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Title **Preliminary plan for research and monitoring in the Ross Sea region, in association with spatial marine protection**

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ABSTRACT

This document provides a preliminary version of a research and monitoring plan to accompany a proposal to CCAMLR for the establishment of a system of MPAs in the Ross Sea region in 2012.

The draft Conservation Measure which with this research and monitoring plan is associated includes eight protection objectives as identified in Sharp & Watters (2011). Within each of these eight objectives there are identified *specific objectives* each of which is associated with an explicit spatial distribution or 'target area' defining the geographic extent of the feature (e.g. key ecosystem processes, habitats, species, populations and/or life-history stages) that has been identified as a priority for protection. This draft MPA research and monitoring plan is structured consistent with these specific objectives and priority features. Pursuant of each specific objective we identify the following categories of inquiry: i) research and monitoring to ensure that the boundaries of the priority feature as defined in the target area remain accurate, and/or to determine to what extent those boundaries may be moving; ii) research and monitoring to further understand the ecosystem role and importance of the priority feature, and/or to understand the environmental or biological processes that affect it, including potential threats from fishing; and iii) research and monitoring to demonstrate the extent to which achievement of the specific objective is being met, i.e. to demonstrate whether identified or plausible threats are being effectively mitigated by the MPA

New Zealand welcomes feedback from and collaboration with other Members in the development of a draft research and monitoring plan. The plan will be revised following discussion for resubmission to SC-CCAMLR-XXXI in September 2012.

SUMMARY OF FINDINGS AS RELATED TO NOMINATED AGENDA ITEMS

Agenda Item	Findings
3	This document provides a preliminary version of a research and monitoring plan to accompany proposal to CCAMLR for the establishment of a system of MPAs in the Ross Sea region in 2012.

1 BACKGROUND

This document provides a preliminary version of a draft research and monitoring plan to accompany a proposal to CCAMLR for the establishment of a system of MPAs in the Ross Sea region in 2012.

1.1 Objectives of CCAMLR MPAs

CCAMLR Conservation Measure 91-04(2011): "General framework for the establishment of CCAMLR Marine Protected Areas", provides guidance on the principal aims of research and monitoring activities associated with CCAMLR MPAs, as follows:

(i) 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) protection of key ecosystem processes, habitats and species, including populations and life-history stages;

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

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

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

2.1 Ross Sea region MPA proposal

The draft Conservation Measure which with this research and monitoring plan is associated includes eight protection objectives as identified in Sharp & Watters (2011) and following a synthesis of the work presented in two papers on bioregionalization and spatial mapping of ecosystem processes in the Ross Sea region (Sharp et al. 2010; Ainley et al. 2010). High level objectives 1 and 2 on protection of representative pelagic and benthic bioregions are here combined into Protection Objective 1. An additional Protection Objective (Protection Objective 8) has been added regarding protected areas as "reference areas to provide opportunities for better understanding of the Antarctic marine ecosystem without human interference". The research and monitoring plan is presented in relation to these eight Protection Objectives.

Within each of these eight objectives there are identified *specific objectives* each of which is associated with an explicit spatial distribution or 'target area' defining the geographic extent of the feature (e.g. key ecosystem processes, habitats, species, populations and/or life-history stages) that has been identified as a priority for protection. The Ross Sea region MPA research and monitoring plan is structured consistent with these specific objectives.

2.2 Organisation of the Research and Monitoring Plan with respect to specific objectives

For each specific objective and corresponding target area the following generic research questions are addressed under the research and monitoring plan, to deliver research and monitoring to ensure

that the specific objective is being met. Particular research activities proposed for each specific objective will be organized below consistent with the following three generic aims:

i) Research and monitoring to ensure that the boundaries of the priority feature as defined in the target area remain accurate, and/or to determine to what extent those boundaries may be moving.

ii) Research and monitoring to further understand the ecosystem role and importance of the priority feature, and/or to understand the environmental or biological processes that affect it, including potential threats from fishing.

iii) Research and monitoring to demonstrate the extent to which achievement of the specific objective is being met, i.e. to demonstrate whether identified or plausible threats are being effectively mitigated by the MPA.

For each specific objective and each of these three generic aims we summarize briefly the main approach to how this research could be carried out. More detailed information on proposed research approaches, with scientific references to research already ongoing or comparable research carried out elsewhere, will be appended in Annex 1.

2.3 Capacity to deliver

In this document we identify research and monitoring activities that are likely to have at least a reasonable chance of securing necessary logistic and funding support. It is not the purpose of this plan to suggest who could or should carry out any research presented. Given the vagaries of research funding, no one CCAMLR Member can guarantee that the research and monitoring identified here will occur. However commitment by all CCAMLR Members to pursue common research objectives under the auspices of a Ross Sea region MPA research and monitoring plan will encourage research collaboration and shared long-term planning between the research programmes of different Member countries with an interest in the Ross Sea region, and may help individual programmes to secure resources to contribute to those common objectives.

2.4 Timescales of research

CM 91-04 paragraph 8 states that conservation measures designating CCAMLR MPAs shall be reviewed every 10 years or within an alternate timeframe agreed by the Commission. Research carried out and information collated under the MPA research and monitoring plan is envisaged to form the main part (though not necessarily exclusively) of new scientific information to be considered in the periodic review. The Scientific Committee (SC XXX paragraph 5.22) advises that 'scientific review needs to consider the timescales of the relevant ecological processes, and may vary from a few years to several decades.' In this document where we refer to "short term", this refers to 1-5 years hence; "medium term" refers to 5-20 years hence; "long term" refers to decades to centuries hence.

2.5 Study area

In 2011 CCAMLR agreed nine planning domains within which MPA designation should proceed [SC-CAMLR XXX, paragraph 5.20]. The Ross Sea region as defined in this document corresponds to CCAMLR planning domain 8, defined as the region south of 60°S and between 150°E and 150°W (Figure 1). This area includes statistical Subarea 88.1, and SSRUs 88.2A and 88.2B.

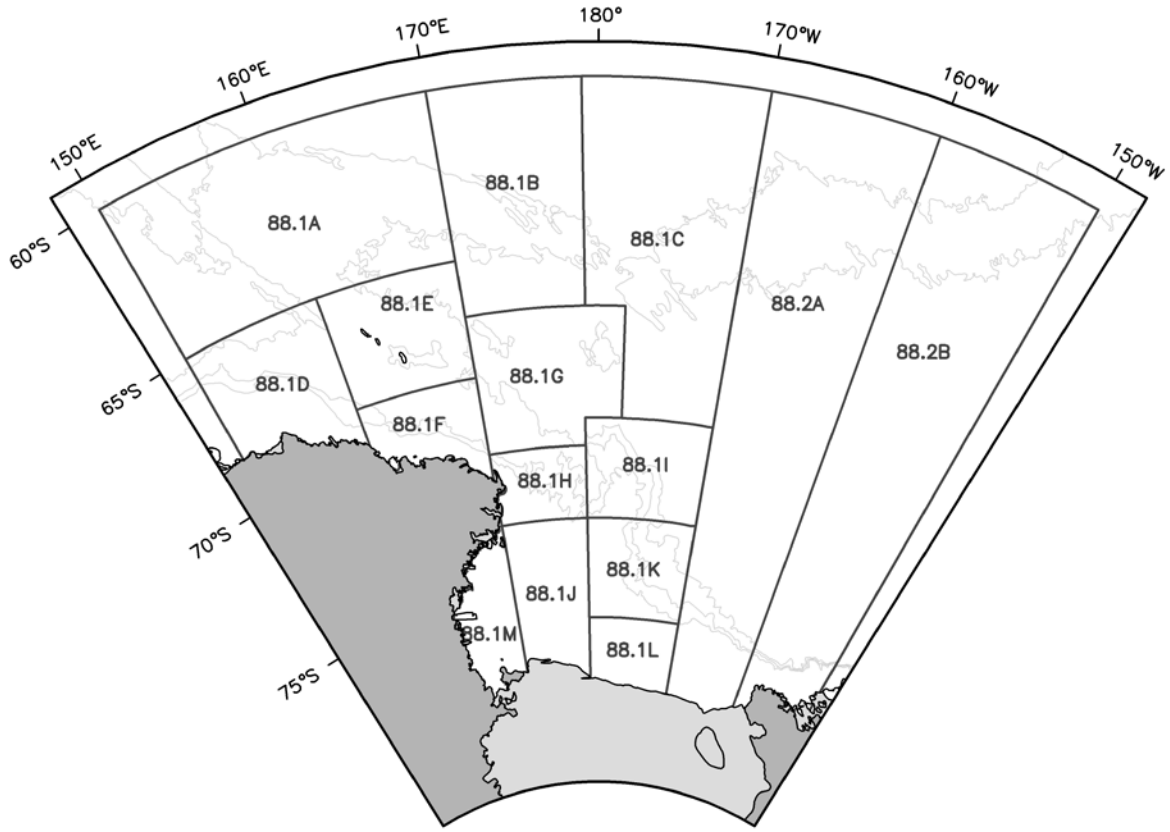

Figure 1: Ross Sea region defined for the purposes of this work, showing Subarea 88.1, SSRU 88.2A, and SSRU 88.2B. Depth contours shown at 1000, 2000, 3000 and 4000 m.

3 RESEARCH AND MONITORING PLAN

Protection Objective 1: To protect a representative portion of benthic and pelagic marine habitats
CCAMLR has committed to protecting a representative portion of benthic and pelagic marine environments, to ensure that all habitats are included in a system of MPAs even in data-poor areas where location-specific observations may be lacking.

Specific Objective 1.1: Protect a representative portion of benthic marine environments
The Ross Sea region includes 18 benthic bioregions identified in paper WG-EMM-10/30.

Research and monitoring activities (see Annex 1[1.1] for details):

(i) a) Remote sensing, model-based and in situ monitoring of large-scale oceanographic and environmental properties upon which the bioregionalisation is based.
b) Ongoing analysis of spatial distribution of benthic organisms, using, for example, bycatch in the long line fishery and research voyages with underwater video where available.

(ii) a) Improved univariate and multivariate approaches to fitting biology and environment (e.g. BRT, GDM), including assessment of geographic stationarity, and environmental overlap of training and predictive data domains.
b) Post-fitting validation of bioregions at different spatial scales.

(iii) Not relevant: bioregions are defined to achieve representative protection in the absence of location-specific observations of priority features that may be threatened by fishing.

Specific Objective 1.2: Protect a representative portion of pelagic marine environments
The Ross Sea region includes 17 pelagic bioregions identified in paper WG-EMM-10/30.

Research and monitoring activities (see Annex 1[1.2] for details):

(i) a) Remote sensing, model-based and in situ monitoring of large-scale oceanographic and environmental properties upon which the bioregionalisation is based.
b) Ongoing analysis of spatial distribution of key pelagic organisms (*inter alia* phytoplankton, meso and macrozooplankton, krill, silverfish, myctophids), using, for example, remote sensing of ocean colour, multifrequency acoustics and continuous plankton recorder tows.

(ii) a) Improved univariate and multivariate approaches to fitting biology and environment (e.g. BRT, GDM), including assessment of geographic stationarity, and environmental overlap of training and predictive data domains.
b) Validate bioregions at different spatial scales.

(iii) Not relevant: bioregions are defined to achieve representative protection in the absence of location-specific observations of priority features that may be threatened by fishing.

Protection Objective 2: To protect large-scale ecosystem processes responsible for the productivity and functional integrity of the ecosystem
In the Southern Ocean there are spatially predictable features – often in association with fronts, eddies and gyres, upwelling conditions facilitating vertical nutrient transfer, or ice dynamics – where productivity is high and energy assimilation to higher trophic levels is rapid, supporting top predator populations. Protection in these locations serves to safeguard functional ecosystem integrity and minimise the risk of unanticipated ecosystem effects of fishing including trophic cascades. This is of particular importance for the highly productive and intact Ross Sea shelf ecosystem, where the potential for top-down trophic ecosystem control is higher, and where ongoing long-term research and monitoring programmes enable scientists to study ecosystem dynamics unaffected by human influence.

Specific Objective 2.1 Protect a proportion of the Ross Sea shelf front
The Ross Sea Shelf Front in combination with dynamic summer ice cover forms a zone of elevated productivity that is actively targeted by pelagic top predators, including seabirds, pinnipeds and cetaceans.

Research and monitoring activities:

(i) a) Map the position of the Ross Sea shelf front seasonally and interannually using satellite remote sensing of ocean properties, *inter alia*, sea surface temperature, sea surface height (altimetry), ocean colour. See Annex 1[2.1] for details.
b) Undertake hydrodynamic modeling, including validation (e.g. drifters, ADCP). See Annex 1[2.1] for details.

(ii) a) Monitor utilization of the Ross Sea shelf front by top predators (e.g. using satellite tagging). See Annex 1[4] for details.
b) Sample the biology and ecology of the Ross Sea shelf front with focus on species of high ecological importance as indicated by functional ecological studies and trophic modeling.
c) Generate spatially- and seasonally-disaggregated ecosystem models. See Annex 1[2.1-2.5] for details.

(iii) a) Compare predator utilization of areas inside and outside of the MPA.
b) Undertake targeted surveys to compare species composition inside and outside the MPA.

Specific Objective 2.2 Protect a proportion of the Polar Front

The Polar Front is an oceanic transition zone marked by enhanced productivity and targeted seabird foraging.

Research and monitoring activities:

(i) a) Map the position of the Polar Front seasonally and interannually using satellite remote sensing of ocean properties including, *inter alia*, sea surface temperature, sea surface height (altimetry), ocean colour.
   b) Undertake numerical hydrodynamic modeling, including validation (e.g. drifters, ADCP). See Annex 1[2.2] for details.

(ii) Monitor utilization of the Polar Front by seabirds using satellite tagging; See below 2.1-2.5 and Annex 1[2.1-2.5] for details.

(iii) [In the absence of an identifiable threat to seabirds utilizing the Polar Front, threats to this area are likely to be effectively mitigated by representative levels of protection]

Specific Objective 2.3 Fully protect the Balleny Islands and surrounding waters

The area around the Balleny Islands is characterised by complex oceanographic conditions arising from intersecting ocean currents, a recurrent deep-water polynya and also transient polynyas. These conditions boost local marine productivity and provide access to pelagic prey species (including Antarctic krill and possibly Antarctic silverfish) important for top predators. The islands support populations of at least four species of seal and ten species of seabirds, many of which are spatially constrained during the breeding season to forage only in the vicinity of breeding colonies on the islands. Of particular scientific interest are breeding colonies of chinstrap penguins that constitute an extreme distributional anomaly, the next nearest colony being more than 4000 km distant. The area is also important for several whale species, in particular humpback whales which appear to annually migrate almost exclusively to this area within the Ross Sea region.

Research and monitoring activities:

(i) Because the islands themselves are a fixed feature, research to better characterize boundaries is limited to defining the spatial extent of their influence on surrounding waters, i.e.:
   a) Map the influence of the Balleny Islands on polynya formation and local hydrographic conditions using remote sensing;
   b) Map the foraging extent of land-based top predators using satellite tagging;
   c) Map the spatial affinity of mobile top predators (e.g. humpback whales and seabirds) to the islands using satellite tagging

(ii) Undertake periodic research voyages to the Balleny Islands and surrounding area to
   a) Monitor abundance and distribution of key pelagic prey species (krill, myctophids, silverfish?) via acoustic survey;
   b) Survey top predators via visual census;
   c) Track migratory top predators via satellite tagging or photo ID matching (whales);
   d) Stable isotope and fatty acid analyses to characterize foodweb structure;
   e) Aerial and shore-based inventory of predator colonies (Weddell seals, Adelie and chinstrap penguins) See Annex 1[2.3] for details.

(iii) Full protection of this area will ensure that risks are highly mitigated. Undertake ecosystem modeling to investigate potential indirect impacts of harvest activities on this area.

Specific Objective 2.4 Protect a high portion of the Ross Sea polynya marginal ice zone

As the Ross Sea Polynya forms in early summer, conditions associated with rapid ice edge retreat in the marginal ice zone favour high diatom productivity and rapid trophic assimilation supporting top predators, including whales, seals, penguins, and flying seabirds.

Research and monitoring activities:

(i) Map the position of the Ross Sea polynya marginal ice zone (MIZ) seasonally and interannually using satellite remote sensing of sea ice, especially, microwave ice modeling. See Annex 1[2.4] for details.

(ii) a) Monitor relevant dynamic properties of the MIZ (e.g. primary production, ice concentration, ice albedo) via remote sensing.

b) Monitor utilization of the MIZ by seabirds and top predators using satellite tagging and visual census from research vessels. See below 2.1-2.5 and Annex 1[2.1-2.5] for details.

(iii) Very high protection (90+%) of this area will ensure that risks are highly mitigated. Undertake ecosystem modeling to investigate potential indirect impacts of harvest activities on this area.

Specific Objective 2.5 Protect a high proportion of the multi-year ice zone in the eastern Ross Sea

Stable multi-year ice floes in the eastern Ross Sea provide essential habitats for crabeater seals and Ross seals (summer breeding and moulting), and for Emperor and Adelie penguins (late summer moulting).

Research and monitoring activities:

(i) Map the position of multi-year ice zone in the eastern Ross Sea seasonally and interannually using satellite remote sensing of sea ice, especially, microwave observations. See Annex 1[2.5] for details.

(ii) Monitor to what extent do the stable multi-year ice floes in the eastern Ross Sea provide essential habitats for crabeater seals and Ross seals (summer breeding and moulting), and for Emperor and Adelie penguins (late summer moulting)? See below 2.1-2.5 and Annex 1[4.1, 4.2, 4.1-4.4(seals)] for details.

(iii) Very high protection (90+%) of this area will ensure that risks are highly mitigated. Undertake ecosystem modeling to investigate potential indirect impacts of harvest activities on this area.

Protection Objective 3: To protect core distributions of trophically dominant pelagic prey species

Food web models indicate that trophic energy transfer to higher trophic levels in the pelagic zone occurs primarily via three abundant pelagic prey species. Protecting these species, especially in the productive and functionally intact Ross Sea shelf ecosystem where top-down ecosystem control is more likely, protects food web function and minimises the risk of unforeseen ecosystem effects of fishing, including trophic cascades or predation release.

Specific Objective 3.1: Protect a proportion of the core distribution of Antarctic krill

In the Ross Sea region Antarctic krill in association with the continental slope and in close proximity to the northern Victoria Land coast support large populations of top predators, including greater than 50% of the Ross Sea population of Adelie penguins at Cape Adare. Further north Antarctic krill are likely the single most important species supporting trophic ecosystem function, including in the vicinity of the Balleny Islands (objective 2.3 above).

Research and monitoring activities:

(i) Map the distribution of Antarctic krill in the Ross Sea region using multifrequency acoustic surveys from research vessels, coupled with a relatively small amount of mark identification sampling (midwater trawls), validation sampling (e.g. oblique trawls) and target strength analyses. See Annex 1[3.1] for details.

(ii) Much research on the biology and ecology of Antarctic krill is underway and relevant. See below 3.1-3.3 and Table[3.1, 3.1-3.3] for details.

(iii) [In the absence of a current fishery for krill risks are potential not current]; Undertake ecosystem modeling to investigate potential indirect impacts of harvest activities on this area.

Specific Objective 3.2: Protect a high proportion of the core distribution of Antarctic silverfish
Antarctic silverfish are the single species most responsible for trophic energy transfer to higher trophic levels in the highly productive Ross Sea shelf ecosystem, constituting 40% of the total diet of top predators here. Trophic models indicate that Antarctic silverfish have a very high 'ecological importance' in the Ross Sea shelf ecosystem, meaning that even minor changes in the abundance of Antarctic silverfish can be expected to propagate through the food web to affect other species.

Research and monitoring activities:

(i) Map the distribution of Antarctic silverfish in the Ross Sea region using multifrequency acoustic surveys from research vessels, coupled with a relatively small amount of mark identification sampling (midwater trawls), validation sampling (e.g. oblique trawls, benthic trawls) and target strength analyses of different stages (larval/post larval, juvenile, adult). See Annex 1[3.2] for details.
(ii) Much research on the biology and ecology of Antarctic silverfish is underway and relevant. See below 3.1-3.3 and Annex 1[3.2, 3.1-3.3] for details.
(iii) Very high protection (90+%) of this area will ensure that risks are highly mitigated. Undertake ecosystem modeling to investigate potential indirect impacts of harvest activities on this area.

Specific Objective 3.3: Protect a high proportion of the core distribution of crystal krill
Crystal krill are an important prey species for penguins and crabeater seals, and also for Antarctic silverfish which in turn support the full suite of abundant top predator populations in the Ross Sea shelf ecosystem. Trophic models indicate that crystal krill have a high 'ecological importance' in the Ross Sea shelf ecosystem.

Research and monitoring activities:

(i) Map the distribution of crystal krill in the Ross Sea region using multifrequency acoustic surveys from research vessels, coupled with a relatively small amount of mark identification sampling (midwater trawls), validation sampling (e.g. oblique trawls) and target strength analyses. See Annex 1[3.3] for details.
(ii) Much research on the biology and ecology of crystal krill is underway and relevant. See below 3.1-3.3 and Annex 1[3.3, 3.1-3.3] for details.
(iii) Very high protection (90+%) of this area will ensure that risks are highly mitigated. Undertake ecosystem modeling to investigate potential indirect impacts of harvest activities on this area.

3.1-3.3 Higher-level research relevant to Protection Objective 3:

a) Investigate functional linkages between these three trophically dominant pelagic prey species and other low- to mid-trophic level species, especially: (1) mesozooplankton (especially copepods, amphipods, pteropods, salps); (2) cephalopods (including squids and octopods); and (3) small fishes (especially small notothenioides on the Ross Sea shelf; myctophids to the north of the Ross Sea slope). See Annex 1[3.1-3.3A, also 1.1,1.2(cephalopods)] for details.

b) Investigate the biology and ecology (e.g. distribution, abundance, energetics, feeding and role as prey) of common, middle trophic level species such as meso- and macro-zooplankton, small demersal fishes, cephalopods as affected by oceanographic and climatic drivers, especially changing ice dynamics. See Annex 1[3.1-3.3A; also 1.1,1.2(phytoplankton, cephalopods)] for details.

c) Undertake ecological modeling focused on estimating mass balance models (perhaps spatially and seasonally disaggregated) and thence ecological importance (e.g. Pinkerton & Grieve 2012). See Annex 1[3.1-3.3A] for details.

d) Investigate the risk of unforeseen ecosystem effects of fishing (including trophic cascades, predation release and biologically-mediated regime shift) via ecosystem modeling. Develop indicators as early-warning signals of ecosystem effects of fishing. See Annex 1[3.1-3.3B] for details.

Protection Objective 4: To protect core foraging areas for land-based top predators or those that may experience direct competition from fisheries

Top predators on prey species that are also targeted by fisheries may be subject to negative ecosystem effects arising from direct competition with fishing. Predators are particularly vulnerable to localized prey depletion at times of the year when their foraging is spatially constrained, e.g. by the need to return to land-based colonies, or by specialized foraging behaviour targeting particular habitats or foraging niches. Assigning marine protection in these areas greatly reduces the risk of adverse ecosystem effects by ensuring that the rational use of marine resources by fisheries occurs elsewhere, where risks are lower. Protecting areas in close proximity to predator colonies also ensures the ongoing integrity of long-term scientific research and monitoring efforts studying predator colony population dynamics as a potential indicator of environmental change.

Specific Objective 4.1: Protect a high proportion of the summer breeding season foraging area of Adelie penguins.

The Ross Sea region supports more than a million breeding pairs (38% of the world population) of Adelie penguins at colonies on the Victoria Coast. Summer foraging areas have been mapped via satellite tagging. Future fisheries for pelagic resources (e.g. krill) within the foraging range of these colonies could threaten these populations and disrupt ongoing scientific research in which penguins serve as sensitive indicators of ecosystem function and long-term environmental change. Protecting the western Ross Sea shelf and the continental slope near Cape Adare will protect these penguin populations from localized prey depletion affecting their breeding success and will safeguard the integrity of scientific monitoring.

Research and monitoring activities:

(i) Map the foraging areas of Adelie penguins in the Ross Sea region during the summer breeding season via electronic tagging. See Annex 1[4.1] for details.

(ii) Much research on the biology and ecology of Adelie penguins in the Ross Sea is underway and relevant. See Annex 1[4.1] for details.
   a) Monitor changes in breeding colony size via aerial and in situ censusing.
   b) Monitor seasonal and annual changes in diet via stomach contents and stable isotope analysis.
   c) Monitor breeding success and chick survival via colony surveys and mark-recapture experiments.
   d) Examine correlations with ice dynamics arising from climate change or stochastic iceberg-calving events.
   e) Monitor the distribution/feeding/foraging of Adelie penguins outside their summer spatially constrained foraging areas.

(iii) Very high protection (90+%) of this area will ensure that risks are highly mitigated. Undertake trophic modeling to investigate potential indirect impacts of harvest activities on this area.

Specific Objective 4.2: Protect a high proportion of the summer breeding season foraging area of Emperor penguins.

The Ross Sea region supports nearly 80,000 breeding pairs (26% of the world population) of Emperor penguins at colonies on the Victoria Coast and at Cape Colbeck in the western Ross Sea. Preferred summer foraging areas have been mapped via satellite tagging. As with Adelie penguins, protecting

these areas will eliminate the threat of direct trophic competition from potential future fisheries, and ensure the consistency of ongoing scientific monitoring.

Research and monitoring activities:

(i) Map the foraging areas of emperor penguins in the Ross Sea region during the summer breeding season via electronic tagging. See Annex 1[4.2] for details.

(ii) Much research on the biology and ecology of emperor penguins in the Ross Sea is underway and relevant. See Annex 1[4.2] for details.
   a) Monitor changes in breeding colony size via aerial and in situ censusing.
   b) Monitor seasonal and annual changes in diet via stomach contents and stable isotope analysis.
   c) Monitor breeding success and chick survival via colony surveys and mark-recapture experiments.
   d) Examine correlations with ice dynamics arising from climate change or stochastic iceberg-calving events.
   e) Monitor the distribution/feeding/foraging of emperor penguins outside their summer spatially constrained foraging areas.

(iii) Very high protection (90+%) of this area will ensure that risks are highly mitigated. Undertake trophic modeling to investigate potential indirect impacts of harvest activities on this area.

Specific Objective 4.3: Protect a high proportion of the summer breeding season foraging area of Weddell seals

An estimated 20,000-30,000 breeding Weddell seals inhabit the Ross Sea shelf and slope during summer at breeding colonies in the western Ross Sea and one minor colony at Cape Colbeck in the eastern Ross Sea. Best available evidence suggests that Antarctic toothfish are a minor but potentially important component of the Weddell seal diet, and Weddell seals are the main natural predator on Antarctic toothfish in the Ross Sea. Foraging ranges relative to colony locations and preferred summer foraging habitats have been mapped via satellite tagging. Protecting these areas eliminates the risk of localized prey depletion by the existing toothfish fishery affecting Weddell seal foraging success during the breeding season.

Research and monitoring activities:

(i) Map the foraging areas of Weddell seals in the Ross Sea region during the spatially constrained periods, especially focusing on foraging by lactating Weddell seals, females immediately after pup weaning and before moulting, and post-weaning pups before dispersal (e.g. electronic tagging). See Annex 1[4.3] for details.

(ii) Much research on the biology and ecology of Weddell seals in the Ross Sea is underway and relevant. See Annex 1[4.3] for details.
   a) Map and monitor for changes in the location and/or sizes of Weddell seal breeding colonies (via in situ, aerial or satellite censusing).
   b) Obtain quantitative estimates of consumption of toothfish by Weddell seals in Ross Sea close to breeding colonies (using e.g. biochemical markers of diet, DNA analysis of scats, direct observations of foraging activity).
   c) Compare prey consumption in lactating Weddell seals, females after pup weaning and before moulting, and pups between weaning and disperion. See Annex 1[4.3(ii)] for details.
   d) Monitor toothfish abundance at locations along the Victoria Coast in different proximities to Weddell seal colonies.

(iii) Very high protection (90+%) of these areas will ensure that risks are highly mitigated. Spatial modeling of the toothfish stock, pre-recruit survey, and other surveys of toothfish inside the MPA are relevant. See Annex 1[5] for details.

Specific Objective 4.4: Protect a high proportion of the preferred summer foraging area of Type C killer whales

Type C killer whales are a distinct species of specialist fish-feeder orca known to prey on Antarctic toothfish during part of the summer season. Type C killer whales are thought to comprise the majority of all killer whales in the Ross Sea shelf, where they appear to be highly resident during the summer, foraging preferentially around and under fast ice in the marginal ice zone of the Ross Sea polynya or coastal polynyas. Distributions outside of the summer season are unknown. Killer whales worldwide are known to exhibit highly specialized and selective predation behaviour. Where they are abundant they may also exert strong top-down ecosystem control on their chosen prey, such that intelligent prey-switching behaviour by killer whales may be responsible for destabilizing ecosystem effects including trophic cascades and population collapses of their newly preferred prey. In Southern Ocean toothfish fisheries there is a serious additional risk that learned depredation behaviour by killer whales can reduce fisheries profitability and seriously undermine the science upon which effective fisheries management relies. In the Ross Sea region killer whales have not yet learned to follow and target fishing vessels to steal toothfish; displacing fishing effort away from preferred killer whale foraging areas and into deeper water where killer whales do not occur can effectively eliminate this risk.

Research and monitoring activities:

(i) Map the foraging area of type C killer whales in the Ross Sea region during the summer breeding season. Existing information may be improved using, *inter alia*, at sea censusing and electronic (positional) tagging. Specialist observers are likely to be needed to distinguish between different types of killer whales. See Annex 1[4.4] for details.

(ii) Much research on the biology and ecology of Weddell seals in the Ross Sea is underway and relevant. See Annex 1[4.3] for details.
   a) Improve knowledge of the basic spatial, seasonal and demographic characteristics of type C killer whales in the Ross Sea region.
   b) Evaluate the importance of Antarctic toothfish as prey via stable isotope analyses and dedicated research to observe foraging behaviors;
   c) Disaggregate existing ecosystem models to distinguish between three distinct killer whale variants.

(iii) Very high protection (90+%) of this area will ensure that the risk of localized depletion affecting toothfish availability for killer whales is highly mitigated.
   a) Spatial modeling of the toothfish stock, pre-recruit survey, and other surveys of toothfish inside the MPA are relevant. See Annex 1[5] for details.
   b) Obtain systematic feedback from scientific observers, fishers, and scientists aboard fishing vessels in the Ross Sea region including outside the MPA to determine to what extent the risk of learned depredation behavior by killer whales has been avoided.

Protection Objective 5: To protect areas of known importance in the life cycle of Antarctic toothfish

Antarctic toothfish are an important component of the Ross Sea regional ecosystem and the target of a valuable fishery. Available evidence indicates that toothfish sequentially inhabit a series of habitats in the Ross Sea region and subarea 88.2 as part of a large-scale life-cycle migration and periodic spawning migrations. Protecting these habitats in part or in full is a potentially valuable means of controlling the spatial distribution of toothfish removals, for example to minimise the risk of ecosystem effects of fishing or genetic selectivity effects, or to improve the science upon which management of the fishery is based.

Specific Objective 5.1: Fully protect subadult toothfish settlement areas on the Ross Sea shelf

Sub-adult or 'pre-recruit' toothfish are thought to enter the Ross Sea from Subarea 88.2 and settle preferentially in a series of deeper-water troughs in the southern Ross Sea shelf and Terra Nova Bay.

Full protection of these areas serves to eliminate the risk that top predators that prey on toothfish will encounter direct competition from fishing, or that localized changes in toothfish abundance in this area will exert indirect food web effects on the Ross Sea shelf ecosystem. Protection in this area also enables scientists to monitor toothfish recruitment into the Ross Sea stock unconfounded by localized effects of the commercial fishery operating in the same area, with benefits for the scientific assessment of current stock status.

Research and monitoring required (see Annex 1[5.1] for details):

(i) a) Map the distribution of pre-recruits (sub-adults) of Antarctic toothfish in the Ross Sea region using the annual pre-recruit survey.

ii) a) Understand factors affecting toothfish spatial distributions using spatial modeling tools like BRT, prey/predation distributions, with focus on of pre-recruits (sub-adults).

b) Monitor changes in biomass of toothfish inside protected area, for example, using pre-recruit survey and/or periodic research fishing inside MPA.

c) Monitor pre-recruit toothfish diet via stomach sampling, stable isotopes, fatty acid analysis

(iv) Full protection of this area will ensure that the risk of localized depletion affecting pre-recruit settlement, or confounding the ability of the pre-recruit survey to accurately estimate trends in recruitment abundance, are highly mitigated

Specific Objective 5.2: Fully protect dispersal corridors for maturing toothfish

The pre-recruit settlement areas identified in objective 5.1 are adjacent to deeper-water corridors that bisect the Ross Sea shelf and are likely used by maturing toothfish dispersing to preferred adult feeding habitats on the Ross Sea slope. Fully protecting these areas ensures that the commercial fishery catches primarily mature toothfish in locations where ecosystem risks are lowest.

Research and monitoring required (See Annex 1[5.2] for details):

(i) a) Map the movements and spatial distribution and abundance of Antarctic toothfish in the Ross Sea region using, inter alia, tag-recapture analyses, electronic tagging, spatial population model (Dunn & Rasmussen 2009; Dunn et al. 2009), stable isotope analyses of toothfish and prey.

b) Seek additional survey strata in the pre-recruit survey to better understand fish movement patterns from pre-recruit settlement zones to the Ross Sea slope

(ii) Improve knowledge of spatial patterns of predation on toothfish in the Ross Sea region, using, e.g. spatial toothfish-predator ecological modeling to estimate the ecological importance of movement in the life cycle of toothfish.

(iii) a) Full protection of this area will ensure that the risk of localized depletion affecting toothfish migration is highly mitigated

Specific Objective 5.3: Protect a proportion of preferred adult toothfish feeding areas on the Ross Sea slope

The Ross Sea slope is the preferred adult feeding ground for the Ross Sea region Antarctic toothfish stock. Protecting a proportion of this area allows for the design of scientific research comparing fished vs. unfished areas to monitor fishery effects, and may help to maintain the full range of size classes of larger fish in these areas, to counter potential genetic selectivity effects of the fishery affecting toothfish growth and maturity over time.

Research required (see Annex 1[5.3] for details):

(i) a) Map the spatial distribution and abundance of Antarctic toothfish in the Ross Sea region using, inter alia, tag-recapture analyses, electronic tagging, Spatial Population Model (Dunn & Rasmussen 2009; Dunn et al. 2009), stable isotope analyses of toothfish and

prey, and targeted surveys with high tagging rates at the outer edges of the known distribution, to better inform estimates of movement

(ii) a) Improve knowledge of the diet of Antarctic toothfish in the Ross Sea slope region, and the abundance, spatial distribution and ecology of key prey species, *inter alia*, *Macrourus* sp., icefish, deep sea cod, eel cod in the whole Ross Sea region.

(iii) a) Research fishing inside and outside MPA in Ross Sea slope region to compare toothfish characteristics in fished and unfished (protected) area. Monitor for relative changes in factors such as length-at-age, growth, maturity over time.

b) Research fishing inside and outside MPA in Ross Sea slope region to compare toothfish diet and prey species in fished and unfished (protected) area. Monitor for differences in toothfish feeding ecology and abundance/ecology of prey.

Specific Objective 5.4: Protect a proportion of toothfish spawning areas west of the Ross Gyre divergence.

Antarctic toothfish are known to spawn on seamounts and underwater features of the Pacific-Antarctic Ridge in the north of the Ross Sea region. In the northwest, ocean currents associated with the Ross Gyre are thought to supply fertilized eggs and larvae to the Balleny Islands and westward to the Antarctic continent west of the Ross Sea. Protecting toothfish in a proportion of spawning habitats supplying these areas will safeguard the viability of this spawning stock and may help to maintain the full range of size classes of larger fish in these areas, to counter potential genetic selectivity effects of the fishery over time. Protecting a portion of this area also protects other demersal fish and benthic invertebrate communities associated with the Pacific-Antarctic Ridge, a geographic overlap zone that includes endemic species.

Research required:

(i) Map the spawning areas of Antarctic toothfish in the Ross Sea region west of the Ross Gyre divergence, using spatial histology analysis of toothfish caught by the fishery. See Annex 1[5.4] for details.

b) identify likely spawning areas via egg and larval dispersal simulations matched to observed length frequencies;

c) identify spawning and larval settlement areas via otolith microchemistry

(ii) a) Improved knowledge of the spawning ecology and early life history of Antarctic toothfish in the Ross Sea region, using, for example a winter research fishing survey on spawning toothfish would be useful, ichthyological research survey in the area around the Balleny Islands. See Annex 1[2.3] for details.

b) Improved hydrodynamic information on the Ross Sea water structure and circulation, including likely changes in the region as a result of climate change, e.g. based on fine- to moderate-scale regional oceanographic model of the Ross Sea region nested in a global climate model.

(iii) The protection provided by the MPA in terms of helping to fulfill CCAMLR principle II(a) (i.e. maintaining reproductive capability of toothfish in the Ross Sea region) should be considered within the larger management of the Ross Sea toothfish fishery, including the fishery tagging programme, stock assessment, annual fishery characterization, pre-recruit survey of the Ross Sea and other future surveys, and other CCAMLR conservation measures. See Annex 1[5.4] for details. Longline survey comparisons of fished vs. unfished spawning habitats may reveal differences in length frequencies over time, perhaps indicative of spawning site fidelity.

Specific Objective 5.5: Protect a proportion of toothfish spawning areas east of the Ross Gyre divergence.

Eggs and larvae originating from toothfish spawning east of the Ross Gyre divergence are thought to be carried eastward and deposited at the Antarctic continent in Subarea 88.2, after which at least a

portion of juvenile toothfish move westward and ultimately recruit to the Ross Sea stock. Protecting toothfish in a proportion of these spawning habitats will safeguard the viability of the spawning stock and may help to maintain the full range of size classes of larger fish in these areas, to counter potential genetic selectivity effects of the fishery over time. Protecting a portion of this area also protects other demersal fish and benthic invertebrate communities associated with the Pacific-Antarctic Ridge, a geographic overlap zone that includes endemic species.

Research required: [[as with 5.4, above]]

Protection Objective 6: To protect coastal areas of high ecosystem importance

Where localized areas of high ecosystem importance can be located with great precision, these locations may warrant high protection to prevent disruptive ecosystem effects that could be expected to affect the ecosystem more widely. In the Ross Sea these locations are often associated with polynya formation or particular ice-associated niche habitats.

Specific Objective 6.1: Protect the persistent winter polynya in the southern Ross Sea shelf

The persistent (including winter) polynya in the southern Ross Sea shelf is the site the early summer phytoplankton bloom responsible for extremely high primary productivity. The subsequent fate of carbon assimilation associated with this productivity has important implications for understanding both global climate change and trophic ecosystem function. It is also possible that top predators (e.g. Type C killer whales, see objective 4.4) over-winter in the polynya, where they would be particularly vulnerable to localized prey depletion from fisheries, due to extreme spatial confinement. Protecting the polynya will eliminate this risk.

Research and monitoring required:

(i) Map the position and characteristics (e.g. size, duration, associated primary productivity) of the persistent winter polynya in the Ross Sea region, seasonally and interannually, using satellite remote sensing. Analyse spatial changes in polynya characteristics over time and compare with changes in polynyas in other parts of the Ross Sea region and Southern Ocean. See Annex 1[2.4, 2.5; 6.1] for details.

(ii) Better understanding of the ecological role of the persistent winter polynya over the southern Ross Sea shelf, including whether it is used by overwintering populations of type- C killer whales and Weddell seals, using electronic tagging of predators. Process studies to understand links between physical processes and primary production in polynyas; throughput efficiency and export of the microbial food web in polynyas; middle trophic level repackaging of organic material in polynyas. See Annex 1[6.1-6.6, 4] for details.

(iii) Full protection of this area will ensure that risks are highly mitigated. Undertake ecosystem modeling and lateral transport via hydrodynamic modeling to investigate potential indirect impacts of harvest activities to this area.

Specific Objective 6.2: Protect the locations of recurrent coastal polynyas

In the Ross Sea, strong winds off the Antarctic land mass lead to early summer polynya formation at predictable locations along the coast, in turn affecting the availability of light, nutrients and trace elements fueling primary productivity and trophic assimilation for higher trophic level prey species, and access through the ice for air-breathing top predators.

Research and monitoring required:

(i) Map the position and characteristics (e.g. size, duration, associated primary productivity) of recurrent coastal polynyas in the Ross Sea region, seasonally and interannually, using satellite remote sensing. Analyse changes in polynya characteristics over time and

compare with changes in polynyas in other parts of the Ross Sea region and Southern Ocean. See Annex 1[2.4, 2.5; 6.2] for details.

(ii) Improved understanding of the ecological role of recurrent coastal polynyas in the Ross Sea ecosystem, particularly in relation to, primary production (remote sensing) and as habitat for air breathing predators (electronic tagging). Process studies to understand links between physical processes and primary production in polynyas; throughput efficiency and export of the microbial food web in polynyas; middle trophic level repackaging of organic material in polynyas. See Annex 1[6.1-6.6, 4] for details.

(iii) Full protection of these areas will ensure that risks are highly mitigated. Undertake ecosystem modeling to investigate potential indirect impacts of harvest activities to this area.

Specific Objective 6.3: Protect Terra Nova Bay

Terra Nova Bay includes a consistent and highly productive polynya and provides an important nursery area for post-larvae and juvenile silverfish. Protection is warranted to protect these features and to ensure the ongoing integrity of research and monitoring activities of high global importance to understand climate change and marine ecosystem function, for which long-term time-series already exist in this location, unconfounded by other human impacts.

Research and monitoring required:

(i) Map changes to Terra Nova Bay polyna, seasonally and interannually (including size and duration of polynya, characteristics of primary production) using satellite remote sensing. Analyse changes in characteristics over time and compare with changes in other parts of the Ross Sea region and Southern Ocean. See Annex 1[2.4, 2.5; 6.3] for details.

(ii) Improve knowledge of the ecological importance of Terra Nova Bay in the Ross Sea ecosystem, especially with regard to spawning and early life stages of Antarctic silverfish. Link characteristics of the Terra Nova Bay region with research voyages and/or research from Italian and Korean research bases (especially on ichthyology and zooplankton) in the Terra Nova Bay region. See Annex 1[6.3] for details.

(iii) Full protection of this area will ensure that risks from the fishery are highly mitigated. Undertake ecosystem modeling to investigate potential indirect impacts of harvest activities to this area.

Specific Objective 6.4: Protect larval and juvenile fish habitats associated with platelet ice formation along the Victoria Coast

Platelet ice formation in shallow waters of the Victoria Land Coast provides important habitat for fish and invertebrate larvae. Protecting a coastal buffer in this area eliminates the risk that localized fisheries-associated changes in demersal fish or benthic invertebrate communities could indirectly affect larval survival in unpredictable ways, and safeguards the integrity of ongoing shallow-water research and monitoring.

Research and monitoring required:

(i) The formation of platelet ice is highly constrained to shallow water in the vicinity of the coast and is unlikely to move. See Annex 1[2.4, 2.5; 6.4] for details.

(ii) Improve techniques to map and elucidate the ecological role of platelet ice formation along the Victoria Land coast in the Ross Sea ecosystem. Process studies to understand links between physical processes/habitat structure of platelet ice and ecological processes, especially early life stages or developmental stages of fish and invertebrates.

(iii) Full protection of this area will ensure that risks are highly mitigated. Undertake ecosystem modeling to investigate potential indirect impacts of harvest activities to this area.

Specific Objective 6.5: Protect the Pennell Bank polynya

Polynya formation occurs earlier over Pennell Bank in the northern Ross Sea relative to the rest of the Ross Sea polynya. As a consequence this location may be of particular importance for air-breathing top predators.

Research and monitoring required:

(i) Map the position and characteristics (e.g. size, duration, associated primary productivity) of Pennell Bank polynya in the Ross Sea region, seasonally and interannually, using satellite remote sensing. Analyse changes in polynya characteristics over time and compare with changes in polynyas in other parts of the Ross Sea region and Southern Ocean. See Annex 1[2.4, 2.5; 6.5(i)] for details.

(ii) Improve understanding of the ecological role of the Pennell Bank polynya in the Ross Sea ecosystem and how is this changing. Particular focus on use of the Pennell Bank polynya by air breathing predators (e.g. electronic tagging studies). Process studies to understand links between physical processes and primary production in polynyas; throughput efficiency and export of the microbial food web in polynyas; middle trophic level repackaging of organic material in polynyas. See Annex 1[6.1-6.6, 4] for details.

(iii) Very high protection (90+%) of this area will ensure that risks are highly mitigated. Undertake ecosystem modeling to investigate potential indirect impacts of harvest activities to this area.

Protection Objective 7: To protect known rare or vulnerable benthic habitats

Bottom fishing activities may have direct impacts on vulnerable benthic organisms which provide biogenic habitats and may be important for benthic ecosystem function. While bottom fishing impacts are also managed under other CCAMLR Conservation Measures 22-06 and 22-07, areas with known rare or vulnerable benthic communities of scientific importance may warrant MPA designation.

Specific Objective 7.1: Protect benthic habitats associated with the Balleny Islands and adjacent seamounts

The Balleny Islands chain is unique in the region, with steep topographic features formed by volcanic activity, and associated unique and poorly studied benthic communities.

Research and monitoring required (see Annex 1[7.1-7.6] for details):

(i) a) Map the benthic communities of the Balleny Islands and adjacent seamounts, using for example, underwater video, net and trawl sampling.

b) Map the physical and oceanographic characteristics of the Balleny Islands and adjacent seamounts.

(ii) a) Directed surveys using deployed cameras, benthic sampling, or SCUBA to improve knowledge of the benthic ecology of the Balleny Islands and adjacent seamounts,

(iii) Full protection of these habitats will ensure that risks are eliminated.

Specific Objective 7.2: Protect Admiralty Seamount

Admiralty Seamount includes two locations at which dense communities of a previously undescribed species of stalked crinoids have been observed; these communities are thought to be an isolated geographic remnant of formerly widespread communities in the Paleocene era, of high scientific importance for understanding the evolutionary history of ocean life.

Research and monitoring required (see Annex 1[7.1-7.6] for details):

(i) a) Map the benthic communities of the Admiralty Seamount, using for example, underwater video, net or trawl sampling.

b) Map the physical and oceanographic characteristics of the Admiralty Seamount, and evaluate “uniqueness” within the Ross Sea region.

(ii) a) Investigate whether species-environment modeling is useful for investigating benthic community distribution in the Ross Sea region, e.g. BRT, GDM.

(iii) Full protection of these habitats will ensure that risks are eliminated.

Specific Objective 7.3: Protect the Cape Adare slope

The continental slope near Cape Adare has been observed to support dense communities of vulnerable benthic taxa, where the narrow continental shelf and prevailing currents provide localized refuge from iceberg scour.

Research and monitoring required (see Annex 1[7.1-7.6] for details):

[as for 7.2, above]

Specific Objective 7.4: Protect the southeast Ross Sea slope

Complex oceanographic and underwater topographic confluences in the southeast Ross Sea continental slope suggest a highly heterogeneous (and potentially unique for the region, but under-studied) benthic environment in this area.

Research and monitoring required (see Annex 1[7.1-7.6] for details):

[as for 7.2 above]

Specific Objective 7.5: Protect benthic communities in McMurdo Sound

McMurdo Sound includes notable and diverse benthic communities and is the area of considerable scientific exploration. Its location at the terrestrial-marine interface adjacent to the McMurdo Dry Valley ASMA enhances its relevance for protection to ensure the integrity of ongoing science and monitoring activities in the area.

Research and monitoring required:

[as for 7.2 above]

Protection Objective 8: Reference areas to provide opportunities for better understanding of the Antarctic marine ecosystem without human interference

The Ross Sea shelf is the best studied stretch of high latitude continental shelf ocean in the Southern Hemisphere. Well established shore and vessel based research programmes in association with research bases in McMurdo Sound and Terra Nova Bay, have given rise to many long-term time series datasets characterizing the climatic, oceanographic, and ecological setting and dynamics of the Western Ross Sea. As the site of bottom water formation driving oceanic circulation on a global scale, and a potential carbon sink, this area is of particular importance for understanding global environmental change. The Intergovernmental Panel on Climate Change projects that on the basis of current climate trends the Ross Sea region, will be the last area on Earth to support a sea-ice associated community of organisms. The Ross Sea shelf ecosystem is highly productive and functionally intact, with the potential for both bottom-up (climatic, oceanographic) and top-down (predator-prey) mechanisms controlling ecosystem, function at different levels. Climate change and associated changes in ice associated habitats can be expected to affect the ecosystem at all levels and in potentially unpredictable ways. By designing marine protection in this area scientists can safeguard the integrity of existing time series data and ongoing research to understand climatic and ecosystem changes, without human interference and associated food-web effects of fishing.

Research and monitoring required:

(i) Inventory, summarise and map research on the effects of climate variability and change being carried out within the Ross Sea region. This should focus on research aiming to elucidate ecosystem structure and function, especially in relation to environmental variability and change, and highlight ongoing time-series/monitoring studies. Country

representatives and international research bodies could be asked to provide summary information, as well as an extensive review of the literature. See Annex 1[8A] for details.

(ii) Summarise the predicted effects of climate variability and change on the environment and ecosystem of the Ross Sea. Identify where these potential or predicted effects would be best studied.

(iii) a) Identify time series currently being carried out within the MPA compared to outside it, and the degree to which the MPA has mitigated the risk that fishing activity would confound these studies. This will likely have to be carried out on a study-by-study basis. See Annex 1[8A] for details.

b) Identify any studies that are only possible because of the existence of the MPA in the Ross Sea region – for example, studies to compare diet of Antarctic toothfish inside and outside the MPA. See Annex 1[8A] for details.

c) Most ongoing climate change research research in the Ross Sea region is focused in the Western Ross Sea in proximity to McMurdo Sound and Terra Nova Bay. This area is fully included in the MPA. Risks that fishery impacts may confound climate change signals at this scale appear to be fully mitigated.

4 CONCLUSIONS

Key conclusions in terms of the required **research and monitoring** associated with the MPA in the Ross Sea regions are given below:

(i) This is a discussion document and we welcome comments, suggestions and constructive criticism to improve the research and monitoring plan.

(ii) CCAMLR Conservation Measure 91-04(2011): "General framework for the establishment of CCAMLR Marine Protected Areas", provides clear requirements for research and monitoring associated with MPAs. Coupled with these requirements, the 8 Protection Objectives and specific objectives used in systematic conservation planning for the Ross Sea region (Sharp & Watters 2011) allows research and monitoring to be organized by three questions: (a) Research and monitoring to ensure that the boundaries of the priority feature as defined in the target area remain accurate, and/or to determine to what extent those boundaries may be moving; (b) Research and monitoring to further understand the ecosystem role and importance of the priority feature, and/or to understand the environmental or biological processes that affect it, including potential threats from fishing; (c) Research and monitoring to demonstrate the extent to which achievement of the specific objective is being met, i.e. to demonstrate whether identified or plausible threats are being effectively mitigated by the MPA.

(iii) Research approaches to address the high level research questions are suggested. These address how research and monitoring should be carried out. A summary of the approach is given in the text, and more details are given in Annex 1, cross-referenced to the Protection Objectives and sub-objectives.

(iv) The suggested research approaches should not be considered definitive. There may be other appropriate and valid approaches to address the high level research questions.

Key conclusions in terms of the **capacity to deliver** research and monitoring in the Ross Sea regions are given below:

(v) Research in the Southern Ocean in general, and in the Ross Sea region in particular, is highly international and collaborative. No single country has the research resources to deliver the MPA research and monitoring plan outlined here. In keeping with the international nature of Southern Ocean science, and the inclusive and participative ethos of CCAMLR,

all countries with interests in harvesting, conservation or protection in the Ross Sea region should undertake research in the region.

(vi) Four nations have, or will soon have, research bases in the Ross Sea region, and so are well placed to carry out long-term research on the oceanography, climate and ecosystem of the Ross Sea region: USA, Republic of Korea, Italy and New Zealand. It should be investigated to what extent the research priorities of these countries align with the high level objectives of the MPA research and monitoring plan for the Ross Sea region.

(vii) The research activities presented in the MPA Research and Monitoring plan overlap considerably with large-scale Southern research programmes currently underway. These programmes include SCAR, SOOS (Rintoul et al. 2012), ICED, IMOS, CEMP, and Sentinel.

(viii) Remote sensing is a key tool for delivery of research and monitoring in the Ross Sea region. Much effort is made by the international remote sensing science community to ensure long-term consistency and compatibility of remotely-sensed datasets as sensors change. It is hence reasonable to expect that measurements of key environmental and ecosystem properties – like sea ice, phytoplankton and temperature – will continue and improve in quality the medium and long-term (decades hence). Research effort specific to the Ross Sea could add research values to these observations by providing local interpretation and analysis. There is also the potential to develop new remote sensing approaches specifically targeted at research associated with MPA research and monitoring (e.g. remote counting of Weddell seals by satellite, aircraft or helicopter overflights).

(ix) Dedicated research voyages will be required in the Ross Sea in the future to address some research questions. At present, there may tentatively be the potential for the following research voyages in the Ross Sea, though it is stressed that none of these is confirmed: 2013/14 RV *Italica* (Italy); 2014/15 RV *Araon* (Korea); 2014/15 RV *Tangaroa* (New Zealand); 2015/16 RV *Palmer* (USA). As none of these research voyages is confirmed as yet, no research plans have been determined. We hope that this Ross Sea regional research and monitoring plan provides ideas, priorities and research context when planning any future research voyages in the region.

(x) Research made possible by the commercial fishery for toothfish in the Ross Sea region is likely to provide an important part of the MPA research and monitoring plan. In particular, data from fishing vessels provided to CCAMLR and from scientific observers onboard vessels, is likely to be the most important and relevant sources of annual data to monitor key fishes of the Ross Sea region. The requirements and priorities of scientific observers should hence be examined to ensure that their efforts address the highest priority aims of the research and monitoring plan.

(xi) "Opportunisitic" sampling from vessels transiting through or spending time in the Ross Sea region is likely to be a cost-effective way of obtaining data relevant to MPA research and monitoring. Most promising opportunities for underway sampling are (1) water properties from a pumped surface supply and analysed for pCO2, chl-a, nutrients, alkalinity; (2) Continuous Plankton Recorder measurements of upper ocean mesozooplankton relative abundance, in conjunction with the Southern Ocean CPR survey (Graham Hosie, Australian Antarctic Division) CRC; (3) multifrequency acoustics (e.g. 12, 38, 70, 120, 200 kHz); (4) Acoustic Doppler Current Profiler (ADCP) measurements of water column currents for model validation. It is noted that (1) there is often more cost associated with opportunistic sampling than immediately anticipated; (2) if "opportunistic" sampling is to contribute to long time-series of data used for monitoring the effectiveness of an MPA, long-term commitment to the sampling is required, and the measurements must be accorded the appropriate importance by the agencies involved at the outset.

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7 Annex 1

[This document is compiled as a reference list and is not included here]