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Science supporting the joint New Zealand–United States proposal for the establishment of a marine protected area in the Ross Sea Region

Delegations of the USA and New Zealand

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Abstract

The Commission has asked the Scientific Committee to review the science supporting a joint New Zealand-United States proposal to establish a marine protected area (MPA) in the Ross Sea Region (RSR). A substantial amount of material has already been presented to the Scientific Committee and its working groups, and here we provide an abridged and annotated summary of that material. We organize our summary by linking spatial data to the specific protection and scientific objectives of the jointly proposed MPA, and we summarize science pertaining to coastal areas and the continental shelf, the continental slope, the Balleny Islands and vicinity, and the northern RSR. A set of maps (provided in an Appendix) illustrates the distributions of animals and ecosystem process areas in relation to the boundaries of the jointly proposed MPA. When all relevant distributions are simultaneously overlaid on a single map it is clear that the MPA can achieve significant protection and science outcomes, the latter of which may help the Scientific Committee to understand the ecosystem effects of fishing distinct from those of climate change and thus improve the management of toothfish fisheries generally. To achieve the protection and science objectives of the jointly proposed MPA, the Commission will need to redistribute catches taken by the longline fishery for Antarctic toothfish. About 20% of the historical catch taken by the fishery was removed from within the boundaries of the proposed MPA. Although it is not possible to estimate a specific period of time for which the proposed MPA would need to remain in force, several decades are needed to deliver the science outcomes related to understanding the distinct effects of climate change and fishing.

Introduction

In 2012 New Zealand and the United States jointly proposed that CCAMLR establish a marine protected area in the Ross Sea Region. Members subsequently agreed to hold an intersessional meeting of the Scientific Committee to "review and advise the Commission on the science already considered by the Scientific Committee and any additional available science relevant to assist the Commission's deliberations on the proposals [the joint New Zealand-U.S. proposal for a marine protected area in the Ross Sea Region and the joint Australia-France-E.U. proposal for a system of marine protected areas in East Antarctica], in accordance with CM 91-04" (CCAMLR XXXI, paragraph 7.105). This paper is intended to aid the Scientific Committee's review of the science supporting the joint New Zealand-U.S. MPA proposal for the Ross Sea Region (originally submitted to the Commission as CCAMLR-XXXI/16 Rev. 1). Here we provide an abridged and annotated summary of several scientific documents that are relevant to the establishment of an MPA in the Ross Sea Region (RSR) and were previously considered by the Scientific Committee (SC-CAMLR), the Working Group on Ecosystem Monitoring and Mangement (WG-EMM), the Working Group on Fish Stock Assessment (WG-FSA), and the 2011 CCAMLR Workshop on Marine Protected Areas (WS-MPA). These documents include SC-CAMLR-XXX/9, SC-CAMLR-XXX/10, WG-EMM-10/11, WG-EMM-10/12, WG-EMM-10/30, WG-FSA-10/24, and WS-MPA-11/25. Here we also reference WG-EMM-11/10, WG-EMM-12/23, WG0EMM-12/53, WG-FSA-12/14, and WG-FSA-12/42 that present results which were underutilized or not utilized in the development of the joint New Zealand-U.S. proposal (hereafter simply referred to as the joint proposal). Note that we only cite CCAMLR documents. In many cases, these documents are not the primary sources for the data and inferences presented here. Citing CCAMLR documents is convenient and indicates the breadth of information already presented to SC-CAMLR, but readers are encouraged to refer to the primary sources.

During its discussion of the joint proposal for an MPA in the RSR, the Commission considered several policy issues that were or can be informed by existing scientific work. These policy issues are identified in paragraph 7.77 of CCAMLR XXXI and, in paraphrased form, include

i. establishing protection objectives and defining geographic boundaries for the MPA;
ii. regulating human activities that are threats to the protection objectives;
iii. adapting, if necessary and possible, to the effects of climate change; and
iv. determining the length of time for which the MPA should be designated.

These policy issues lead to four, parallel scientific questions.

i. "Where are the things that are important to protect?"
ii. "What factors increase risks that the objectives will not be achieved?"
iii. "How might the effects of climate change differ from and combine with those of fishing?"
iv. "How much time is required to achieve the objectives?"

In this paper we describe the spatial distributions of physical properties, animals, ecosystem processes, and fishing effort to address the first of these questions and summarize the scientific results that were used in an iterative process of establishing the policy objectives and proposed boundaries specified in the joint proposal. The second question is addressed in a separate paper submitted to the intersessional meeting of SC-CAMLR. The summary provided here also indicates how, by contrasting a "lightly fished" zone with a fully developed fishing ground, the jointly proposed MPA might provide answers to the third question. The fourth question is also briefly addressed in this paper.

The joint proposal states 10 specific objectives for an MPA in the RSR. Here we categorize these objectives into "protection objectives" and "science objectives" (objectives in the following list are numbered as they appear in proposal itself).

Protection Objectives:

i. “to conserve ecological structure and function throughout the Ross Sea Region at all levels of biological organization, by protecting habitats that are important to native mammals, birds, fishes, and invertebrates;
iv. to protect a representative portion of benthic and pelagic marine environments;
v. to protect large-scale ecosystem processes responsible for the productivity and functional integrity of the ecosystem;
vi. to protect core distributions of trophically dominant pelagic prey species;
vii. to protect core foraging areas for land-based predators or those that may experience direct trophic competition from fisheries;
viii. to protect coastal locations of particular ecological importance;
ix. to protect areas of importance in the life cycle of Antarctic toothfish; and
x. to protect known rare or vulnerable benthic habitats.”

Science Objectives:

ii. “to provide a reference area in which fishing is limited, to better gauge the ecosystem effects of climate change and fishing, and to provide other opportunities for better understanding the Antarctic marine ecosystem; and
iii. to promote research and other scientific activities (including monitoring) focused on marine living resources.”

There are intimate links between the biogeography of the RSR and the specific objectives listed above. The next four subsections of this paper are organized in an effort to clarify these geographic links. Note that the second science objective (“to promote research and other scientific activities (including monitoring) focused on marine living resources”) applies to the entire RSR, and here we simply indicate that New Zealand and the United States envision that establishment of the proposed MPA and adoption of a final Research and Monitoring Plan will be useful to researchers who write and submit proposals to receive funding from their National Antarctic Programs or other sources.

Coastal areas and the continental shelf

Spatial data relevant to protection objectives for coastal areas and the continental shelf

Five benthic bioregions and eight pelagic bioregions have been classified in coastal areas and over the continental shelf of the RSR (WG-EMM-10/30, Figures 1 and 2, Tables 1 and 2). These bioregions are defined on the basis of physical properties such as depth, temperature, and sea-ice characteristics (WG-EMM-10/30, pp. 27-37). Some bioregions occur near the coastline, and others occur near the outer edge of the shelf. Similarly, some bioregions occur over the western shelf, some occur over the central shelf, and others occur over the eastern shelf. Although the bioregions identified in WG-EMM-10/30 were classified on the basis of physical properties, the transitions that occur between the coastline and the outer edge of the shelf and from west-to-east are mirrored in the structure of the marine ecosystem itself, *e.g.*, in the compositions of fish communities which change with depth (WG-EMM-10/11, pp. 34-36; WG-FSA-12/14, Figure 76) and benthic communities which change with bottom topography and sediment type (WG-EMM-10/11, Figure 22). The bioregions are, therefore, useful proxies of floral and faunal biodiversity in the RSR, and including portions of each bioregion within the jointly proposed MPA can facilitate precautionary management to conserve biodiversity. Thus, to protect "a representative portion of benthic and pelagic marine environments" and the biodiversity occurring within these environments, both in coastal areas and on the continental shelf, New Zealand and the United States propose a large MPA that includes at least a proportion of most bioregions in the RSR. The pelagic and benthic bioregions, and how these are overlaid by the boundaries of the joint proposal, are illustrated in the Appendix (Figures A1 and A2 respectively).

The spring *Phaeocystis* and summer diatom blooms are primary drivers of biological production on the continental shelf of the RSR. These blooms are largely iron-limited and forced by oceanographic circulation and wind mixing, seasonal variation in solar insolation, and the formation of polynyas (WG-EMM-10/11, pp. 11-25). Interannual variation in the timing and location of these blooms is substantial, but, in spring and fall, chlorophyll concentrations are generally highest on the western margin of the continental shelf (WG-EMM-10/11, Figure 16). In summer, high chlorophyll concentrations can occur over the entire shelf (WG-EMM-10/11, Figure 16), and during this time shelf waters generally have higher chlorophyll concentrations than anywhere else within the RSR (WG-EMM-10/11, Figure 17). Interannual variation in primary production is linked to variations in sea-ice extent, duration, etc., and three "ecosystem process areas" characterizing the spatial distribution of sea ice and accounting for such variation have been identified on the continental shelf: the "Ross Sea shelf front intersection with seasonal ice," the "Ross Sea polynya Marginal Ice Zone," and the "Eastern Ross Sea multi-year ice" area (WS-MPA-11/25, Figure 2a). These three ecosystem process areas are geographical indicators of the spatial links between primary production and upper trophic levels because they were partly defined by the presence of seabirds and marine mammals, which forage in these areas (see WG-EMM-10/30, pp. 38-40). Given the substantial interannual variation in sea-ice characteristics (e.g., WG-EMM-10/11, Figure 11), uncertainty in how these characteristics might change in the future (e.g., WG-EMM-10/11, Figure 14), and the importance of sea-ice habitats in annually defining the spatial template on top of which primary production links to upper-level predators, New Zealand and the United States propose to protect "large-scale ecosystem processes responsible for the productivity and functional integrity of the ecosystem" on the continental shelf by establishing an MPA that would be sufficiently large to account for interannual variation in the location of biological production. Ecosystem process areas that determine the productivity and functional integrity of the marine ecosystem in the RSR are illustrated in the Appendix (Figure A3).

Three pelagic species dominate middle trophic levels on the continental shelf: Antarctic krill, crystal krill, and Antarctic silverfish. These three species are the principal prey of seabirds and marine mammals that forage over the continental shelf (WG-EMM-10/12, Figure 5); silverfish are also important prey of Antarctic toothfish (WG-FSA-10/24; WG-FSA-12/14, Figure 74). Antarctic krill generally occur over the outer margin of the shelf, at the shelf-slope transition where relatively warm intrusions of Modified Circumpolar Deep Water occur over the shelf (WG-EMM-10/11, Figures 25 and 26). Crystal krill and Antarctic silverfish are widely distributed over the entire shelf, but the distribution of these species has limited overlap with Antarctic krill (WG-EMM-10/11, Figures 25 and 26). Since krill and silverfish are the main conduits for energy transfer from primary producers to upper-level predators (WG-EMM-12/53), New Zealand and the United States propose "to protect core distributions of trophically dominant pelagic prey species," by establishing an MPA that extends over most of the continental shelf. The core distributions of trophically dominant pelagic prey species are illustrated in the Appendix (Figure A4).

Coastal areas and the continental shelf in the RSR are important foraging grounds for several species of predators, including those that breed on land (e.g., Adélie and emperor penguins) and those that might experience direct competition with the toothfish fishery (e.g., Weddell seals and Type C killer whales). Adélie and emperor penguins are abundant in the RSR (WG-EMM-10/12, Table 1); these birds eat krill and silverfish (WG-EMM-10/12, Figure 5) and breed at several colonies along the coasts of Victoria Land, Ross Island (and other islands), and Marie Byrd Land (WG-EMM-10/11, Figures 40 and 41; WG-EMM-10/30, Figures 9 and 10). At one time or another during the year, these birds utilize practically the whole continental shelf as a foraging ground (WG-EMM-10/11, Figures 39 and 43). The western and eastern sides of the shelf are particularly important to these penguins during spring and early summer (WG-EMM-10/11, Figures 40 and 41; WG-EMM-10/30, Figures 9 and 10; WS-MPA-11/25, Figure 2c), while the central shelf becomes more important during late summer and fall (WG-EMM-10/11, Figure 42). Weddell seals are also abundant over the continental shelf of the RSR (WG-EMM-10/12, Table 1). These seals eat fish, including Antarctic silverfish and toothfish (WG-EMM-10/11, pp. 43-44; WG-EMM-10/12, Figure 5), and bear their young at locations along the coasts of Victoria Land, Ross Island, and Marie Byrd Land (WG-EMM-10/11, Figure 36). Available tracking data indicate that Weddell seals spend considerable time foraging over the western and eastern sides of the continental shelf, but fewer observations have been made of Weddell seals foraging over the central portion of the shelf (WG-EMM-10/11, Figure 36; WG-EMM-10/12, Figure 3; WS-MPA-11/25, Figure 2d). Type C killer whales also eat Antarctic toothfish, and these predators forage under and around fast ice and within the marginal ice zone (WG-EMM-10/30, pg. 44) as well as over banks on the continental shelf (WG-EMM-10/11, pg. 41). Habitat models also indicate that Type C killer whales forage widely along the outer, western (including north of Cape Adare), and southern margins of the continental shelf (WG-EMM-10/11, Figure 32; WG-EMM-10/12, Figure 6; WS-MPA-11/25, Figure 2d) and locally within McMurdo Sound (WG-EMM-10/30, pg. 44; WS-MPA-11/25, Figure 2d). When the foraging habitats of Adélie penguins, emperor penguins, Weddell seals, and Type C killer whales are overlayed on a map of the RSR, it is apparent that protecting these habitats requires a large MPA encompassing all coastal areas and extending over most of the continental shelf. The core foraging areas of land-based predators or those that may experience direct trophic competition from fisheries are illustrated in the Appendix (Figure A5).

Several other species of predators also forage in coastal areas and over the continental shelf of the RSR. Results from habitat models fitted to visual observations collected at sea emphasize the importance of coastal areas (e.g., McMurdo Sound and near the Ross Ice Shelf), the eastern continental shelf, and the outer edge of the shelf to Antarctic minke whales, crabeater seals, Antarctic petrels, and snow petrels (WG-EMM-10/12, Figure 6). Given their positions in food webs, the success (or failure) of predator populations is ultimately determined by a complex integration of physical and ecological conditions within the marine ecosystem. An ecosystems that can support a community of large, robust predator populations is therefore likely to be a “healthy” ecosystem in which ecosystem structure and function is conserved at all levels of biological organization. One of the protection objectives (the first protection objective) stated in the joint proposal is to protect the habitats supporting such communities, and, this objective can be met by including large areas over the western and eastern halves of the continental shelf and over the outer margin of the continental shelf within an MPA. A small MPA would be unlikely to achieve the protection objectives related to predators in the RSR because these animals forage over large areas. Habitats that are important to the larger Ross Sea community of Adélie and emperor penguins, Antarctic and snow petrels, Weddell and crabeater seals, minke and killer whales, and light-mantled sooty albatrosses are illustrated in the Appendix (Figure A6)

Coastal locations and other relatively small or localized areas over the continental shelf are particularly important sources of biological production in the RSR. Polynya formation is active in these areas, thus establishing the physical conditions, e.g., solar insolation, nutrient input, and wind-driven mixing, needed to catalyze such production (WG-EMM-10/30, pg. 40). The production in polynyas is transferred through the food web, and, therefore, the importance of coastal locations to achieving several other protection objectives is emphasized throughout this subsection. Terra Nova Bay is particularly noteworthy (WG-EMM-11/30, pg. 45). Terra Nova Bay is a recognized nursery for Antarctic silverfish; unusually retentive oceanographic circulation and high primary production in the bay support the early life stages of this important prey species. Two Antarctic Specially Protected Areas also occur in Terra Nova Bay (ASPA 161 and the newly established ASPA at Cape Washington), and the joint proposal to include Terra Nova Bay within the MPA is consistent with the management plans of these ASPAs. Other locations along the Victoria Land coast also have ecological importance. Platelet ice and anchor ice are formed along the coastline, providing important habitats for various fishes and a potential dispersal mechanism (when anchor ice breaks off and floats away) for benthic invertebrates (WG-EMM-11/30, pg. 45). Coastal locations and other small or localized areas that are of particular ecological importance are illustrated in the Appendix (Figure A7).

Coastal areas and the continental shelf of the RSR provide important habitats for Antarctic toothfish; these habitats have also been important fishing grounds for the longline fishery. Although there is uncertainty about the life history and ontogenetic movements of Antarctic toothfish, it is clear that the continental shelf provides critical rearing and growing habitat. On average, juvenile fish are mostly observed in relatively shallow depressions near the Ross Ice Shelf and in Terra Nova Bay while larger sub-adults are mostly observed in deeper waters, including in trenches that cut across the continental shelf and connect the depressions to the continental slope (WG-FSA-10/24, Figure 4; WG-FSA-12/14, Figures 18-22; WS-MPA-11/25, Figure 2e). These observations were made from the longline fishery. Large, maturing and adult toothfish have also been caught on the shelf (WG-EMM-10/11, WG-FSA-10/24, WG-FSA-12/14), and it has been hypothesized that spawning may occur on the shelf (WG-FSA-12/14, pg. 23). Antarctic toothfish are an important component of the food web in the RSR (WG-EMM-10/11, pg. 37; WG-EMM-10/30, pp. 46-47), and, on the shelf, these fish act both as predators of various invertebrates and fishes (e.g., WG-FSA-12/14, Figure 75) and as prey for Weddell Seals (WG-

EMM-10/11, pp. 43-44; WG-FSA-10/24, pg. 25) and Type C killer whales (WG-EMM-10/30, pp. 44-45; WG-FSA-10/24, pg. 25). Protecting areas of importance to Antarctic toothfish can also provide protections that extend throughout the food web. Areas of importance in the life cycle of Antarctic toothfish are illustrated in the Appendix (Figure A8).

Benthic biodiversity is high in coastal areas and over the continental shelf of the RSR, and, generally, these areas form a benthic biodiversity "hotspot" within the Southern Ocean (WG-EMM-10/11, pg. 26). Spatial variation in the diversity of benthic communities is linked to spatial variation in the physical conditions that influence the flux, both vertically and horizontally, of organic material to and across the bottom. When this flux is not limiting seafloor and sediment characteristics determine faunal composition of the benthos (WG-EMM-10/11, pp. 26-31, WG-EMM-10/30, pg. 19). Observations collected during several cruises suggest that vulnerable benthic taxa (e.g., sponges, bryozoans, and gorgonians) are widespread over the continental shelf (e.g., locations of "SFP" and "SFR" communities in WG-EMM-10/11, Figure 21), but there is notable spatial variation in the presence of these taxa. Providing protection to achieve other objectives (e.g., to protect the distributions of silverfish and crystal krill or the foraging areas of upper-level predators) can simultaneously protect vulnerable benthic taxa that are variably, but widely, distributed over the continental shelf. Vulnerable benthic communities and taxa have also been observed in coastal areas, where underwater photography demonstrates that the faunal composition of benthic communities varies substantially over short distances (e.g., WG-EMM-10/11, Figure 23). McMurdo Sound is recognized as a particularly important study area where deep-water benthic communities comprised of vulnerable taxa occur in relatively shallow water (WG-EMM-10/30, pg. 48) and where detailed, long-term studies of these communities were initiated in the late 1960s (WG-EMM-10/11, pg. 31). Two, rich scallop beds located within Terra Nova Bay (WG-EMM-12/23, Figure 1) are recognized as Vulnerable Marine Ecosystems (VMEs). "To protect known rare or vulnerable benthic habitats," in coastal areas and on the continental shelf, New Zealand and the United States primarily emphasize protection of McMurdo Sound (WS-MPA-11/25, Figure 2f), but including Terra Nova Bay as an area of emphasis for benthic protection would also be consistent this objective. Known rare or vulnerable benthic habitats are illustrated in the Appendix (Figure A9).

The continental slope

Spatial data relevant to protection objectives for the continental slope

The continental slope is uniquely important within the marine ecosystem of the RSR. Five pelagic bioregions and four benthic bioregions have been identified on the continental slope (WG-EMM-10/30, Figures 1 and 2, Tables 1 and 2), and representative portions of these bioregions, which are proxies for biodiversity and indicate faunal differences (e.g., like those illustrated in WG-FSA-12/14, Figure 76), occur within the proposed MPA (Figures A1 and A2). Productivity along the continental slope is largely determined by the dynamics of the Slope Front (or Shelf Front) (illustrated in Figure A3), where relatively warm water from offshore and cold water from the shelf are mixed to form new water masses, where there is a westward flowing current along the shelf break, and where upwelling enhances biological production at all trophic levels (WG-EMM-10/11, pg. 12). Productivity in the Slope Front is also enhanced by its intersection with the Marginal Ice Zone (WG-EMM-10/30, pg. 38). Antarctic krill are the dominant pelagic prey over the continental slope (Figure A4), particularly where Circumpolar Deep Water is upwelled, but crystal krill and Antarctic silverfish are important at the shelf-slope transition (WG-EMM-10/11, Figures 25 and 26; WG-EMM-10/30, pg. 41). The enhanced production over the continental slope supports a large community of predators that forage here (WG-EMM-10/30, pg. 41). The predators that forage over the continental slope include Adélie and emperor penguins, Antarctic and snow petrels, light-mantled sooty albatross, Weddell and crabeater seals, and Antarctic minke whale (Figures A5 and A6). To protect this community and the prey that support it, New Zealand and the United States designed the jointly proposed MPA to include portions of the continental slope. These protection objectives were, however, balanced against Members' interest in fishing along the continental slope, where Antarctic toothfish are abundant. Thus, the jointly proposed MPA purposefully does not include important fishing grounds on the slope surrounding Mawson and Iselin Banks (CCAMLR-XXXI/16 Rev. 1, SC-CAMLR-XXX/9, SC-CAMLR-XXX/10). The continental slope is important within the lifecycle of Antarctic toothfish (Figure A8), and, in general, the slope is also the most productive fishing ground. The continental slope is considered an important feeding area where toothfish grow and mature (WG-FSA-10/24, WG-FSA-12/14). The length range of toothfish captured on the slope is wide, but the average size of fish captured on the slope is larger than that of fish caught on the continental shelf and smaller than that of fish caught in the northern RSR (WG-FSA-10/24, WG-FSA-12/14). It is uncertain where toothfish spawn, but spawning may be geographically widespread with limited dispersal of eggs and larvae (WG-FSA-12/14, pg. 23). Given the size range of fish found on the continental slope, protecting this habitat can potentially protect toothfish during much of their life history. Although benthic biodiversity is considered to be high on the slope, the faunal composition changes with depth (WG-EMM-10/11, pp. 26-30). The physical mechanisms determining where rare and vulnerable benthic communities occur on the slope are thought to be the same mechanisms that operate on the continental shelf. Vulnerable marine taxa have been observed near Cape Adare, and physical conditions at the eastern margin of the slope suggest that vulnerable taxa should be prevalent (WG-EMM-10/30, pg. 48; WS-MPA-11/25, Figure 2). These two areas are illustrated in Figure A9. Several VME Risk Areas have been identified from relatively high bycatches of VME taxa by the longline fishery. These risk areas occur within the jointly proposed MPA and are illustrated in Figure A9.

Spatial data relevant to science objectives for the continental slope

New Zealand and the United States proposed an MPA intended to ensure that fishing would continue at a level sufficient to maintain the flow of data from the toothfish tagging program while simultaneously providing contrast between a fully developed fishing ground and a fishing ground where, on average, the catch is expected to be a relatively small fraction of that taken from the fully developed ground. In the joint proposal, the Special Research Zone is identified both as a zone where catches and tagging rates are intended to maintain the integrity of the tagging program (a paper being submitted to the Working Group on Statistics, Assessments, and Modeling will address this issue) and as a "lightly fished" zone because catches taken from this zone are also intended to be a fraction of catches taken from the fully developed fishing ground over Mawson and Iselin Banks. The fully developed fishing ground includes a part of SSRU 88.1H and all of SSRU 88.1I. During the 2007/08 through 2011/12 fishing seasons, the average catch of toothfish from SSRUs 88.1H, I, and K combined was 2012t, and the average catch of toothfish from SSRU 88.1K alone was about 678t. If the average catch in the SRZ is about 290t per fishing season (which, at least initially, the joint proposal aims to achieve) and the balance of catches normally taken from SSRU 88.1K (which, geographically, is almost the same as the SRZ) are redistributed to Mawson and Iselin Banks, we expect the average catch from the SRZ to be less than 0.15 times the average catch from the fully developed fishing ground (290/[2012+678-290] = 0.12). This is why New Zealand and the United States refer to the SRZ as a "lightly fished" zone. If the ratio of catches taken from the SRZ to those taken from the fully developed fishing ground over Mawson and Iselin Banks is maintained at a level of about 0.15 or less, we expect, over a period of decades, to contrast ecosystem structure and function between the lightly fished SRZ and the fully developed grounds while simultaneously maintaining the integrity of the toothfish tagging program. We admit that we do not presently know whether a target ratio of 0.15 will provide sufficient contrast; this can only be known after a period of some time. Observing contrasts between a lightly fished area and a fully developed fishing ground is, in our opinion, the scientifically most powerful way to understand the ecosystem effects of fishing (which may occur in the fully developed fishing ground) distinct from those caused by climate change (which will occur in both the SRZ and the fully developed fishing ground). There are several scientific approaches to observe such contrasts, and these methods of data collection are emphasized in Annex C of the joint proposal (Priority Elements for Scientific Research and Monitoring in Support of the Ross Sea Region Marine Protected Area).

Contrasting the SRZ against the fully developed fishing grounds over Mawson and Iselin Banks requires that, as much as possible, these areas are ecologically comparable. Indeed, environmental conditions in the SRZ and over Mawson and Iselin Banks are comparable, and the complex of bioregions and ecosystem process areas overlaying the SRZ and Mawson and Iselin Banks are unique within the RSR (SC-CAMLR-XXX/9, Figure 2). Furthermore, the densities and age (size) compositions of Antarctic toothfish in the SRZ and over Mawson and Iselin Banks are similar (WG-FSA-12/14 and WG-FSA-12/42). We hypothesize that the physical properties of continental slope within the SRZ and around the perimeters of Mawson and Iselin Banks (as represented by the unique complex of bioregions) enhance production and explain why these areas are important to toothfish, to native mammals and birds, and to the longline fishery. The complex of bioregions appears to contain two ecological units with similar structure and function. As illustrated in Figure A10, the boundaries of the jointly proposed MPA partition these two units to provide the basis for observing future contrasts between the SRZ and Mawson and Iselin Banks.

The Balleny Islands and vicinity

Spatial data relevant to protection objectives for the Balleny Islands and vicinity

The Balleny Islands are unique within the Southern Ocean and globally. Nine pelagic bioregions and 12 benthic bioregions have been identified in the vicinity of the Balleny Islands (here defined as all of SSRU 88.1E and F, the southwestern corner of SSRU 88.1B, the eastern third of SSRU 88.1G, and the area around the Scott Seamounts) (Figures A1 and A2). The large number of bioregions within a relatively small area suggests extremely high biodiversity in the vicinity of the Balleny Islands, which can likely be categorized as a biodiversity "hot spot." One of the pelagic bioregions and three of the benthic bioregions are unique to the Balleny Islands, with the three benthic bioregions being the smallest bioregions in the RSR. New Zealand and the United States propose to protect a "representative portion of benthic and pelagic marine environments," and thus the biodiversity within them, by overlaying the proposed MPA onto all of these bioregions. The Balleny Islands, because their steep topography juts into the prevailing current, have a pronounced impact on sea-ice dynamics, and multiple polynyas are formed in the area (WG-EMM-10/30, pg. 39). Like other polynyas, increased light, mixing, and nutrient input enhance production, essentially making the islands themselves responsible for the productivity and functional integrity of the marine ecosystem. An ecosystem process area acknowledging these island impacts has been identified from sea-ice imagery and included within the jointly proposed MPA (Figure A3). Enhanced productivity in the vicinity of the Balleny Islands supports high densities of Antarctic krill (with the core distribution of this prey species extending to the islands, Figure A4) and possibly Antarctic silverfish which, in turn, support abundant predator populations (WG-EMM-10/30, pg. 39). Humpback, fin, blue, and minke whales have been observed foraging in the vicinity of the Balleny Islands (WG-EMM-10/11, Figures 30 and 31), and ten species of seabirds and four species of pinnipeds are known to occur on the islands, some of which breed there (WG-EMM-10/30, pg. 39). Scott Seamount is an important foraging habitat for Antarctic petrels and light-mantled sooty albatrosses (WG-EMM-10/12, Figure 6). Scott Seamount is also geographically important in the lifecycle of Antarctic toothfish. The seamount may be a movement corridor for toothfish moving between the continental slope and seamounts in the northern RSR, or, if spawning is widespread (see WG-FSA-12/14, pg. 23), a spawning ground. New Zealand and the United States included the Scott Seamount inside the jointly proposed MPA to protect habitats important to predators and toothfish (Figures A6 and A8). Vulnerable benthic communities also occur in the vicinity of the Balleny Islands. The islands themselves provide unique habitats for fishes that are endemic to the area and where sub-Antarctic and Antarctic fish fauna have overlapping distributions (WG-EMM-10/30, pg. 48). Vulnerable Marine Ecosystems have been observed on Admiralty Seamount, where unique, dense communities of stalked crinoids may provide clues about the evolution benthic invertebrates in the Southern Ocean (WG-EMM-11/10). New Zealand and the United States propose to protect the vulnerable benthic habitats that occur in the vicinity of the Balleny Islands by including them within the MPA (Figure A9).

The northern RSR, including seamounts in the Pacific Antarctic Ridge

Spatial data relevant to protection objectives for the northern RSR

In general, less data are available from the northern RSR than from the continental shelf and slope. The northern RSR contains three pelagic bioregions (Figure A1) that, from north-to-south, are defined by the Antarctic Circumpolar Current, the Polar Front, and the maximum pack-ice extent (WG-EMM-10/30, Figure 2, Table 2); these bioregions are circumpolar and not unique to the RSR. The northern RSR also contains four benthic bioregions (Figure A2), and at least two of these are also unlikely to be unique to the RSR (e.g., the abyssal plain and bathymetric features associated with tectonic ridges). Two of the four benthic bioregions are limited to the northwestern RSR (WG-EMM-10/30, Figure 1). Protecting a "representative portion of benthic and pelagic marine environments" in the northern RSR requires an MPA that has coverage extending across the north-south plane (to include the three pelagic bioregions) and which includes the northwestern RSR. The jointly proposed MPA meets these requirements. The Polar Front is a key feature in the northern RSR (Figure A3). Productivity is enhanced at the Polar Front, and it is an important foraging area for seabirds (WG-EMM-10/12, Figure 6; WG-EMM-10/30, pg. 39). Antarctic krill have a circumpolar distribution and do occur as far north as the Polar Front (WG-EMM-10/11, Figure 25), but are most abundant farther south (WG-EMM-10/11, pg. 34). Available data on the distributions of predators in the northern RSR are extremely limited. It is known that sperm whales feed on adult toothfish in this region (WG-FSA-12/14, Figure 6), and the jointly proposed MPA may limit competition between the fishery for Antarctic toothfish and sperm whales. During the austral winter, Adélie penguins extend as far north as the maximum sea-ice extent (WG-EMM-10/11, Figure 42), where their survival is likely determined by the availability of Antarctic krill (WG-EMM-10/30, pg. 39). Although development of a krill fishery in the northern RSR seems unlikely (experience in the Antarctic Peninsula region demonstrates that it is difficult to reliably find fishable concentrations of krill in the open ocean), an MPA in the northern RSR might also limit competition between Adélie penguins and a new krill fishery. Light-mantled sooty albatross forage at the southern margin of the northern RSR (WG-EMM-10/12, Figure 6), and humpback, fin, blue, and killer whales have also been observed here (WG-EMM-10/11, Figures 30 and 32 respectively). It is uncertain where toothfish spawn, but, based on observations of fish with maturing gonads, it is hypothesized that spawning occurs over the seamounts in the northern RSR (WG-FSA-10/24, Figure 14). Subsequently, eggs and larvae originating west of about 180°, are thought to be dispersed south and then west to (or past) the Balleny Islands, but eggs and larvae originating east of about 180° are dispersed east and then south, roughly following the clockwise flow of the Ross Gyre (WG-FSA-10/24, pg. 27; WS-MPA-11/25, pg. 37). This bifurcation was considered in the design of the jointly proposed MPA, and, to protect areas that are important in the lifecycle of Antarctic toothfish, it is why the MPA overlays seamounts in both the northwestern and northeastern RSR. By overlaying seamounts in the northwest and the northeast, the jointly proposed MPA will also protect Antarctic toothfish if spawning is widespread with limited dispersal of eggs and larvae (as per WG-FSA-12/14, pg. 23). Benthic biodiversity is largely unexplored in the northern RSR, and, since the northern RSR is generally less productive than the continental shelf and slope, benthic communities may be less dense in the northern RSR (except possibly for chemosynthetic communities, but we are not aware that any such communities have been discovered in the RSR). These points suggest that the jointly proposed MPA would simply provide precautionary protection to rare and vulnerable benthic habitats in the northern RSR. VME taxa are included in the bycatch of the longline fishery, and new VMEs may be discovered over time, particularly if fishing extends farther east along the Pacific Antarctic Ridge.

Spatial data relevant to science objectives for the northern RSR

Similar to the opportunities that would be provided by contrasting the SRZ against the fully developed fishing grounds over Mawson and Iselin Banks, the joint proposal offers opportunities to contrast an unfished reference area against a fully developed fishing ground in the northern RSR (Figure A10). The jointly proposed MPA includes a General Protection Zone (GPZ) that overlays seamounts in SSRUs 88.2A and B, and, except for research fishing, directed harvests of toothfish would be prohibited in this zone. The seamounts farther west along the Pacific Antarctic Ridge, in SSRU 88.1C, have been open to fishing for more than a decade. The seamounts within the GPZ are ecologically comparable to those occurring farther west. Biodiversity differences between the GPZ and SSRU 88.1C are likely to be minimal because the two areas include the same pelagic and benthic bioregions (Figures A1 and A2), and, within the RSR, the Polar Front generally occurs above the entire length of the Pacific Antarctic Ridge (Figure A3). Although SSRUs 88.2A and B have historically been closed to fishing, available data from sperm whale stomachs demonstrate that the seamounts within the GPZ provide habitat for adult toothfish (WG-FSA-12/14, Figure 6). Observing future contrasts between the GPZ and a fully developed fishing ground farther west can be done in a ways that are analogous to those suggested for observing contrasts between the SRZ and Mawson and Iselin Banks and will almost certainly require well-designed research fishing within the GPZ.

Synthesis

Figures 1 and 2 respectively illustrate the protection and scientific outcomes that can be achieved from the MPA jointly proposed by New Zealand and the United States; these outcomes are placed in context with the recent distribution of fishing effort. The jointly proposed MPA offers substantial protection outcomes; this conclusion is supported by the dense overlay of habitats and ecosystem process areas that occur within the proposed boundaries of the MPA (Figure 1). The proposed MPA largely overlaps areas that are currently closed to fishing (either because depths are less than 550m or because zero catch limits have been established in Conservation Measures 41-09 and 41-10), but, to achieve the protection objectives for the MPA, New Zealand and the United States propose to redistribute all recent fishing effort from areas near the Ross Ice Shelf and Cape Adare and a portion of the recent fishing effort inside the SRZ (on the continental slope between 180° and 170°W). About 20% of the historical catch by the fishery would be displaced by the MPA, however New Zealand and the United States also propose to open several areas that are currently closed to fishing if the MPA enters into force (the seamounts within the Spawning Protection Zone, during the period when this zone is proposed to be open, and the seamounts outside of the GPZ in SSRUs 88.2A and B). As noted previously, the jointly proposed MPA also offers substantial science outcomes, and it is our view that developing contrasts between the SRZ and the fully developed fishing ground over Mawson and Iselin Banks is the scientifically most powerful way to understand the ecosystem effects of fishing distinct from those of climate change. Similar contrasts can be developed over the seamounts in the northern RSR. Indeed, developing such contrasts while maintaining the continuity and integrity of the existing toothfish tagging program, which underpins the stock assessment of toothfish, has the potential to improve management of toothfish fisheries throughout the Southern Ocean. As illustrated in Figure 2, the science outcomes that can be achieved by the MPA only involve displacement of fishing effort from the SRZ.

The period for which an MPA is designated can be linked to the objectives for the MPA. We cannot assess how much time is required to achieve the protection objectives stated in the joint proposal (objectives i and iv-x). To some degree, however, the time required to achieve the protection objectives will depend on whether the threats to the objectives are immediate or will emerge over time and on whether these threats have undesirable impacts that will last for short periods of time or for long periods of time. The time required to achieve protection objectives like those stated in the joint proposal is also a policy decision that is linked to the time period over which the Commission agrees that its specific objectives for an MPA remain relevant and are desirable. At least several decades are required to achieve the first science objective (“to provide a reference area in which fishing is limited, to better gauge the ecosystem effects of climate change and fishing, and to provide other opportunities for better understanding the Antarctic marine ecosystem”). The impacts of climate change will unfold over several decades and only be understood over the long term because seasonal and interannual variation in physical and ecological processes generally dominate signals over the shorter time scales (e.g., WG-EMM-10/11, Figure 11). Furthermore, alternative climate-change models often forecast widely different conditions at fixed points in the future (and some do not even forecast similar trends) (e.g., WG-EMM-10/11, Figure 14). Because such differences lead to substantial uncertainty in the period of time it might take to recognize changes of a magnitude that might be of interest to decision makers and there are substantial uncertainties in how physical changes might propagate through the food web in the RSR, we cannot advise the Commission that a specific period of time is required to observe a specific level or type of change or to observe a difference between a lightly fished area (or an unfished reference area) and a fully developed fishing ground. Thus, we limit our advice to emphasizing the long-term, empirical study of contrasts between these areas over several decades (observed in ways consistent with the priorities listed in Annex C of the joint proposal).

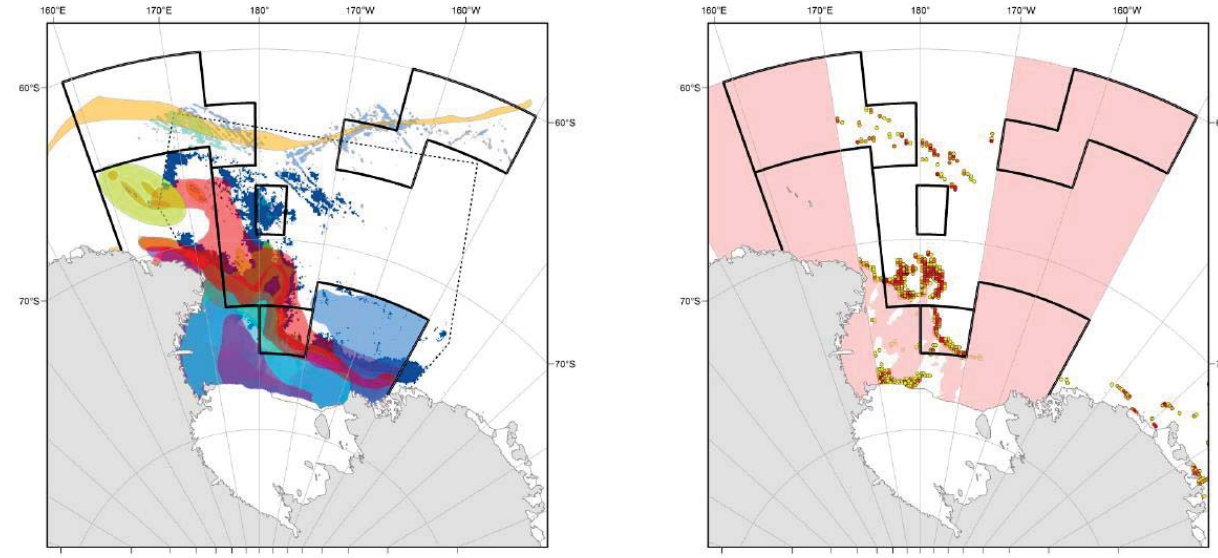

Figure 1. Potential protection outcomes offered by the jointly proposed MPA (left panel) and an illustration of *status quo* conditions in the toothfish fishery (right panel). Protection outcomes are mapped using all the layers illustrated in Figures A3-A9 and are adapted from figures presented in WS-MPA-11/25 and SC-CAMLR-XXX/9. To simplify the presentation, representativeness outcomes (i.e., the layers in Figures A1 and A2) are not illustrated. In the right panel, colored circles indicate the relative concentration of fishing effort (cumulative longline sets during the period spanning the 2009/10-2011/12 fishing seasons; red is relatively more effort; yellow is relatively less effort) and areas shaded in red are currently closed to longline fishing because depths are less than 550m or the catch limit is zero.

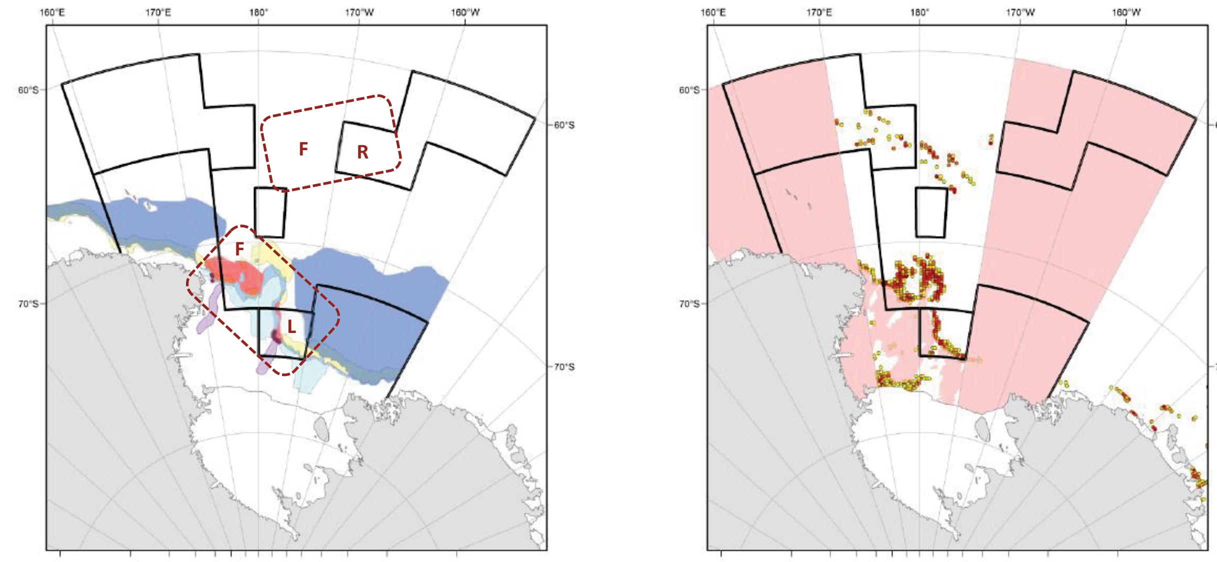

Figure 2. Potential science outcomes offered by the jointly proposed MPA (left panel) and an illustration of *status quo* conditions in the toothfish fishery (right panel). Science outcomes are mapped using the layers illustrated in Figure A10 and are adapted from Figure 2 in SC-CAMLR-XXX/9. In the left panel, the dashed rectangle overlaying the continental slope identifies a unique complex of bioregions. The boundaries of the proposed MPA bisect this complex so that comparisons can be made between the area marked “L” (lightly fished SRZ) and the area marked “F” (fully developed fishing ground over Mawson and Iselin Banks). As described in the text, similar comparisons between a fully developed fishing ground (also marked “F”) and an unfished reference area within the MPA (marked “R”) are envisioned for the northern RSR, roughly within the area bounded by the northern dashed rectangle. The seamount topography is not illustrated in this figure but can be viewed in Figure A8. See Figure 2 for a description of the right panel.

References

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WG-FSA-10/24	Hanchet, S.M. Updated species profile for Antarctic toothfish (*Dissostichus mawsoni*).
WG-FSA-12/14	Petrov, A.F. *Dissostichus mawsoni* biology and distribution.
WG-FSA-12/42	Stevenson, M.L., Hanchet, S.M., Mormede, S., and Dunn, A. A characterisation of the toothfish fishery in Subareas 88.1 and 88.2 from 1997/98 to 2011/12.
WS-MPA-11/25	Sharp, B.R., and Watters, G.M. Marine protected area planning by New Zealand and the United States in the Ross Sea Region.

Appendix

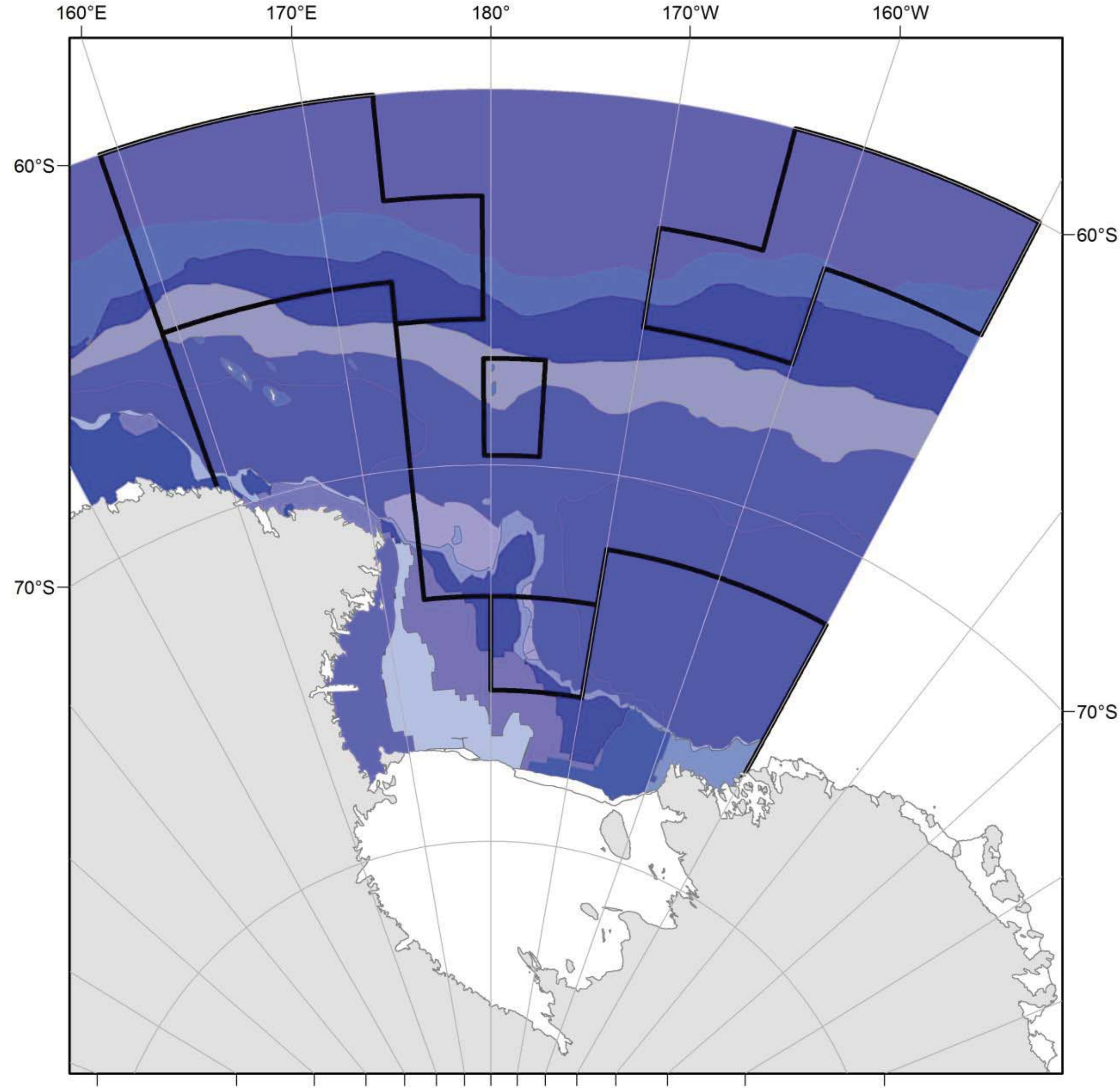

Figure A1. Pelagic bioregions and the boundaries of the joint New Zealand-U.S. proposal for an MPA in the RSR. The bioregions are adapted from WG-EMM-10/30, Figure 2.

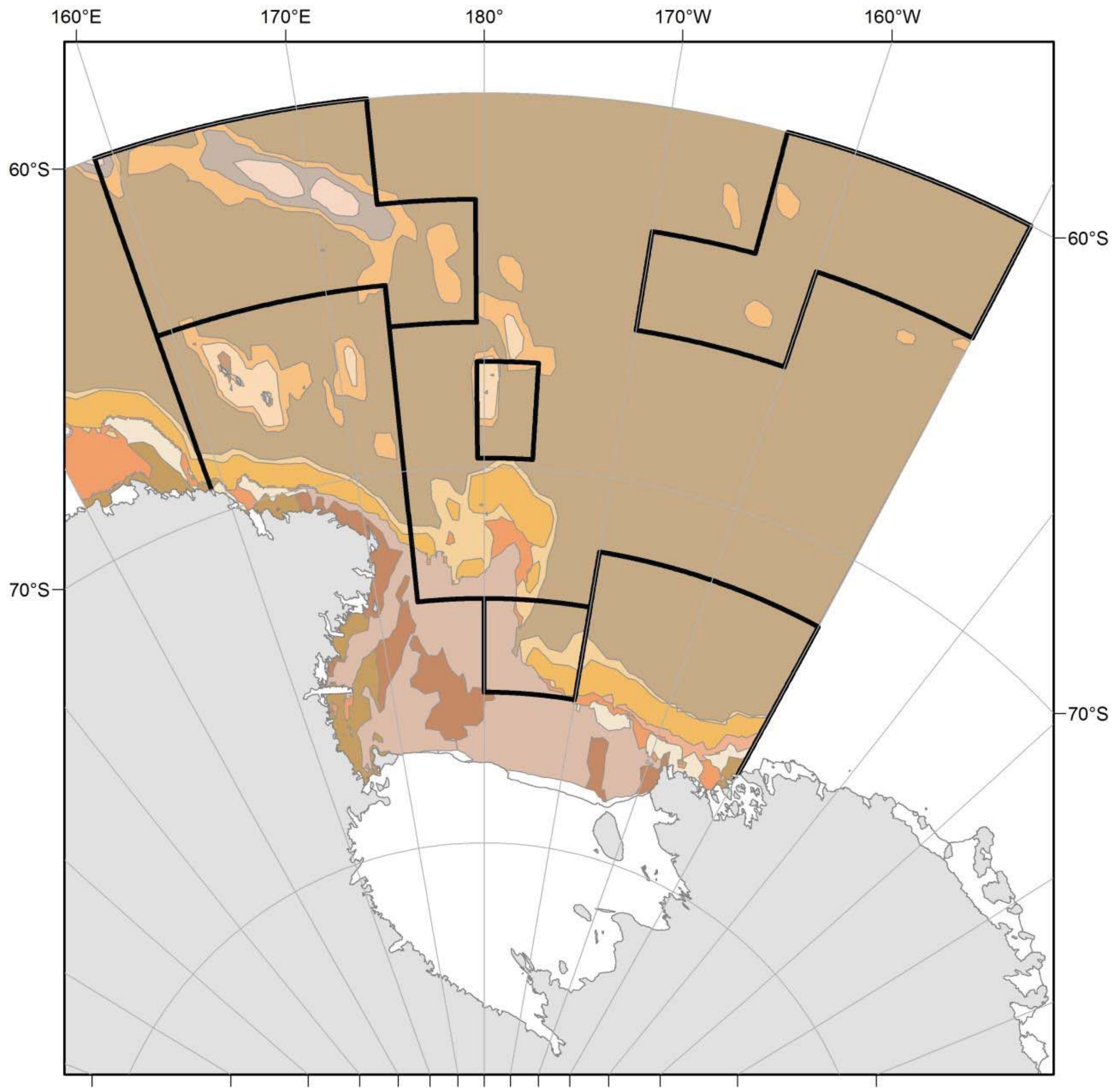

Figure A2. Benthic bioregions and the boundaries of the joint New Zealand-U.S. proposal for an MPA in the RSR. The bioregions are adapted from WG-EMM-10/30, Figure 1.

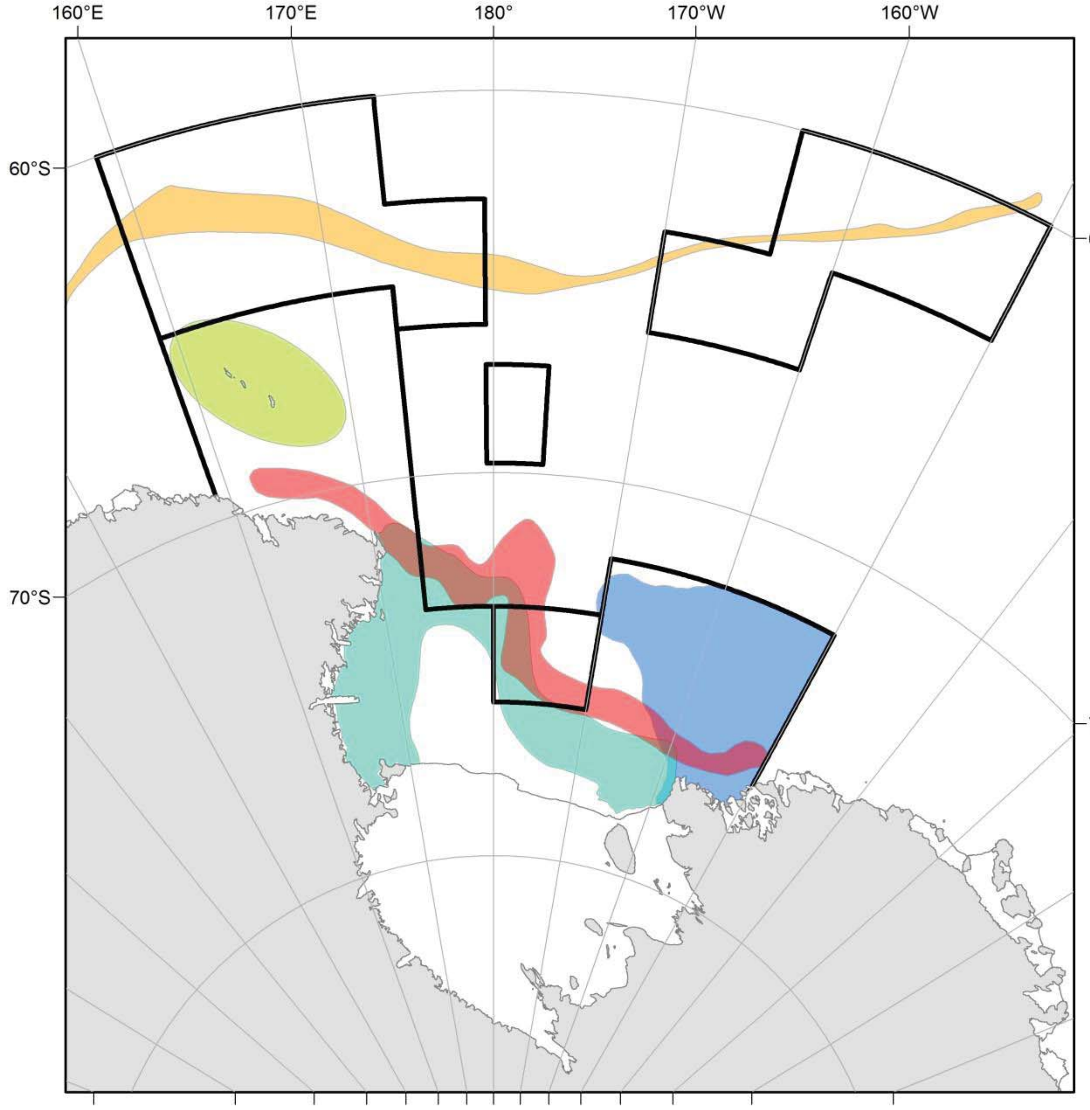

Figure A3. Ecosystem process areas that determine the productivity and functional integrity of the marine ecosystem and the boundaries of the joint New Zealand-U.S. proposal for an MPA in the RSR. The ecosystem process areas are adapted from WS-MPA-11/25, Figure 2a.

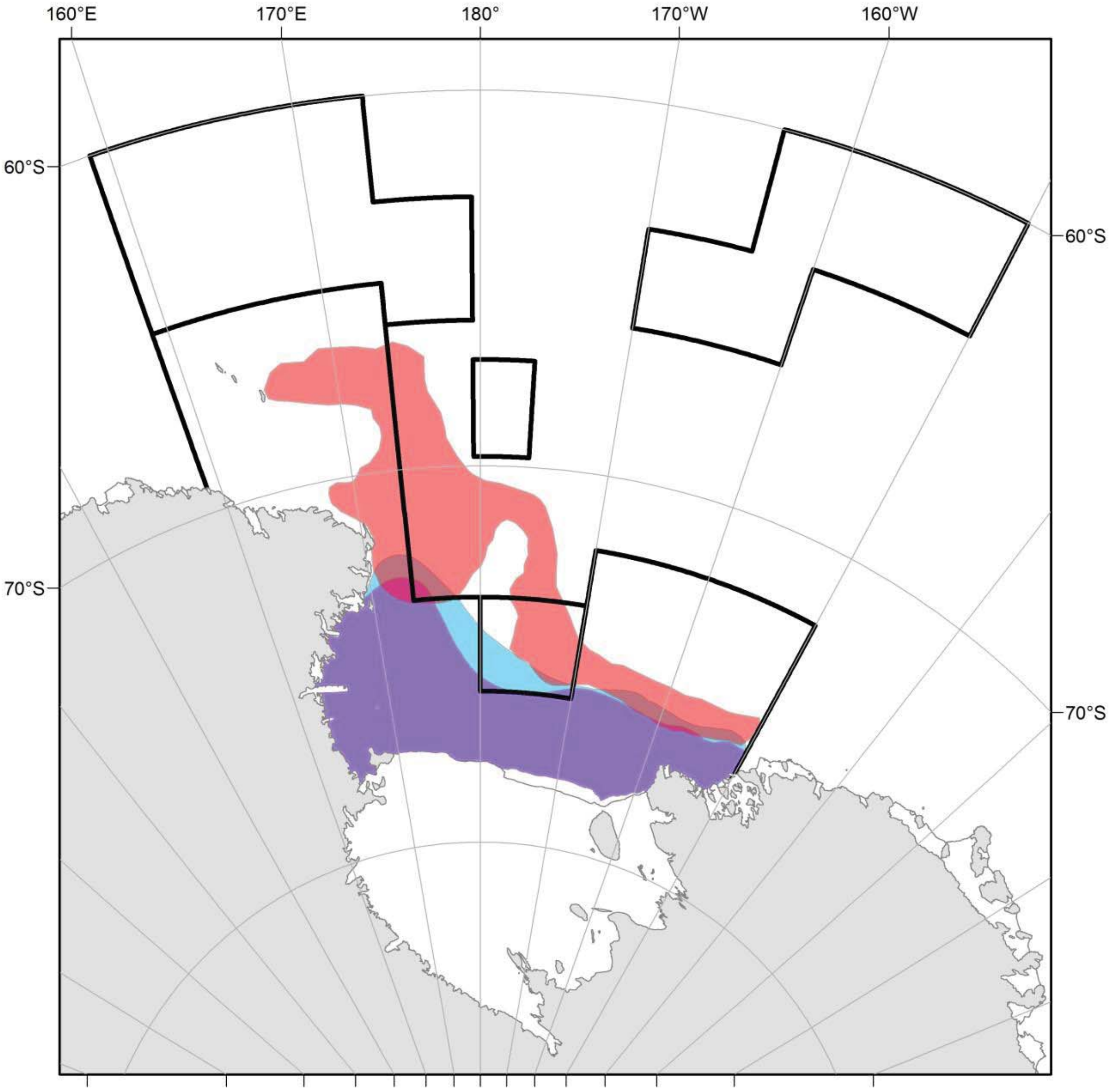

Figure A4. Core distributions of trophically dominant pelagic prey species and the boundaries of the joint New Zealand-U.S. proposal for an MPA in the RSR. The prey distributions are adapted from WS-MPA-11/25, Figure 2b.

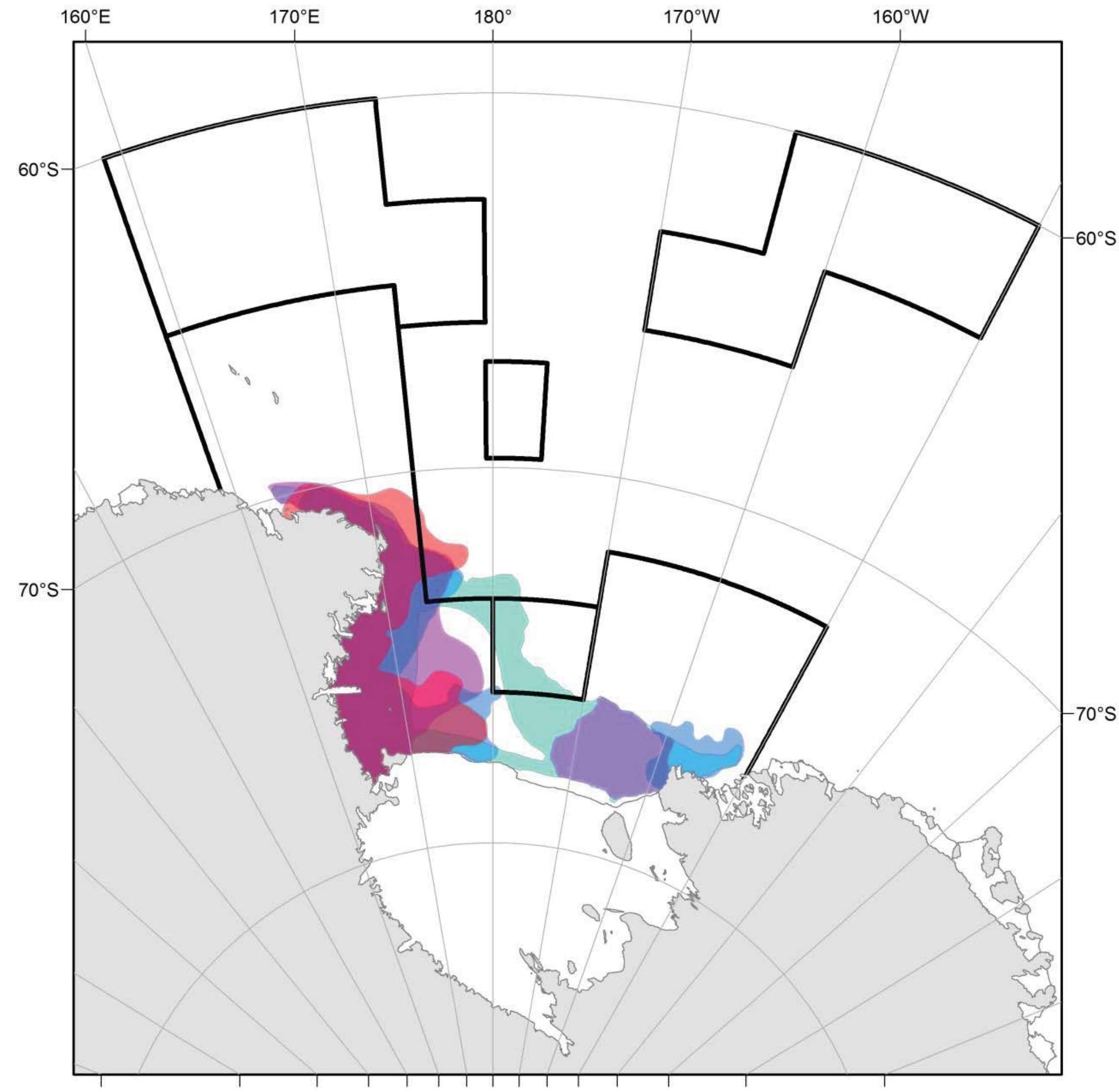

Figure A5. Core foraging areas of land-based predators or those that may experience direct trophic competition from fisheries and the boundaries of the joint New Zealand-U.S. proposal for an MPA in the RSR. The foraging areas are adapted from WS-MPA-11/25, Figures 2c and 2d.

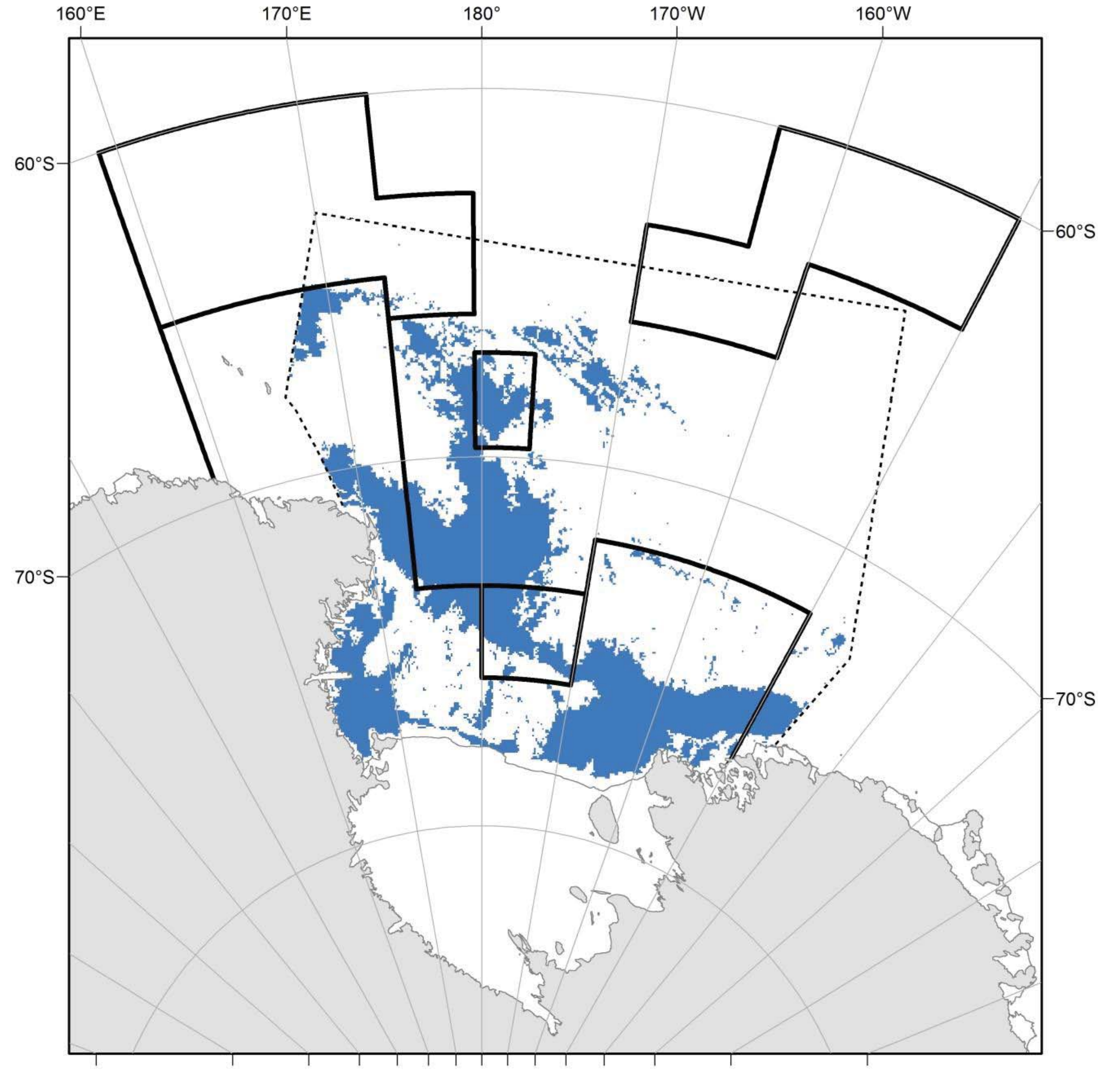

Figure A6. Important habitats for native mammals and birds and the boundaries of the joint New Zealand-U.S. proposal for an MPA in the RSR. The habitat map is adapted from SC-CAMLR-XXX/9, Figure 1; the grey dashed line indicates the area within which habitat modeling was conducted.

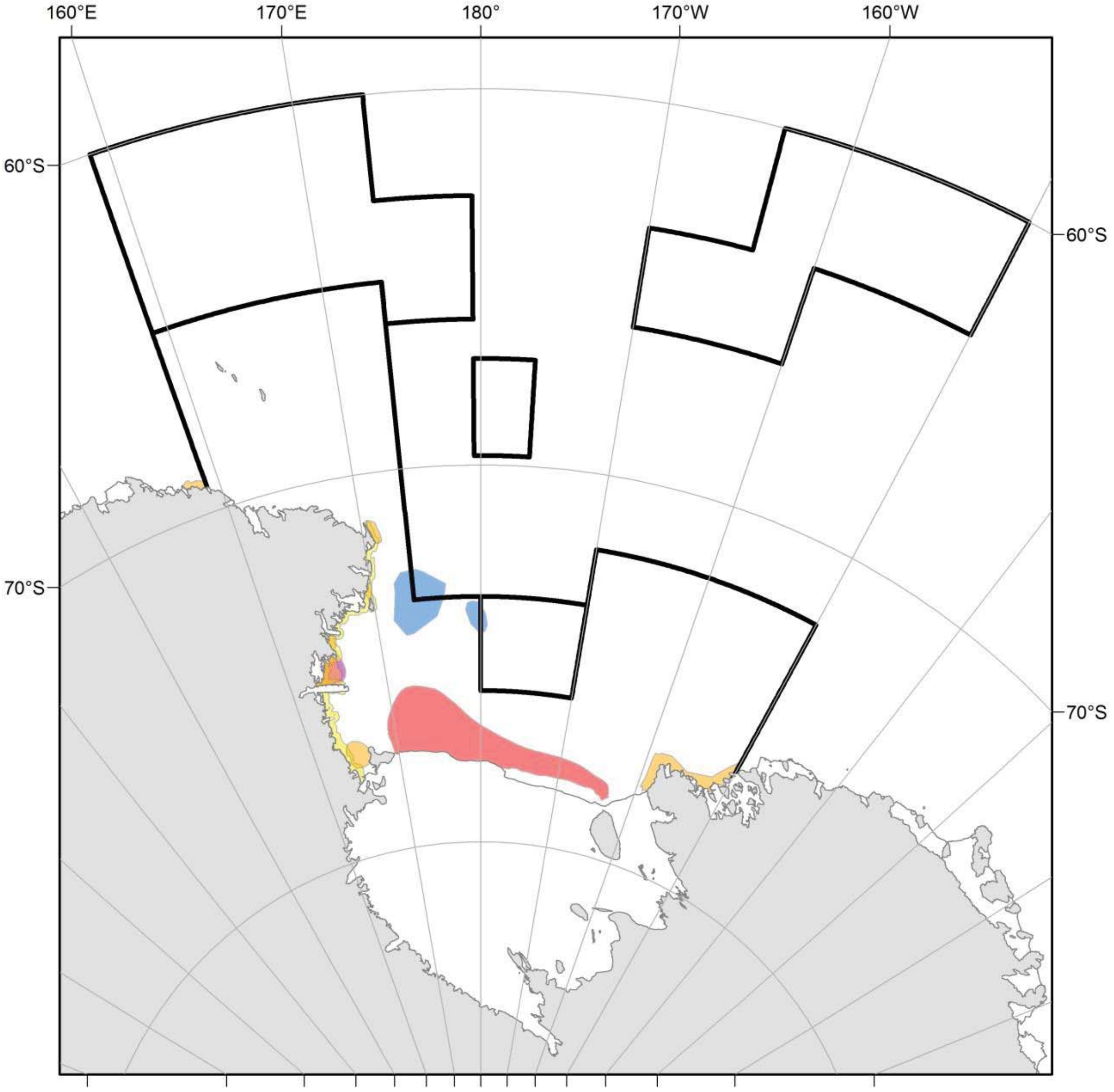

Figure A7. Coastal locations and other small or localized areas that are of particular ecological importance and the boundaries of the joint New Zealand-U.S. proposal for an MPA in the RSR. The coastal locations and localized areas are adapted from WS-MPA-11/25, Figure 2f.

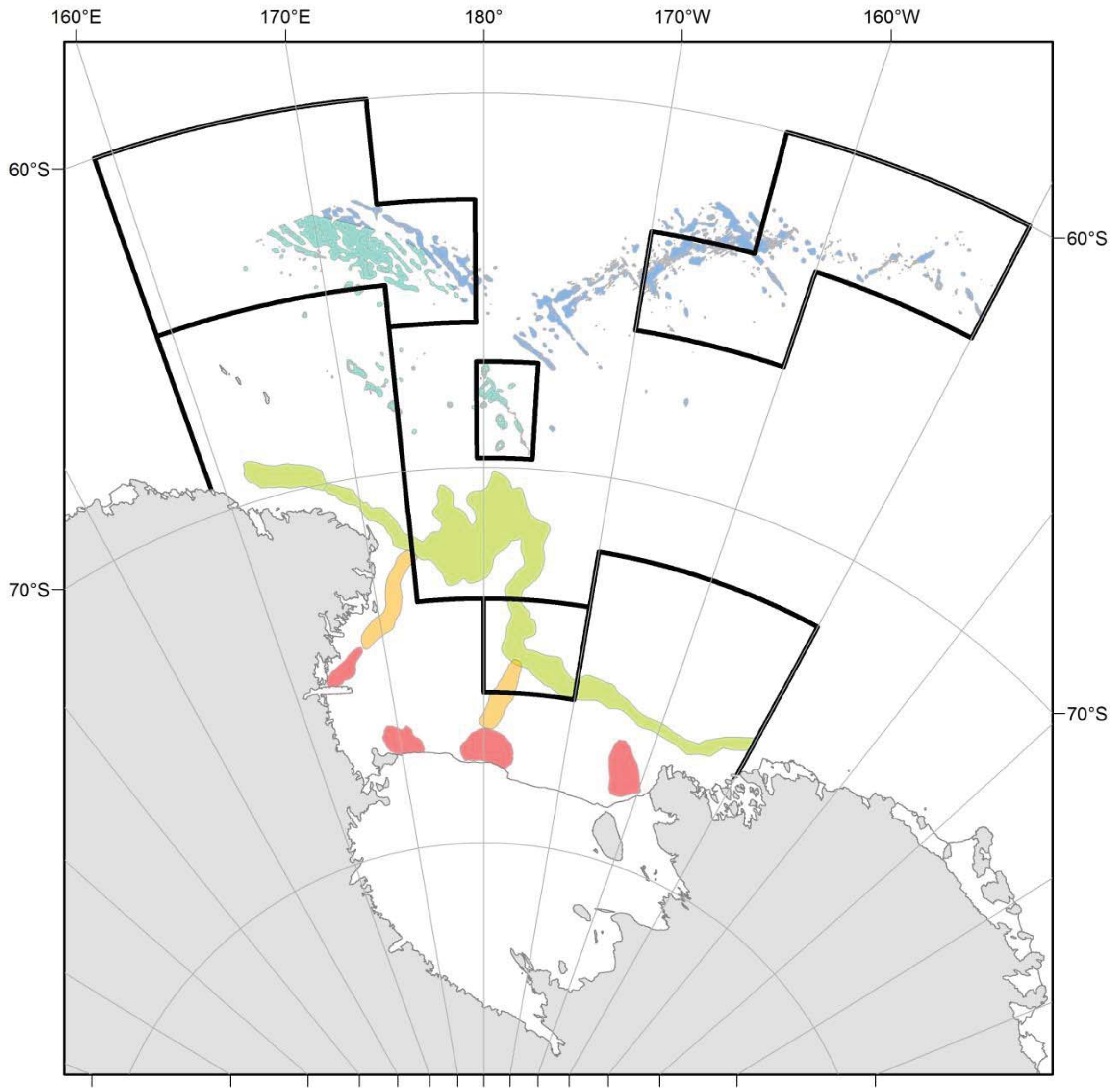

Figure A8. Areas of importance in the life cycle of Antarctic toothfish and the boundaries of the joint New Zealand-U.S. proposal for an MPA in the RSR. The toothfish areas are adapted from WS-MPA-11/25, Figure 2e.

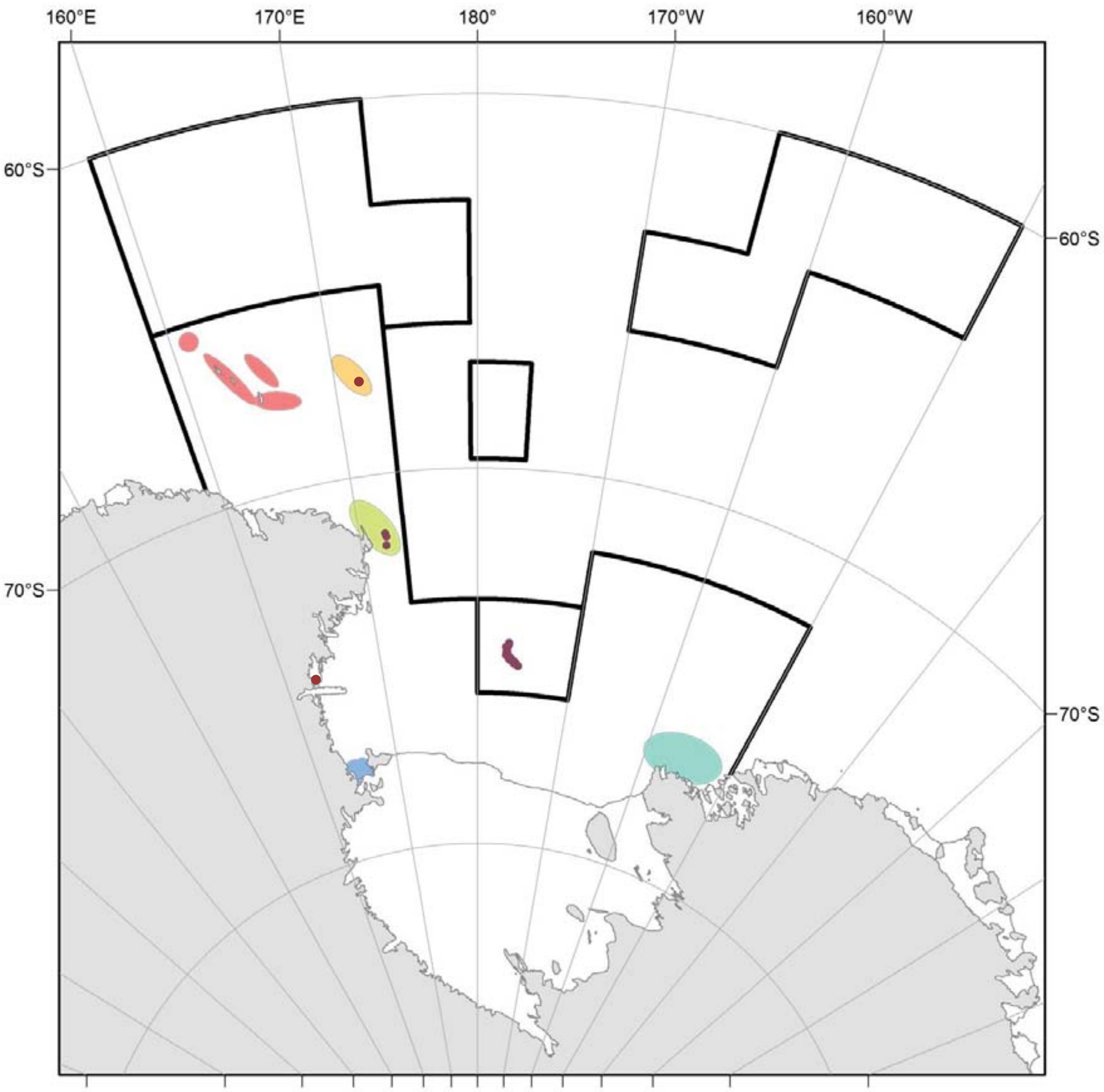

Figure A9. Known rare or vulnerable benthic habitats and the boundaries of the joint New Zealand-U.S. proposal for an MPA in the RSR. The colored polygons are adapted from WS-MPA-11/25, Figure 2f. The small purple circles are Vulnerable Marine Ecosystems and VME Risk Areas that have respectively been identified from underwater imagery and bycatches of VME indicator taxa in the longline fishery.

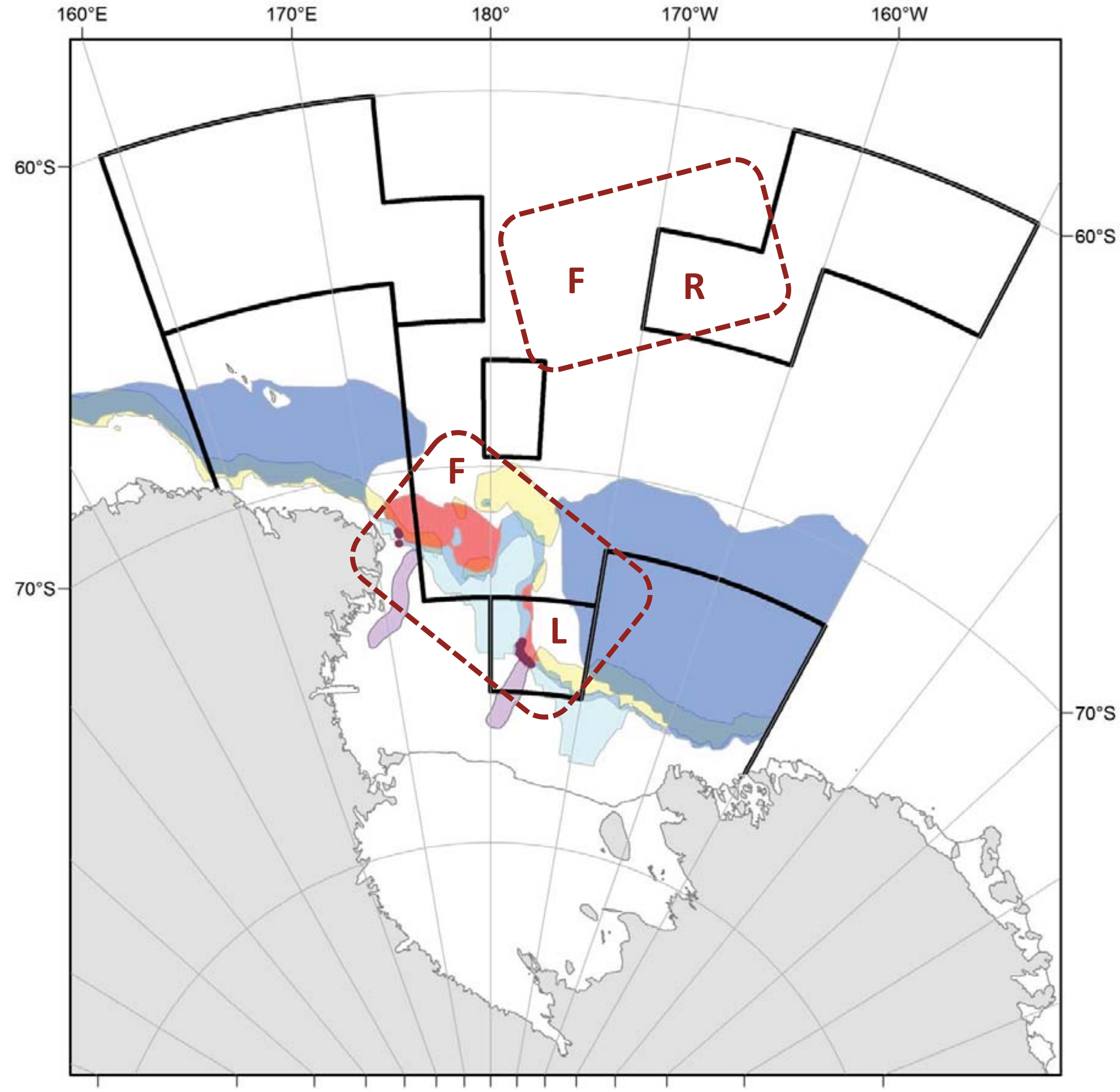

Figure A10. The complex of bioregions that overlay the SRZ and Mawson and Iselin Banks and establish the basis for contrasting ecosystem structure and function in a "lightly fished" area and a fully developed fishing ground. The dashed rectangle overlaying the continental slope identifies the complex of bioregions; this complex is unique to the RSR. The boundaries of the proposed MPA bisect this complex so that comparisons can be made between the area marked "L" (lightly fished SRZ) and the area marked "F" (fully developed fishing ground over Mawson and Iselin Banks). As described in the text, similar comparisons between fully developed fishing grounds (also marked "F") over the northern seamounts and an unfished reference area within the MPA (marked "R") are envisioned for the northern RSR, roughly within the area bounded by the northern dashed rectangle. The seamount topography is not illustrated in this figure but can be viewed in Figure A8. The bioregions are adapted from SC-CAMLR-XXX/9, Figure 2.