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The Ross Sea region Marine Protected Area Research and Monitoring Plan

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Summary

1. Conservation Measure (CM) 91-05 requires that research and monitoring associated with the Ross Sea region Marine Protected Area (RSRMPA) deliver 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
- (iii) what management actions may be required to improve the achievement of the objectives for this MPA.

2. The specific objectives for the RSRMPA fall into three main categories: representativeness, threat mitigation and scientific reference areas (CM 91-05, Annex 91-05/C, paragraph 2). Research associated with the RSRMPA should seek to address these categories as follows.

- (i) representativeness – research and monitoring to assess whether the RSRMPA is protecting an adequate proportion of all benthic and pelagic environments in the Ross Sea region
- (ii) threat mitigation – research and monitoring to assess the extent to which threats to the achievement of Article II.3 and the specific objectives of the RSRMPA are being effectively avoided or mitigated by the MPA, in locations where the risk of ecosystem impacts from harvesting activities may otherwise be high
- (iii) scientific reference areas – research and monitoring where the RSRMPA provides opportunities to examine Antarctic marine ecosystems where no, or limited, fishing has taken, or is taking, place, to understand, for example, the effects of fishing, environmental variability and climate change on Antarctic marine living resources.

3. Research and monitoring undertaken in accordance with this Research and Monitoring Plan should also seek to address the following questions (CM 91-05/C, paragraph 1).

- (i) Do the boundaries of the RSRMPA continue to adequately encompass the priority populations, features and areas (see the features listed in paragraph 1 of CM91-05/B, and reproduced in Appendix 1) included pursuant of the MPA specific objectives?
- (ii) What are the ecosystem roles of the identified habitats, processes, populations, life-history stages, or other priority features?
- (iii) How are the priority features potentially affected by fishing, climate change, environmental variability, or other impacts?

(iv) Does the structure and function of the marine ecosystem differ between areas inside and outside the RSRMPA, or do the populations or subpopulations of marine organisms that occur or forage inside the RSRMPA differ from those that occur or forage outside this protected area?

4. Research topics intended to help satisfy the requirements of paragraphs 1 to 3 above are identified in Tables 1 and 2 below. The link between the RSRMPA specific objectives and the associated mapped features and populations of priority for protection are given in Table 3, with the distribution maps given in the Appendix.

4bis. Members are encouraged to collaborate and address the topics identified in the Table 1 and 2. As needed, Tables 1 and 2 shall be updated to reflect progress in implementing this Research and Monitoring Plan. The topics identified in Tables 1 and 2 are not exhaustive; other topics may be added to these tables.

5. Scientific research and monitoring conducted pursuant to this Research and Monitoring plan shall be open and transparent. All interested Members are encouraged to collect, access and analyse data, including baseline data, indicators of scientific effort and progress, and indicators that describe ecosystem outcomes and services that derive from this plan. These data collected pursuant to this plan will be used as a basis to evaluate the effectiveness of the RSRMPA.

6. The data collected by any Member shall be standardised where appropriate and made available to all Members directly or via the Secretariat consistent with the Rules for Access and Use of CCAMLR Data (CM 91-05/C). Timelines for establishing baseline data and indicators needed to evaluate the effectiveness of the RSRMPA are included in this plan.

7. This Research and Monitoring Plan is intended to be flexible, enabling, focused on achievement of management objectives, and useful for evaluating the RSRMPA. The Research and Monitoring Plan is intended to be a 'living' document that will develop and evolve over time as information is collected, new questions raised and new techniques developed.

Table 1. Research and monitoring topics that address the questions posed in Annex 91-05/C, paragraph 1, emphasize work throughout the various geographic areas within the Ross Sea region, and are directly relevant to the specific objectives of the RSRMPA. Topic identification numbers (IDs) also appear in Table 2, where they characterise how each of the topics listed here links to the specific objectives of the RSRMPA. Values in parentheses, and following the text description of each topic indicate how that topic aligns with the "priority elements" identified in Annex 91-05/C; the values in parentheses indicate row numbers from Annex 91-05/C, Table 2. Members are encouraged to address other topics that do not appear in this list but which link to the specific objectives of the RSRMPA.

ID	Research and monitoring topics	Questions identified in CM 91-05/C, paragraph 1
Topics that are relevant to the entire RSR		
1	Bioregionalisation and mapping biodiversity (3, 9, 10)	(i)–(iv)
2	Physical and biological changes to important habitats, including those related to ocean circulation (and acidification), sea-ice, variations and trends in primary production and carbon sequestration, and climate change (18, 19, 21, 22)	(i)–(iv)
3	Functional ecology (i.e. process studies to understand the origin of ecological patterns and processes at all scales) (1, 2, 5, 6–8, 12, 14, 17)	(i)–(iv)

4	Evolutionary biology (i.e., process studies to understand the origin of observed patterns in biodiversity) (1, 14, 17)	(i)–(iv)
5	Effects of spatio-temporal variation in fishing effort, tagging rates, and fish movement on the Antarctic toothfish stock assessment (11–14)	(iii)
Topics that emphasize the continental shelf and slope in the General Protection Zone (GPZ), Special Research Zone (SRZ), and areas outside the RSRMPA*		
6	Trends in Antarctic krill, crystal krill, and Antarctic silverfish populations and demographic processes in relation to physical drivers, climate change, and possible fishery effects (1, 4, 6, 7)	(iii), (iv)
7	Effects of changes in the availabilities of Antarctic krill, crystal krill, Antarctic silverfish, and Antarctic toothfish on their respective predators (e.g., Adélie and emperor penguins, Weddell seals, and Type C killer whales) in relation to fishing, physical forcing, and climate change, including effects on colony locations, abundance, condition, life history, foraging ecology, and demography (1–7)	(iii), (iv)
8	Distributions and movements of Antarctic toothfish and their predators among habitats in the Ross Sea region and neighbouring regions (e.g. the Amundsen Sea) in relation to their respective ontogenies and population structures and possible fishing and environmental effects (1, 3, 5, 12, 14)	(i), (iii), (iv)
9	Vertical and seasonal distributions of Antarctic toothfish, with effects on availability to capture by predators and fisheries (1, 2, 5, 6, 12)	(ii)
10	Dependence of Antarctic krill, crystal krill, Antarctic silverfish, and their predator populations on key coastal habitats (1–7, 12)	(ii), (iii)
11	Population structure (including genetic variation), distribution, and ecological roles of Antarctic toothfish in the coastal margins and southern shelf compared to the continental slope and other offshore areas (1, 6, 9, 11, 12, 14)	(i), (ii), (iv)
12	Factors necessary for successful Antarctic silverfish spawning, including spatio-temporal distribution of spawning and nursery areas (4, 7, 15)	(ii), (iii)
13	Factors responsible for spatio-temporal patterns of enhanced trophic productivity at retreating marginal ice edges and in polynyas within context of climate change (1, 6, 8, 18, 19, 21, 22)	(ii), (iii)
14	Variation in Antarctic toothfish recruitment, with links to environmental effects, ecological factors, and fishing (1, 6, 14, 16, 18)	(ii), (iii)
15	Importance of areas under sea ice and the Ross Ice Shelf and other ice shelves for Antarctic krill, crystal krill, Antarctic silverfish, and Antarctic toothfish, e.g. for dispersal or protection from mammalian predators (1–7, 12, 14, 18, 19, 21)	(ii)
16	Factors affecting the spatio-temporal distribution, abundance, density, swarming behaviour, and swarm composition of Antarctic krill, and extent to which these patterns affect or reflect the top-down effects of niche differentiation by pelagic top predators and fisheries (1–7, 17–19, 21, 22)	(ii), (iii), (iv)
17	Movements and foraging requirements of crabeater seals and emperor penguins in the eastern Ross Sea region (1–7, 17, 19)	(ii), (iii)
18	Composition, abundance, condition, and ecology of the demersal fish community, including effects of predation by Antarctic toothfish and of different toothfish densities (1, 3, 7, 12–14)	(ii), (iii), (iv)
19	Effects of local exploitation rates and variations in Antarctic toothfish density on the size, condition, age composition, growth, and ecological roles of toothfish (1, 3, 6, 11, 13, 14)	(ii), (iii), (iv)
20	Potential Antarctic toothfish spawning on the Ross Sea slope (1, 3, 14, 16)	(ii)
21	Structure, function, distribution, diversity, and abundance of benthic communities, including potential fishing impacts on benthic invertebrates and prevalence of vulnerable marine ecosystems (1, 3, 6, 20)	(i)–(iv)
22	Ecological role of Antarctic krill in demersal slope environment (1, 2, 4, 5, 17, 20)	(ii)
Topics that emphasize the Balleny Islands and vicinity		
23	Dependence of local biota on habitats, sea-ice, and oceanographic conditions occurring around the Balleny Islands, including likely effects of climate change (1–6, 14, 15, 18, 19)	(ii), (iii)
24	Pelagic prey targeted by mobile top predators in the vicinity of the Balleny Islands, including the foraging ecology of cetacean stocks (e.g. East Australian humpback whales) and their dependence on these prey resources (1–6)	(ii), (iii)
25	Historic and climate factors accounting for the presence and abundance of chinstrap penguins and other air breathing predators at the Balleny Islands (1, 2, 5, 6)	(ii), (iii)
26	Potential endemic or regionally anomalous benthic communities associated with the Balleny Islands (1, 3, 9, 10)	(i)
27	Potential importance of the Balleny Islands as nursery areas for Antarctic toothfish and Antarctic silverfish, including population structures relative to, and connectivities with, other areas in the RSR (1, 3, 4, 7, 12, 14–16)	(ii)
Topics that emphasise seamounts in the GPZ and northern RSR		

28	Timing, frequency, and duration of Antarctic toothfish spawning migrations to the northern Ross Sea region, including sex-specific effects, potential spawning-site fidelity, potential effects on stock assessment, and physical drivers (1, 3, 9, 10, 12, 14–16)	(ii)–(iv)
29	Spawning behaviour and dynamics of Antarctic toothfish, including trends in abundance of fish in various body conditions (e.g. “axe-handle” fish) and potential effects on spawning performance due to localised changes in toothfish density, changes in toothfish sex ratio, potential disruption by fishing activity, exposure to top predators, and climate change (1, 3, 9, 10, 12–14, 16, 18)	(ii)–(iv)
30	Factors affecting recruitment of Antarctic toothfish, including egg and larval advection and dispersal, post-larval settlement, and physical drivers (1, 3, 9, 12, 14–16, 18, 19, 21)	(ii)–(iv)
31	Environmental factors and physical drivers that determine the distribution and abundance of benthic organisms and community diversity on seamounts, including potential effects of climate change (1, 3, 9, 10, 20)	(iii), (iv)
32	The potential importance of benthic habitats and invertebrate communities to Antarctic toothfish (1, 3, 7, 9, 10, 12, 14, 20)	(ii)
33	Endemic or regionally endemic benthic communities associated with the environmental setting and geographical positions of seamounts, including Scott and Admiralty seamounts (1, 3, 9, 10, 18, 20)	(i), (iv)
34	The distribution and stock structure of Antarctic toothfish on Scott and Admiralty seamounts, around the Balleny Islands, in northwestern and northeastern seamount areas, and further north into the South Pacific (north of 60°S) (1, 3, 9, 10, 12, 14–16)	(i), (iv)

Topics that emphasise the KRZ and northwestern RSR

35	The dependence of pelagic top predators on localized, predictable hotspots of krill abundance and krill swarm composition, and potential impacts from local competition with fisheries (1–5, 6, 17–19, 21)	(ii), (iii)
36	Relative distributions, biomasses, and ecological roles of Patagonian and Antarctic toothfish in the northwestern Ross Sea region, and likely effects of fishing (1, 3, 6, 9, 12, 14, 16)	(i)–(iii)
37	Representativeness of benthic habitats in the northwestern Ross Sea region (3, 9, 20)	(i), (iv)
38	Spatial dynamics and demography of Antarctic krill, including physical drivers and effects of climate change (1, 3, 4, 6, 8, 17–19, 21, 22)	(ii), (iii)

*Comparative analyses of similar data collected from the GPZ, the SRZ, and similar habitats outside the RSRMPA will, given different local harvest rates, provide the spatial framework needed to “better gauge the ecosystem effects of climate change and fishing” as per specific objective (ii) of the RSRMPA.

Table 2. Linkages among the research and monitoring topics identified in Table 1, the specific objectives of the RSRMPA, and the geographic locations identified in the RSRMPA Management Plan (Annex 91-05/B). The contents of most cells are topic identification numbers from Table 1. Specific objectives and associated priority features for protection are as listed in Table 3; associated mapped distributions are as shown in Appendix 1, Figures 1 to 10. Cells filled in black indicate potentially implausible or impossible objective-location combinations (e.g., combinations that are not physically possible, like those between objective (x)e, southern McMurdo Sound, and all locations other than the continental shelf in the General Protection Zone). GPZ = General Protection Zone; SRZ = Special Research Zone; KRZ = Krill Research Zone; Shelf = continental shelf; Slope = continental slope; Blvicinty = Balleny Islands and vicinity; NSmts = northern seamounts; ScottSmt = Scott Seamount; EastRS = eastern Ross Sea, NW = northwestern Ross Sea region; and Outside = areas outside the RSRMPA.

	GPZ						SRZ		KRZ*	
Objective	Shelf	Slope	Blvicinty	NSmts	ScottSmt	EastRS	Shelf	Slope	NW	Outside
(i)	see the entries below									
(ii)	18	18, 19, 21					5, 8, 18	5, 8, 18, 19, 21		5, 8, 18, 19, 21
(iii)**	3, 4	3, 4	3, 4	3, 4, 36, 37	3, 4	3, 4	3, 4	3, 4	3, 4	3, 4, 13, 14, 28, 29, 30, 32, 33, 34
(iv)a	1, 2	1, 2	1, 2	1, 2, 31	1, 2, 31	1, 2	1, 2	1, 2	1, 2	1, 2, 31
(iv)b	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2
(v)a	2, 13, 15, 16	2, 13, 15, 16	23			2, 13, 15, 16	2, 13, 15, 16	2, 13, 15, 16		2, 13, 15, 16
(v)b				2, 7, 16, 22, 30, 35, 38					2, 7, 16, 22, 30, 35, 38	2, 7, 16, 22, 30, 35, 38
(v)c			23, 24, 25, 27, 32							
(v)d	13					13	13			
(v)e						17				
(vi)a		7, 10, 15, 22	7, 15			7, 15		7, 15, 22	7, 10, 15, 22	7, 10, 22
(vi)b	7, 10, 15					7, 10, 15	7, 15			
(vi)c	7, 10, 12, 15, 27					7, 10, 12, 15, 27	7, 12, 15, 27			
(vii)a	6, 10	6	6						6, 10	6
(vii)b	6, 10	6				6, 10, 17			6, 10	6
(vii)c	6, 9, 10	6, 9				6, 9, 10	6, 9	6, 9	10	6, 9
(vii)d	6, 9, 10	6, 9				6, 9, 10	6, 9	6, 9	10	6, 9
(viii)a	10, 13									
(viii)b	10					10			10	
(viii)c	10, 11, 12									
(viii)d	10									
(viii)e	13						13			13
(ix)a	5, 8, 9, 11, 18, 32									
(ix)b	5, 8, 9, 11, 18, 32						5, 8, 9, 11, 18, 32			

(ix)c		5, 8, 9, 11, 18, 19, 20, 21, 32						5, 8, 9, 11, 18, 19, 20, 21, 32		5, 8, 9, 11, 18, 19, 20, 21, 32
(x)a			23, 26							
(x)b			33	31, 33	33					
(x)c	21, 26	21, 26								
(x)d	21	21				21				
(x)e	10, 11									
(x)f					31					
Xi									16, 35, 36, 38	

*Many of the specific features and processes illustrated in Annex 91-05/C X do not necessarily occur within the KRZ. However, many research and monitoring topics are applicable to the KRZ, and those are indicated here.

**All research and monitoring topics indicated in this table will nominally support achievement of specific objective (iii). However, topics listed in this row are either relevant to habitats and processes outside the MPA that have not been mapped (e.g., potential spawning habitats of Antarctic toothfish on the seamounts along the Pacific–Antarctic Ridge), life-history studies that are difficult to link to a specific objective but are mandated by Annex 91-05/C (e.g., Topic 36), or cannot be linked to other objectives until specific projects are proposed and implemented (e.g., in the cases of Topics 3 and 4).

Background

8. This Research and Monitoring Plan is organised geographically with reference to the following areas (see Figure 1):

- (i) the Ross Sea continental shelf
- (ii) the Ross Sea continental slope
- (iii) the Balleny Islands and vicinity
- (iv) the northern Ross Sea region and seamounts
- (v) the northwestern Ross Sea region

9. A summary of the process by which the Ross Sea region MPA was developed was described in SC-CAMLR-XXXIII/BG/23. Subsequent development was described in the text of the Commission reports from 2015 and 2016.

RSRMPA projects

10. A list of RSRMPA projects will be developed and be an integral component of this Research and Monitoring Plan. The RSRMPA project list will detail the projects that Members have proposed, are undertaking, or have undertaken to address the topics listed in Tables 1 and 2. The RSRMPA project list will be an electronic database that will describe the following information about each project:

- (i) principal scientist and point of contact
- (ii) project summary or abstract
- (iii) geographic area
- (iv) specific objectives and priority features (from CM 91-05/B) to be addressed
- (v) specific baseline data for the topic and hypothesis
- (vi) specific indicators that describe outcomes

- (vii) when the research will or has taken place
- (viii) what data will be or has been collected
- (ix) location of data archive and conditions of data access

11. The RSRMPA project list will be searchable by Members and the Secretariat and provide functionality that facilitates scientific transparency and collaboration, provision of effort indicators (see “Indicators” below), and provides links to the RSRMPA Data Repository (see “Data Management” below).

11bis. RSRMPA projects proposed by Members shall be submitted for evaluation by the Scientific Committee or its subsidiary bodies and must be endorsed by the respective Commissioner or Scientific Committee Representative. Members are encouraged to submit Projects as early as possible in order to facilitate collaboration and minimise unnecessary duplication of scientific effort.

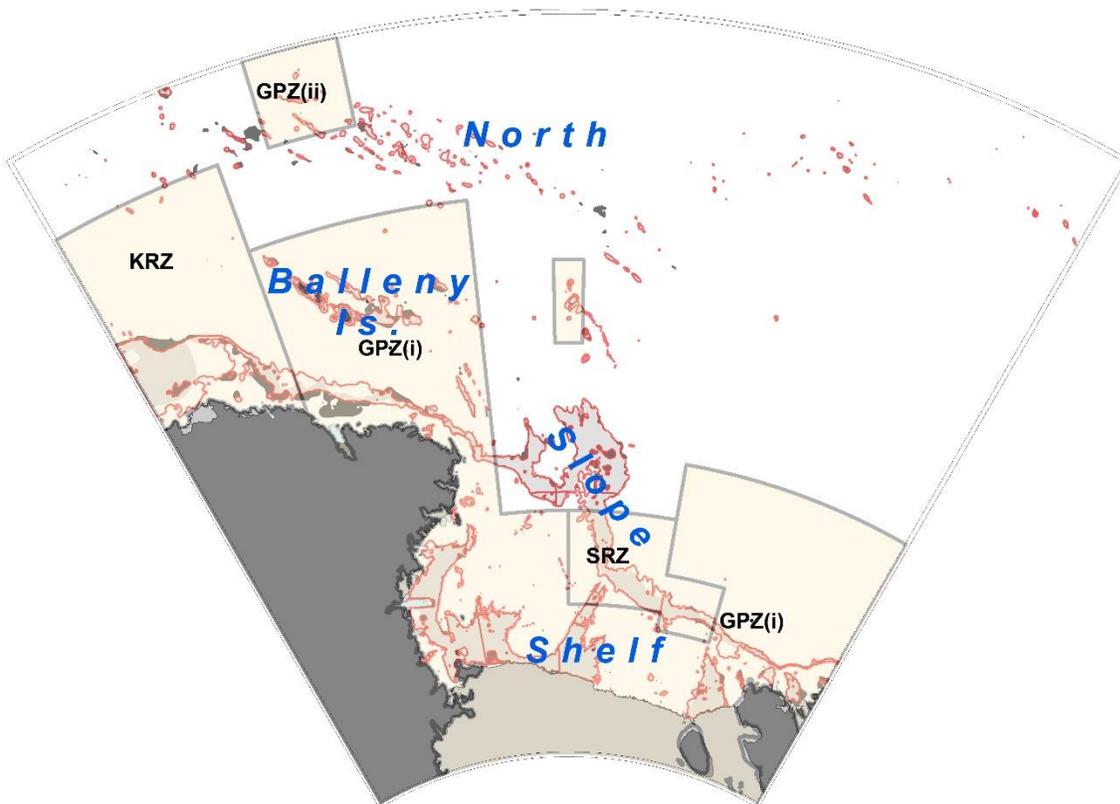


Figure 1: The Ross Sea region Marine Protected Area, and geographic areas for the organisation of the Research and Monitoring Plan as specified in CM 91-05/C. GPZ = General Protection Zone; SRZ = Special Research Zone; KRZ = Krill Research Zone. [INSERT NEW MAP SHOWING GEOGRAPHIC AREAS]

Objectives of the RSRMPA and the priority research questions

12. The specific objectives of the RSRMPA are listed in CM 91-05 (paragraph 3) and given in Table 3. These fall into three main categories: *representativeness*, *threat mitigation*, and *scientific reference areas* (CM 91-05, Annex 91-05/C, paragraph 2).

Table 3: The RSRMPA specific objectives and associated mapped features or populations of priority for protection within the MPA (spatial distributions are shown in Appendix1, Figures 1 to 10). The category of protection objective, including (for threat-based objectives) the nature of the likely potential threat from fishing, and the corresponding level of protection sought for each feature or population during the MPA planning process, are also shown for each priority feature or area.

R = Representativeness; S = Scientific Reference Area; T1 = direct impact from existing or potential toothfish fisheries; T2 = plausible trophic interaction with existing or potential toothfish fisheries; T3 = direct impact from potential future krill fishery; T4 = plausible trophic interaction with future krill fishery. Note that objectives (ii) and (xi) apply to the entire MPA but in particular to the SRZ and KRZ respectively.

Specific objective	Sub-objective	Description and boundary of priority feature or area	Geographic area	Category of MPA objective	MPA zone
(i) conserve natural ecological structure		All	All	All	All areas
(ii) scientific reference areas		Special Research Zone (SRZ)	Slope	S	SRZ
(iii) promote research		All	All	All	All areas
(iv) representativeness of benthic and pelagic environments		Benthic bioregionalisation	All	R	All areas
		Pelagic bioregionalisation	All	R	All areas
(v) large-scale ecosystem processes/ areas					
	a	Ross Sea shelf front intersection with seasonal ice	Slope	T ₄	GPZ (i)
	b	Polar Front	North	-	GPZ (ii)
	c	Balleny Islands and proximity	Balleny	T ₁ ,T ₂ ,T ₃ ,T ₄	GPZ (i)
	d	Ross Sea polynya Marginal Ice Zone	Shelf	T ₄	GPZ (i)
	e	Eastern Ross Sea multi-year ice	Slope	T ₄	GPZ (i)
(vi) tropically dominant pelagic prey species					
	a	Antarctic krill core distribution	Slope	T ₃	GPZ (i)
	b	Crystal krill core distribution	Shelf	T ₃ ,T ₄	GPZ (i)
	c	Antarctic silverfish core distribution	Shelf	T ₂ ,T ₄	GPZ (i)
(vii) key top predator foraging distributions					
	a	Adélie penguin summer core foraging distribution	Shelf	T ₄	GPZ (i)
	b	Emperor penguin summer core foraging distribution	Shelf	T ₄	GPZ (i)
	c	Weddell seal summer core foraging distribution	Shelf	T ₂	GPZ (i)
	d	Type C killer whale core summer foraging distribution	Shelf	T ₂	GPZ (i)
(viii) coastal/localized areas of particular ecosystem importance					
	a	Southern Ross Sea shelf persistent winter polynya	Shelf	T ₂ ,T ₄	GPZ (i)
	b	Coastal polynyas	Shelf	T ₂ ,T ₄	GPZ (i)
	c	Terra Nova Bay (including the TNB polynya)	Shelf	T ₁ ,T ₂ ,T ₃ ,T ₄	GPZ (i)
	d	Victoria coast – coastal buffer and platelet ice formation	Shelf	T ₁ ,T ₂ ,T ₄	GPZ (i)
	e	Pennell Bank polynya	Shelf	T ₂ ,T ₄	GPZ (i)
(ix) <i>D. mawsoni</i> life cycle areas					
	a	Sub-adult toothfish settlement areas on the Ross Sea shelf	Shelf	T ₁ ,T ₂	GPZ (i)

	b	Dispersal trenches for maturing toothfish	Shelf	T ₁ ,T ₂	GPZ (i)
	c	Adult feeding areas on the Ross Sea continental slope	Slope	T ₁	GPZ (i)
(x) rare or vulnerable benthic habitats	d	Toothfish spawning/life cycle	North (+ others)	-	GPZ (ii)
	a	Balleny Islands and adjacent seamounts	Balleny Is	T ₁	GPZ (i)
	b	Admiralty Seamount	North	T ₁	GPZ (i)
	c	Cape Adare proximity continental slope	Slope	T ₁	GPZ (i)
	d	Southeast Ross Sea continental slope	Slope	T ₁	GPZ (i)
	e	Southern McMurdo Sound	Shelf	T ₁	GPZ (i)
	f	Scott Seamount	North	T ₁	GPZ (iii)
(xi) promote research of Antarctic krill		Krill Research Zone (KRZ)	Northwest	S	KRZ

13. The link between the priority research questions for the RSRMPA Research and Monitoring Plan and the specific objectives in each geographic area are identified in Table 3.

- (i) *Do the MPA boundaries continue to adequately encompass the priority populations, features, and areas included pursuant of the MPA objectives?*

14. The boundaries of the RSRMPA were designed to meet the specific objectives listed in CM 91-05 by encompassing, in whole or in part, the mapped priority features summarised in Table 1 and given in the figures in Appendix 1. Research to improve or validate these mapped distributions and to assess adequacy of protection targets is a high priority.

- (ii) *What are the ecosystem roles of the identified habitats, processes, populations, life-history stages, or other priority features?*

- (iii) *How are the priority features potentially affected by fishing, climate change, environmental variability, or other impacts?*

15. Accurately determining the potential effects of fishing, and distinguishing these from environmental drivers (including climate change) or effects from other human activities requires knowledge of the ecological relationships between the feature or population protected and other components of the ecosystem.

16. As many of the species in question are mobile and the Ross Sea environment varies seasonally and annually, knowledge of inter-species interactions will need to account for seasonal life-cycle movements and spatio-temporally dynamic resource requirements (e.g., prey) in time and space. Such knowledge was used in the design of the RSRMPA. For example, objectives to protect top predator foraging areas (specific objectives (vi)a-(vi)d) focused on those times and locations where predators are likely to depend on the species that are targeted by fisheries. Research to better understand trophic processes occurring in key locations, and their importance at the wider ecosystem scale, is a high priority.

17. Some priority features refer to dynamic but relatively predictable oceanographic fronts or ice dynamics (e.g., specific objectives (v) and (viii)); these features were used as proxies for species that are dependent upon them. For example, specific objectives (v)a, (v)d, and (viii)b are intended to protect pelagic top predators preferentially foraging in those locations from localised competition with krill fisheries. In the Ross Sea region MPA, priority features have been defined with respect to ecosystem processes and key prey species (specific objective (vi)). Where predator species are subject to additional

spatial constraints on their foraging in key periods, (i.e., because they are constrained to the vicinity of coastal breeding colonies) these species are mapped separately (e.g., specific objective (vii)).

- (iv) *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?*

18. The threat-based objectives (specific objectives (v)–(x)) seek to anticipate and prevent the ecosystem effects of fishing that may otherwise impair achieving the requirements of Article II.3. For the RSRMPA to be successful, these kinds of effects should not occur; accordingly, the RSRMPA seeks to protect a high proportion of the area in which these kinds of effects are thought to be likely. In contrast, under specific objective (ii) the RSRMPA was designed to allow comparison of the effects of toothfish fishing by establishing a controlled comparison between areas with lower local exploitation rates in the SRZ versus those in areas outside the MPA. At the same time, toothfish fishing in the SRZ was also designed to maintain the continuity and integrity of the toothfish tagging program used for assessing toothfish abundance, and to improve understanding of toothfish distribution and movement (CM 91-05/B, paragraph 1(ii)).

Life history research for targeted populations

19. Research into toothfish spawning is a high priority within this Research and Monitoring Plan. The life cycle of Antarctic toothfish includes portions of all of the geographic areas in the Ross Sea region. The research to better understand toothfish movements and life cycle in all areas is included in Tables 1 and 2, including in areas outside the RSRMPA and where there are no toothfish-specific RSRMPA objectives. A summary of toothfish research priorities within the Ross Sea region, supported by the CCAMLR Scientific Committee, is given in WG-FSA-14/60 (SC-CAMLR-XXXIII, paragraph 3.209). Toothfish surveys and other research activities proposed in that document are a high priority, in areas both inside and outside the RSRMPA.

Supporting research

20. A large amount of potential research is not specifically included in this plan. Research to answer the research and monitoring topics listed in Table 1 will need to include supporting science from a range of disciplines not focused on the particular questions required for evaluation of the specific objectives of the RSRMPA (e.g. climate, oceanography, and sea-ice dynamics). Supporting research of this nature, (including the development of new technologies) that contributes to, but does not directly address, the topics in Table 1 is nonetheless a high priority and should be described in the RSRMPA Project List.

Implementation

Baseline data

21. Baseline data will be used to assess changes and whether the RSRMPA is achieving its specific objectives. A large amount of baseline data already exist. Some of these data were used to develop the RSRMPA and the distribution maps provided in Appendix 1. Additional, baseline data also exist and are reported in the literature. Several documents submitted to working groups and workshops of the Scientific Committee (e.g., WG-EMM-10/11, WG-EMM-10/30, and WS-RMP-17/03) contain bibliographies or citation lists that indicate where baseline data can be found. Members are encouraged to collate these data and make them available to the Scientific Committee in advance of the first review

by Scientific Committee of Members activities related to the RSRMPA Research and Monitoring Plan in 2022 (CM 91-05 para. 15).

22. New baseline data will also be collected. These new data will be needed to provide context for new research and monitoring projects that address the topics listed in Tables 1 and 2. The nature and characteristics of these baseline data will be determined by the objectives of the research and monitoring projects that are funded and executed. The likelihood of detecting change can often be increased by collecting baseline data as soon as possible, as change either cumulates over a longer period or the probability of observing a measurable change during the period will increase. Thus, Members are encouraged to collect and report to Scientific Committee or its subsidiary bodies, new baseline data as soon as possible within the timeline of their funded projects. In many cases, data collected for one project can be used as baseline data for subsequent projects. For example, if the results of a project quantifies interannual variation in the biomass or abundance of a particular species, results from a subsequent project might be used to determine whether that variation has changed. Members are encouraged to undertake projects that leverage previously completed work. To ensure that Members consider these issues and identify the baseline data relevant to future projects, a field for describing these data is included in the RSRMPA Project List.

22 bis. Members are encouraged to develop standardised sampling, data collection, and analysis method protocols to facilitate scientific transparency, collaboration between scientists, and the utility of data for use across projects.

Indicators

23. Two categories of indicators will be used to assess the RSRMPA: indicators of scientific effort and progress, and indicators that describe ecosystem outcomes and services. As with the baseline data, some indicators have already been identified (see below), and others will be relevant to projects that have yet to be undertaken.

24. Indicators of scientific effort and progress will be used to assess whether the Membership has demonstrated a commitment to the RSRMPA and acted in good faith. These indicators will also enable the Scientific Committee to assess whether the degree to which specific objectives (ii), (iii), and (xi) of the RSRMPA are being achieved. Members are encouraged to develop and identify additional indicators for consideration by the Scientific Committee.

24bis. The Secretariat will annually query the RSRMPA Project List to compute and report to the Scientific Committee the following indicators of scientific effort and progress since the introduction of the MPA (see Reporting below):

- (i) number of research and monitoring topics listed in Table 1 that have been addressed in projects conducted by Members,
- (ii) number of research and monitoring projects that link to each specific objective of the RSRMPA,
- (iii) number of research and monitoring projects that link to each of the geographic areas identified in Table 2,
- (iv) number of datasets made readily available to the Membership as an outcome of research and monitoring projects conducted pursuant to this plan
- (v) an indicator similar to the common *h*-index (*Hirsch index*, Hirsch (2005)) to be calculated based on advice from the Scientific Committee, that synthesizes the overall impact, to the Antarctic

science community, of the set of research and monitoring projects conducted pursuant to this plan.

26. Indicators that describe ecosystem outcomes and services will be used to track changes in the structure and function of the Antarctic marine ecosystem within the Ross Sea region. These indicators will also facilitate assessments of the degree to which specific objectives (i) and (iv)–(x) of the RSRMPA are being achieved. Members are encouraged to develop and identify additional indicators for consideration by the Scientific Committee.

26bis. Members are encouraged to compute, for each geographic area in the Ross Sea region (including areas outside the RSRMPA and by zone within the RSRMPA), and update the following indicators that describe the status and condition of key populations as frequently as possible:

- (i) numbers of nesting pairs of Adélie and emperor penguins
- (ii) numbers of Weddell seals and Type C killer whales
- (iii) biomasses of Antarctic krill, crystal krill, Antarctic silverfish, and Antarctic toothfish
- (iv) densities of benthic communities containing taxa that comprise vulnerable marine ecosystems

25. The Secretariat will also annually report on the total catches, by zone within the RSRMPA, of Antarctic krill and toothfish to the Scientific Committee or an appropriate subsidiary body in its annual report (see Reporting below).

Data management

27. The Secretariat will provide a transparent mechanism to catalogue and share data collected pursuant to this plan. An RSRMPA Data Repository will be developed that (i) links to the RSRMPA Project List to identify locations (e.g. URLs) where relevant data is deposited in open access data catalogues and (ii) houses data that cannot be found elsewhere. The RSRMPA Data Repository will be accessible to all Members.

Reporting

27bis The Secretariat will provide an annual summary of activities under the RSR MPA Research and Monitoring plan to the Scientific Committee of the projects in the Project List, baseline data that has been submitted, annual catches of Antarctic krill and toothfish, and provide summaries of updates on the indicators of scientific effort and progress, and indicators that describe ecosystem outcomes and service.

References

- Hirsch, J.E. (2005). An index to quantify an individual's scientific research output. PNAS, vol. 102, no. 46, 16569–16572, doi: 10.1073/pnas.0507655102.
- 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 Antarctic waters of CCAMLR Statistical Area 68. CCAMLR Science 15: 35–54.

Appendix 1: Figures and tables

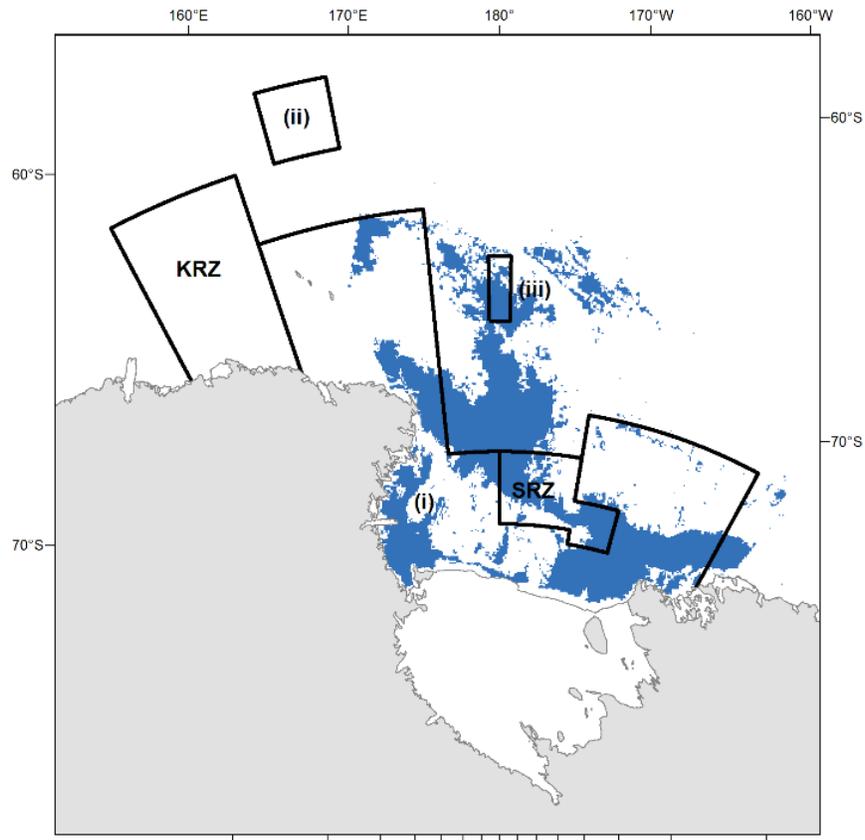


Figure 1: Habitats that are important to native mammals and birds as per objective (i) (updated from SC-CAMLR-XXXIII/BG/23 Rev. 1, Figure 1).

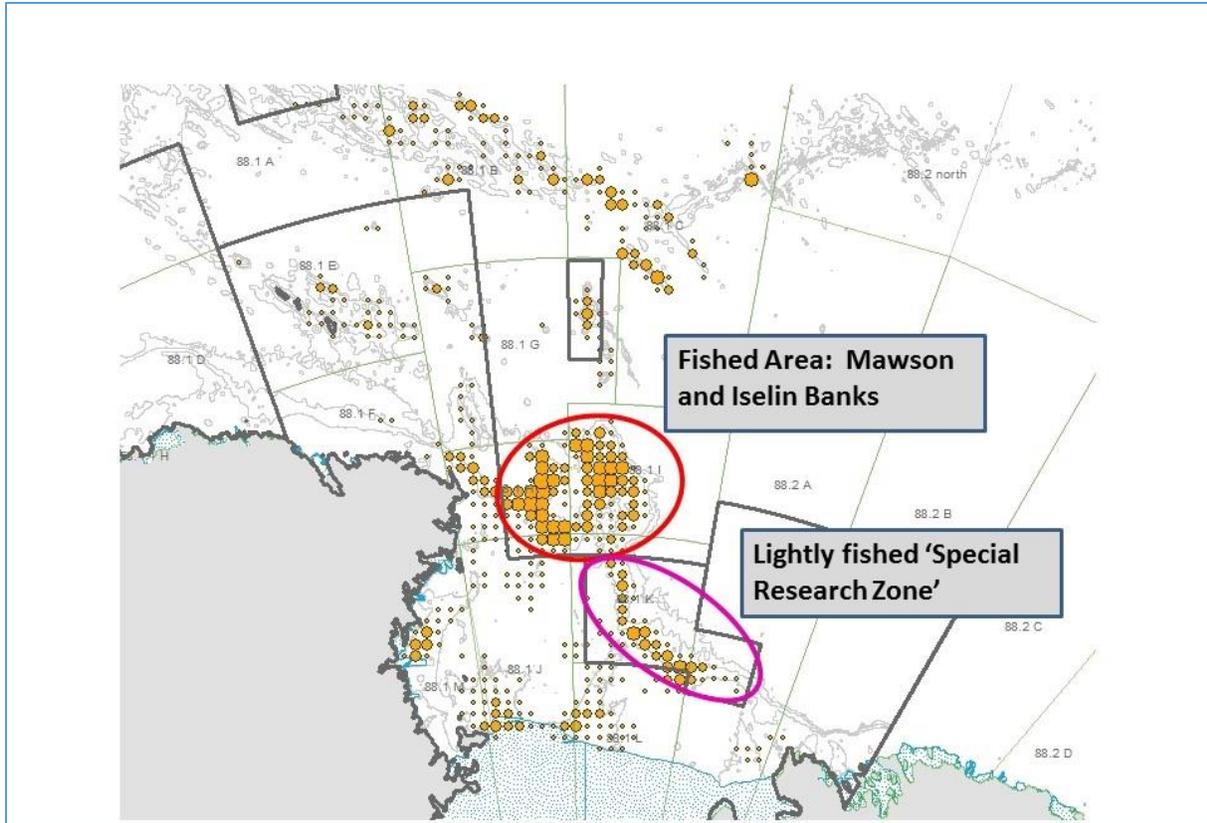


Figure 2: Potential science outcomes offered by establishment of a scientific reference area on the Ross Sea slope (objective (ii)) MPA boundaries on the Ross Sea are designed to enable comparisons between the area of the lightly fished Special Research Zone (SRZ, in purple) and the fully developed fishing ground over Mawson and Iselin Banks (red). Orange circles represent total historical toothfish removals (1998–2013). [updated from SC-CAMLR-IM-I/08]

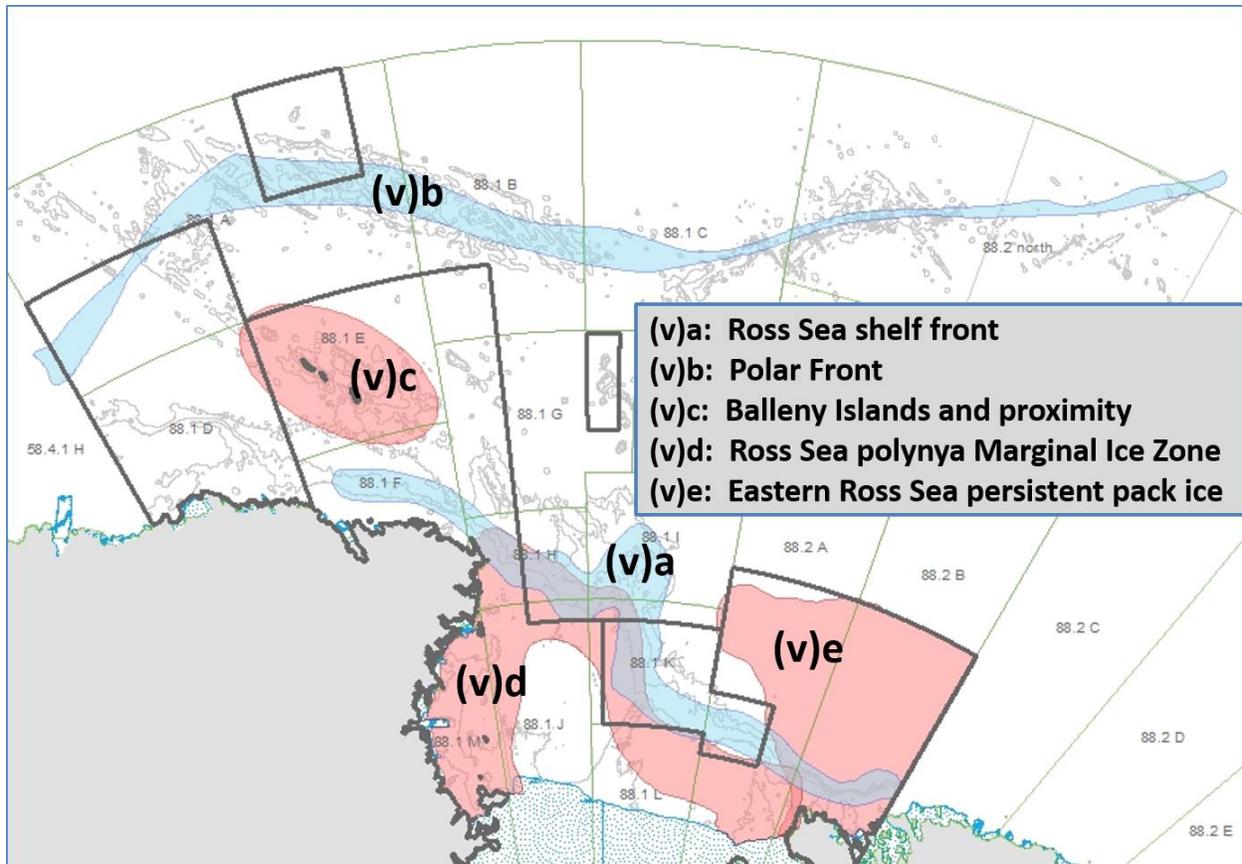


Figure 3: Priority features for protection under objective (v): Large-scale ecosystem processes or features of particular ecosystem importance in association with fronts (blue) or ice dynamics (red). The summer ice-free continental shelf front (objective (v)a) and the Ross Sea polynya Marginal Ice Zone (objective (v)d) are preferred summer foraging areas for pelagic top predators. The Polar Front (objective (v)b) is targeted by flying seabirds. The Balleny Islands (objective (v)c) are an ecosystem hotspot. The eastern Ross Sea persistent pack-ice zone (objective (v)e) is important for moulting seals and penguins. [From WG-EMM-10/30, summarising WG-EMM-10/11]

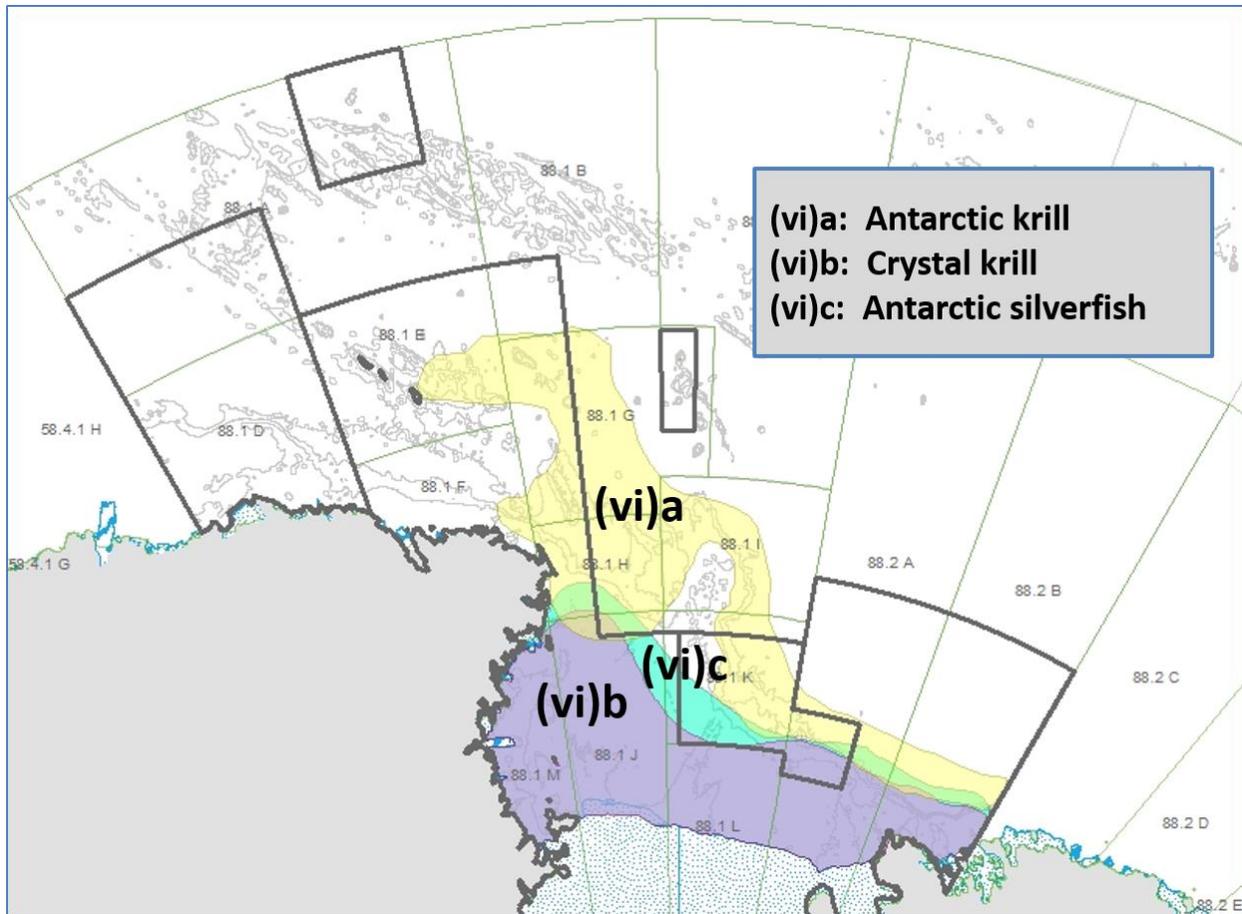


Figure 4: Priority features for protection under objective (vi): Core distributions of tropically dominant pelagic prey species supporting higher trophic level. Antarctic krill (objective (vi)a, yellow); crystal krill (objective (vi)b, purple); and Antarctic silverfish (objective (vi)c, turquoise). [From WG-EMM-10/30, modified as described in WS-MPA-11/25]

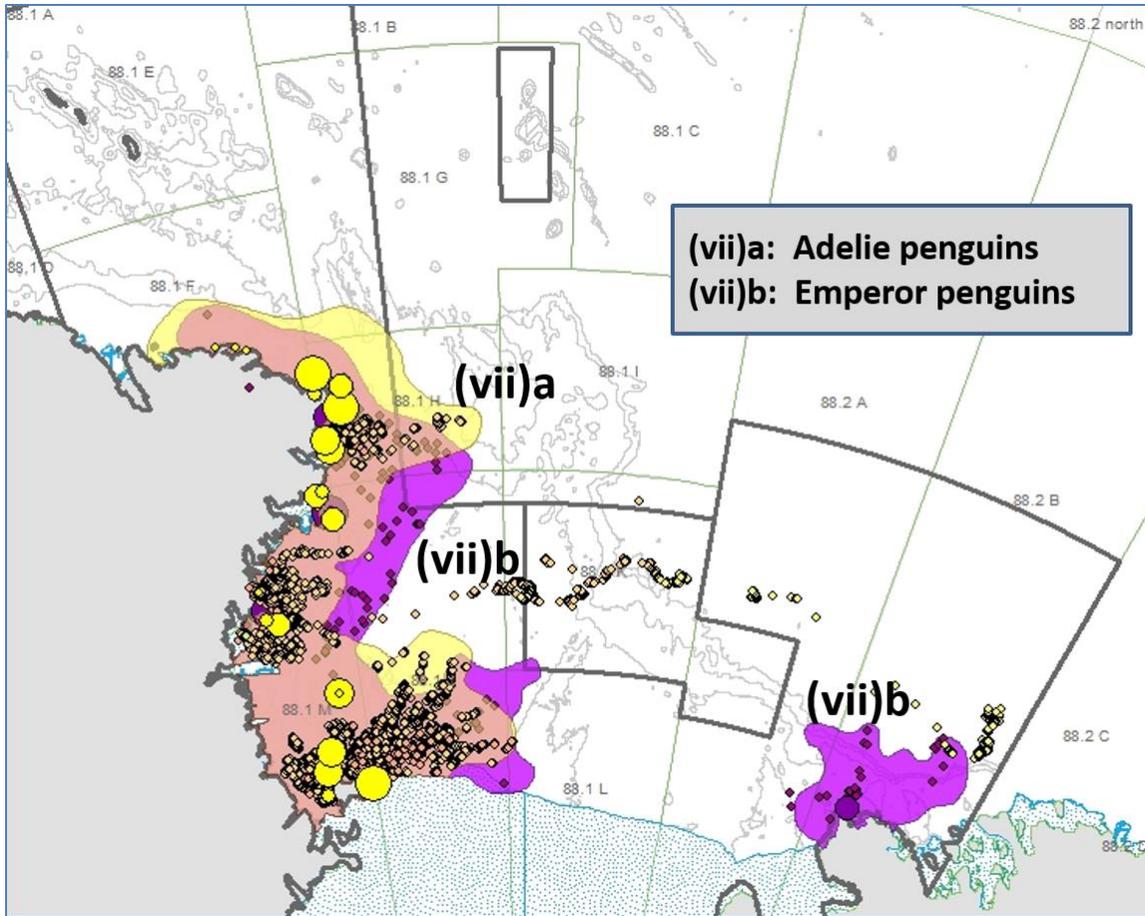


Figure 5: Priority features for protection under objective (vii)a–b: Core breeding (summer) foraging areas for Adélie penguins (objective (vii)a, yellow); and for emperor penguins (objective (vii)b, purple) including colony sizes and summer foraging tracks. [From WG-EMM-10/30; colonies and tracking data from WG-EMM-10/11]

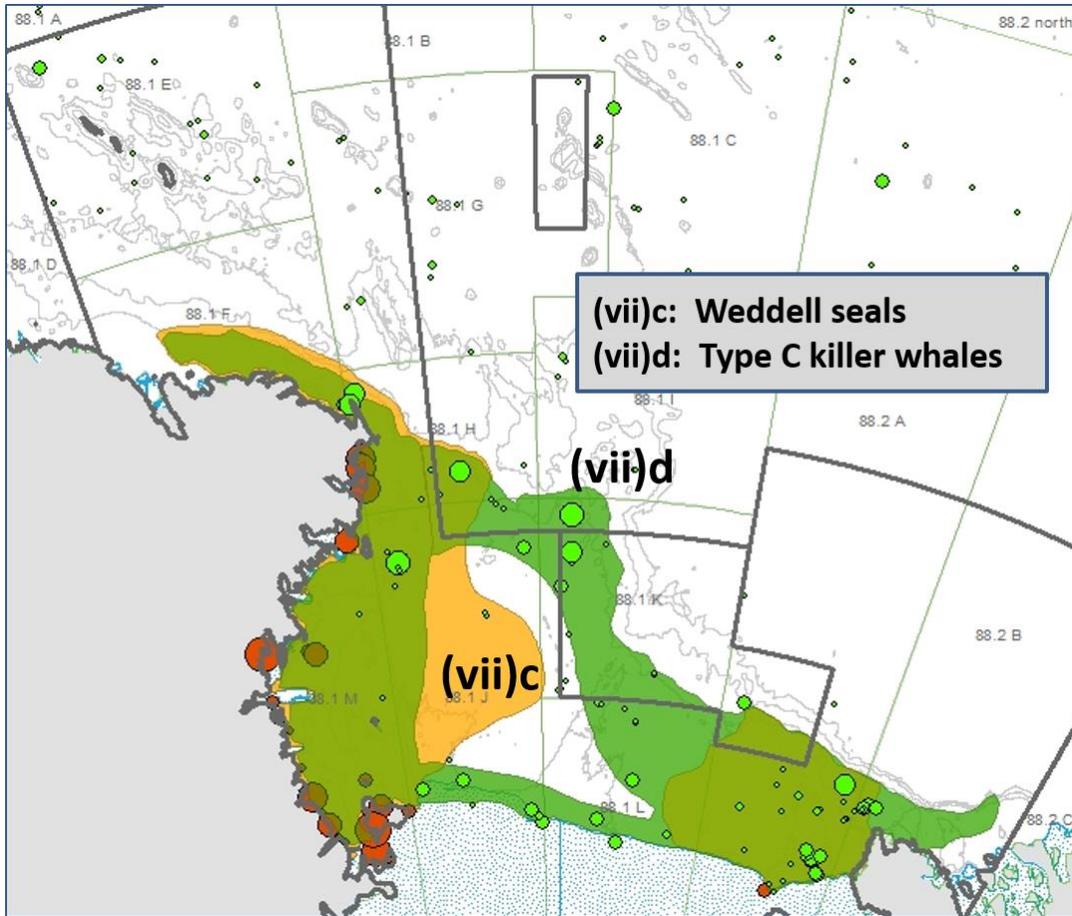


Figure 6: Priority features for protection under objective (vii)c–d: Core foraging areas for Weddell seals (objective (vii)c, orange) during the summer breeding, lactation, and post-weaning recovery phase, including breeding colony locations and sizes; and for Type C killer whales (objective (vii)d, green) during summer including at-sea sightings. [From WG-EMM-10/30, modified as described in WS-MPA-11/25]

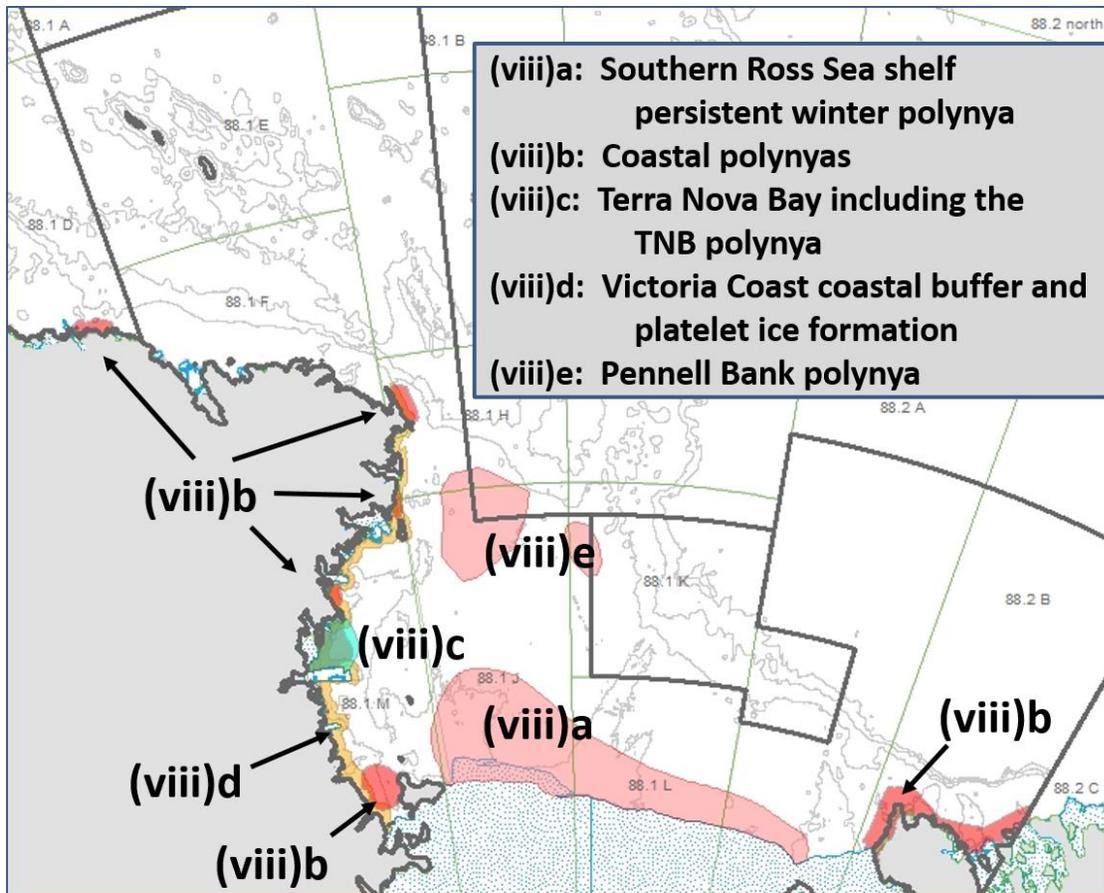


Figure 7: Priority features for protection under objective (viii): Coastal or localised areas of particular ecological importance to the Ross Sea shelf ecosystem. The Southern Ross sea persistent (winter) polynya (objective (viii)a, red). Shallow coastal polynyas (objective (viii)b, red). Terra Nova Bay including the TNB polynya (objective (viii)c, turquoise). The Victoria Coast buffer and platelet ice formation zone (objective (viii)d, orange). Pennell Bank polynya (objective (viii)e, red). [From WG-EMM-10/30, modified as described in WS-MPA-11/25]

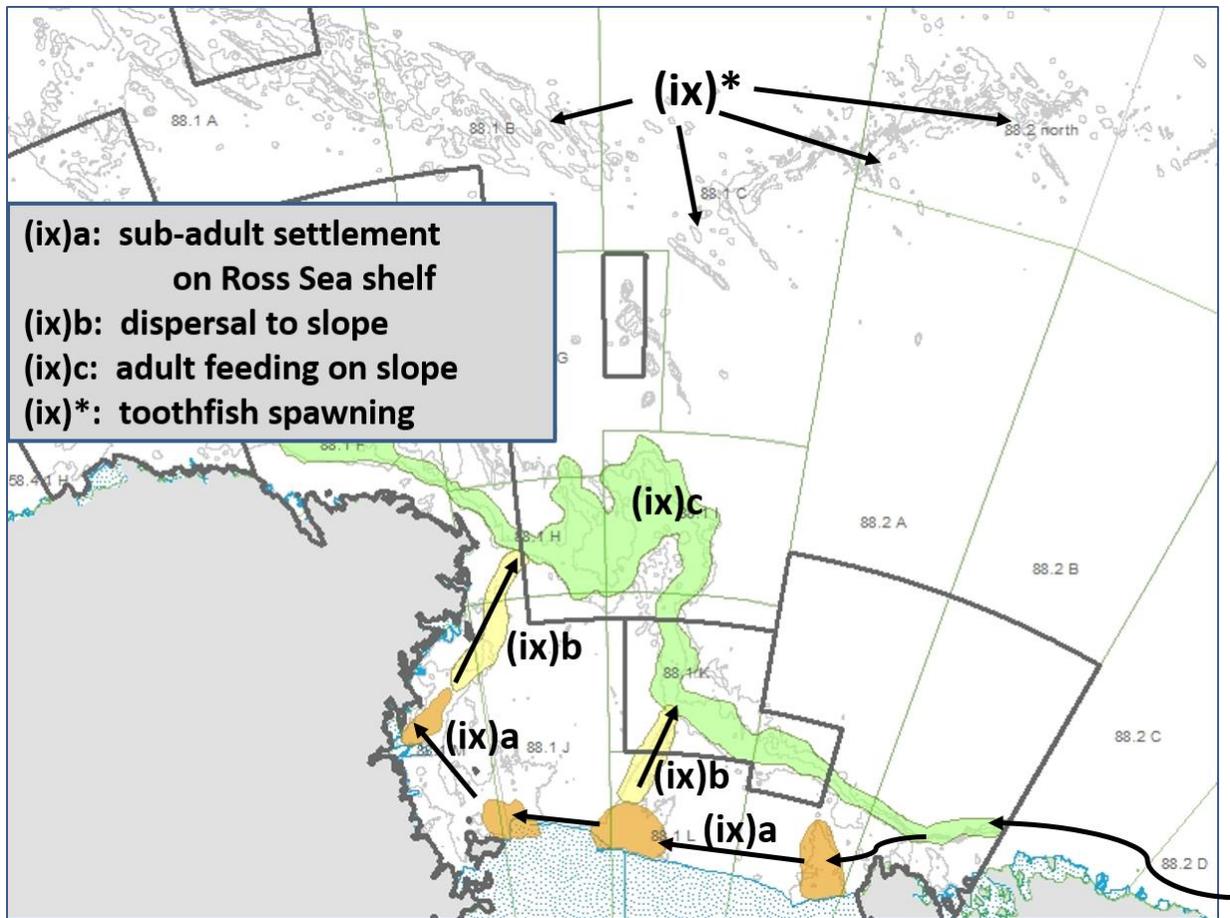


Figure 8: Priority features for protection under objective (ix): Antarctic toothfish life cycle areas, following Hanchet et al. (2008), including: sub-adult settlement areas on the Ross Sea shelf (objective (ix)a, orange); dispersal trenches for maturing toothfish (objective (ix)b, yellow); adult feeding areas on the Ross Sea slope (objective (ix)c, green). [From WG-EMM-10/30, modified as described in WS-MPA-11/25]. Note Antarctic toothfish spawning areas in the northern Ross Sea region (objective (ix)) are not a priority for inclusion within the MPA, but research to understand Antarctic toothfish spawning is identified as high priority.

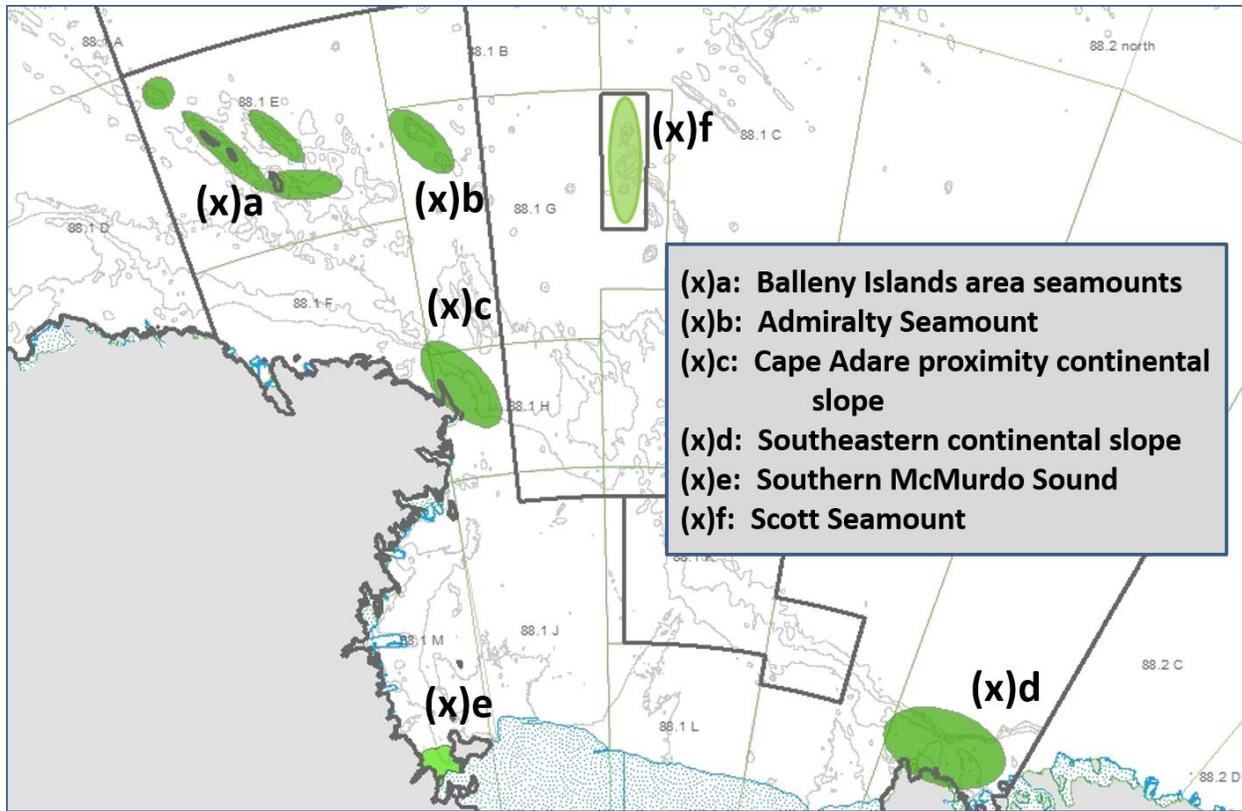


Figure 9: Priority features for protection under objective (x): Areas supporting known rare or vulnerable benthic habitats. (Objective (x)a): Balleny Islands and vicinity seamounts; (Objective (x)b): Admiralty seamount; (Objective (x)c): Cape Adare proximity continental slope. (Objective (x)d): Southeast Ross Sea continental slope; (Objective (x)e): Southern McMurdo Sound. (Objective (x)f): Scott Seamount [from WG-EMM-10/30, modified as described in WS-MPA-11/25]

Table 4: Priority elements for scientific research and monitoring associated with the Ross Sea region marine protected area (Table 2 of CM 91-05 Annex C).

Type of research						Priority elements	Row
	Ross Sea continental shelf	Ross Sea continental slope	Balleny Islands and vicinity	Northern Ross Sea region and seamounts	Northwestern Ross Sea region		
Ecosystem	✓	✓	✓	✓	✓	Directed studies to address biological and ecological questions related to species demography and life history	1
	✓	✓	✓			Monitoring and research on pinnipeds and seabirds, including studies of reproductive biology and success as well as diets and foraging dynamics	2
	✓	✓	✓	✓	✓	At-sea surveys or censuses to estimate the distribution and abundance of marine mammals, seabirds, fishes and invertebrates	3
	✓	✓	✓		✓	Acoustic surveys to map distribution and abundance of Antarctic silverfish and krill, including dedicated research on silverfish in Terra Nova Bay	4
	✓	✓	✓			Radio and archival tagging, remote sensing and shore-based population censuses of marine mammals and seabirds	5
	✓	✓	✓		✓	Ecosystem modelling, informed by diet and stable isotope sampling of key trophic components	6
	✓	✓				Targeted sampling of Ross Sea shelf and slope communities with focus on middle trophic level organisms	7
	✓				✓	Investigate oceanographic drivers of phaeocystis- vs. diatom-dominated production and consequences for higher-level trophic ecosystem function	8
				✓		Vessel-based surveys of demersal fish and benthic communities of Pacific–Antarctic fracture zone	9
				✓		Repeat surveys of Admiralty and Scott seamounts	10
	✓					Continued annual survey for sub-adult toothfish in southern Ross Sea shelf; see SC-CAMLR-XXX/07	11
Fisheries	✓	✓		✓		Focused tag deployments and/or electronic archival or acoustic tags to examine/ validate toothfish life-cycle, abundance, movement and behavioural hypotheses	12
		✓		✓		Paired stratified surveys of slope habitats with contrasting local exploitation rates to monitor effects of fishing on Antarctic toothfish and demersal fishes	13
	✓	✓	✓	✓		Surveys and sampling to investigate life history hypotheses and biological parameters, including stock structure, of Antarctic toothfish	14

Type of research	Ross Sea continental shelf	Ross Sea continental slope	Balleny Islands and vicinity	Northern Ross Sea region and seamounts	Northwestern Ross Sea region	Priority elements	Row
			✓			Targeted surveys to investigate the importance of the Balleny Islands as a potential nursery area for Antarctic silverfish and Antarctic toothfish	15
				✓		Winter surveys to improve knowledge of spawning and eggs/larvae/early life stages of Antarctic toothfish	16
					✓	Surveys and sampling to investigate life history hypotheses, biological parameters, ecological relationships and variations in biomass and production of Antarctic krill	17
Climate change/ oceanography	✓	✓	✓	✓	✓	Meteorological and oceanographic research, including satellite remote sensing, to characterise physical properties and dynamics of phytoplankton and zooplankton	18
	✓	✓	✓	✓	✓	Sea-ice remote sensing (type, concentration and extent)	19
	✓	✓		✓		Long-term monitoring of benthic ecosystem function	20
	✓	✓	✓			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	21
	✓	✓				Investigate deep bottom water formation (relevant to global oceanic circulation), slope water intrusion and cross-shelf nutrient exchange	22