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COMMISSION POUR LA CONSERVATION
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КОМИССИЯ ПО СОХРАНЕНИЮ
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A draft plan for research and monitoring in the Ross Sea region, in association with spatial marine protection

Delegations of New Zealand and the USA

SUMMARY

This document provides a draft research and monitoring plan to accompany a proposal to CCAMLR for the establishment of an MPA in the Ross Sea region. The purposes of research and monitoring associated with this spatial protection are to deliver the scientific knowledge sufficient to allow the Scientific Committee to advise the Commission on: (i) the degree to which the specific objectives of the MPA are being achieved; (ii) the degree to which the MPA objectives are still relevant in different areas of the MPA; and (iii) what management actions may be required to improve the achievement of the objectives for this MPA.

This draft MPA research and monitoring plan is structured spatially: (i) Ross Sea continental shelf; (ii) Ross Sea continental slope; (iii) Balleny Islands and vicinity; and (iv) Northern Ross Sea region and seamounts.

This draft research and monitoring plan includes the activities considered to be of high priority at the time of writing but also achievable in the short to medium term. This plan is not intended to be exhaustive, exclusive nor fixed. Advances in knowledge and/or changes to ecosystems, management and fisheries in the Southern Ocean may mean that some research and monitoring activities identified here may become less relevant over time, and other activities not identified here may become more important. The plan will require periodic update involving ongoing discussion and coordination among all CCAMLR Members.

Feedback from and collaboration with other Members in the further development of a draft research and monitoring plan is welcomed.

1 BACKGROUND

CCAMLR SM-II/4 describes a proposal for the establishment of a Marine Protected Area in the Ross Sea region, including the priority elements for a research and monitoring plan (Annex C), as required under CM 91-04, paragraph 3. This paper provides additional information consistent with the priority elements identified in that proposal, toward the development of a full research and monitoring plan to accompany and support the adoption and implementation of a Ross Sea region MPA. It is our intention that all CCAMLR Members with an interest in designing or conducting research in this area are encouraged to contribute to the ongoing development of this plan, both before and after the formal adoption and subsequent implementation of an MPA, and to collaborate on an ongoing basis in the actual design and delivery of the research priorities agreed therein.

The requirement and general guidance for research and monitoring plans to accompany MPAs is established in CM 91-04, paragraph 5, as follows:

> (i) This plan shall specify, to the extent necessary, the scientific research to be undertaken in the MPA, including, inter alia:
>
> (a) scientific research pursuant to the specific objectives of the MPA;
> (b) other research consistent with the specific objectives of the MPA; and/or
> (c) monitoring of the degree to which the specific objectives of the MPA are being met

It is clear that research undertaken the context of MPA research and monitoring plans should be linked to the specific objectives of the MPA, but at present there is no single agreed structure or format for these plans, either as part of or independent from 'MPA Reports' (see SC-CAMLR-XXXI

paragraphs 5.33-5.37 and 5.57-5.59). In 2012 the Scientific Committee considered two submissions toward the development of a Ross Sea region research and monitoring plan (WG-EMM-12/46 and -12/57) with very different structure and providing varying levels of detail, and recommended the following (SC-CAMLR-XXXI paragraph 5.58):

> '... the research and monitoring plan should identify research activities within various regions or spatial areas within the MPA consistent with the specific objectives of the MPA in that area.... the research and monitoring plan should be organized geographically and would ideally identify research and monitoring that relates to the achievement of multiple objectives simultaneously.... the plan should identify research that is achievable in practice."

The format of this paper has been prepared consistent with this advice.

1.1 Objectives of a Ross Sea region MPA

CCAMLR SM-II/4 proposes a Ross Sea region MPA to achieve the following specific 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;

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;

iii) to promote research and other scientific activities (including monitoring) focused on marine living resources;

iv) to protect a representative portion of benthic and pelagic marine environments:
- a. benthic bioregions, and
- b. pelagic bioregions;

v) to protect large-scale ecosystem processes responsible for the productivity and functional integrity of the ecosystem:
- a. Ross Sea shelf front intersection with seasonal ice,
- b. Polar front,
- c. Balleny Islands and proximity,
- d. Ross Sea polynya marginal ice zone, and
- e. Eastern Ross Sea multi-year ice;

vi) to protect core distributions of trophically dominant pelagic prey species:
- a. Antarctic krill,
- b. Crystal krill, and
- c. Antarctic silverfish;

vii) to protect core foraging areas for land-based top predators or those that may experience direct trophic competition from fisheries:
- a. Adelie penguins,
- b. Emperor penguins,
- c. Weddell seals, and
- d. Type C killer whales;

viii) to protect coastal locations of particular ecological importance:
   a. southern Ross Sea shelf persistent winter polynya,
   b. recurrent coastal polynyas,
   c. Terra Nova Bay,
   d. Victoria Coast platelet ice formation zone, and
   e. Pennell Bank polynya;

ix) to protect areas of importance in the life cycle of Antarctic toothfish:
   a. Subadult toothfish settlement areas on the Ross Sea shelf,
   b. Dispersal corridors for maturing toothfish,
   c. Adult toothfish feeding areas on the Ross Sea slope,
   d. Northwestern *D. mawsoni* spawning areas, and
   e. Northeastern *D. mawsoni* spawning areas;

x) to protect known rare or vulnerable benthic habitats:
   a. Balleny Islands and adjacent seamounts,
   b. Admiralty seamount,
   c. Cape Adare slope,
   d. Southeast Ross Sea slope,
   e. McMurdo Sound, and
   f. Scott Seamount and adjacent underwater features.

1.2 Purpose and rationale for priority research and monitoring activities under this plan

Research activities carried out consistent with this plan will inform the periodic review of the MPA under CM 91-04 paragraph 8.

To eliminate repetition and enable specificity, the specific rationale for each identified research activity is not repeated in every instance; instead we identify which specific MPA objective(s) are addressed by each research activity, and the rationale for the research is as required under CM 91-04 paragraph 5(i) (above) and described in CCAMLR SM-II/4 Annex C paragraphs 1 and 2. The full CCAMLR SM-II/4 Annex C is appended to this document.

Scientific justification for the objectives themselves, and particular mapped features or areas associated with each objective, are detailed in papers SC-CAMLR-IM-I/08 and SC-CAMLR-IM-I/09 and in previous CCAMLR submissions summarized or cited in those documents (see especially WG-EMM-10/10, WG-EMM-10/30, and WS-MPA-11/25).

1.3 Geographic scale and location of priority research and monitoring activities

The Ross Sea region corresponds to CCAMLR MPA 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.

Consistent with the advice of WG-EMM (above) the research and monitoring plan will be organized geographically as follows:

1. Ross Sea continental shelf
2. Ross Sea continental slope
3. Balleny Islands and vicinity
4. Northern Ross Sea region and seamounts
5. All areas

Where research spans more than one of these areas, it is presented in the area to which it is most relevant. The final "All areas" section includes research and monitoring that is relevant to all areas in the Ross Sea region.

Particular mapped features or areas relevant to each specific objective are shown in SC-CAMLR-IM-I/08 and SC-CAMLR-IM-I/09. Where research priorities are identified for particular locations at scales smaller than these mapped features, these are identified in the text. Note that objectives i and iii are integrative in nature and apply generically to all locations, so are not identified separately in association with particular research activities.

1.4 Participation, capacity to deliver and evolution of this plan

Consistent with the advice of SC-CAMLR-XXXI paragraph 5.59, all CCAMLR members and other nations are encouraged, as far as possible, to engage and collaborate in research and monitoring in the Ross Sea region MPA. Other research that is consistent with the objectives of the MPA, but not explicitly outlined here, is also encouraged.

In this document we identify priority research and monitoring activities that are likely to deliver the advances in scientific understanding required to allow the Ross Sea region MPA to be evaluated and improved. Activities proposed here are at a scale and level of ambition that are likely to secure necessary logistic and funding support in the short to medium term. Because ecosystem science is by nature integrative and multi-disciplinary, some of the research and monitoring activities identified in this paper are not specific to CCAMLR's mandate and may fall outside of CCAMLR's competency; achieving this priorities would benefit from improved coordination with other global multinational research endeavours (e.g. SCAR, SOOS). This plan does not, and is not intended to, suggest who could or should carry out any of the identified research activities. 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 an agreed Ross Sea region MPA research and monitoring plan, and to share the results of that research within CCAMLR, 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. The existence of such a plan may also help individual programmes to secure resources to contribute to those common objectives.

Suggestions to improve, expand, reprioritise or extend research and monitoring associated with this draft Ross Sea research and monitoring plan are welcome.

1.5 Prioritisation of identified research and monitoring activities

In Section 2 below, the order of the identified research and monitoring activities should not be taken as suggesting order of priority.

2 New or expanded priority research and monitoring activities or programmes:

2.1 Ross Sea continental shelf

- Expand the existing Weddell seal and Type C killer whale programmes at McMurdo Sound (Burns & Kooyman, 2001; Pitman & Ensor, 2003; Andrews et al., 2008; Ponganis & Stockard 2007) using, for example, biochemical and electronic technologies, (e.g. electronic tagging technology and animal-mounted oceanographic sensors, Thums et al., 2008). Proven animal-mounted sensors ("Crittercam", Fuiman et al. 2002) may help to address spatial and seasonal foraging/habitat utilisation for all identified predator species, and simultaneously collect physical oceanographic data in areas visited by these predators but otherwise inaccessible to oceanographic sensors (e.g. under ice). Tracking of type C killer whales using small boats/helicopters/ice-edge have been useful in establishing foraging patterns of killer whales elsewhere (Altmann 1974; Mann 2000). *[Protection objectives vii(c-d), viii(a-b)]*

- Establish a long-term top predator colony population monitoring programme in the Terra Nova Bay area, to simultaneously address research priorities for Weddell seals, killer whales, Adelie penguins, and Emperor penguins in this area, to be analyzed in parallel with existing and expanded programmes in the McMurdo Sound area. As has been carried out on populations in the southwestern Ross Sea, research could include population size (satellite-based photographic surveillance, aerial surveying, census), demography, condition (weights), diet (regurgitation and scats, isotopes), and large and small scale movement patterns (satellite and archival tags, PIT tags). This programme would ideally involve coordination between researchers at existing (Italian) and planned (Korean, Chinese) permanent research stations in this area. Substantial shore-based monitoring of Adelie penguins in the southwest Ross Sea has been carried out collaboratively by New Zealand and US researchers for over 20 years (e.g. Ainley, 2002) and this should continue. *[Protection objectives ii, vii(a-d), viii(b-c)]*

- Undertake aerial overflights of the Victoria Coast at a frequency of once every 2-3 years, using cameras and semi-automated digital processing technology (McNeill et al. 2011; McNeill & Barton 2011, 2012; Gordon & Barton 2012a, b) to census breeding colony populations of Weddell seals, Emperor penguins, adn Adelie penguins. Adelie and emperor penguins have been monitored in this way for over 10 years (Lyver et al., 2013). For Weddell seals, this research was proposed to CCAMLR, including draft methodologies (Siniff & Ainley, 2008). At-sea censusing of killer whales (with identification to ecotype). Use satellite based photographic data for census of seals and penguins sensu (LeRoux, Univeristy of Minnesota) *[Protection objectives ii, vii(a-d), viii(a-d)]*

- Continue subadult survey for Antarctic toothfish in southern Ross Sea (annual scientific stratified survey to monitor for changes to toothfish recruitment: Hanchet et al., 2012; Parker et al., 2013) and extend exploratory sets westward towards McMurdo Sound and north along Victoria Land coast to recapture deployed tags and investigate/monitor Antarctic toothfish abundance in areas where predator foraging occurs. Investigate distribution of Antarctic toothfish throughout the water column on the shelf using vertically stratified sampling (as has been proposed before, e.g. Delegation of Russia, 2004) or electronic technologies. Obtain samples for Antarctic toothfish diet analysis (stomach analysis: e.g. Stevens et al., 2012; stable isotope analysis: Bury et al., 2008). *[Protection objectives viii(a-d), ix(a-b)]*

- Conduct dedicated research voyage(s) to Ross Sea shelf and slope (every 2-5 years) to measure/monitor distribution of middle trophic levels groups: Antarctic silverfish, crystal and Antarctic krill, octopods, small demersal fishes, zooplankton. Combine acoustic methods (O'Driscoll et al, 2011) with established and proven sampling technologies such as benthic

trawls, midwater trawls, video/camera methods, zooplankton nets, video/optical zooplankton methods. (Hanchet et al., 2008). Co-ordination between Members and the use of research vessels of different nationalities should enable the area to be surveyed more frequently than would be possible by any single nation alone. Core methodologies should be standardised to ensure consistent time-series. *[Protection objectives vi(b-c), viii(a-e)]*

- Further develop acoustic methods from ships-of-opportunity and research vessels for long-term monitoring of krill, silverfish and myctophids in the Ross Sea region. For example, multi-frequency acoustic data (12, 38, 70, and 120 kHz) have been used to discriminate acoustic marks of silverfish from those of krill and other associated species, and hence to estimate biomass of krill and silverfish in the Ross Sea region (O'Driscoll et al., 2011) building on previous acoustic surveys in the Ross Sea (e.g. Sala et al., 2002; Azzali et al., 2006; Taki, et al., 2008). Carry out further mark-identification (midwater) trawls over Ross Sea shelf (and slope) to improve discrimination. Obtain samples for estimating target strengths (e.g. computed tomography scans). *[Protection objectives v(a-e), vi(a-c), viii(a-e)]*

- Initiate Continuous Plankton Recorder (CPR) monitoring of Ross Sea shelf using ships of opportunity (supply ships, tourist vessels, fishing vessels) and using research vessels (periodically, as available) for validation. The surveys should characterize and monitor surface zooplankton distributions, especially copepods, pteropods and species known to be prey of silverfish (Pinkerton et al., 2013). The CPR has been deployed successfully from New Zealand fishing vessels between New Zealand and the Ross Sea for 5 seasons (2008-2013). The physical specimens were identified using standard protocols as part of the SCAR Southern Ocean Continuous Plankton Recorder (SO-CPR) survey, established in 1991 (Reid et al. 2003; Hosie et al. 2003). Apply statistical analysis for investigating change over time and establishing distributions of key zooplankton (e.g. Pinkerton et al., 2010b). *[Protection objectives v(a-e), vi(c), viii(a-e)]*

- Establish acoustic mooring in Terra Nova Bay, in conjunction with shore and boat-based surveying, to investigate and monitor silverfish ecology over annual cycle, including links to seasonal sea-ice of silverfish and silverfish prey. Upward-looking ADCP sensors have successfully been used as part of moorings for some time. The mooring may act as a focus for small-boat research from bases in the region. *[Protection objectives vi(c), viii(c)]*

- Continue and standardize the 35+ year time series programme of Antarctic toothfish sampling through the ice at McMurdo Sound (Raymond, 1975; Ainley et al., 2012) as a means of monitoring local effects of drivers such as climate and oceanographic change, fisheries, and top predators on toothfish. *[Protection objectives ix(a)]*

- The McMurdo Sound benthic community is probably the longest and best examined benthic area on the Antarctic shelf and hence provides a high latitude reference area for understanding and monitoring the effects of climate change on Antarctic coastal benthic ecosystems. Research should continue to characterise and monitor the McMurdo Sound benthic ecosystem by building on well-established diver transects in McMurdo Sound and along the Victoria Land coast to Terra Nova Bay as part of latitudinal-gradient approach to understanding ecosystem function and change over the high Antarctic shelf (e.g. IceCUBE project, 2008). Observations of the under-sea-ice community should be carried out to assess the role of the sea-ice in key species including e.g. crystal krill (Kirkwood, 1996) and copepods (Pasternak & Schnack-Schiel, 2001). *[Protection objective x(e)]*

- Build on previous deployments of oceanographic instrumentation (including current meters, ADCP) in the McMurdo Sound and Terra Nova Bay regions to measure circulation below the Ross Sea ice shelf and along the Victoria Land coast, to help understand water mass structure,

circulation, bottom-water formation, mixing processes, ice formation/melt and polynya development and persistence in key regions. Note that this links with research to develop high-resolution coupled oceanographic-biogeochemical models of the Ross Sea region. *[Protection objectives viii(a-e)*]

2.2 Ross Sea continental slope

- The following research proposed above for the shelf region is also relevant to the slope region: (1) abundance, movement, foraging/diet of priority air-breathing predators: Adelie penguins, emperor penguins, Weddell seals, killer whales; (2) research vessel surveys of key biota (krill, silverfish, myctophids, zooplankton, cephalopods); (3) use of vessels of opportunity transiting the Ross Sea slope area to monitor middle trophic level groups using CPR and multi-frequency acoustics. *[Protection objectives ii, v(a, d), vi(a), viii(e)]*

- Paired stratified fishing surveys of fished vs. unfished strata on the slope to monitor effects of fishing on Antarctic toothfish and demersal fishes, including: (i) changes to size-frequency of toothfish; (ii) density-dependent changes in growth rates or age-at-maturity of toothfish (iii) localised predation-release of toothfish prey and corresponding changes in toothfish diet; (iv) effects on toothfish condition. In particular, tagging (e.g. archival, satellite-tracked, acoustic) of toothfish in 88.1K should be used to determine (i) movement rates both within 88.1K and between 88.1K and adjacent slope SSRUs; (ii) why recapture rates of tagged toothfish are so low in 88.1K compared to other areas (Delegation of New Zealand, 2013). SSRU 88.2A has had a zero catch limit since 2005, although research fishing has been carried out in several years since then with about 150 tags released in 2010/11 and 2011/12 (Kulish & Gordeev 2013). It is important that the research fishing outlined above include paired strata in the south-east of 881K and west of 88.2A. *[Protection objectives ii, ix(b-c)]*

- Research survey (using research or fishing vessels, or combination of both) of distribution and biomass of medium-sized demersal fish (grenadiers, icefish, eel cods) over the Ross Sea slope (using e.g. benthic trawls, video/camera). This builds on research carried out to date (Hanchet et al., 2008) and would use established sampling techniques. The focus should be on species of demersal fishes that form the main prey for toothfish in the slope region, including grenadiers, icefish, eel cods and squid (Stevens et al., 2012; Pinkerton et al., 2013). Samples of key medium-sized demersal fishes of Ross Sea slope should be analysed to improve knowledge of: growth rates, natural mortality, reproduction (including investigating whether particular year classes can be identified), diet and trophic level (Pinkerton et al., 2012). Establish periodic (every 2-5 years) monitoring of demersal fish abundance on Ross Sea slope using research vessels with stratified survey design. *[Protection objectives ii, ix(c)]*

- Continue and expand research on Antarctic toothfish ecology (especially using fishery and observer data and samples from fishery observers), with special focus on the Ross Sea slope which is thought to be the main feeding ground for maturing/adult Antarctic toothfish, is the area where fishing is concentrated, and is also the region where effects of the fishery on toothfish prey is most likely (Hanchet et al., 2008; Pinkerton et al., 2010a). Research to date on Antarctic toothfish in the slope region should be expanded, including: diet/tracer (stomach contents: Stevens et al., 2012; fatty acids: Yeon et al., 2012; stable isotopes: Bury et al., 2008), life-cycle and ecology (Hanchet 2006, Hanchet et al., 2008), histology (Parker & Grimes, 2010). Investigate distribution of toothfish throughout the water column on the slope using vertically stratified sampling or electronic technologies. Initiate archival/satellite tagging of toothfish in Mawson Bank (area of high fisheries yield) to elucidate movement patterns. Develop methods to characterise toothfish population movement and migration dynamics through the slope and

between shelf, slope and northern region habitats, including between areas inside and outside the boundaries of the MPA. Continue spatial population modelling of Antarctic toothfish (Mormede et al., 2013). *[Protection objectives ii, v(a), ix(b-c)]*

- Conduct oceanographic measurements in the Ross Sea slope region to help understand water mass structure (including bottom water formation), circulation, cross-shelf exchange (including nutrient budgets) and mixing processes in this region for inclusion in high-resolution coupled oceanographic-biogeochemical models of the Ross Sea region. [*Protection objectives ii, v(a)]*

- Survey of structure-forming benthic invertebrates on the Ross Sea slope using established techniques (video/camera survey; high resolution side-scan/multibeam sonar mapping; habitat classification approaches) following on from two New Zealand research voyages (BioRoss 2004 and BioRoss 2008). Aim to build on previous research in region (e.g. Barry et al. 2003) by focus on Cape Adare and southeast slope regions. Where possible, combine sampling from research vessels of benthic invertebrates with oceanographic, middle trophic level, and demersal fish data collection. *[Protection objectives v(e), viii(e), x(c-d)]*

2.3 Balleny Islands and vicinity

- Carry out research voyages to Balleny Islands every 4-5 years, including shore landings and wide-area survey of Balleny Island region. Previous research visits to the Balleny Islands have included shallow-water (SCUBA and photographic) sampling and shore-based census of predator colonies from R/V Tiama in 2006 (unpublished data); acoustic, mid-water, and benthic sampling from the R/V Tangaroa again during IPY-CAML in 2008 (Hanchet et al, 2008), and dedicated whale research in 2010Gales, 2010; Gales et al., 2010). The research proposed to be carried out on the voyage(s) are given below. *[Protection objectives v(c), x(a)]*

- Carry out ground visits/landings on the Balleny Islands to quantitatively survey nesting seabirds. Genetic sampling of Chinstrap penguins to understand connectivity between Balleny Islands populations and elsewhere around Antarctica (Macdonald et al. 2002). Initiate tagging programme for Balleny Islands penguins. Use techniques established at McMurdo Sound (where appropriate) to study feeding/diet of penguins (regurgitation, isotopes, scat analysis). Carry out aerial overflights for predator colony counts every 4-5 years, if possible synchronized with selective shore landings to enable ground truthing of aerial censusing methods. *[Protection objectives v(c)]*

- Combine small boat, land-based, aerial-surveying and other methods to quantify numbers of seals (Weddell, crabeater, and southern elephant seals) and whales (especially humpback whales) near Balleny Islands. Use techniques developed in McMurdo Sound and elsewhere to establish ecological monitoring of marine mammals, including: large-scale movements/philopatry/connectivity (satellite tagging, photo-ID, genetic tagging); foraging behavior/diet ("focal follows", biopsy sampling, underwater acoustics, "critter-cam", suction tags). This research should be linked to ongoing tagging/photographic-ID/ecological studies of southern elephant seals (e.g. Walters et al. submitted; van den Hoff et al., 2002), and ongoing research on humpback whales in southwest Pacific (Constantine et al., 2012). *[Protection objectives v(c)]*

- Initiate diver and research-vessel based benthic sampling (including multibeam sonar) around the Balleny Island to investigate/sample/map mega and macrobenthic taxa, following on from (Page et al., 2002) and recent research voyages to the Balleny Islands (IPY-CAML; Tiama). Establish role of sea ice in structuring Balleny Islands benthos. *[Protection objectives v(c), x(a)]*

- Use multifrequency acoustic survey of the Balleny Islands region coupled with mesopelagic net sampling (e.g. O'Driscoll et al., 2011; MOCNESS - Midwater Opening-Closing Net Sampling System) to determine abundance of middle trophic level biota in the region, including krill, zooplankton, squid, and midwater fishes (myctophids, possibly silverfish) (Hanchet et al., 2008; Sharp et al. 2010). Similar research work in the region has already occurred (Quartermain 1964; Timonin 1987; Hanchet et al., 2008). Investigate whether multifrequency acoustic and/or Continuous Plankton Recorder (CPR) transects through the Balleny Islands region are feasible as part of ship-of-opportunity surveying of Ross Sea region (see research proposed in Shelf region). If the timing of the research voyage(s) permits, make under-ice observations to elucidate the role of sea-ice in the vicinity of the Balleny Islands as a habitat for key biota, especially krill (Kirkwood, 1996; Brierley et al. 2002), and mesozooplankton (Pasternak & Schnack-Schiel, 2001). *[Protection objectives v(c), vi(a,c)]*

- Carry out sampling of demersal fishes (e.g. trawl survey, underwater video and camera, longlines) around the Balleny Islands. Use genetic and/or microchemistry methods to understand stock connectivity between Antarctic toothfish at Balleny Islands and Ross Sea stock (shelf, slope). This work is already underway within the current Ross Sea fishery region and should be extended to the Balleny Islands region. Use samples of fish collected to investigate fish ecology/connectivity (growth rates, natural mortality, reproduction, diet/trophic level). *[Protection objectives v(c), ix(b)]*

2.4 Northern Ross Sea region and seamounts

- Research proposed for other parts of the Ross Sea region has substantial overlap with that here, including: (1) movement/foraging of priority air-breathing predators (Adelie penguins, emperor penguins, Weddell seals, killer whales) in wider Ross Sea region; (2) distribution/biomass of key middle trophic levels (krill, myctophids, zooplankton) in wider Ross Sea region using acoustic and underway zooplankton sampling; (3) high-resolution coupled oceanographic-biogeochemistry modelling of the Ross Sea region; (4) satellite observation of the region (ocean colour/primary productivity; sea surface temperature; altimetry; sea ice); (5) role of seamounts and other benthic features in movement/feeding/spawning of toothfish; (6) paired fished-unfished comparison of seamounts to monitor/elucidate effects of fishing. *[Protection objectives v(b), vi(a), vii(a-d), ix(b, d-e)]*

- Conduct scientific voyage(s) to improve knowledge of spawning and early life stages of Antarctic toothfish, especially with regard to use of the Pacific-Antarctic Fracture Zone and islands/seamounts for reproduction. A detailed plan for a "winter-fishing" survey of this kind was presented to CCAMLR in 2008 (Delegation of New Zealand 2008). Approaches proposed include: tracking and tagging of Antarctic toothfish, including satellite, depth-recording (archival), acoustic methods; histological/egg/larval surveys near to spawning times; multibeam sonar to map depth over northern seamounts and PAFZ (bathymetric datasets are inadequate here); feeding studies (stomach and tracers including fatty acids, stable isotopes); genetic analysis for site fidelity; by-catch characterization to understand availability of demersal fish prey. Fishery-based research on Patagonian toothfish to the north (including distribution, stock unit ID, and abundance) to understand and monitor for changes in the relative ecological importance of Antarctic and Patagonian toothfish under the combined effects of climate change and fishing. *[Protection objectives ix(d-e)]*

- Conduct scientific voyage(s) to improve knowledge of distribution and abundance of Antarctic and Patagonian toothfish, especially with regard to use of the Pacific-Antarctic Fracture Zone

and islands/seamounts between 150ºE and 150ºW (in particular the unfished areas in the north of SSRUs 88.1A, 88.2A, and 88.2B). Fishery-based research on Patagonian toothfish to the north (including distribution, stock unit ID, and abundance) to understand and monitor for changes in the relative ecological importance of Antarctic and Patagonian toothfish under the combined effects of climate change and fishing. Results would also inform the spatially explicit operating models for Antarctic toothfish currently being developed for management strategy evaluations (Mormede et al., 2013) *[Protection objectives ii, ix(d-e)]*

- Conduct research voyage followed by periodic surveys (e.g 5-10 years) of Admiralty and Scott seamounts to further characterise (including ecological role) and monitor for change in benthic communities. These areas were visited as part of the IPY-CAML voyage in 2008 and substantial data on these seamounts already exists, allowing change to be investigated on repeat visits (Hanchet et al., 2008). *[Protection objectives x(f)]*

- Monitor utilization of the Polar Front by seabirds (flying birds and penguins) using satellite tagging linked to large-scale oceanographic and environmental observations (Raymond et al., 2010). Changes to foraging locations of seabirds over time could be interpreted in terms of oceanographic changes by using satellite observations of the wider Ross Sea area and maps of potential prey items built up from censusing of middle trophic level biota through the region. *[Protection objectives ii, v(b), vii(a-b)]*

2.5 All areas

- Satellite remote sensing provides long-term, large-area data on the Ross Sea region at low cost to CCAMLR Members. Satellite data of the Ross Sea should be used to monitor for large-scale change and place other monitoring/research results arising from research in the MPA in oceanographic/climate context. The main satellite observations relevant to research and monitoring of the Ross Sea MPA are: (1) **Sea-ice** has a fundamental role in structuring the ecology of the Ross Sea region, from primary producers to top predators. Internationally, satellite observations of sea ice (especially concentration and extent) are used to examine change in the Southern Ocean (e.g. Parkinson 2002; Stammerjohn et al. 2008). Satellite-based laser and radar altimeters optimized for polar observations have been launched over the last decade (Zwally et al., 2002; Wingham et al, 2006), with the determination of global sea-ice thickness/distribution being one of the major objectives of these missions. Detailed proposals for further developing/validating satellite based methods to estimate ice thickness are available (Williams, 2012); (2) satellite **ocean colour** remote sensing is widely used to monitor for changes in phytoplankton abundance and primary production, including in the Southern Ocean and in sea ice (Comiso, et al., 1993; Arrigo et al., 1998, 2000; Arrigo & Van Dijken, 2004). Satellite observations of ocean colour should be used to understand spatial and temporal dynamics of primary production, including examining whether functional groups of phytoplankton in the Ross Sea region can be distinguished remotely; (3) long-term, validated, consistent data sets of satellite **sea surface temperature** (SST) data exist (e.g. Reynolds & Smith, 1994) and should be used to observe change in oceanography over the Ross Sea region; (4) **sea surface height** from satellite altimetry is normally used to show positions of fronts and other features of the circulation field, but no coverage is available in the Southern Ocean south of c. 66°S so that numerical models, in situ methods and SST satellite data are more likely to be useful indicators of change in frontal features and hydrography in the Ross Sea region (Rickard et al., 2010). Analysis of these satellite and model-based resources should be continued in the context of understanding environmental change in the Ross Sea region. 5) Space-based high resolution photography has been shown to be effective in estimating seal populations during haul out on land (Michelle LeRoux, Univeristy of Minnesota). Space-based sentinels can be

validated against visual surveys to provide continuity between visual surveys. *[Protection objectives v(a-e), viii(a-e)]*

- Develop and validate improved higher resolution oceanographic model of the Ross Sea region (shelf, slope and northern area), nested within global climate-ocean models. The improved model should resolve effects of sea-ice (especially poynyas), ice shelf cavity, cross-shelf exchange and deep bottom-water formation. The geochemical-physical model should be integrated with a lower-food web biogeochemical model (nutrients, including iron, phytoplankton, detritus, zooplankton grazers) to understand climate-ocean-primary production linkages, including resolution of different functional groups of phytoplankton (e.g. phaeocystis-diatoms on shelf). This modelling capability is well established globally, and prototype Ross Sea models currently exist (Dinniman et al., 2003) and are currently being further developed in New Zealand and US. *[Protection objectives v(a-e), viii(a-e)]*

- Apply improved univariate and multivariate approaches to fitting biology and environment (e.g. Boosted Regression Trees, Generalised Dissimilarity Analysis), including assessment of geographic stationarity, and environmental overlap of training and predictive data domains, to the Ross Sea region (Guisan & Zimmermann 2000; Leathwick et al. 2006; Elith et al. 2007; Elith et al. 2008). These methods should be further developed to: (1) improve and validate bioregionalisation of the Ross Sea region; (2) investigate functional links between species and the environment to understand changes in species' environmental envelopes due to climate change; (3) extend (where feasible) species distributional information to large scales (e.g. Pinkerton et al., 2010b). *[Protection objectives iv(a-b)]*

- Substantial research is ongoing worldwide on numerical modeling to understand ecosystem function (e.g. Plaganyi 2007) including focussed on the Ross Sea (e.g. Smith, et al., 2007; Pinkerton et al., 2010a). Research is needed to apply international best-practice in ecosystem modelling to monitor the performance of the Ross Sea MPA. Ecological models should also be used for hypothesis generation (e.g. the risk of ecosystem effects of fishing, effects of climate change, including trophic cascades, predation release and regime shift) and to prioritise/evaluate monitoring. Ecosystem models should also be used to help develop indicators as early-warning signals of ecosystem effects of fishing and climate change (e.g. Polovina & Howell, 2005; Shannon et al., 2009). *[Protection objectives i, ii]*

3. Changes to Research and Monitoring Plan

This draft research and monitoring plan includes the activities considered to be of high priority at the time of writing but also achievable in the short to medium term. This plan is not intended to be exhaustive, i.e. it does not identify all research and monitoring that is, or may be, relevant to the design, management or evaluation of a Ross Sea region MPA. Advances in knowledge and/or changes to ecosystems, management and fisheries in the Southern Ocean may mean that some research and monitoring activities identified here may become less relevant over time, and other activities not identified here may become more important. Hence, the plan will require periodic update involving ongoing discussion and coordination among all CCAMLR Members.

4 FIGURES

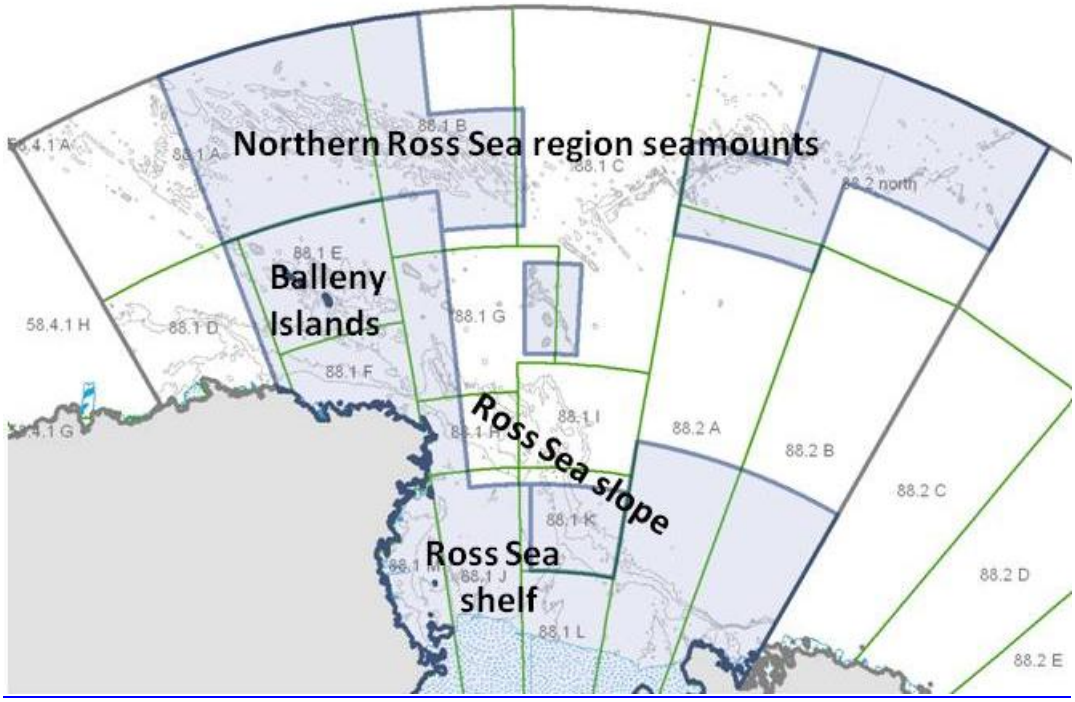

Figure 1: The Ross Sea region, showing geographic regions within which this draft research and monitoring plan is organized, relative to existing SSRUs and proposed MPA boundaries.

5 REFERENCES

Ainley, D.G. (2002). The Adelie Penguin: Bellwether of Climate Change. Columbia University Press, New York, USA.

Ainley, D.G.; Nur, N.; Eastman, J.T.; Ballard, G.; Parkinson, C.L.; Evans, C.W.; DeVries, A.L. (2012). Decadal trends in abundance, size and condition of Antarctic toothfish in McMurdo Sound, Antarctica, 1972–2011. Fish and Fisheries, http://dx.doi.org/10.1111/j.1467-2979.2012.00474.x

Altmann, J. (1974). Observational study of behaviour: sampling methods. Behaviour 49: 227-276.

Andrews, R.; Pitman, R.; Ballance, L. (2008). Satellite tracking reveals distinct movement patterns for Type B and Type C killer whales in the southern Ross Sea, Antarctica. Polar Biology 31(12): 1461-1468.

Arrigo, K.R.; DiTullio, G.R.; Dunbar, R.B.; Robinson, D.H.; Van Woert, M.; Worthen, D.L.; Lizotte, M.P. (2000). Phytoplankton taxonomic variability in nutrient utilization and primary production in the Ross Sea. Journal of Geophysical Research C105: 8827-8846.

Arrigo, K.R.; Robinson, D.H.; Worthen, D.L.; Schieber, B.; Lizotte, M.P. (1998). Bio-optical properties of the southwestern Ross Sea. Journal of Geophysical Research 103(C10): 21683-21695.

Arrigo, K.R.; Van Dijken, G.L. (2004). Annual changes in sea-ice, chlorophyll a, and primary production in the Ross Sea, Antarctica. Deep-Sea Research II 51(1-3): 117-138.

Azzali, M.; Leonori, I.; De Felice, A.; Russo, A. (2006). Spatial-temporal relationships between two euphausiid species in the Ross Sea. Chemistry and Ecology (Suppl.) 22: 219-233.

Barry, J.P.; Grebmeier, J.; Smith, J.; Dunbar, R.B. (2003). Bathymetric versus oceanographic control of benthic megafaunal patterns in Brewer, P. G., and J. C. Goldman. 1976. Alkalinity changes generated by phytoplankton growth. Limnology and Oceanography 21: 108–17.

Brierley, A.S.; Fernandes, P.G.; Brandon, M.A.; et al. (2002). Antarctic krill under sea ice; elevated abundance in a narrow band just south of the ice edge. Science 295: 1890-1892.

Burns, J.M.; Kooyman, D.L. (2001). Habitat use by Weddell seals and emperor penguins foraging in the Ross Sea, Antarctica. American Zoologist 41: 90-98.

Bury, S.J.; Pinkerton, M.H.; Thompson, D.R.; Hanchet, S.; Brown, J.; Vorster, L. (2008) Trophic study of Ross Sea Antarctic toothfish (*Dissostichus mawsoni*) using carbon and nitrogen stable isotopes CCAMLR document WG-EMM-08/27, Hobart, Australia.

Comiso, J.C.; McClain, C.R.; Sullivan, C.W.; Ryan, J.P.; Leonard, C.L. (1993). Coastal Zone Color Scanner pigment concentrations in the Southern Ocean and relationships to geophysical features. Journal of Geophysical Research 98: 2419-2451.

Constantine, R.; Jackson, J.A.; Steel, D.; Baker, C.S.; et al. (2012). Abundance of humpback whales in Oceania using photo-identification and microsatellite genotyping. Marine Ecology Progress Series 453: 249-261.

Delegation of New Zealand (2008). Application to undertake winter scientific research in CCAMLR Subarea 88.1 (SSRUs 88.1B, 88.1C, and 88.1G) in the 2008/09 season. CCAMLR document WG-FSA-08/62, Hobart, Australia. 17 p.

Delegation of New Zealand (2013). Review of the toothfish fishery in SSRU 881K from 1997–98 to 2011–12 and opportunities for scientific research. CCAMLR document SC-CAMLR-IM-I-BG/XX, Hobart, Australia.

Delegation of Russia (2004). On experimental approach to extend boundaries of exploratory fishery on Antarctic toothfish (*D. mawsoni*) in the Ross Sea (Subareas 88.1 and 88.2) in the meso- and bathypelagial layers. CCAMLR document SC-CAMLR-XXIII/BG/19, pp 8.

Dinniman, M.S.; Klinck, J.M.; Smith Jr., W.O. (2003). Cross-shelf exchange in a model of the Ross Sea circulation and biogeochemistry. Deep-Sea Research II 50: 3103–3120.

Elith, J.; Graham, C.H.; Anderson, R.P.; Miroslav, D.; et al. (2007). Novel methods improve prediction of species' distributions from occurrence data. Ecography 29: 129-151.

Elith, J.; Leathwick, J.R.; Hastie, T. (2008). A working guide to boosted regression trees. Journal of Animal Ecology 77: 802–813.

Fuiman, L.A.; Davis, R.W.; Williams, T.M. (2002). Behavior of midwater fishes under the Antarctic ice: observations by a predator. Marine Biology 140: 815–822.

Gales, N. (2010). Antarctic whale expedition: Preliminary science field report and summary. R.V. Tangaroa Feb/Mar 2010. Report to SORP 2010. Australian Marine Mammal Centre, Australian Antarctic Division, Hobart, Australia.

Gales, N.; Double, M.C.; Robinson, S.; Jenner, C.; Jenner, M.; King, E.; Gedamke, J.; Paton, D.; Raymond, B. (2010). Satellite tracking of southbound East Australian humpback whales (*Megaptera novaeangliae*): challenging the feast or famine model for migrating whales. IWC document SC/61/SH17.

Gordon, S.; Barton, K. (2012a). Guidelines for the aerial photography of Ross Sea region Adelie penguin colonies. Antarctica New Zealand, Christchurch, New Zealand, 88p.

Gordon, S.; Barton, K. (2012b). Guidelines for the Adelie Census Image Processing, Counting, Validation and Data Storage. Antarctica New Zealand, Christchurch, New Zealand, 21p.

Guisan, A.; Zimmermann, N.E. (2000). Predictive habitat distribution models in ecology. Ecological Modelling 135: 147-186.

Hanchet, S.M.; Rickard, G.J.; Fenaughty, J.M.; Dunn, A.; Williams, M.J. (2008). A hypothetical life cycle for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region. CCAMLR Science 15: 35-53.

Hanchet, S.M. (2006). Species profile for Antarctic toothfish (*Dissostichus mawsoni*). CCAMLR document WG-FSA-06/26, Hobart, Australia.

Hanchet, S.M.; Mitchell, J.; Bowden, D.; Clark, M.; Hall, J.; O'Driscoll, R.; Pinkerton, M.; Robertson, D. (2008). Preliminary report of the New Zealand RV Tangaroa IPY-CAML survey of the Ross Sea region, Antarctica, in February-March 2008. CCAMLR document WG-EMM-08, Hobart, Australia.

Hanchet, S.M.; Mormede, S.; Dunn, A.; Jo, H.-S. (2012). Results of a research survey to monitor abundance of pre-recruit Antarctic toothfish in the southern Ross Sea, February 2012. CCAMLR document WG-SAM-12/29, Hobart, Australia.

Hosie, G.W.; Fukuchi, M.; Kawaguchi, S. (2003). Development of the Southern Ocean Continuous Plankton Recorder Survey. Progress in Oceanography 58(2-4): 263-283.

IceCUBE (2008). Update from IceCUBE, Water & Atmosphere 16(1), p 4.

Kirkwood, J.M. (1996). The development of *Euphausia crystallorophias* in Ellis Fjord, Vestfold Hills, Antarctica. Polar Biology 16: 527–530.

Kulish, E.F.; Gordeev, I.I. (2012). Report of the 1st and the 2nd stage of research fishing conducted by Russian Federation in SSRU 882A in 2010–2012 (this is a revision of WG-SAM-12/08). CCAMLR document WG-FSA-12/15, Hobart, Australia.

Leathwick, J.R.; Elith, J.; Francis, M.P.; Hastie, T.; Taylor, P. (2006). Variation in demersal fish species richness in the oceans surrounding New Zealand: an analysis using boosted regression trees. Marine Ecology Progress Series 321: 267-281.

Lyver, P.O'B.; M. Barron; K.J. Barton; S. Gordon; D. Ainley; A. Pollard; P.R. Wilson; M.H. Pinkerton (2013). Abundance and variation in Adélie penguin (*Pygoscelis adeliae*) populations in the Ross Sea region. CCAMLR document WG-EMM-13/xx, Hobart, Australia.

Macdonald, J.A.; Barton, K.J.; Metcalf, P. (2002). Chinstrap penguins (*Pygoscelis antarctica*) nesting on Sabrina Islet, Balleny Islands, Antarctica. Polar Biology 25: 442-447.

Mann, J. (2000). Unraveling the dynamics of social life: Long-term studies and observational methods. In: Mann, J.; Connor, R.C.; Whitehead, H. (eds). Cetacean Societies: Field studies of dolphins and whales, pp. 45-64. University of Chicago Press, Chicago and London.

McNeill, S.; Barton, K. (2011). Resolutions of anomalies in the Adélie penguin semi-automated count software. Landcare Research Contract Report LC179, Lincoln, NZ, 6p.

McNeill, S.; Barton, K. (2012). Modifications of penguin counting software for validation. Landcare Research Contract Report LC866, Lincoln, NZ, 3p.

McNeill, S.; Barton, K.; Lyver, P.O'B.; Pairman, D. (2012). Semi-automated penguin counting from digital aerial photographs. International Geoscience and Remote Sensing Symposium, 24-29 July 2011, Vancouver, Canada, 4312-4314.

Mormede, S.; Dunn, A.; Hanchet, S.M.; Parker, S.J. (2013). A spatially explicit population dynamics operating model for Antarctic toothfish in the Ross Sea region. CCAMLR document WG-SAM-13/xx, Hobart, Australia.

O'Driscoll, R.L.; Macaulay, G.J.; Gauthier, S.; Pinkerton, M.H.; Hanchet, S. (2011). Distribution, abundance and acoustic properties of Antarctic silverfish (*Pleuragramma antarcticum*) in the Ross Sea. Deep-Sea Research Part II 58(1-2): 181–195.

Page, M.J.; Alcock, N.; Gordon, D.; Kelly-Shanks, M.; Nelson W.; NeiU, K.; Watson, J. (2002). Preliminary assessment of the biodiversity of benthic macrobiota of the western Ross Sea, Antarctica. Final Research Report for Ministry of Fisheries Research Project ZBD2000102 Objectives 1.2 & 3. 47 p. (Unpublished report held by the Ministry of Fisheries, Wellington, New Zealand.)

Parker, S.J.; Grimes, P.J. (2010). Length- and age-at-spawning of Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea. CCAMLR Science, 17: 53–73.

Parker, S.; Hanchet, S.M.; S. Mormede, A. Dunn (2013) Results of the second research survey to monitor abundance of pre-recruit Antarctic toothfish in the southern Ross Sea, February 2013. CCAMLR document WG-EMM-13/xx, Hobart, Australia.

Parkinson, C.L. (2002). Trends in the length of the Southern Ocean sea-ice season, 1979–99. Annals of Glaciology 34: 435–440.

Pasternak, A.F.; Schnack-Schiel, S.B. (2001). Feeding patterns of dominant Antarctic copepods: an interplay of diapause, selectivity, and availability of food. Hydrobiologia 453/454: 25–36.

Pinkerton, M.H.; Bradford-Grieve, J.M.; Hanchet, S.M. (2010a). A balanced model of the food web of the Ross Sea, Antarctica. CCAMLR Science, 17: 1–31.

Pinkerton, M.H.; Smith, A.N.H.; Raymond, B.; Hosie, G.W.; Sharp, B.; Leathwick, J.R.; Bradford-Grieve, J.M. (2010b). Spatial and seasonal distribution of adult Oithona similis in the Southern Ocean: Predictions using boosted regression trees. Deep-Sea Research I 57: 469–485.

Pinkerton, M.H.; McMillan, P.; Forman, J.; Marriott, P.; Horn, P.; Bury, S.; Brown, J. (2012). Distribution, morphology, growth, reproduction, diet and trophic position of two species of grenadier (*Macrourus whitsoni* and *M. caml*) in the Ross Sea region of the Southern Ocean (CCAMLR Subareas 88.1 and 88.2). CCAMLR document WG-FSA-12/54, Hobart, Australia.

Pinkerton, M.H.; J. Forman; S.J. Bury; J. Brown; P. Horn; R.L. O'Driscoll (2013). Diet and trophic niche of Antarctic silverfish (*Pleuragramma antarcticum*) in the Ross Sea, Antarctica. Journal of Fish Biology 82: 141–164.

Pitman, R.L.; Ensor, P. (2003). Three forms of killer whales (*Orcinus orca*) in Antarctic waters. Journal of Cetacean Research and Management 5(2): 131-139.

Plagányi, E.P. (2007). Models for an ecosystem approach to fisheries. *FAO Fish. Tech. Pap.,* 477, FAO, Rome (Italy).

Polovina, J.J.; Howell, E.A. (2005). Ecosystem indicators derived from satellite remotely sensed oceanographic data for the North Pacific. ICES Journal of Marines Science 62: 319-327.

Ponganis, P.J.; Stockard, T.K. (2007). The Antarctic toothfish: how common a prey for Weddell seals? Antarctic Science 19(4): 441-442.

Quartermain, L.B. (1964). The Balleny Islands: A descriptive and historical outline. Antarctic Division, Department of Scientific and Industrial Research, Christchurch. 42 p.

Raymond, J.A. (1975). Fishing for Antarctica's largest fish, the Antarctic cod. Marine. Technical Science Journal 9: 32-35.

Raymond, B.; Shaffer, S.A.; Sokolov, S.; Woehler, E.J.; Costa, D.P., et al. (2010). Shearwater Foraging in the Southern Ocean: The Roles of Prey Availability and Winds. PLoS ONE 5(6): e10960. doi:10.1371/journal.pone.0010960.

Reynolds, R.W.; Smith, T.M. (1994). Improved global sea surface temperature analyses using optimum interpolation. Journal of Climate 7: 929-948.

Rickard, G.J; Roberts, M.J.; Williams, M.J.M.; Dunn, A.; Smith, M.H. (2010). Mean circulation and hydrography in the Ross Sea sector, Southern Ocean: representation in numerical models. Antarctic Science 22: pp 533-558.

Sala, A.; Azzali, M.; Russo, A. (2002). Krill of the Ross Sea: distribution, abundance and demography of *Euphausia superba* and *Euphausia crystallorophias* during the Italian Antarctic Expedition (January–February 2000). Sci. Mar. 66: 123–133.

Shannon, L.J.; Coll, M.; Neira, S. (2009). Exploring the dynamics of ecological indicators using food web models fitted to time series of abundance and catch data. Ecological Indicators 9: 1078-1095.

Sharp, B.R.; Parker, S.J.; Pinkerton, M.H. (2010). Bioregionalisation and spatial ecosystem processes in the Ross Sea region. CCAMLR document WG-EMM-10/30, Hobart, Australia.

Siniff, D.B.; Ainley, D.G. (2008). Aerial surveys of Weddell seals during 2007–08, with notes on the history of aerial censuses in the Ross Sea and recommendations for continued count effort. CCAMLR document WG-EMM 08/23, Hobart, Tasmania.

Smith, W.O.; Ainley, D.G.; Cattaneo-Vietti, R. (2007). Marine ecosystems: the Ross Sea. Philosophical Transactions of the Royal Society, London B, Biological Science 362: 149-166.

Stammerjohn, S.E.; Martinson, D.G.; Smith, R.C.; Yuan, X.; Rind, D. (2008). Trends in Antarctic annual sea ice retreat and advance and their relation to El Nin˜o Southern Oscillation and Southern Annular Mode variability. Journal of Geophysical Research 113, C03S90, doi:10.1029/2007JC004269.

Stevens, D.W.; Dunn, M.R.; Pinkerton, M.H.; Forman, J.S. (2012). Diet of Antarctic toothfish (*Dissostichus mawsoni*) from the Ross Sea region, Antarctica. CCAMLR document WG-FSA-12/52, Hobart, Australia.

Sutton, P.J.H.; Bowen, M.; Roemmich, D. (2005). Decadal temperature changes in the Tasman Sea. New Zealand Journal of Marine and Freshwater Research 39: 1321-1329.

Taki, K.; Yabuki, T.; Noiri, Y.; Hayashi, T.; Naganobu, M. (2008). Horizontal and vertical distribution and demography of euphausiids in the Ross Sea and its adjacent waters in 2004/2005. Polar Biology 31: 1343–1356.

Thums, M.; Bradshaw, C.J.; Hindell, M.A. (2008). A validated approach for supervised dive classification in diving vertebrates. Journal of Experimental Marine Biology and Ecology 363: 75-83.

Timonin, V.P. (1987). Distribution pattern and age composition of larval *Euphausia superba* Dana in the Pacific and Indian Ocean sectors of the Antarctic Ocean. Biologo-Okeanografisheskie Issledovaniya Tikhookeanskogo Sektora Antarktiki 119-135.

van den Hoff, J.; Burton, H.R.; Hindell, M.A.; Sumner, M.D.; McMahon, C.R. (2002). Migrations and foraging of juvenile southern elephant seals from Macquarie Island within CCAMLR managed areas. Antarctic Science 14: 134-145.

Walters, A.R.; Lea, M.-A.; van den Hoff, J.; Field, I.C.; Virtue, P.; Pinkerton, M.; Hindell, M.A. (submitted). Identifying nutritional independence, diet and foraging habitat of recently weaned southern elephant pups using stable isotopes.

Williams, M.J. (2012). Validation and development of satellite-based observation of sea-ice thickness in the Ross Sea region. Unpublished document, NIWA, Wellington, New Zealand.

Wingham, D.J.; et al. (2006). CryoSat: a mission to determine the fluctuations in Earth's land and marine ice fields. Adv. Space Res., 37(4), 841–871 (doi: 10.1016/j.asr.2005.07.027)

Yeon, I.; Jo, H.-S; Lim, C.; Hanchet, S.M.; Lee, D.-W.; Kang, C.-K. (2012). Fatty acid analysis to infer diet of Antarctic toothfish caught in February 2012 in the southern Ross Sea. CCAMLR document WG-FSA-12/61, Hobart Australia.

Zwally, H.J.; Schutz, B.; Abdalati, W.; et al. (2002). ICESat's laser measurements of polar ice, atmosphere, ocean and land. Journal of Geodynamics 34(3–4): 405–445.

CONSERVATION MEASURE 91-XX (2013)
Ross Sea Region Marine Protected Area
Annex C

PRIORITY ELEMENTS FOR SCIENTIFIC RESEARCH AND MONITORING IN SUPPORT OF THE ROSS SEA REGION MARINE PROTECTED AREA

This Annex identifies priorities for scientific research[1] pursuant to the objectives of the Ross Sea Region MPA and monitoring to evaluate the extent to which these objectives are being achieved. Other research that is consistent with the objectives of the MPA but not explicitly outlined here, is encouraged.

1. Research and monitoring undertaken in accordance with the Research and Monitoring Plan should seek to address the following questions:

- Do the MPA boundaries continue to adequately encompass the priority populations, features and areas included pursuant of the MPA objectives?
- What are the ecosystem roles of the identified habitats, processes, populations, life-history stages, or other priority features?
- How are the priority features potentially affected by fishing, climate change, environmental variability, or other impacts?
- Does the structure and function of the marine ecosystem differ between areas inside the MPA and areas outside the MPA, or do the populations or subpopulations of marine organisms that occur or forage inside the MPA differ from those that occur or forage outside the MPA?

2. The MPA objectives fall into three main categories: representativeness, threat mitigation, and scientific reference areas. Research associated with the MPA should seek to address these categories as follows:

- Representativeness - Research and monitoring to assess whether the MPA is protecting an adequate proportion of all benthic and pelagic environments in the Ross Sea Region.
- Threat mitigation - Research and monitoring to assess the extent to which threats to the achievement of Article II (3) and the objectives of this MPA are being effectively avoided or mitigated by the MPA, in locations where the risk of ecosystem impacts from harvesting activities may otherwise be high.
- Scientific reference areas - Research and monitoring where the MPA provides opportunities to examine Antarctic marine ecosystems free from or with limited human impact, to understand, for example, the effects of fishing, environmental variability, and climate change on Antarctic marine living resources.

3. The Research and Monitoring Plan will be organized geographically, as follows:

[1] In accordance with Article VI of the CAMLR Convention.

- Ross Sea continental shelf
- Ross Sea continental slope
- Balleny Islands and vicinity
- Northern Ross Sea region and seamounts

4. Priority research and monitoring activities are identified in Table 1. Members are encouraged, as far as possible, to collaborate and repeat the types of activities identified in Table 1.

5. The Scientific Committee will evaluate results arising from research and monitoring activities and advise the Commission on:

- the degree to which the specific objectives of the MPA are being achieved;
- the degree to which the specific objectives are still relevant in different areas of the MPA; and
- what management actions may be required to improve the achievement of the objectives for this MPA.

Table 1. Priority elements for scientific research and monitoring associated with the Ross Sea Region Marine Protected Area

Type of Research	Ross Sea continental shelf	Ross Sea continental slope	Balleny Islands and vicinity	Northern Ross Sea Region and seamounts	Priority elements
Ecosystem	✔	✔	✔	✔	Directed studies to address biological and ecological questions related to species demography and life history
	✔	✔	✔		Monitoring and research on pinnipeds and seabirds, including studies of reproductive biology and success as well as diets and foraging dynamics
	✔	✔	✔	✔	At-sea surveys or censuses to estimate the distribution and abundance of marine mammals, seabirds, fishes and invertebrates
	✔	✔	✔		Acoustic surveys to map distribution and abundance of Antarctic silverfish and krill, including dedicated research on silverfish in Terra Nova Bay
	✔	✔	✔		Radio and archival tagging, remote sensing and shore-based population censuses of marine mammals and seabirds
	✔	✔	✔		Ecosystem modelling, informed by diet and stable isotope sampling of key trophic components
	✔	✔			Targeted sampling of Ross Sea shelf and slope communities with focus on middle trophic level organisms
	✔				Investigate oceanographic drivers of phaeocystis- vs. diatom-dominated

Type of Research	Ross Sea continental shelf	Ross Sea continental slope	Balleny Islands and vicinity	Northern Ross Sea Region and seamounts	Priority elements
					production and consequences for higher-level trophic ecosystem function
				✔	First vessel-based surveys of demersal fish and benthic communities of Pacific-Antarctic fracture zone
				✔	Repeat surveys of Admiralty and Scott seamounts
Fisheries	✔				Continued annual survey for pre-recruit toothfish in southern Ross Sea shelf; see SC-CAMLR-XXX/7
	✔	✔		✔	Focused tag deployments and/or electronic archival or acoustic tags to examine/ validate toothfish life-cycle, abundance, movement and behavioural hypotheses
		✔		✔	Paired stratified surveys of fished vs. unfished slope and seamount habitats to monitor effects of fishing on Antarctic toothfish and demersal fishes
	✔	✔	✔	✔	Surveys and sampling to investigate life history hypotheses and biological parameters, including stock structure, of Antarctic toothfish
			✔		Targeted surveys to investigate the importance of the Balleny Islands as a potential nursery area for Antarctic silverfish and Antarctic toothfish
				✔	Winter surveys to improve knowledge of spawning and eggs/larvae/early life stages of Antarctic toothfish
Climate change / oceanography	✔	✔	✔	✔	Meteorological and oceanographic research, including satellite remote sensing, to characterize physical properties and dynamics of phytoplankton and zooplankton.
	✔	✔	✔	✔	Sea-ice remote sensing (type, concentration and extent)
	✔	✔		✔	Long-term monitoring of benthic ecosystem function
	✔	✔	✔		Development and validation of high resolution circulation model of the Ross Sea shelf and slope (e.g. ROMS), including resolving effects of sea-ice (especially polynyas), ice shelf cavity, cross-shelf exchange and deep bottom-water formation in the Ross Sea. Addition of biological model
	✔	✔			Investigate deep bottom water formation (relevant to global oceanic circulation), slope water intrusion and cross-shelf nutrient exchange