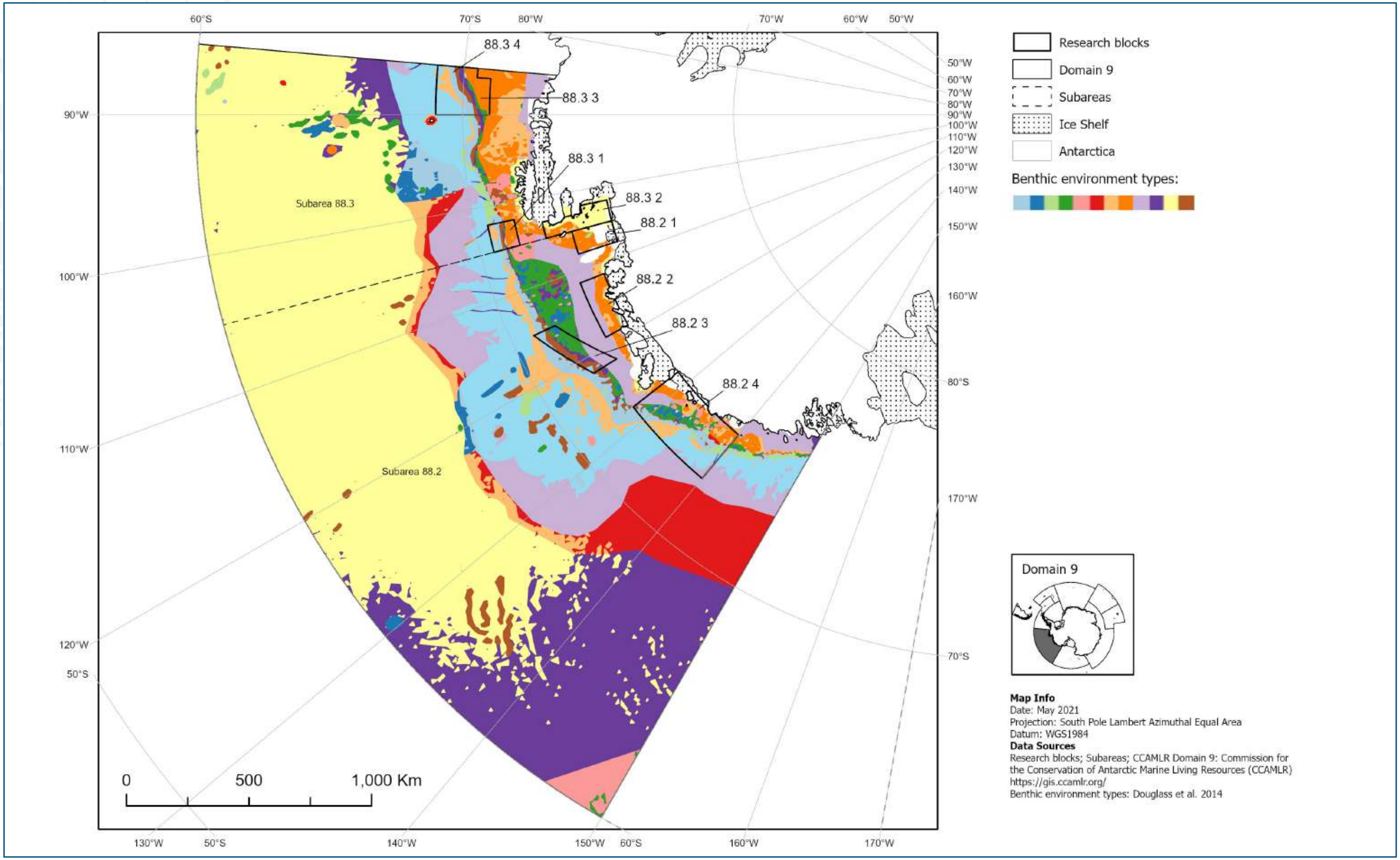

Figure 11. Research blocks and underlying benthic environment types.

4.3. Remaining protection gap analysis

DOMAIN 9 LEVEL

VMEs are currently the only form of spatial protection in Domain 9 and comprise a mere 0.1 percent of the total area. An analysis of current management and gaps within Domain 9 using benthic environment types provides an initial indication and basis to inform further work as data becomes available.

With regard to benthic environment types, the location of VMEs in Domain 9 corresponds with 35 percent of all Lower slope >-4500m environment types, and as such VMEs provide a significant contribution to protection targets for this environment type. In Domain 9 VMEs also correspond with 17 percent of all Seamount -1000m to 1500m environments and provide a moderate contribution to protection targets for this environment. This indicates that some of the rarer environment types within the domain are partly protected and likely contributes to some level of protection for associated benthic species assemblages. However, there are twenty-six other benthic environment types within Domain 9 that currently receive no formal protection. This indicates that these environments and associated species assemblages may require targeted protection via a MPA network.

In contrast to patterns of protection, 5 percent of Domain 9 is under research fishing blocks. A dominant proportion of area of the following environment types are located within research blocks, leaving limited areas of these environment types free of the impacts of fisheries.

- Cross Shelf Valley -100 to -200m (76.59 percent)
- Upper Slope -100m to -200m (63.58 percent)
- Cross Shelf Valley -200m to -500m (63.46 percent)
- Coastal Terrane (62.97 percent)
- Bank -2000m to -3000m (58.54 percent)
- Upper slope -1500m to -2000m (50.90 percent)

5. NEXT STEPS IN DOMAIN 9 PLANNING

Domain 9 in the Amundsen-Bellingshausen Sea remains the only CCAMLR MPA planning domain without an established or proposed MPA. The primary objective of MPA planning in the region is to design and establish MPAs that contribute to the conservation of Antarctic marine living resources in accordance with Article II and IX of the Convention [12]. The general objectives outlined in Chapter 3 classify MPAs within Domain 9 as a tool for the protection of special ecosystems, habitats, features, and representative areas of Domain 9 as a planning region. Designing a MPA that meets these objectives can be achieved with a planning approach that uses available data and established analytical approaches with proven application in previous Southern Ocean and other international MPA planning situations.

5.1. Systematic conservation planning

We describe the next steps in a planning process for MPA design in Domain 9 that leverages best practices in systematic conservation planning. We start by describing the foundational principles of systematic conservation planning and then the broader process that is followed.

COMPREHENSIVE, ADEQUATE AND REPRESENTATIVE PROTECTED AREA SYSTEMS

The CAR - Comprehensive, Adequate, and Representative – conservation planning principles are widely accepted as best practice for protected area design [85]. The goal of the CAR principles is to find a system of protected areas that comprehensively captures viable representatives of all biodiversity features.

Comprehensive – protects a bit of everything

Adequate – protects enough of everything to ensure persistence

Representative – protects the full ecological range of each feature

The CAR principles serve to inform the design of resilient protected areas that reflect available data and knowledge of the biodiversity of the region. The scientific community widely agrees that meeting these principles translates into a minimum 30 percent target for habitats and species [86]. Reviews of MPA size and effectiveness demonstrate that MPAs that include a representative amount of 20-40 percent of habitats and species are most effective for conserving biodiversity, providing connectivity, avoiding species collapse and ensuring sustainable fisheries [40,86,87]. On the basis of this evidence, the IUCN World Conservation Congress passed a resolution in 2014 calling on nations to protect at least 30 percent of the ocean in highly protected MPAs 'to reverse existing adverse impacts, increase resilience to climate change and sustain long-term ocean health' [88].

PROCESS

Systematic conservation planning is a transparent and repeatable process that follows a set of eleven stages [89]. We consider stages one to nine as the planning stages (denoted as A in Figure

12) while stage ten and eleven reflect implementation and ongoing assessment and adjustment of implementing protected areas.

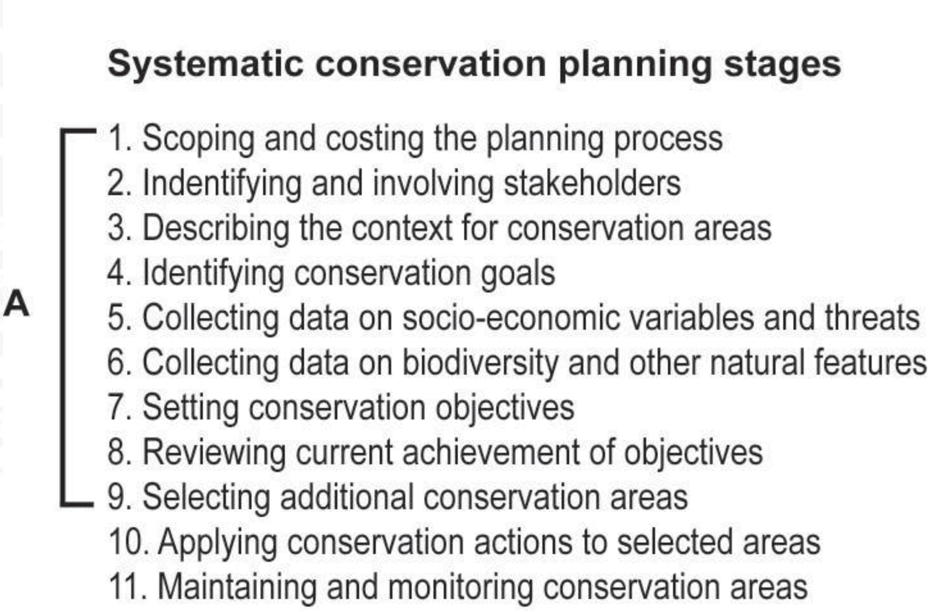

Figure 12. The 11 stages of systematic conservation planning as defined by [89]

The previous chapters provide the foundations for the initial stages of a planning process in particular stages one to six in which stakeholders are identified and engaged, goals identified, and relevant data collected. The next steps in a full planning process would build upon this through further data collation, setting of objectives, and engaging in spatial planning to meet targets. Next steps for each of these is detailed below.

DATA

As noted in Chapter 3, the initial analytical approaches required for MPA planning in Domain 9 already exist in the form of bioregionalisation analyses. In addition to the benthic and pelagic bioregionalisations, there are a range of data sets including modelled species distributions that are available for Domain 9. We have collated all publicly available data and identified which broad objectives each dataset can be used for targeting in spatial planning. The next step in a planning process would be to review the existing data, identify other datasets not currently collated, and any outstanding data to be collected.

Research by individual countries as well as joint research programs have been conducted in Domain 9 in recent decades. These research efforts offer valuable site-specific data for integration into MPA planning in the region. For example, this data can be used to validate existing modelled and remote sensed data products, identify gaps in knowledge or areas for future research, monitoring and evaluation, as well as form the basis for hypotheses for future research efforts. The authors are in the initial stages of identifying and assessing the relevance of various research for MPA planning and welcome correspondence regarding any other known research results and available data.

A data focussed workshop is an important next step to review the quality and level of completeness of data and to identify further sources. Some of the research know to the authors that holds relevance to MPA planning in Domain 9 includes the ASPIRE project [90], research as part of the International Thwaites Glacier Collaboration [91], research as part of the Korean Polar Research

Institute (KOPRI) LIONESS-TG project and the Australian Antarctic Gateway Partnership (AGP) [92]. Additional fisheries data exists as reported to CCAMLR under ongoing research fishing arrangements in the region by a wider variety of countries, with related research held by these fishing nations themselves.

SPECIFIC OBJECTIVES, TARGETS AND ASSOCIATED DESIGN CRITERIA

General objectives likely to be adopted during MPA development in Domain 9 are presented in Section 3.2 of this report. These set out the broad goals, specific objectives as well as targets for protection for a marine protected area system in Domain 9.

OVERALL TARGETS TO INFORM MPA SIZE

Reviews of MPA size and effectiveness demonstrate that MPAs that include a representative amount of at least 20-40 percent of habitats and species are most effective for conserving biodiversity, providing connectivity [93], protecting adequate amounts of species home ranges, avoiding species collapse, and ensuring sustainable fisheries [40,86,87]. A review of 144 studies in 2016 found that on average 37 percent high-level protection is needed to achieve goals such as: protect biodiversity, provide connectivity, avoid species collapse and ensure sustainable fisheries [94]. International scientific reviews in 2003 (40 studies) and 2010 (33 studies) confirmed these higher figures and suggested that 20-40 percent coverage is needed [35,86,87].

On the basis of this evidence, the International Union for Conservation of Nature (IUCN) World Conservation Congress passed a resolution in 2014 calling on nations to protect at least 30 percent of the ocean in highly protected MPAs 'to reverse existing adverse impacts, increase resilience to climate change and sustain long-term ocean health' [88]. In 2019 the 'Post-2020 Global Biodiversity Framework' was developed and includes an objective to protect at least 30 percent of all land and seas by 2030. In May 2021, the Conference of Parties to the Convention on Biodiversity (CBD) is set to discuss this new target [1]. An area of 30 percent strict reserve within a MPA is beneficial not only to conservation outcomes, but will also ensure fisheries benefits, displayed in multiple case studies across varying marine ecosystems [3]. Additionally, case studies show that strict protection of 20-30 percent of a fished habitat is unlikely to diminish catch while providing greater potential for biodiversity conservation, and rebuilding overfished regions [89].

TARGETS FOR INDIVIDUAL CONSERVATION VALUES

Specific objectives and associated targets would be the focus of initial workshops and work by the proponent(s) (see section 5.2 and 5.3). These specific objectives relate strongly to the targets set for individual conservation values. Targets will typically range from 10 percent for coarse filter surrogates such as regionalisations through to 100 percent for rare or unique features. Targets used in previous planning processes in Southern Ocean have been summarized in Appendix 4 as indicative target ranges that could be used in a workshop setting to guide negotiation of targets for Domain 9.

In addition to conservation targets for individual features there are design criteria that are recommended to ensure MPAs deliver on multiple goals such as size and spacing requirements for species. For example, for MPAs to conserve biodiversity and benefit fisheries, the area of the MPA must be large enough to ensure the persistence of species [87]. Optimal MPA size for fisheries benefits can be determined by the spatial extent of home range size, and migration movements (e.g.

for spawning) of the target species. If these criteria are met then target species are likely to be protected and able to provide both biodiversity and fisheries benefits [35,95–97]. Given the large home ranges of some species present in the region (e.g. Antarctic toothfish, *Dissostichus mawsoni*) [98,99], large MPAs spaced closely together may be needed to support both conservation and fisheries goals. Identification of key design criteria – such as size of individual MPAs or overall targets for protection at a regional level (such as 30 percent of total area) – are often negotiated and agreed upon alongside selection of individual conservation feature targets.

REVIEWING CURRENT TARGETS MET

The analysis presented in Chapter 4 outlines the existing protection measures and the percentage of features protected within these. Once specific objectives and associated targets are set for each conservation feature this analysis can be used to fulfil this step.

VMEs are the only spatial protection (affording temporary precautionary management or monitoring) in Domain 9 and comprise a mere 0.1 percent of the total area. The location of VMEs in Domain 9 corresponds with 35 percent of all Lower slope >-4500m environment types, and 17 percent of all Seamount -1000m to 1500m environments. This indicates that some of the rarer environment types within the Domain are partly protected and likely contributes to some level of protection for associated benthic species assemblages. However, there are twenty-six other benthic environment types within Domain 9 that currently receive no formal protection. This indicates that these environments and associated species assemblages may require targeted protection via a MPA network.

SELECTING ADDITIONAL CONSERVATION AREAS

As marine protected areas can only manage direct actions that occur within their boundaries, the placement is critical to realising conservation benefits. Global, local and national analyses inform where it would be optimal to locate MPAs to meet representativeness targets [7,31,94]. Recent global analyses to determine priority areas for MPA establishment identified 35 percent of priority areas in places classified as marine wilderness, such as the Southern Ocean [31]. Similarly, another study also recommended prioritising protection in lesser impacted areas (such as those classified as marine wilderness) to maximise ecological benefits [94]. The Southern Ocean, and in particular Domain 9, meet these criteria as a high priority region for establishing large MPAs that protect marine wilderness and address gaps in protection of representative marine habitats.

Our preliminary gap analysis based upon registered VMEs in Domain 9 (Chapter 4) indicates that there is likely to be a large proportion of targets that remain formally unprotected and that additional conservation areas will need to be designed to fill these gaps. While there are many decision support tools that can be used to support the design of further MPAs, Marxan is widely used globally and has been used in several planning processes in the CCAMLR area. Marxan solves the minimum set reserve design problem [100], aiming to meet user-defined conservation targets (i.e. 30 percent of a species protected) and minimising the overall cost of the proposed conservation plan, and can be used in interactive stakeholder design sessions to rapidly generate and modify possible MPA design solutions [101]. It has been used in successful design and implementation of high profile MPAs such as the Great Barrier Reef Marine Park, California MPAs, Tun Mustapha and many others. Marxan was used to assist design of the designated South Orkney Islands southern shelf MPA and the proposed Weddell Sea and Domain 1 MPAs (See Appendix 1

5.2. Integrating stakeholders in the planning process

Involving stakeholders early and often in the planning process is best practice (**Error! Reference source not found.**). This is particularly true for stakeholders with a strong interest in the spatial location of existing management actions (such as research blocks) or likely future interest (e.g. opening of commercial fisheries). These values can then be integrated into the planning process through identification of relevant spatial data and choices in decision support tools for selecting conservation areas. Given the relevant fisheries interests in the region, as exhibited by exploratory toothfish fishing in the Amundsen Sea and research fishing in the Bellingshausen, choices around how to incorporate these interests in the process are critical. We discuss possible approaches to integration of fisheries management and MPA planning below.

INTEGRATING MPA PLANNING WITH EXISTING FISHERIES MANAGEMENT ASSESSMENTS

As discussed in Chapter 3, a key interest in Domain 9 is the existing toothfish research blocks and the potential for commercial fisheries to open. Spatial planning tools such as Marxan can accommodate these interests by including a spatially explicit cost layer for fisheries [102]. Including fishing as a cost ensures that marine protected areas will be designed in a way that minimizes impacts to fishing. This is considered to be a minimum standard approach for ensuring such stakeholder interests are acknowledged and included in the planning process and is consistent with how planning in other Domain's has acknowledged these multiple values. However, incorporating stakeholder values as a cost to conservation may erroneously frame the relationship between fishing and marine protection as one that is antagonistic or costly. In reality, effectively designed MPAs can provide benefits for both conservation and fisheries. Integration of fisheries values not only as a cost to be avoided, but as a benefit to be planned for, upfront in the MPA design and implementation process may reduce possible negative impacts to fishers and in fact increase MPA benefits to fisheries [103]. Furthermore, by including these stakeholders in the conversation as a positive value to plan for there is potential to decrease political opposition to MPAs and thus increase likelihood of MPA implementation post design phase [104].

A key consideration in the planning process, and in particular choice of analytical approaches, is to what extent to frame stakeholder interests as costs or benefits, and the extent to which marine protected area design and fisheries management can be modelled in tandem for integrated design and assessment. Full integration often requires technical advances in existing fisheries stock models [35]. Key technical requirements for integration include spatial fisheries models and assessment which often require specific data in order to model both the spatial dynamics of the total stock as well as the spatial structure of age classes within the stock.

This has been done in the Ross Sea based on targeted research fishing to build spatially explicit datasets of stock and stock structure to inform spatial fishery model [105,106]. The spatially explicit toothfish population model was used to test the impacts of the Ross Sea Marine Protected Area as well as alternative interventions such as spatially explicit quotas [103]. This work found that the MPA increased total biomass and catch which is important for the continued sustainable operation of fisheries within the Ross Sea. However, the work did note intensified effort within particular fishing areas – as expected from consolidation of fishing effort into a smaller fishing area. The example of integrating MPA design and stock assessment models in the Ross Sea and others [33,93,103,107] demonstrate how understanding the likely effects of a MPA on an existing fishery can help to optimise the design (size, location and connectivity) of the MPA network in the planning stage for simultaneous conservation and fisheries benefit.

POTENTIAL BENEFITS OF INTEGRATION IN DOMAIN 9

There are a range of political, conservation, fisheries and strategic benefits which could eventuate from an integrated approach to MPA planning in Domain 9. Including fisheries values in planning from the outset reflects the importance of these values for countries currently associated with fishing in the region. Creating an inclusive planning approach can create an authorizing environment for MPA implementation. Furthermore, including fishery models in the MPA design process can demonstrate the benefits to fisheries and thus increase the overall percentage protected – studies show that MPAs delivering fishery benefits range from a minimum of 33 percent of total area to 80 percent of total area with larger percentages in areas without existing commercial fishing [35]. Given Domain 9 has only research fishing and no commercial fishing at this stage, including fishery models explicitly in the planning process may facilitate larger total area protection targets.

5.3. Planning timeline

As noted above, the first step in a full MPA planning process is to scope the planning timeline and costs. Here, we present one possible timeline outlining the steps required to develop a Domain 9 MPA proposal.

MPA development for Domain 9 is likely to take at least three years. For example, the steps involved in arriving at a MPA proposal submitted to the Scientific Committee of CCAMLR (SC-CAMLR) could look like:

- **MPA Workshop 1:** Internal workshop for lead country(s). Present available data and discuss capacity, goals, and approach. Develop planning roadmap. **Output:** planning roadmap for submission to CCAMLR.
- **MPA Workshop 2:** Lead country(s) host CCAMLR technical workshop to present data, proposed objectives, targets, and planning approach. **Output:** report submitted to SC-CAMLR documenting data, objectives, targets and planning approach.
- **MPA Workshop 3:** Internal workshop for lead country(s) and/or CCAMLR workshop to review conservation objectives, targets, prioritization, and preliminary MPA boundaries. **Output:** MPA proposal submitted to SC-CAMLR for consideration.
- **Ongoing:** Review input from SC-CAMLR and other delegations and incorporate into planning process and proposals.

These above steps could be achieved via the following timeline based on the processes undertaken previously by other CCAMLR member nations in their development of MPA proposals (see German Weddell Sea MPA roadmap outlined in Appendix 2.

5.4. Proponent country responsibilities and support

ROLES AND RESPONSIBILITIES

The lead country(s) for a MPA proposal will drive the overall planning process including organisation and hosting of relevant workshops and producing required CCAMLR papers. Relating to the stages of the planning process, the lead country(s) play(s) a central role in determining the planning objectives, targets and goals (proposed as the key topic and decision point of workshop 2), as well as determining the preferred analytical approaches where multiple options are possible, and lastly using decision support outputs to define proposed MPA boundaries and moving these to SC-CAMLR for consideration (proposed as key topic and decision point of workshop 3).

SUPPORT AVAILABLE

Internal CCAMLR working groups and the CCAMLR scientific committee, along with NGO, industry, and scientific stakeholders provide significant input and bring the expertise and experience required to translate MPA goals and objectives into a robust science-based planning process that supports good decision-making. In addition, a Domain 9 MPA planning process can be supported by protected area planning experts. For example, the compilation of the required data is underway by CCG and could provide the underpinnings for workshop 1 and subsequent analyses. Similarly, the use of decision support tools and preparation of models can be supported by work already underway.

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APPENDIX 1

Domain 9 meets the CBD criteria for MPA designation

Table 2. How Domain 9 meets the required criteria identified by the CBD for designating marine protected areas source adapted from CBD (2008) [42].

Criteria	Domain 9 Values
Uniqueness or rarity	*Rare or isolated features.* Some of the shallowest and deepest seamounts in the CCAMLR area are located within Domain 9. The area surrounding Peter I Island contains the Belgicaguyot, one of only two seamounts in the CCAMLR Area with a mount in the 100-200m bathome, and Lecointeguyot, one of only five seamounts with a mount in the 0-100m bathome within the CCAMLR Area. The deep ocean and shelf environment seabed temperatures within Domain 9 are some of the warmest within the CCAMLR area. *Unique benthic features.* The Amundsen-Bellingshausen domain is the only domain to contain Deep island coastal terrane and coastal terrane geomorphic feature types deeper than 1000m, which are found around Peter I island and within Pine Island Bay respectively. These deep coastal terrane environmental types are the deepest within the CCAMLR Area. Protecting these areas will provide protection for species assemblages unique to these environments. *Unique and rare pelagic regions:* Domain 9 represents 16 of the 19 pelagic ecoregions in the CCAMLR area, primarily pelagic regions 15 (41%), 9 (17%), 10 and 11 (both 12%). The remaining 12 pelagic regions each span less than 5% of the domain. Domain 9 contains the only location of pelagic region 13 in the Pacific Ocean sector of the CCAMLR Area, which corresponds with the Lecointe Guyot. *Restricted Environment Types.* Environment types unique to the Amundsen and Bellingshausen ecoregions are currently not protected. The opportunity exists to protect biodiversity in these areas from threats [44].
Special importance for life history stages of species	Domain 9 contains a diversity of benthic and pelagic environment types, spanning the full extent of the home ranges of some important species present in the region (e.g. *Dissostichus mawsoni* (Antarctic toothfish)) [45–47].

Importance for threatened, endangered or declining species or habitats	*Vulnerable Marine Ecosystems (VMEs):* three small VME areas in Domain 9 include cold water coral and sponge fields, seamounts, and hydrothermal vents and these types of ecosystems would benefit from further protection. *Areas experiencing rapid change:* The Pine island Glacier is melting rapidly, opening up new habitats for biological colonisation and ecological succession. Protecting these areas from additional human impacts would allow scientific study of the effects of rapid physical changes on marine food webs and the broader ecosystem.
Vulnerability, fragility, sensitivity or slow recovery	The Amundsen and Bellingshausen Seas are adjacent to the West Antarctic Ice Sheet which is the most rapidly melting ice sheet in Antarctica [8]. Many species in the Southern Ocean have suffered from direct and indirect over-exploitation, with many populations still yet to recover to pre-harvesting levels.
Biological productivity	*Significant features.* Some of the highest primary productivity in the CCAMLR Area occurs within Domain 9 [44]. The polynya directly off the coast of Martin Peninsula and west of the Thwaites iceberg tongue has the most persistently high summer productivity in the CCAMLR Area. Protecting areas of high primary productivity will have positive cascading effects throughout the ecosystem.
Biological diversity	*Areas of high Ecological Significance.* Recent circum-polar analysis of marine predator tracking data identified the Amundsen and Bellingshausen Seas as Areas of Ecological Significance (AES) of high importance for representation of biological diversity [59].
Naturalness	Due to remote location and extensive sea ice, many areas in Domain 9 remain free from intensive resource extraction, widespread pollution and invasive species.
Opportunity for novel scientific study	*Areas with rapid sea ice retreat.* The influence of a changing sea ice regime in the marine environment is not yet well-understood, and areas with rapid sea ice retreat such as the Antarctic Peninsula and Bellingshausen Sea provide an opportunity for scientists to study ecosystem impacts in the absence of large-scale human interference.

APPENDIX 2

Example planning process for domains 3-4 (Weddell Sea)

CCG provided MPA planning support to Germany during their planning process for the proposed Weddell Sea MPA.

Available data relevant to the MPA planning was collated, analysed and described in a data dossier produced by CCG in 2012.Follow on support included participation and presentation at MPA planning workshops (both internal and a CCAMLR member and stakeholder workshop hosted by Germany). Data collation, processing and sharing. Spatial conservation planning advice including use of Marxan, conservation objectives, targets and MPA design.

The following roadmap reflects the detailed workflow conducted by German agencies and support groups that lead to submission of the MPA proposal for the Weddell Sea.

ORIGINAL GERMAN WEDDELL SEA MPA ROADMAP PROPOSAL 2012-2014

Note: This document references the timeline in the original German planning proposal. The actual timeline for final submission of the MPA varied from this roadmap

October 2012:

Germany proposal to take lead in developing Weddell Sea MPA for consideration in 2014 was welcomed by the Commission at CCAMLR annual meeting.

Mid April to June 2013

- Research of relevant MPA literature (incl. CCAMLR documents)
- Inventory of existing geo-referenced data
- Rough localisation of the Weddell Sea region that will be focus of the project
- Submission of a document to CCAMLR focussing on the scheduled work regarding the establishment of a Weddell Sea MPA and giving an overview of the existing geo-referenced data

July 2013

Milestone 1: Meeting of the CCAMLR Working Group on Ecosystem Monitoring and Management (WG-EMM, 1-10 July 2013)

Deliverable 1

Presentation at WG-EMM about the scheduled work regarding the establishment of a Weddell Sea MPA, including an overview of the existing geo-referenced data supported by examples of GIS maps

Deliverable 2

Colloquium during the WG-EMM (4 July 2013) to discuss the work schedule of the Weddell Sea MPA project with members of the WG-EMM

July to September 2013

• Implementation of the results developed from the WG-EMM meeting

• Continuation of literature research and data inventory

• Organisation of a national workshop for the establishment of a marine

CCAMLR-MPA in the Weddell Sea

Milestone 2: Realisation of a national workshop (11-13 September 2013)

Deliverable 4

Briefing and integration of all relevant German experts focused on Antarctic research and nature conservation, in the working approach to establish a Weddell Sea MPA

Deliverable 5

Check-up of and potential addition to the data inventory

September to October 2013

• Implementation of the results developed from the national workshop

• Continuation of literature research and data inventory

• Preparation of a preliminary report about the data compilation

Milestone 3: Meeting of the CCAMLR Scientific Committee (SC, 21-25 October 2013, Hobart, Tasmania)

Deliverable 6

Submission of a preliminary report on the scientific data compilation and analyses in support of the development of a CCAMLR MPA in the Weddell Sea and its presentation as a German paper at the meeting of SC-CAMLR (incl. perspective of the work scheduled for 2014)

November to April 2014

• Implementation of the results of SC-CAMLR meeting

• Organisation of an international workshop

Milestone 4: Organisation of an international workshop (early Apr. 2014, Bremerhaven)

Deliverable 7

Discussion with experts of other CCAMLR Member States of the scientific data compilation and analyses carried by the AWI in support of the development of a CCAMLR MPA in the Weddell Sea

April to July 2014

• Implementation of the results of the international workshop (incl. short report about the results of the workshop)

• Preparation of a report about preliminary scientific results regarding the establishment of a Weddell Sea MPA

• Generation of preliminary draft text modules for a proposal regarding the Weddell Sea MPA conservation measures and the corresponding research and monitoring plan according to CCAMLR (Conservation Measure 91-04)

Milestone 5: Meeting of the CCAMLR WG-EMM (early July 2014)

Deliverable 8

Submission of the project report and presentation of preliminary results regarding the scientific analyses in support of the development of CCAMLR MPA conservation measures in the Weddell Sea

July to October 2014

• Implementation of the results of the WG-EMM meeting

• Revision and completion of the scientific work

• Further development of text modules for a proposal in respect of the Weddell Sea MPA conservation measures including a research and monitoring plan according to CCAMLR

• Development of a proposal regarding priority elements for a research and monitoring plan

Milestone 6: Meeting of SC-CCAMLR and the CCAMLR Commission (end of October/early November 2014, Hobart, Tasmania)

Deliverable 9

Submission of a working paper and presentation of the results of the scientific work carried out in support of the development of CCAMLR MPA in the Weddell Sea

Deliverable 10

Based on the working paper, presentation of a proposal for CCAMLR MPA in the Weddell Sea including a management plan and priorities for a research and monitoring plan

APPENDIX 3

Pelagic regions table

Table 3. Pelagic regions description. Adapted from Raymond [48].

Pelagic region number	Description
1	Polynya margins on the continental shelf, the South Orkneys plateau, and areas off Adelaide and Biscoe Island in the West Antarctic Peninsula. Moderately shallow (to ~1000 m) with ice cover ~20–50% and SST <2°C.
2	Polynyas on the continental shelf, as well as areas off the Danco Coast of the Peninsula and the South Orkney Islands, and part of Banzare Bank. Low ice cover (~0–20%) and cold sea surface temperatures (<2°C).
3	Shallow shelf areas with ~25–60% ice cover. Restricted distribution, generally limited to East Antarctica.
4	Shallow areas with high ice cover (~75–95%). Patchy distribution scattered around the continental shelf.
5	Shelf areas with almost perennial ice cover (~75–100%).
6	Similar to 7, but shallower and with lower ice cover. Widely but sparsely distributed around the continental shelf.
7	Moderate depths (~200–1000 m) and ice cover (~50–75%). Many areas correspond to general regions around polynyas (see eg. Arrigo & van Dijken 2003). Also areas of the southern Scotia Arc.
8 -11	Sea ice zone. Clusters 8–11 form an approximately latitudinal, deep water continuum of increasing ice cover and decreasing SST. The northernmost limit (of cluster 10) is generally just south of the mean maximum winter sea ice extent.
12	Moderate depth (~1000–2500 m) and sea ice cover (~40%). Restricted to parts of the southern Scotia Arc, and isolated pockets north of the Balleny Islands and off the West Ice Shelf.
13, 14	13: Shallow (~200–1000 m) parts of the northern Kerguelen, Crozet, and South Georgia plateau areas, Conrad Rise. 14: Deeper (~500–2000 m) parts of the same plateaus, also Bouvetøya and the northern tip of the southern Kerguelen plateau.
15	Deep oceanic waters, encompassing approximately the southern Antarctic Circumpolar Current front and the Polar Front.
16	Deep oceanic waters, bounded approximately on the north by the Sub-Antarctic Front.

APPENDIX 4

Conservation values, data sources and target ranges table

The following table provides a complete list of conservation values grouped by broad conservation objective and the available spatial data sourced for the purpose of conservation planning. Descriptions of these data are described in further detail in the data dossier.

We have reviewed and summarized the target ranges used in two CCAMLR planning processes (Antarctic Peninsula and Weddell Sea) to demonstrate the alignment between the listed conservation values for Domain 9 against other planning processes and as an indication of likely targets.

There is strong alignment in objectives, targets and corresponding data sets used across planning processes. While objectives are sometimes grouped in different ways they broadly reflect protection of 1) benthic habitats, processes and special features, 2) pelagic habitats, processes and features, 3) habitat and life cycles of krill and fish species as key components of food web, 4) essential habitats for mammals and birds, 5) other unique features.

Targets for broad surrogates (such as bioregionalisations) and process objectives were in the 10-20 percent range while targets for special features were in the 30-100 percent range. While there was strong alignment in target ranges across the two planning processes on average the targets for the Antarctic Peninsula (AP) were lower than for the Weddell Sea (WS) – for example targets for habitats in the Antarctic Peninsula were 10 percent compared to 20 percent in Weddell Sea. Targets for krill and fish life cycle habitats were 20-50 percent (AP) compared to 35-75 percent (WS). Targets for mammals and birds were 50 percent (AP) compared to 20-100 percent.

Table 4. List of conservation values by broad objective, associated data source and targets from the Antarctic Peninsula and Weddell Sea planning processes.

Conservation feature (by broad objective)	Data source	Moderate target scenario (range of scenarios if known) – Antarctic Peninsula	Moderate target scenario (range of scenarios if known) – Weddell Sea
Protect benthic habitats and processes			
Benthic bioregionalisation	Depth classes nested in 18 geomorphic features resulted in 50 environmental types	10%	20%

	(Douglass et al. 2014) [43]		
Canyons	Sometimes contained within the regionalisation (Douglass et al. 2014)[43] and also contained in geomorphological data (Post A. L. 2016) [71]	50% (20-80%)	60%
Troughs		N/A	60%
Ridges		N/A	60%
Plateaus		N/A	60%
Seamounts		50% (20-80%)	60%
Seabed temperature	(<1deg) incorporated as proxy for potential habitat for special echinoderm communities occur (Guillaumot et al. 2018) [72]	10%	20%
Protect pelagic habitats and processes			
Pelagic regionalisation	20 regions established using depth, sea surface temperature and ice coverage (Raymond 2011)[48]	10%	20%
Polynyas	(CCG 2012) [79]	50% (30-80%)	100%
Sea ice cover	Minimum summer and maximum winter extent (Guillaumot et al.2018, Spreen et al. 2008, Melsheimer et al. 2019) [72,108,109]	20%	N/A
Chlorophyl	High clorophyl locations (Guillaumot et al.2018, Feldman & McClain 2010)[72,110]	30% (20-50%)	N/A
Important areas for fish and krill life cycles			
Adult krill	Biogeographic Atlas of the Southern Ocean (Cuzin-Roudy et al 2014) [73]	N/A	35%

Larval krill	,,	Target ranged 5 – 100% depending on individual nursery	50%
Ice krill habitat	,,	20%	35%
Adult silverfish	Modelled for study area using methods of (Teschke et al 2019) [111]	N/A	35%
Larval silverfish	‘’	N/A	35%
Icefish 0-150m, 150-500m	Bathymetry (GEBCO 2020) [70]	50% (20-80%)	N/A
Demersal fish nesting sites	(Duhamel et al 2014) [74]	N/A	100%
Demersal fish occurrence	‘’	N/A	75%
Toothfish	Modelled based on CCAMLR data [112], bathymetry GEBCO 2020 [70], Bioregionalisation Douglass et al 2014 [43], sea ice (Post A.L. 2016) [71], seabed temperature (Guillaumot et al. 2018) [72] (Duhamel et al 2014) [74]	N/A	75%
Myctophids	(Freer et al 2019) [75]	N/A	N/A
Cephalopods	(Xavier et al 2016) [76]	N/A	N/A
Essential habitats for mammals and birds (top predators)			
Adelie Penguins foraging/breeding	Marine environmental data layers for Southern Ocean species distribution modelling (Guillaumot et al 2018) [72] Important Bird Areas	50% (20-80%)	100% within 50km, 50% out to 100km
Adelie Penguins non-breeding		50% (20-80%)	20%

	(IBAs) (Handley et al 2021) [77]		
Emperor Penguins foraging/breeding	MAPPPD Penguin Colonies [113]	50% (20-80%)	N/A
Emperor Penguins non-breeding		50% (20-80%)	N/A
Antarctic petrel foraging	Important Bird Areas (IBAs) (Handley et al 2021) [77]	50% (20-80%)	40%
Seabird foraging areas	Important Bird Areas (IBAs) (Handley et al 2021) [77]	50% (20-80%)	N/A
Furseal breeding	Marine environmental data layers for Southern Ocean species distribution modelling (Guillaumot et al 2018) [72]	50% (20-80%)	N/A
Furseal non-breeding		50% (20-80%)	N/A
Leopard seal		50% (20-80%)	N/A
Crabeater seal		50% (20-80%)	40%
Elephant seal	(Hindell et al 2020) [49]	50% (20-80%)	N/A
Ice seal habitat	Marine environmental data layers for Southern Ocean species distribution modelling (Guillaumot et al 2018) [72]	50% (20-80%)	N/A
Minke whale		50% (20-80%)	N/A
Sperm whale		50% (20-80%)	N/A
Blue whale		50% (20-80%)	N/A
Humpback whale	RAADT [59]	50% (20-80%)	N/A
Unique habitats/features			
Sponges		N/A	100%
Cold water shelf echinoderm	Southern Ocean Echinoids Database (Fabri-Ruiz et al 2017) [78]	N/A	35%
Unique shallow water areas		N/A	100%
Areas of Ecological Significance	RAADT [59] AquaMaps Species Richness [114]	N/A	N/A

APPENDIX 5

Percentage of total benthic environment type within research blocks

Table 5. Percentage of total benthic environment type within research blocks

Environment type	Percentage of total environment type within research blocks
Amundsen:Cross Shelf Valley:-100m to -200m	76.59%
Amundsen:Upper Slope:-100m to -200m	63.58%
Amundsen:Cross Shelf Valley:-200m to -500m	63.46%
Amundsen:Coastal Terrane:Not applicable	62.97%
Amundsen:Bank:-2000m to -3000m	58.54%
Amundsen:Upper Slope:-1500m to -2000m	50.90%
Amundsen:Cross Shelf Valley:-2000m to -3000m	49.59%
Amundsen:Bank:-1000m to -1500m	48.61%
Amundsen:Cross Shelf Valley:-1500m to -2000m	46.91%
Amundsen:Bank:-500m to -1000m	42.29%
Amundsen:Upper Slope:-1000m to -1500m	38.20%
Amundsen:Upper Slope:0m to -100m	36.09%
Amundsen:Upper Slope:-200m to -500m	34.96%
Amundsen:Bank:-1500m to -2000m	32.63%
Amundsen:Upper Slope:-2000m to -3000m	30.91%
Amundsen:Lower Slope:-2000m to -3000m	26.34%
Amundsen:Upper Slope:-500m to -1000m	22.76%
Amundsen:Cross Shelf Valley:-500m to -1000m	22.62%
Amundsen:Bank:0m to -100m	21.36%
Amundsen:Bank:-200m to -500m	19.47%
Amundsen:Upper Slope:-3000m to -4500m	17.45%
Amundsen:Shelf:Not applicable	17.07%

Environment Type	Percentage of total environment type within research blocks
Amundsen:Bank:-100m to -200m	17.01%
Amundsen:Cross Shelf Valley:-1000m to -1500m	9.50%
Amundsen:Canyon Slope Commencing:Not applicable	7.47%
Amundsen:Lower Slope:-3000m to -4500m	6.42%
Pacific Basin:Canyon Slope Commencing:Not applicable	1.83%
Pacific Basin:Lower Slope:-3000m to -4500m	1.11%