Annex 11

Report of the Workshop on Climate Change 2023 (WS-CC-2023)
(Cambridge, United Kingdom and Wellington,
New Zealand, 4 to 8 September 2023)

Contents

Page

Opening of the meeting 505
Workshop opening: welcome, workshop structure, housekeeping, adoption of agenda. 505

Expected effects and risks of climate change on Antarctic Marine Living Resources 505
Invited presentation: Climate change and Antarctic Marine Living Resources 505
Climate change effects on harvested species 506
Climate change effects on dependent and related species 508
Summary of the discussion 511

Spatial management approaches to ensure objective of the Convention is met 512
Invited presentation: Climate change and management approaches for marine living resources 512
Climate change considerations for CCAMLR's management approach 515
Specific climate change considerations for spatial management 519

Information, including monitoring and metrics, needed to support management decisions, and mechanisms to develop and integrate these 519
Climate change information needed to support management decisions 519
Mechanisms to improve input, and use of, relevant scientific information and advice on climate change throughout CCAMLR's work program 522

Report adoption 525

Close of the Meeting 525

References 525

Tables 527

Figures 532

Attachment I: Perspectives on the hub-based hybrid meeting format from participants 535

Attachment II: List of participants 539

Attachment III: Agenda 548

Attachment IV: List of Documents 549

Attachment V: Terms of Reference Climate Change Workshop 552

Report of the Workshop on Climate Change 2023 (WS-CC-2023)
(Cambridge, UK and Wellington,
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Opening of the meeting

Workshop opening: welcome, workshop structure, housekeeping, adoption of agenda.

1.1 The Workshop on Climate Change (WS-CC-2023) was held in a hub-based, online hybrid format from 4 to 8 September 2023. Two in-person hubs were organised to occur during local business hours; one in Wellington, New Zealand, and one in Cambridge, United Kingdom (UK). In addition, the UK hub had two sub-hubs, with participants in Qingdao, China, and in Paris, France. This hub-based, online hybrid design was implemented as a trial. Additional details on the design and comments on the feasibility are discussed in Attachment I.

1.2 The meeting conveners, Dr R. Cavanagh (United Kingdom) and Mr E. Pardo (New Zealand) welcomed participants (Attachment II) and outlined how the Workshop would be conducted.

1.3 The agenda was adopted (Attachment III).

1.4 Documents submitted to the meeting are listed in Attachment IV and the Working Group thanked all authors of papers for their valuable contributions to the work presented to the meeting. The Terms of Reference for the Workshop are included as Attachment V.

1.5 In this report, paragraphs that provide advice to the Scientific Committee and its other Working Groups have been indicated in grey. These recommendations as well as additional suggested actions are summarised in Tables 1 and 2.

1.6 A glossary of acronyms and abbreviations used in CCAMLR reports is available online at https://www.ccamlr.org/node/78120.

1.7 The report was prepared by T. Earl (UK), S. Grant (SCAR), S. Parker (Secretariat) and C. Waluda (UK).

Expected effects and risks of climate change on Antarctic Marine Living Resources

Invited presentation: Climate change and Antarctic Marine Living Resources

1.8 Each hub received a recorded presentation entitled ‘Climate change and Antarctic Marine Living Resources’ from Dr J. Melbourne-Thomas (Australia) and Dr T. Bracegirdle (UK) which included descriptions of how the physical environment of the Southern Ocean is changing and predicted to change as well as how these changes are likely to affect the ecology of the organisms living there.

1.9 The Workshop welcomed the keynote presentation and suggested that region-specific analysis and effects on species may be useful to better inform CCAMLR, noting that Marine Ecosystem Assessment for the Southern Ocean (MEASO) has developed sector scale/finer scale analyses (WS-CC-2023/12). The Workshop recognised the need to consider the range of environmental and biological conditions that support species and recognised that certain life-history stages may be more vulnerable to the effects of climate change than others.

Climate change effects on harvested species

1.10 WS-CC-2023/01 provided an overview of a new research project to evaluate climate change risks to toothfish populations in Subareas 48.3 and 48.4. Relevant environmental, biological, and fishery information will be reviewed, synthesised and used to undertake a risk assessment of climate-driven change to toothfish populations in the region, and to consider what this means in terms of management. Work with stakeholders is already underway and future findings will be submitted to WG-FSA.

1.11 The Workshop welcomed the research project and discussed how climate change risks to toothfish could be taken into account in fishery management, noting that CCAMLR decision rules could be modified by including uncertainty in trophic effects and the effects of climate change on early life stages.

1.12 WS-CC-2023/04 presented the results from two studies in the Southern Indian Ocean which examined isotherm drift (using climate velocity) at the surface of the ocean compared with depth, as well as a study on marine heatwave impacts. The authors note that isotherm drift in the mesopelagic layers can be faster than at the ocean's surface in climate models under global warming, which could potentially shear vertical pelagic habitats with consequent effects for organisms travelling within one or more oceanic layers. The authors also note that marine heatwaves and global warming could shift the Polar Front (as defined by the northernmost extension of winter waters) locally, therefore potentially influencing marine top predator distribution and foraging patterns. The authors highlight the importance of accounting for the vertical dimension when considering potential impacts of climate change on pelagic ecosystems.

1.13 The Workshop welcomed this paper and the specific questions and considerations from the scientific and management perspectives. The Workshop noted that a collation of Antarctic circumpolar moorings data held by the Southern Ocean Observing System (SOOS) would be useful to understand environmental changes with depth and suggested that an analysis could be undertaken in order to identify gaps in the monitoring of climate change related variables that could be relevant to CCAMLR. The Workshop further noted that CCAMLR Members should ensure that existing datasets are up to date before embarking on a gap analysis.

1.14 The Workshop noted that Argo, BioArgo, under ice and deep ocean observations could be used to create a three-dimensional (3D) view of the ocean and impacts on habitats, and that the relationship between CCAMLR and SOOS could help identify products and appropriate experts to develop routine reporting of these products.

1.15 The Workshop encouraged Members to supply relevant data to SOOS noting that SOOSmap is a data discovery tool, comprising circumpolar standardised and curated data. The Workshop recommended that the Scientific Committee tasks the Secretariat with liaising with SOOS to develop information for use by CCAMLR.

1.16 The Workshop noted the current recommendation by WG-ASAM to collect acoustic data on mesopelagic organisms (but not including physical environmental data) to depths of 1 000 m and observed that toothfish longlines might provide a suitable platform for collecting physical environmental data throughout the water column. In addition, the Workshop noted that the location of the Polar Front could be monitored during North-South transits by scientific vessels.

1.17 WS-CC-2023/08 provided a review of Antarctic toothfish (*Dissostichus mawsoni*) biology and used species distribution models with climate model projections to examine how abiotic and biotic impacts could potentially affect future species distributions. The authors examined the effects of projected climate change scenarios on toothfish distributions as they relate to existing and proposed CCAMLR Marine Protected Areas (MPAs). The results tentatively suggest that medium to high climate change scenarios may decrease areas with high fish availability around the continent but that some of the remaining high fish availability areas would be covered by the Ross and Weddell Sea (P1) MPA Proposals.

1.18 The Workshop welcomed the paper and noted that predictions of which areas would be most vulnerable and where fish availability may increase were important for monitoring and noted that climate change impacts may be different for different life stages. The Workshop considered this aspect to be important given the different ways in which climate change could influence the distribution of different life stages.

1.19 The Workshop noted that using only one high resolution ocean model (FESOM-RecoM) may introduce a bias in the analysis and noted that a range of models with different predictions exist such that ranking different models by their respective fit to historical data may be useful in choosing which models to use for predicting changes to distributions. The Workshop also suggested that certain locations, like Division 58.4.3b, are key spawning areas for Antarctic toothfish and could be included in future analyses but were out of the scope of this study.

1.20 The Workshop also noted that although MPA proposals considered the distributions of Antarctic and Patagonian toothfish as part of their design, MPAs may also act as climate change refugia for these species. Additionally, the Workshop noted that biological differences between the two species (e.g., antifreeze glycoprotein present in Antarctic toothfish) may result in different vulnerabilities to the effects of climate change.

1.21 WS-CC-2023/22 introduced the Climate Genomics of Antarctic Toothfish (ClimGenAT) project, which developed genetic tools to understand climate change impacts on species in the Southern Ocean, with a particular focus on Antarctic toothfish. The project aimed to explore how climate change may impact Antarctic toothfish distribution and connectivity using genomics.

1.22 The Workshop noted that the methodologies presented could be used to identify spawning areas and location changes and could be applied to other species including Patagonian toothfish and highlighted the use of neutral (non-selected) genetic markers to understand population structure versus functional (selected) genetic markers, which can help to identify adaptation to changing conditions.

1.23 The Workshop welcomed the project and noted that data from Argo floats may also be informative in understanding habitats critical to toothfish larvae, such as the Ross Sea Gyre.

1.24 WS-CC-2023/P01 described extreme events that have been observed in Antarctica in recent years that are significantly different to the average ranges of variability across a variety of realms (ocean, atmosphere, cryosphere, biosphere etc). The paper considered the likely causes and implications of such phenomena and concluded that such extreme events are virtually certain to become more frequent and more intense if the ambition of the Paris Climate Agreement is not met. The authors noted that terrestrial and marine protected area tools can be used to minimise additional human stressors on key environments.

1.25 The Workshop welcomed the paper and discussed the importance of tipping points and cascading effects, especially for fisheries management in the next decade and noted that while there may not be sufficient capacity to monitor and predict these effects, these are important issues to address and account for in management approaches. The Workshop also noted that the frequency and intensity of extreme events is of importance because species may not have time to recover in-between successive events.

1.26 The Workshop recalled the approach used in Conservation Measure (CM) 24-04 which provides precautionary protection for newly exposed marine areas following collapse or retreat of ice shelves, and suggested this could serve as a model for how to minimise additional human stressors to facilitate the study of other extreme events.

1.27 The Workshop noted that the use of genomic techniques may be beneficial to understand the degree of isolation between populations, especially after an extreme event, which is important when multiple weather and climate events (spatially and/or temporally related) generate large scale impacts.

1.28 The Workshop recommended that Scientific Committee collate a list of important variables to be monitored following an extreme event to facilitate a coordinated and timely response to such events and their physical/biological effects both on marine components and land-based predators.

1.29 The Workshop noted that it is important to consider all life stages when considering potential climate change impacts on harvested species. The Workshop highlighted the work of the SCAR krill expert group (SKEG) on the krill stock hypothesis and current work on toothfish (e.g., WS-CC-2023/08 and WS-CC-2023/22) as valuable contributions to the understanding of the impacts of climate change on early life history stages.

Climate change effects on dependent and related species

1.30 WS-CC-2023/11 outlined key activities being undertaken by the Scientific Committee on Antarctic Research (SCAR) affiliated groups (in some instances in collaboration with CCAMLR) that may be of interest to SC-CAMLR, particularly in relation to the integration of scientific information on climate change and ecosystem interactions into CCAMLR's work program. SCAR will continue to provide scientific advice to CCAMLR on the impacts of climate change, the status of Antarctic environments and ecosystems, and information to support action on mitigation and adaptation. This advice will draw upon global synthesis reports, peer-reviewed literature, and expertise from across the full range of SCAR's international scientific research programmes, science

groups, expert groups and co-sponsored programmes. The authors encouraged the Workshop to make specific requests for information from SCAR programmes and expert groups relevant to the development of future work on climate change.

1.31 The Workshop welcomed the paper and noted recent SCAR activities related to climate change including collaboration between SCAR and CCAMLR on ecosystem interactions, SCAR's coordination of a Decade Collaborative Centre as part of the UN Decade of the Ocean for Sustainable Development, the Antarctic Climate Change and the Environment (ACCE) report, and MEASO. The Workshop noted that SCAR will continue to provide advice on climate change mitigation and adaptations.

1.32 The Workshop recommended the Scientific Committee continue the collaboration with SCAR to address CCAMLR specific science needs, by making further requests for specific information from SCAR.

1.33 WS-CC-2023/12 Rev. 1. Presented outcomes of the first MEASO, providing a detailed assessment of the current knowledge on status, trends and drivers of change in the Southern Ocean ecosystem. MEASO areas reflect regions within which the dynamics of sea-ice, ocean and benthic habitats combined remain ecologically similar across the region. While they do not perfectly overlap with CCAMLR management areas, and extend north of the Convention Area, they remain suitable for advising CCAMLR on climate change effects on ecosystems and form a suitable basis for monitoring and assessing trends. Summary information and infographics highlight the outcomes of MEASO relevant to CCAMLR, including the pathways of climate impacts into Southern Ocean ecosystems. MEASO has collated and described tools for assessing and managing impacts of climate change, including (i) modelling to support assessment and design of management procedures, (ii) the potential engagement of the SOOS and its regional working groups in facilitating integrated observing of sentinel variables from across the food web, (iii) the breadth of stakeholder engagement that can support the development of management strategies, and (iv) risk assessments.

1.34 The Workshop welcomed the study and noted two general priorities for disentangling climate impacts from other changes: (i) the need for sustained time-series observations of different parts of the food web, taken simultaneously in an area in order to distinguish between changes affecting krill-based and fish-based energy pathways and how climate drivers may interact with these, along with monitoring in different areas to account for different climate impacts in different places, and (ii) models of food webs and ecosystems coupled with Earth System models to help assess the potential for change in CCAMLR areas. The Workshop also noted that not all climate models were suitable for the Southern Ocean and that risk assessments could help to identify what and where to monitor in more detail, especially in the next decade.

1.35 WS-CC-2023/13 presented a summary of the likely effects of climate variability and change on Antarctic skates as a case study for bycatch species. The authors suggest that the most at-risk life history stage for skates may be egg cases. To date, there are only two documented egg case nurseries in the Southern Ocean. The authors recommend that efforts should continue to identify, characterise, and protect areas of essential habitat for bycatch species, including fish nest areas and skate egg case nurseries.

1.36 The Workshop noted that little is known about the effects of climate change on bycatch species in CCAMLR fisheries and supported the recommendations of this study to (i) undertake studies to understand the physiological effects of climate change on marine fishes caught as bycatch in the CCAMLR Convention Area, noting that species may have varying levels of adaptability and that it may not be appropriate to generalise risks and effects to species groups, and (ii) continue to identify, characterise and protect areas of essential habitat for bycatch species, including fish nest areas and skate egg case nurseries.

1.37 The Workshop recalled discussion by WG-EMM-2023 about how to best protect essential fish habitat and the impacts of climate change on such areas, such as fish nurseries and nests (WG-EMM-2023, paragraph 7.73) and noted that the impact of climate change on other bycatch species such as grenadiers also needs to be taken into consideration.

1.38 WS-CC-2023/14 summarised a virtual workshop held by the International Whaling Commission (IWC) in 2021 which considered climate change in the context of the conservation and management of cetaceans. The paper provided a brief overview of discussions including the role of whales in nutrient cycling and the food web and the need for flexible management strategies to deal with uncertainty. The IWC encouraged stronger collaboration with CCAMLR and asked for climate change to specifically be addressed in species management plans alongside other anthropogenic pressures.

1.39 The Workshop welcomed the paper and recognised the importance of collaboration between IWC and CCAMLR, noting that Dr N. Kelly (Australia) is the SC-IWC observer to SC-CAMLR and vice versa, and recommended that the collaboration continues, especially noting the importance of considering marine mammals in the current enhancement of the CCAMLR Ecosystem Monitoring Program (CEMP) (WG-EMM-2023, paragraph 5.14).

1.40 The Workshop recognised the need for information sharing between CCAMLR and IWC with respect to food webs and krill consumption by whales, and the value of these data for informing the estimate of natural mortality of krill.

1.41 WS-CC-2023/15 highlighted the need for pairing biological and environmental information to detect, interpret and manage the responses of benthic habitats, communities, and higher predators to climate change impacts. The authors presented details of the SCAR Antarctic Near-shore and Terrestrial Observing System (ANTOS), which aims to use long-term data to understand complexities and drivers of variability and change in benthic communities across different spatial and temporal scales. The authors recommended i) CCAMLR supports and endorses the SCAR ANTOS initiative and its implementation; ii) communication and, where appropriate, coordination between ANTOS and CEMP and other initiatives for long-term observation programmes; and iii) monitoring of key environmental parameters and benthic communities in tandem.

1.42 The Workshop welcomed the paper and supported the recommendations for coordination between ANTOS and CEMP and other initiatives for long-term observation programmes (e.g., in the establishment of sentinel monitoring sites) and encouraged the authors to participate in the current CEMP review.

1.43 The Workshop noted the importance of monitoring key environmental parameters and benthic communities in tandem, in order to understand natural variability and detect and attribute climate change and/or fishing impacts. The Workshop further noted that there was an opportunity to evaluate the effects of climate change on Vulnerable Marine Ecosystems (VMEs). Information on density and composition of benthic megafaunal indicator taxa provided through CM 22-06 (Annex B) can be used as a baseline to examine and monitor potential impacts of climate change on VMEs far into the future.

1.44 WS-CC-2023/P02 modelled a time series of environmental variables as they relate to the Antarctic silverfish populations. The authors found that silverfish larvae and adults can only exist in a narrow range of temperatures below 2° C. Silverfish abundance is likely related to sea ice, as well as salinity and chlorophyll availability, which can influence life cycle and spawning cues. If silverfish are unable to find suitable habitat or environmental conditions, there may be knock-on effects for predators such as penguins or seals.

1.45 The Workshop welcomed the paper and recognised this direct link between climate change and an important species Antarctic silverfish (*Pleuragramma antarctica*) in the West Antarctic Peninsula, due to the Amundsen Sea Low (a climatological low pressure region centred over the Amundsen Sea) likely impacting sea ice distribution and therefore silverfish spawning habitats. The Workshop noted that the advance of sea ice in autumn can directly influence spawning which can result in trophic cascades, which can reduce the prey field for those species which feed on silverfish.

Summary of the discussion

1.46 The Workshop discussed the importance of links between CCAMLR and other organisations such as SCAR and its range of programmes and affiliated groups (WS-CC-2023/11; WS-CC-2023/12) and noted that CCAMLR will benefit by developing specific requests for information required for management and streamlining the flow of information from such organisations. The Workshop noted that the papers summarising IPCC SROCC for CCAMLR (SC-CAMLR-39/BG/12; WG-EMM-2021/P07) provide a good example of a targeted synthesis providing information in a format of specific relevance to CCAMLR.

1.47 The Workshop discussed the importance of standardising climate modelling frameworks to guide the choice of physical climate model data from which to project future distributions of species. This may help to address scenario and model uncertainty and to reduce model bias.

1.48 The Workshop recommended that the Scientific Committee request advice from SCAR to help develop a framework for using climate models to drive ecological projections for AMLR and dependent and related species.

1.49 The Workshop discussed extreme events and recalled a recent paper reporting on record low sea ice extent which has led to regional breeding failure of emperor penguin colonies (Fretwell et al., 2023).

1.50 The Workshop noted that both extreme events and longer-term changes (e.g., changes in sea ice) must be considered to understand the effects of climate change on ecosystems and species including land-based predators.

1.51 The Workshop acknowledged that extreme events could occur on both seasonal and short (e.g., daily) time scales, recognised that effects might vary depending on the organism, its life stage, and the type of event, and noted that those occurring on seasonal timescales are likely to be of highest priority in terms of potential effects on populations and ecosystems.

1.52 The Workshop recommended that the Scientific Committee develop a catalogue of the different types of extreme events, their time scales and the species and life stages that they are likely to affect (building for example on information in WS-CC-2023/12) which would be a useful aid to communicating data needs to climate modellers.

1.53 The Workshop noted that climate change may result in invasive species entering the CCAMLR Convention Area and managing the effects of these species would need to be considered in future monitoring and management.

1.54 The Workshop noted the impact of extreme temperature and sea ice reduction on land-based predators and the need for better data on local meteorological conditions, noting similar discussions took place during WG-EMM-2023 (WG-EMM-2023, paragraph 5.30). The Workshop discussed the need for better understanding of what causes extreme events and further analysis of how particular characteristics of extreme events (intensity, duration etc.) translate into positive or negative impacts on biological processes.

1.55 The Workshop noted that extreme events might affect land-based animals more quickly than aquatic species and highlighted the importance of understanding the response of land-based predators to climate change, particularly considering the long-term data available from CEMP.

1.56 The Workshop noted that the both the frequency and intensity of extreme events and ability of species (such as fur seals) to recover may have cumulative effects on those species and ecosystems.

1.57 The Workshop noted that while many of the papers discussed during the meeting focussed on finfish species, there is substantial evidence that krill are also sensitive to climate change (Johnston et al., 2022). Understanding the physiological and ecological mechanisms of how extreme events might impact krill is also needed.

1.58 The Workshop noted the importance of disentangling the effects of historical exploitation and climate change on populations and suggested that future comparative studies between Southern Ocean regions with different rates of change in the physical environment might be useful in this regard.

Spatial management approaches to ensure objective of the Convention is met

Invited presentation: Climate change and management approaches for marine living resources

2.1 Each hub received a recorded presentation given by Dr A. Hollowed (United States of America) entitled ‘Climate-linked decision-relevant & adaptation-informing scenarios for ecosystems' describing a case for a polar research partnership between Arctic and Antarctic management organisations as they both face similar challenges.

2.2 The Workshop thanked Dr Hollowed for her presentation and noted that this work could provide a model to develop fisheries management in the Southern Ocean to account for the effects of climate change. The presentation included the following bullet points which could be applicable to fisheries in the Convention Area and could provide a guide for Scientific Committee:

(i) Ecological Understanding

(a) Identify stocks & understand ecological linkages through fishery dependent and independent monitoring and analysis

(b) Develop catch by fleet simulator and ecosystem linked assessments for short-term forecasts

(c) Develop of end-to-end ecosystem models (e.g., Atlantis, MIZER, Ecopath)

(d) Understand oceanographic mechanisms through seasonal coordinated monitoring of ocean physics, chemistry, primary and secondary production

(e) Forecast (3-9 months) distribution and abundance of target species to assess understanding

(f) Assess skill of available re-analysis models and Earth system models (ESMs) output relative to observations. Evaluate where higher resolution ocean models are needed.

(ii) Climate Informed Pathways

(a) Build high resolution models to improve retrospective and forecasting performance

(b) Assess improvement in retrospective performance

(c) Identify ESMs that provide reasonable representations of key oceanographic processes (seasonal ice, carbon cycling, ecoregions)

(d) Project climate impacts on oceanography using high resolution model and selected ESMs for shared socio-economic pathways (SSPs)/ representative concentration pathways (RCPs)

(e) Project climate impacts on marine life using climate enhanced assessment and end-to-end models under status quo fishing and no fishing

(f) Develop information pathway for uptake of climate informed advice within CCAMLR (e.g., Fisheries Ecosystem Plan).

(iii) Operationalised System

(a) Annual workshops in CCAMLR to consider forecasts and evolving understanding

(b) Update projections climate ready management strategies based on evolving science

(c) Develop ensemble modelling techniques to project uncertainty

(d) Maintain forecasts annually and update projection modelling suites every 5-7 years

(e) Consider management plan amendments to implement Climate Ready Fishery Management

(f) Revise MEASO projections and forecasts.

(iv) Final thoughts on Polar Research Partnership (PRP)

(a) Implementing ACLIM type research nodes in Antarctica will be more challenging due to the need for international cooperation and agreement

(b) Within CCAMLR the focus may be simpler due to management of only four fisheries

(c) Common issues of protection of prey base for seabirds and marine mammals

(d) Regional scenario planning differs from global scenario planning – regional specific ecosystem goals and harvest strategies

(e) Linkages across scale matter - bidirectional flow of information is central

(f) Perhaps pick a few regions as test cases.

2.3 The Workshop noted the importance of using appropriate ESMs that realistically represent sea ice dynamics, and that not all ESMs are appropriate for the Southern Ocean. ESMs seek to simulate all relevant aspects of the Earth system and include physical, chemical, and lower trophic level (phytoplankton and some zooplankton) biological processes. Global climate models, the predecessors to ESMs, only included physical processes. Physical downscaling of ESMs can provide high-resolution oceanographic models. With respect to ecosystem models, MEASO has provided a synthesis of models that have been developed for the Southern Ocean (McCormack et al., 2021), while in the Arctic climate-enhanced multispecies stock assessment models have been developed.

2.4 The Workshop noted that some aspects of the approach presented by Dr Hollowed were not directly transferable to CCAMLR, as they were developed for a different management system. Applying such an approach within CCAMLR may present different challenges. In addition, the short-term forecasting of the abundance and distribution of some key fish species would be difficult to operationalise within CCAMLR due to data and analyst availability. The Workshop noted the opportunities and willingness of fishing vessel operators to contribute to data collection.

2.5 The Workshop noted that scientists and managers should engage to develop approaches to better communicate uncertainties from complex biological models. In particular, presenting models with and without climate trends together would aid with understanding model differences due to potential effects of climate change, and increase confidence in model outputs.

2.6 The Workshop noted the benefit of large multi-national funding sources for supporting coordinated data collection and analysis. It further noted that multi-member toothfish research, synoptic surveys for krill and the CEMP provided examples of CCAMLR members pooling resources to maximise scientific benefits. The Workshop noted the benefits of engagement with SCAR and SOOS to maximise breadth of expertise in scientific engagement, as well as building on initiatives such as the International Polar Year (2032-2033), the UN Decade of Ocean Science (2021-2030), and projects coordinated under the UN Decade Collaborative Centre for the Southern Ocean, such as 'Antarctica In Sync' (https://www.iybssd2022.org/en/a-circumpolar-assessment-of-the-connections-between-ice-ocean-climate-environment-and-life/).

Climate change considerations for CCAMLR's management approach

2.7 Paper WS-CC-2023/02 presented a handbook for the adaptation of fisheries management to climate change. The handbook combines adaptive and ecosystem-based management approaches and is designed to guide fisheries managers, scientists and industry through a risk assessment process that can identify feasible options for responding to climate change. The approach provided in the handbook was designed to be inclusive and would involve all relevant stakeholders, scalable so it could be applied with differing degrees of detail and adjusted for the available information and resources, and flexible such that it could be applied to a wide range of fisheries and/or types of risks. The authors noted that this approach to assessing climate change risk to fisheries could be adapted for CCAMLR to help inform management decisions and adaptive management responses.

2.8 The handbook proposed a multi-step process (Figures 1-3) to assess:

(i) Ecological Risk: How is the environment (habitats) changing and what are the impacts on species, food webs and ecosystems.

(ii) Fishery Risk: How might the interactions of fisheries be changing in terms of their spatial and temporal operations and the direct and indirect impacts on species, food webs and ecosystems?

(iii) Management Risk: What management strategies, including modifying existing strategies, are needed to support the Commission's objective in Article II?

2.9 Dr P. Ziegler (Australia) noted that the risk assessment approach had been applied to the Patagonian toothfish fisheries in Division 58.5.2 at Heard Island and McDonald Islands and at Macquarie Island, with involvement from stakeholders including fishing industry, scientists and managers. Dr Ziegler offered to share the results of these assessments with relevant CCAMLR working groups when they are available.

2.10 The Workshop noted that the approach provided by this handbook could be used for initial assessment of stocks within CCAMLR. The Working Group noted that these assessments could be focused on a regional scale rather than across the entire Convention Area. Additional assessments could be triggered by extreme climate events or when new information of long-term change becomes available.

2.11 The Workshop recommended that Scientific Committee review this approach for the adaptation of fisheries management to climate change within CCAMLR.

2.12 The Workshop noted that some of the aspects labelled as 'risks' may better be described as ecological responses, and that some risks such as extreme weather may exist even in the absence of climate change.

2.13 Paper WS-CC-2023/05 presented a current project which investigates tools that could contribute to climate-adaptive management for Patagonian toothfish. Preliminary results suggest three potential areas for discussion:

(i) adapting the current methodology (developing additional stock status indicators);

(ii) developing a risk management approach that includes multiple scenarios associated with future recruitment (ideally based on an understanding of the environmental drivers of recruitment variability but in the meantime different scenarios could consist of using different hypotheses regarding the use of historical recruitment values for projections);

(iii) enhancing stock resilience by protecting key areas such as spawning hotspots or key life history stages. The authors also highlight the need for regular monitoring of Patagonian toothfish recruitment.

2.14 The Workshop encouraged caution in interpreting trends in the estimated recruitment series from stock assessments which may be influenced by changes in the fishery or data collection informing the model. The Workshop noted that between-year variation in recruitment was high, even where there was little change in the spawning stock biomass (SSB), highlighting the importance of short-term environmental conditions.

2.15 The Workshop noted that depth restrictions already exist in many fisheries for the protection of juvenile life stages, and that spawning area closures may have unwanted effects of concentrating fishing effort in other areas.

2.16 The Workshop noted that the approach described in WS-CC-2023/05 could be relevant to all managed species, not just Patagonian toothfish. The further development of alternative methods to include recruitment uncertainty in stock assessment forecasts was included in the table of future actions proposed by the Workshop (Table 1).

2.17 Paper WS-CC-2023/09 described the concept of fishery carbon sink (Tang et al., 2011, 2022), which included the removed carbon from aquatic ecosystem by harvesting and the stored carbon by harvested organisms in the ecosystem (Tang et al., 2022). Meanwhile, rational harvesting will increase the productivity of the remaining target population (Pitcher and Hart, 1982). The paper also assessed the net carbon sink of krill fishery from the 1972/1973 to 2021/2022 fishing seasons and suggested that the krill fishery can increase the carbon sink of the Southern Ocean. The authors proposed that CCAMLR should develop a fishery management approach with a fishery carbon sink perspective, combined with ecosystem-based marine living resources conservation.

2.18 The Workshop noted that further work was needed to investigate carbon cycling in the ecosystem in the Convention Area, including the role of fisheries.

2.19 Some participants had reservations about the methodologies used in WS-CC-2023/09 and suggested that the overall carbon footprint of the fishing activity, including the carbon output of the fishing vessels and from the use of the harvested krill, should be included. In addition, alternate carbon pathways such as mesopelagic zooplankton and fish should be taken into account in the function of carbon sinks.

2.20 The Workshop noted a glossary of terms is needed for both carbon cycling/sequestration and ocean acidification and that CCAMLR should consider adopting the language used by the IPCC as a good starting basis. The Workshop further noted that ESMs as described in the keynote presentation by Dr Hollowed could be a useful way to evaluate interactions of the global carbon cycle and interaction with humans.

2.21 The Workshop also noted that an increase in productivity did not necessarily lead to an increase in carbon sequestration when a critical tipping point is passed, and that existing work has started to quantify the negative impacts of fishing on the ocean carbon sink, such as two recent workshops (ICES WKFISHCARBON, Ocean Carbon & Biogeochemistry: Fish Fisheries and Carbon) and the paper by Cavan and Hill (2022).

2.22 The authors of WS-CC-2023/09 stressed that the paper was focused on the carbon sink function of a fishery only. They further noted that when other aspects of a fishery are involved, it should be considered in a 'global' context, including the positive and relative effects (Hilborn et al., 2023) of a rational fishery to and the food provision service of the ecosystem.

2.23 Paper WS-CC-2023/21 proposed approaches to incorporating climate change research into CCAMLR fisheries management. The authors reviewed potential pathways of climate change impacts on stocks, habitats, and fishery management, and summarised the different mechanisms available in current CCAMLR stock assessment approaches to capture impacts of climate change on toothfish, icefish, and krill stocks. The authors recalled that other regional management bodies have developed organisational structures such as expert groups or workplans to advise specifically on management responses to the impacts of climate change. Resilient management solutions will likely include multiple stakeholders and need to be robust to data-limited stock assessments. The authors put forward key questions and recommendations for CCAMLR's climate change workshop to consider.

2.24 The Workshop noted that the paper raised useful issues and actions for consideration by Scientific Committee (Table 1) for integrating climate change into the CCAMLR fisheries management processes, including:

(i) Work with adjacent RFMOs and RMBs to identify potential for range shifts due to climate change of exploited species/species of interest, and produce a list of species/stocks straddling or likely to straddle CAMLR Convention Area, as well as identifying data sharing needs;

(ii) Work with relevant RFMOs/RMBs to exchange knowledge of ecosystem impacts of climate change, and lessons learned in incorporating climate change into their activities;

(iii) Identify any non-target species within the CAMLR Convention Area likely to increase in commercial importance;

(iv) Review data collection programmes related to the fisheries to ensure they are adequate to detect significant changes in species life history parameters and distribution that affect management;

(v) Develop methods to incorporate the effects of projected climate change on assumed recruitment patterns or uncertainty for toothfish recruitment into assessment projections;

(vi) Develop a workflow to incorporate information on the effects of climate change in management advice and alternative management approaches, including long-term change in spatial distributions and inclusion of climate change projections.

2.25 The Workshop also noted that data collection plans are likely needed for each fishery, and that these plans should be developed if lacking. Data should be collected at an appropriate frequency to capture information needed to investigate climate change.

2.26 The Workshop recommended that the Scientific Committee consider how often stock assessment parameters should be updated and noted that reference points may be non-stationary under the effects of climate change (Szuwalski et al., 2023).

2.27 The Workshop noted the importance of management strategy evaluations (MSEs) for considering how climate change scenarios might affect target species, which are already in the WG-SAM and WG-FSA workplans (SC-CAMLR-42, Tables 6 and 8) for evaluating the performance of harvest control rules and their application under climate change scenarios.

2.28 The Workshop noted that the inclusion of environmental covariates within stock assessment models may provide a way to improve the modelling of future recruitment, but that it was important to select covariates based on a mechanistic understanding, and with robust testing to avoid including relationships that have poor predictive power for future recruitment.

2.29 Paper WS-CC-2023/P03 summarised potential tools to manage fisheries for climate resilience for CCAMLR, noting progress, gaps, and opportunities for implementation. The tools included ecosystem-based management (EBM), use of climate model outputs (projections and simulations), MPAs, and environmentally informed dynamic stock assessments. The paper urged CCAMLR to continue to use and further develop these tools to safeguard the Southern Ocean under changing climate.

2.30 Some participants noted that MPAs can be a useful tool in increasing resilience to climate change.

Specific climate change considerations for spatial management

2.31 Paper WS-CC-2023/03 presented an exploratory analysis of changes in sea surface temperature and sea ice within the proposed Domain 1 Marine Protected Area for climate change under future emissions scenarios. The authors used ensembles of climate variables from the IPCC-WGI AR6 data for observed current periods (1986 to 2005), and projected medium term (2041 to 2060) and long term (2081 to 2100) forecasts. The goal of this analysis was to contribute to the identification of potential refuge areas where the effects of climate change would be minimal or delayed.

2.32 The Workshop noted that there is an increasing discussion in the scientific literature of the role of climate refugia and encouraged contributions to CCAMLR on this subject, and that the discussion within CCAMLR would benefit from clear definitions of the concepts involved. It further noted that refugia designed for a single species may provide limited protection for other species or life stages, and that this complexity may be important for MPA design.

2.33 Paper WS-CC-2023/10 presented a pilot study on crabeater seals in Terre Adélie to predict the future of krill populations and their predators by assessing krill-predator relationships and identifying key feeding areas. The authors plan to conduct a long-term investigation of these predators in both Terre Adélie and Eastern Antarctica. Results of the study will also provide information on the distribution and density of krill in this area, and will therefore provide a better understanding of the influence of sea ice and its role in the ecosystem in the absence of fishing, contributing to a better understanding of polar ecosystems under the influence of climate change.

2.34 The Workshop welcomed the study and noted that it supported the conclusions reached by WG-EMM-2023 regarding the revision of CEMP data collection to inform ecosystem status. The Workshop noted that it may be useful to include crabeater seals in the CEMP programme and encouraged the authors to contribute to the current review of CEMP.

Information, including monitoring and metrics, needed to support management decisions, and mechanisms to develop and integrate these

Climate change information needed to support management decisions

3.1 Each hub received a recorded presentation given by Dr D. Welsford (Chair of the Scientific Committee), providing an overview of CCAMLR's management and decision-making approaches and the mechanisms for incorporating the effects of climate change.

3.2 The Workshop noted the importance of setting achievable goals and providing targeted advice in developing recommendations and plans for further work on climate change information to support management decisions. It suggested that specific elements could be considered for inclusion in the existing strategic workplan of the Scientific Committee (SC-CAMLR-41, Annex 4). The Workshop recalled that the Scientific Committee had recently agreed new work plans for the Working Groups and noted that these should be updated to include additional work in respect of climate change identified during this workshop SC-CAMLR-41, Tables 6 to 10).

3.3 WS-CC-2023/06 summarised recent (2015 to present) climate change discussions within CCAMLR's Scientific Committee, including some of the issues raised, approaches suggested and outcomes, to provide background information for the Workshop.

3.4 The Workshop welcomed the paper, noting that climate change is now included in the terms of reference of all Working Groups (SC-CAMLR-41, Annex 11). It noted that the revised management approach for the krill fishery currently developed by the Scientific Committee could be a useful example in the development of proactive management approaches to address climate change. It also noted that papers from the 2016 Joint SC-CAMLR/CEP Workshop could be a useful source of information for developing further directions.

3.5 WS-CC-2023/07 Rev. 1. provided an overview of recommendations made by ASOC in recent years on climate change issues, with a focus on providing examples of potential spatial management actions, and the data information needs and data flow required to implement climate change action.

3.6 The Workshop thanked the authors for the paper, noting that it had reflected the importance of progressing climate change discussions in CCAMLR as a matter of urgency.

3.7 WS-CC-2023/17 presents the use of ESMs (see also paragraph 2.3) as global climate simulation models. A study in the Ross Sea region examined the physical and biogeochemical performance of 16 CMIP-5 and 16 CMIP-6 (Coupled Model Intercomparison Project) ESMs relative to present day (1976–2005) observational data sets. Ranking the models from 'best' to 'worst' performing provided a measure of confidence about future Ross Sea region predictions of environmental conditions. Predictions for mid and end of the 21st century were produced for sea ice, temperature, salinity, nutrients and other parameters.

3.8 The Workshop welcomed these efforts to evaluate ESMs for the Convention Area. It noted that climate models and emission scenarios can be a major source of uncertainty when projecting future species distributions, so it is important to use a robust ensemble of climate models from which to base ecological projections.

3.9 The Workshop noted that it would be useful to determine levels of spatial comparison between models, and to identify which suites of ESMs or regional models would be most relevant. Support from climate model experts is important in evaluating the performance of models for the Convention Area, and in developing advice on selecting and using them appropriately. The Workshop suggested that SCAR could contribute to the further development of guidance on the use of climate models e.g., CMIP models for the Convention Area.

3.10 The Workshop identified a need for clear terminology (particularly around the use of terms such as 'business as usual' or 'worst-case'), and the selection of plausible emission scenarios (paragraph 3.22). Transparency about uncertainty and likelihood of projected future climates and ecological outcomes is vital for decision makers to understand the level of confidence they should infer. Further information on definitions and means of communicating climate change information could be useful for the Scientific Committee.

3.11 The Workshop noted that while spatial and temporal resolution of models has improved greatly in recent years, there is still a high level of uncertainty in the representation of sea ice in model projections, although ongoing and increasing research in this area was noted.

3.12 WS-CC-2023/19 described how earth observation satellites and models can provide information on environmental variability and change in the Southern Ocean. 'Essential Climate Variables' (ECVs) are physical, chemical and/or biological properties (or a group of linked variables) that critically contribute to the characterisation of the state of a natural system. The authors proposed defining sets of ECVs for Antarctic systems targeted to CCAMLR purposes; and identifying regions of the Southern Ocean where multiple environmental characteristics are changing in the same way ('bioregions of change').

3.13 The Workshop agreed that the development of a dashboard of ECVs would be an intuitive and rapid way of keeping all Working Groups up to date with the state of the environment in the CAMLR Convention Area, and that this could be conducted at a regional scale to capture spatial differences. Other metrics could be included such as, inter alia, Essential Ocean Variables (EOVs), ecosystem Essential Ocean Variables (eEOVs) and Essential Biodiversity Variables (EBVs).

3.14 The Workshop noted that existing work is being undertaken by the SCAR Antarctic Biodiversity Portal (biodiversity.aq) in collaboration with SOOS, AAD and others, on essential variables in the framework of the ADVANCE (Antarctic bioDiVersity dAta iNfrastrucCturE) project. This includes working on improved coordination and interoperability of a range of diverse tools and facilities that operate globally and create research and policy relevant data products from Antarctic biodiversity data, which will be made available in SOOSmap. The first component of the ADVANCE project was an Essential Variables Workshop held in August 2023. This workshop aimed to create an inventory of Essential Variables (EVs) relevant for the Southern Ocean based on

existing efforts by GEO-BON and MBON, the data requirements, data gaps and workflows for calculating such EVs and develop a framework for developing the workflows required to turn public Southern Ocean biodiversity data into relevant EVs.

3.15 The Workshop recommended that the Scientific Committee identify specific climate variables and metrics for which data are already, or could be, collected, that would be useful in communicating the status of AMLR through time. These should be prioritised in terms of their relevance to CCAMLR and may be specific to individual regions as environmental drivers and marine ecology may vary spatially.

3.16 The Workshop noted that regular reporting on the status of essential climate, ecosystem and ocean variables could be useful in providing the Scientific Committee and its Working Groups with standardised information on change and variability. The Workshop also recalled discussions at WG-EMM-23 on developing an annual report on the state of AMLR in the Convention Area and noted that climate change impacts on AMLR could be considered as part of the CEMP.

3.17 The Workshop noted that it would be useful to provide information on relevant and prioritised essential variables to the CEP and ATCM, and to national Antarctic programmes.

3.18 The Workshop recommended that the Scientific Committee consider forwarding the report from this Workshop to the CEP in order to assist with planning for the proposed joint CEP/SC-CAMLR workshop.

3.19 The Workshop noted that species distribution models (SDMs) or ecosystem models (e.g., Atlantis, Ecosim, Ecopath) linked to climate models are key tools to understand ecological change (see paragraph 2.2). The Workshop noted that it is important to incorporate and communicate uncertainties associated with these models such that confidence levels can be assessed and integrated into management decisions. Mechanistic or process-based models can also provide complementary (and in some cases, opposing) projections as they account for species life histories, behaviours, and optimal physiologies in ways that typical SDMs cannot.

3.20 The Workshop recognised the importance of ground-truthing and model validation, noting that this can be time consuming and expensive, and that coordination and communication of such work would therefore be helpful. The Workshop also highlighted the need to consider which indicators and models will be most useful to CCAMLR, noting that models describing spatial distribution and life history of species are particularly relevant for management.

3.21 The Workshop noted the need for clarity in the use of terms to describe the intended aim of ‘resilience’. As an intrinsic trait of a population or ecosystem, it may not be possible for resilience to be enhanced or increased by regulating other activities. However, resilience may be maintained, or rebuilt where it has been previously lost for example as a result of overfishing.

3.22 The Workshop recommended the Scientific Committee consider ways to develop a glossary of climate related terms, definitions, best practices, and standards to aid in the selection and communication of essential variables, climate models and emission scenarios.

3.23 The Workshop noted that fishing vessels and tourist vessels could potentially be used as platforms for the collection of relevant environmental or climate data, as some vessels are doing this already for some variables. The development of instructions for standardised environmental data collection or instrument calibration would be useful in this regard. The Workshop noted that dialogue with COLTO, ARK and IAATO would be useful in coordinating requests for specific types of data or the deployment of instruments. COLTO confirmed that they would be happy to collaborate with relevant scientific communities to progress this.

Mechanisms to improve input, and use of, relevant scientific information and advice on climate change throughout CCAMLR’s work program

3.24 WS-CC-2023/16 used the examples of recent rapid reductions in sea ice extent and increased occurrence of extreme climate events such as marine heat waves and cyclones to highlight key climate change risks. While noting limitations on model predictions, the authors recommended that CCAMLR notes the value of developing a risk assessment of the potential ecological impacts of changes to critical environmental and ecological parameters due to extreme climate events.

3.25 The Workshop recommended that the Scientific Committee consider the development of a risk assessment for management responses to extreme events. It would be useful to seek further information on whether such assessments are already being undertaken, recognising the considerable resources required for such work. The Workshop noted that there is value in running multiple scenarios, including examining ‘large ensemble’ datasets (for which climate models are run up to 50-100 times) to examine the probability and frequency of extreme events, and that it is useful to understand shorter temporal variability as well as longer term projections.

3.26 The Workshop noted that the Scientific Committee and its working groups could consider using seasonal climate forecasts on a year-to-year basis to understand the ecological implications of extreme climate conditions occurring in a particular year, and how proactive measures could be taken in advance of extreme events. The workshop noted that this approach is used in other fisheries worldwide, including in the Arctic.

3.27 WS-CC-2023/18 presented a summary of research aiming to understand how sea-ice drift, ocean circulation, and prey resources may affect recruitment of Antarctic toothfish in the Ross Sea region. Improving knowledge of the factors affecting recruitment, and especially climate-related factors, will help anticipate future changes to stock productivity and potential future catch levels. The paper examines potential changes in the physical transport pathways by which eggs and larvae are advected; and the biological resources (prey) available for larvae and early-stage juveniles.

3.28 The Workshop noted that understanding early life history is an important component of fish stock management, that sea ice plays an important role in Antarctic toothfish recruitment, and that early life stages are likely to be most vulnerable to the effects of climate change. Understanding how the system may change, and how extreme events link to recruitment failure will be important. It would also be useful to compare development and maturity among different regions and stocks to understand how stocks already respond and adapt to different environments.

3.29 The Workshop recommended that the Scientific Committee considers how information on projected short-term (interannual, multi-year) and long-term (decadal) changes to the recruitment of toothfish should be taken into account in the context of CCAMLR’s principles of conservation and decision rules.

3.30 WS-CC-2023/20 described a method to identify changes to key toothfish stock assessment parameters associated with environmental variability, including climate change. Stock assessment parameters or population processes that could be influenced by climate change were presented in a table that outlined the feasibility to monitor these impacts to the population and assess the severity of climate change impacts on monitored populations. The authors recommended that CCAMLR develops and implements methods for monitoring and evaluation of the effects of climate change on stocks.

3.31 The Workshop noted that the table in WS-CC-2023/20 provides a good framework for monitoring approaches relevant to both harvested and non-harvested species. While the paper is focused on toothfish, similar tables could be developed for other species such as krill and icefish, with relevant parameters. Such information would be applicable to current work on krill fishery management including development of a krill stock hypothesis and parameterisation of the Grym.

3.32 The Workshop noted that methods could be further developed to use existing data to investigate trends in key productivity parameters for all stocks with adequate data. New sample collection, approaches and analyses (e.g., new genomic, bio-informatic and microchemistry methods) should also be considered.

3.33 The Workshop encouraged the development of models to test for long-term change in the spatial distribution of Southern Ocean fish that may be linked to environmental drivers, for example by using spatiotemporal analyses, and incorporating genomic methods. These models could then be coupled with future projections of the environmental state, e.g., from ESMs, to anticipate change in species distributions.

3.34 The Workshop noted that an assessment of feasibility could help to narrow the parameters to a subset for further discussion, and high priority parameters could be included in data collection plans for specific fisheries. It would also be useful to consider the source and relevance of current estimates for productivity parameters used in assessments, as these may not be recent.

3.35 The Workshop recommended that SC develop a template report for monitoring the potential effects of environmental variability and climate change on stock assessments and key stock productivity parameters, for inclusion in the annual CCAMLR Fishery Reports (WS-CC-2023/20, Table 1).

3.36 The Workshop further noted that where trends in key productivity parameters are identified, the effect on yield and management advice of these trends should be considered as part of scenarios to be included in model projections and MSEs in conjunction with decision rules.

3.37 Considering the potential for extensive information needs on fish stock productivity and other relevant parameters, the Workshop welcomed the suggestion that interested individuals create a proposal for a new SCAR Action Group focused on the effects of climate variability and change on fish populations in the Convention Area. This could add capacity and expertise in compiling and coordinating relevant research, including on e.g., finfish life history and population parameters most likely to be correlated with climate variability. The Workshop suggested that such a group might initially prioritize target species (toothfish and icefish), followed by bycatch species, silverfish, mesopelagic fish, and then other species. The Workshop also noted that the SCAR Krill Expert Group is a useful example of successful collaboration between SCAR and CCAMLR on the development of research objectives and priorities.

3.38 The Workshop noted the relevance of 'Antarctica In Sync' (one of a number of activities coordinated through the UN Decade Collaboration Centre for the Southern Ocean, paragraph 2.6) in obtaining relevant climate information, particularly through synchronous observations. It encouraged the Scientific Committee to engage with the 'Antarctica In Sync' programme and other relevant Decade actions to provide input on climate, ocean and ecosystem variables relevant to CCAMLR objectives, and to investigate the potential involvement of fishing vessels.

3.39 The Workshop recommended that the Scientific Committee include further detail on tasks relevant to climate change in its work plan, with the objective of identifying and progressing the work necessary to ensure that CCAMLR can continue to meet its objectives as stated in Article II of the CAMLR Convention in a changing climate. This work is likely to include research and modelling as well as testing and possible refinement of management approaches. In developing this work plan, the SC should consider the elements summarised in Tables 1 and 2.

3.40 The Workshop further recommended that the Scientific Committee identify ways to address the following immediate priorities:

(i) Update the fishery reports to include more information on the potential effects of climate change on harvested species and stocks, and management response to these effects (3.35);

(ii) Develop a web page to explain CCAMLR's response to climate change to the public.

Report adoption

4.1 The report of the Workshop was adopted requiring 4 h and 45 minutes of discussion.

Close of the Meeting

5.1 At the close of the meeting, the Co-conveners thanked the participants for their contributions to a successful workshop. They noted the complex nature of the hub-based hybrid format and the short timescales required of the rapporteurs, as well as for the note takers for the hub sessions to allow for reporting back to Plenary. They noted that despite the challenges, the workshop demonstrated the constructive and collaborative attitudes of the participants to progress this important topic.

5.2 Dr M. Collins (UK) noted the unique format of the meetings and that although challenging for the conveners it was a useful test of the format and thanked the Co-conveners and the Secretariat for their efforts.

5.3 Mr N. Walker (NZ) also thanked the Co-conveners, the Secretariat and the participants for their work, noting the meeting was more complex than normal but that there was good attendance and participation.

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Table 1: Summary of tasks recommended by the Workshop for the Scientific Committee to consider while progressing its work on monitoring and formulating management responses to the effects of climate change, to ensure that CCAMLR can continue to meet its objective in Article II of the Convention in a changing climate. Timescale indicates the time needed to complete the task, with "Short" indicating within the next 1-2 years, "Medium" indicating 3-5 years, "Long" indicating 5+ years, and "C" indicating continuous. TBD indicates no discussion due to the lack of time available during the meeting.

No.	Task	Suggested WG / fora	Timescale	Priority (H/M/L)	Paragraph
1	Work with adjacent RFMOs and RMBs to identify potential for range shifts due to climate change of exploited species/species of interest, and produce a list of species/stocks straddling or likely to straddle CAMLR Convention Area, as well as identifying data sharing needs.	Secretariat WG-FSA	Short	H	2.24
2	Work with relevant RFMOs/RMBs to exchange knowledge of ecosystem impacts of climate change, and lessons learned in incorporating climate change into their activities.	Secretariat	Short (C)	M	2.24
3	Provide public-facing information explaining how climate change variability is included in stock assessments and management of exploited stocks, through a dedicated CCAMLR webpage, and inclusion of information in Fishery Reports.	Secretariat	Short	H	3.40
4	Identify any non-target species within the CAMLR Convention Area likely to increase in commercial importance.	WG-EMM	Short	H	2.24
5	Review data collection programmes related to the fisheries to ensure they are adequate to detect significant changes in species life history parameters and distribution that affect management.	WG-FSA (SISO) WG-EMM WG-ASAM	Short	H	2.24 See 3.32
6	Develop methods to incorporate the effects of projected climate change on assumed recruitment patterns or uncertainty for toothfish recruitment into assessment projections.	WG-EMM WG-SAM WG-FSA	Medium	M	2.16 2.24 See 3.29
7	Develop appropriate parameters for all exploited species (e.g., WS-CC-2023/20 Table 1) to monitor the effects of climate variability/change on parameters and processes relevant to stock assessments.	WG-FSA WG-SAM	Medium	H	3.35 See 3.30
8	Develop a workflow to incorporate information on the effects of climate change in management advice and alternative management approaches, including long-term change in spatial distributions and inclusion of climate change projections.	WG-SAM WG-FSA	Medium	M	2.24
9	Use a risk assessment framework to obtain an initial prioritisation of the likely impacts of climate change on harvested species with focus on regional scale.	WG-EMM WG-FSA	Short	H	2.11 See 2.10
10	Use a risk assessment framework to obtain an initial evaluation of the likely effects of climate change on dependent and bycatch species.	WG-EMM WG-FSA	Medium	M	2.11

(continued)

Table 1 (continued)

11	The Workshop encouraged Members to supply relevant data to SOOS noting that SOOSmap is a data discovery tool, comprising circumpolar standardised, curated data. The Workshop recommended that the Scientific Committee tasks the Secretariat with liaising with SOOS to develop information for use by CCAMLR.	TBD	TBD	TBD	1.15
12	The Workshop recommended that the Scientific Committee request advice from SCAR to help develop a framework for using climate models to drive ecological projections for AMLR and dependent and related species.	TBD	TBD	TBD	1.48
13	The Workshop recommended that the Scientific Committee develop a catalogue of the different types of extreme events, their time scales and the species and life stages that they are likely to affect (building for example on information in WS-CC-2023/12) which would be a useful aid to communicating data needs to climate modellers.	TBD	TBD	TBD	1.52
14	The Workshop recommended that the Scientific Committee consider the development of a risk assessment for management responses to extreme events.	SC	Medium	M	3.25
15	The Workshop recommended that Scientific Committee collate a list of important variables to be monitored following an extreme event to facilitate a coordinated and timely response to such events and their physical/biological effects both on marine components and land based predators.	TBD	TBD	TBD	1.28
16	The Workshop recommended that the Scientific Committee consider forwarding the report from this Workshop to the CEP in order to assist with planning for the proposed joint CEP/SC-CAMLR workshop.	TBD	TBD	TBD	3.18
17	The Workshop recommended that the Scientific Committee include further detail on tasks relevant to climate change in its work plan, with the objective of identifying and progressing the work necessary to ensure that CCAMLR can continue to meet its objectives as stated in Article II of the CAMLR Convention in a changing climate. This work is likely to include research and modelling as well as testing and possible refinement of management approaches.	TBD	TBD	TBD	3.39
18	The Workshop further recommended that the Scientific Committee identify ways to address the following immediate priorities: i) Update the fishery reports to include more information on the potential effects of climate change on harvested species and stocks, and management response to these effects; ii) Develop a web page to explain CCAMLR's response to climate change to the public.	TBD	TBD	TBD	3.40
19	Identify specific information requirements and develop requests for information from other organisations, such as SCAR or SOOS.	SC WG-EMM	Short	M	1.32

(continued)

Table 1 (continued)

20	The Workshop welcomed the paper and recognised the importance of collaboration between IWC and CCAMLR, noting that Dr N Kelly (AUS) is the SC-IWC observer to SC-CAMLR and vice versa, and recommended that the collaboration continues, especially noting the importance of considering marine mammals in the current enhancement of the CCAMLR Ecosystem Monitoring Program (CEMP).	TBD	TBD	TBD	1.39
21	The Workshop recommended that the Scientific Committee consider how often stock assessment parameters should be updated and noted that reference points may be non-stationary under the effects of climate change.	TBD	TBD	TBD	2.26
22	Consider how information on projected short-term (interannual, multi-year) and long-term (decadal) changes to the recruitment of toothfish should be taken into account in the context of CCAMLR's principles of conservation and decision rules.	SC WG-SAM WG-FSA	Medium	H	3.29
23	Develop a template for reporting on monitoring of the potential effects of environmental variability and climate change for stock assessments (potentially based on the parameters described in WS-CC-2023/20), for inclusion in the annual CCAMLR Fishery Reports.	SC WG-FSA	Short	H	3.35
24	Identify specific climate variables and metrics for which data are already, or could be, collected, that would be useful in communicating the status of AMLR through time.	WG-EMM WG-SAM WG-FSA	Medium	H	3.15
25	Develop a glossary of climate related terms and definitions, as well as best practices and standards to aid in the selection and communication of essential variables, climate models and emission scenarios.	SC	Medium	L	3.22

Table 2: Additional work highlighted by the Workshop for consideration within the Scientific Committee's workplan. Timescale indicates the time needed to complete the task, with "Short" indicating within the next 1-2 years, "Medium" indicating 3-5 years, "Long" indicating 5+ years, and "C" indicating continuous. TBD indicates no discussion due to the lack of time available during the meeting.

No.	**Task**	**WG / fora**	**Timescale**	**Priority (H/M/L)**	**Paragraph**
1	Understand causes of extreme weather and climate events, and how particular characteristics of extreme events (intensity, duration etc.) translate into positive or negative impacts on biological processes, including tipping points and cascading effects. Use this understanding to develop monitoring programmes suitable for detecting and monitoring the ecological impact of extreme events.	WG-EMM	Long	M	1.54 See 1.28, 1.52, 3.25
2	Develop mechanisms, potentially analogous to CM 24-04, to respond to the effects of high impact and/extreme events.	SC	Long	M	1.26
3	Develop a gap analysis to identify CCAMLR environmental monitoring needs and the potential to source these data or derived metrics from relevant organisations.	WG-SAM WG-EMM	Short	H	1.13
4	Consider approaches used in Arctic fisheries which could be applicable to Antarctic fisheries.	SC WG-FSA	Short	M	2.2
5	Continue IWC-CCAMLR information sharing to help inform krill management, for example on food webs and krill consumption rates, whale recovery, abundance and distribution.	SC WG-EMM	Long (C)	M	1.40
6	Understand the physiological effects of climate change on marine species including bycatch in the Convention Area (e.g., skates).	WG-EMM	Long	L	1.36
7	Establish coordination between ANTOS and CEMP for long-term monitoring programmes (e.g., in the establishment of sentinel monitoring sites).	WG-EMM	Long	M	1.42
8	Monitor benthic communities in tandem with key environmental parameters, in order to understand natural variability and detect and attribute climate change and/or fishing impacts.	WG-EMM WG-FSA	Medium (C)	L	1.43
9	Obtain and disseminate expert advice (with SCAR support) on best practices for selecting, using and communicating earth system models, regional climate models and emission scenarios when undertaking ecological projections.	WG-EMM	Short	H	3.8, 3.9 and 3.10
10	Investigate impact of uncertainty in trophic effects and climate change on early life stages on uncertainty in CCAMLR Decision Rules.	WG-SAM	Medium	L	1.11
11	Integrate the likely effects of climate change into the Krill Stock Hypothesis.	WG-EMM	Long	M	1.29
12	Evaluate, and consider output/results from genomic techniques to detect climate change adaptations, as well as finer stock boundaries for Patagonian or Antarctic toothfish.	WG-EMM	Long	L	1.27

(continued)

Table 2 (continued)

13	Identify and protect areas of essential habitat such as fish nest areas and skate egg case nurseries.	SC	Short (C)	H	1.36 and 1.37
14	Use CM 22-06 to examine climate change impacts on VMEs and use VMEs to monitor changes in ecosystems.	WG-EMM	Medium	L	1.43
15	Identify bioregions with faster/slower warming to consider for climate refugia, including the development of definitions associated with refugia.	WG-EMM	Medium	L	2.32
16	Develop approaches to better communicate uncertainties from complex climate and ecological models and their future projections to managers.	SC	Medium (C)	H	2.5, 3.10 and 3.19
17	Develop a dashboard of standardised "Essential Climate Variables" to monitor for trends or changes in key physical variables which can be linked to species distributions and population level processes. This could be conducted at a regional scale to capture spatial differences.	WG-EMM WG-SAM	Medium (C)	H	3.13
18	Engage with SCAR on the further development of guidance on use of climate models, e.g., CMIP models, for the Convention Area.	WG-EMM	Medium	M	3.9
19	Further develop methods to use existing data to test for trends in key productivity parameters for all stocks with adequate data. New sample collection, approaches and analyses (e.g., new genomic, bioinformatic and microchemistry methods) should also be considered.	WG-SAM WG-FSA	Medium	H	3.32
20	Develop models to test for long-term change in the spatial distribution of Southern Ocean fish that are linked to environmental drivers, for example by using spatiotemporal analyses, and based on genomic methods. These models could then be coupled with future projections of environmental state, *e.g.*, from ESMs, to anticipate change in species distributions.	WG-SAM	Long	L	3.33
21	The Workshop noted that it would be useful to provide information on relevant and prioritised essential variables to the CEP and ATCM, and to national Antarctic programmes.	SC	Short	M	3.17
22	Engage with the ‘Antarctica In Sync’ programme to provide input on climate, ocean and ecosystem variables relevant to CCAMLR objectives, and to investigate the potential involvement of fishing vessels.	SC	Short	M	3.38
23	The Workshop noted that the Scientific Committee and its working groups could consider using seasonal climate forecasts on a year-to-year basis to understand the ecological implications of extreme climate conditions occurring in a particular year, and how proactive measures could be taken in advance of extreme events. The workshop noted that this approach is used in other fisheries worldwide, including in the Arctic.	TBD	TBD	TBD	3.26

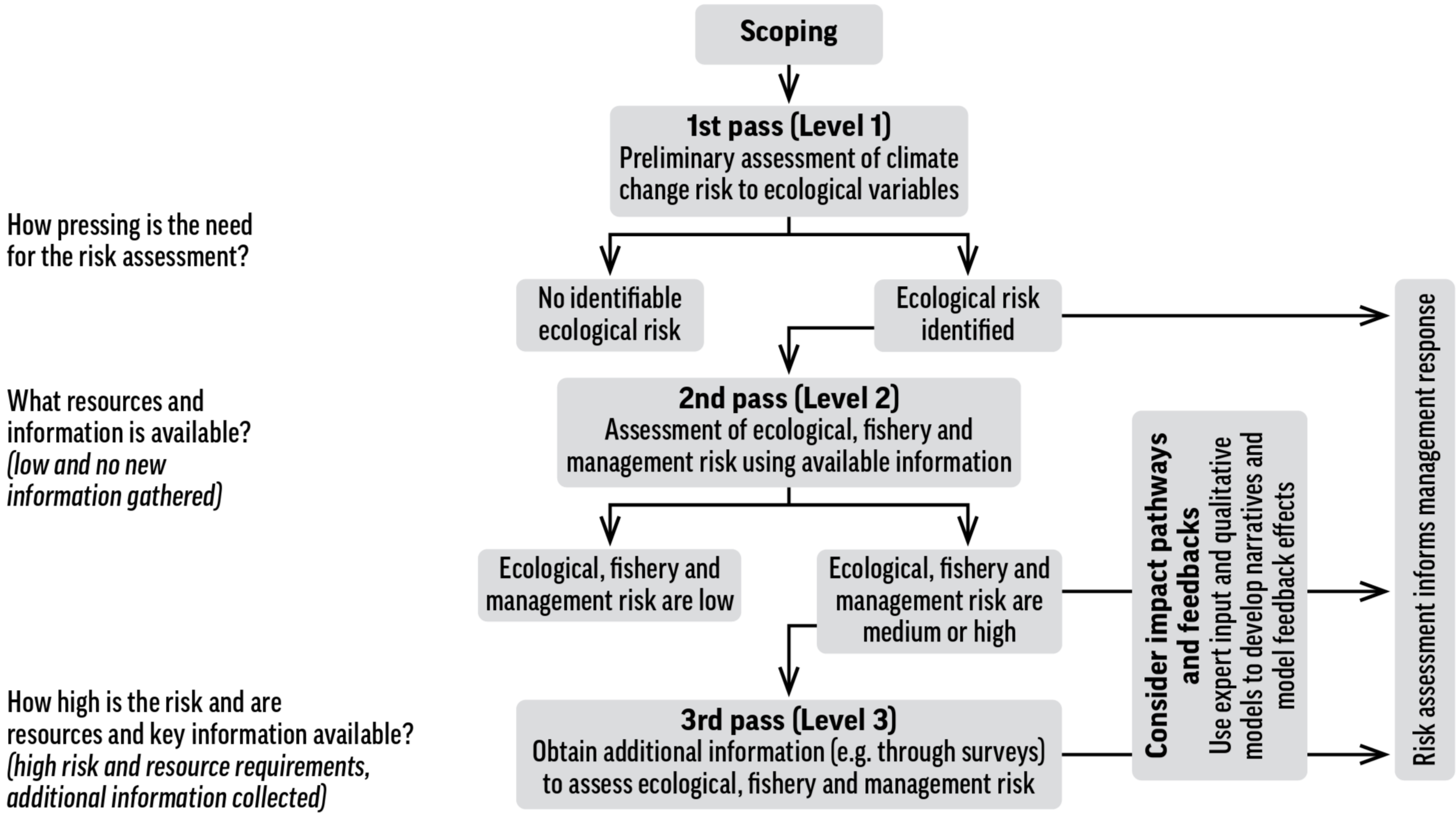

Figure 1: Diagram describing three levels of fishery and ecosystem risk assessment (from WS-CC-2023/02)

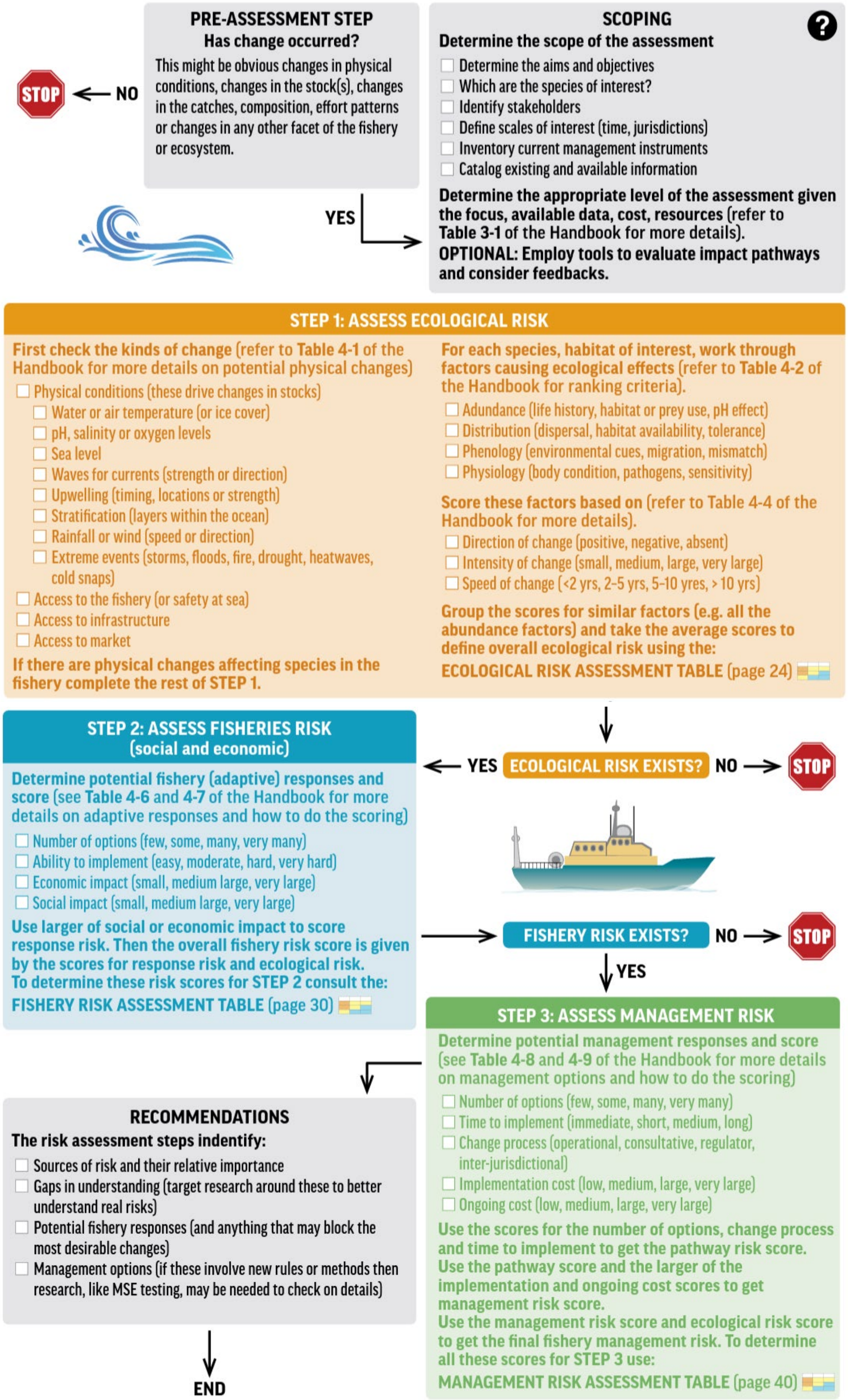

Figure 2: Diagram explaining the key steps to assess ecological, social and economic, and management risks to fisheries associated with climate change (from WS-CC-2023/02).

STEP 1: ASSESS ECOLOGICAL RISK ▶ (see Table 4-4, page 24)

Group the scores for similar factors (e.g. all the abundance factors) and take the average scores to define overall ecological risk using this table. Cross reference the direction of change, intensity of change and the speed of change to find the final level of ecological risk.

Table A: Ecological risk

	Negative Direction of Change				Positive	Absent
	Intensity of Change					
Speed of Change	Very large	Large	Medium	Small		
Next 2 years	High	High	High	Low	Low	None
Next 2-5 years	High	High	Medium	Low	Low	None
Next 5-10 years	High	High	Medium	Low	Low	None
More than 10 years	High	High	Medium	Low	Low	None

STEP 2: ASSESS FISHERIES RISK (social and economic) ▶ (see Table 4-7, page 31)

Tally up the potential options available to the fishery and rate these responses in terms of how easy they will be to implement and any economic and social impacts. Then use larger of social or economic impact to score response risk – cross reference the impact score (which ever is the larger of the social and economic impacts), ease of implementation and the number of options available and this will give you the response risk.

Table B: Response risk

Options available		Economic or social impact (whichever is LARGER)			
	Implementation	Very large	Large	Medium	Small
Few	Hard / very hard	High	High	High	Medium
	Moderate	High	High	Medium	Low
	Easy	Medium	Medium	Medium	Low
Some	Hard / very hard	High	High	Medium	Low
	Moderate	High	High	Medium	Low
	Easy	Medium	Medium	Low	Low
Many or very many	Hard / very hard	High	High	Medium	Low
	Moderate	Medium	Medium	Low	Low
	Easy	Medium	Medium	Low	Low

Then determine the overall fishery risk score by cross referencing the scores for response risk and ecological risk.

> Ecological risk from Table A
> Response risk from Table B

Table C: Fishery risk

	Response risk		
Ecological risk	High	Medium	Low
High	High	High	Medium
Medium	High	Medium	Low
Low	Medium	Low	Low
Absent	None	None	None

STEP 3: ASSESS MANAGEMENT RISK ▶ (see Table 4-9, pages 41 and 42)

Determine the list of potential management responses and score them based on time to implement, how difficult it will be to change the relevant management processes or policies, and any associated implementation or operational costs. Cross reference the scores for the number of tools available, change process and time to implement to get the pathway risk score.

Table D: Pathway risk

Tools available	Process and pathway	Time to implementation			
		Long	Medium	Short	Immediate
Few options	Inter-jurisdictional	High	High	High	High
	Regulator	High	High	High	Medium
	Consultative group	High	Medium	Medium	Medium
	Operational	High	Medium	Low	Low
Some options	Inter-jurisdictional	High	High	High	Medium
	Regulator	High	Medium	Medium	Medium
	Consultative group	High	Medium	Medium	Low
	Operational	High	Medium	Low	Low
Many options	Inter-jurisdictional	High	High	High	Medium
	Regulator	High	Medium	Medium	Low
	Consultative group	High	Medium	Low	Low
	Operational	High	Medium	Low	Low

Then cross reference the pathway score and the cost scores to get the base management risk score.

> Pathway risk from Table D

Table E: Base management risk

	Cost (implementation & ongoing, whichever is LARGER)			
Pathway risk	Very high	High	Medium	Low
High	High	High	Medium	Medium
Medium	High	High	Medium	Low
Low	Medium	Medium	Low	Low

Lastly, cross reference the base management risk score and ecological risk score to get the final fishery management risk.

> Ecological risk from Table A
> Base management risk from Table E

Table F: Fishery management risk

	Base management risk		
Ecological risk	High	Medium	Low
High	High	High	Medium
Medium	High	Medium	Low
Low	Medium	Low	Low
Absent	None	None	None

Figure 3: Diagram explaining the process to assess risk levels for ecological, fisheries and management risks (from WS-CC-2023/02).

Attachment I

Perspectives on the hub-based hybrid meeting format from participants

These comments are a synthesis of comments from participants and were not adopted.

The workshop was comprised of two hub meetings (NZ and UK) occurring during their local business hours for 3 hours each day (Monday-Wednesday). The UK hub included two additional sub-hubs, one in China and one in France. In addition, a daily joint plenary session was held at 1000 to 1200 UTC (Monday-Wednesday) for synthesis of the hub discussions. No meeting was held on Thursday to allow for report preparation. Report adoption was held on Friday in a plenary session at 1000 to 1300 UTC.

The Workshop was well attended with variable numbers of participants attending in different ways across the week (Table A1), noting many participants attended one hub and the plenary, some participants attended both hubs and some attended only report adoption, which had up to 106 participants of the total 129 participants registered.

Workshop participants recognised the importance of including meeting attendance as part of the consideration of climate change across all of CCAMLR's activities. Reflecting on the pros and cons of the hybrid format of this workshop in terms of carbon footprint, engagement of participants, and practical/logistical issues will be useful in planning for future events.

Participants noted several benefits of this arrangement and several shortcomings, compiled here for reference:

Benefits noted

(i) Increased number of participants, inclusivity of specialists for particular agenda items, training opportunities, and broader perspectives as the cost to attend was mostly staff time and the usual space limitations of in-person meetings were overcome by the online option.

(ii) Much lower travel commitment than fully in-person meetings with significantly reduced (a) carbon footprint (very important in the context of climate change), (b) travel costs, (c) conflict with other commitments (including family, caring responsibilities, other travel commitments and a meeting-heavy calendar for many (CCAMLR and otherwise)), (d) exclusion of those unable to travel for health reasons.

(iii) Hub structure allowed for more of the meeting time to occur during local business hours than a single time hybrid meeting.

(iv) The use of in-person hubs retained some of the personal interaction that would be lost with a fully online meeting.

(v) The use of two hubs at the extremes of the time difference with an additional plenary was effective at synthesizing and extending discussion.

Shortcomings noted

Participation

(i) Presentations of papers were generally given in one hub or the other limiting question and answer periods and in-depth understanding/discussion of the papers.

(ii) The flow of discussion was halted, participants were more reserved to engage, and therefore there was less widespread participation in discussions. Participation within hubs was likely better than for online individuals.

(iii) With this format, there is no possibility for break out subgroups to explore some of the more complex topics in greater depth.

Meeting scheduling

(i) The timing of the hubs and plenary was very inconvenient for some participants. An additional third hub, while allowing for more participants to have local time discussions, would compound this problem. The NZ hub timings spread meetings over 15 hours per day, reducing engagement in plenary.

(ii) The time available for summarizing hub discussions, developing and commenting on report text was too constrained.

(iii) Even with short discussion periods, more and longer comfort breaks were needed.

Technical issues

(i) The sound quality made some participants very difficult to understand. In some cases the audio didn't work at all and participants had to text their comments. Technical issues, especially with sound quality reduced effective communication.

(ii) It was often difficult to determine who was speaking at hubs with a wide-angle camera view, requiring reliance on individuals to manage their own cameras during interventions. Speakers often did not identify themselves or turn on their own laptop camera.

(iii) Both sound and video issues are made more complex when mixing completely online participants with other participant groups in a single room. High quality equipment and technical support is necessary to manage the audio and video environment. It is much simpler to either have all online or all in person audio and video arrangements.

(iv) Management of audio and video and presentations at each hub required a person to do this, which reduced their participation.

(v) Significant meeting activity occurred at all times of day, some problems inevitably occurred when no Secretariat support was available, which then temporarily halts progress.

(vi) Logistic support required essentially running three simultaneous meetings, with support work spanning 16 hours each day and therefore five Secretariat staff to be involved with significant overtime.

(vii) Report text development and timing was complex, with rapporteuring needing to occur quickly and all from one hub. Different times zones required careful sequencing of when report text could be commented on. Configuring report text development across time zones was complex with no equitable solution.

General comments

(i) Participants commented that it was important to try different approaches to meetings to reduce carbon footprint and facilitate more participation and that we learn from the experiences.

(ii) The peculiarities of the meeting format, and novel issues raised, created many *ad hoc* decisions and therefore confusion among participants. Despite extensive planning and communication (3 detailed SC circulars), and information posted on the website, the unique aspects created misunderstandings. Written guidance on how to prepare papers, presentations, recommendations, make interventions and participate in mixed-format meetings would be useful.

(iii) Future online meetings should be shorter (less than three days) to minimize issues. If hybrid meetings are considered, a shorter meeting each day with all present may be a better approach.

(iv) Secretariat presence or alternative local designated support team should be available in-person at each hub along with appropriate equipment to ensure convener and meeting support is available during the local operation times.

(v) A 2–3 minute pre-recorded presentation for each paper may have reduced the time taken for presentations, and given both hubs the same information.

(vi) Encourage additional sub-hubs (perhaps one per delegation) in future meetings recognising this does not increase inter-delegation interactions.

Table A1: Summary of the number of participants by hub location and mode of connection for each day of the workshop.

Date	**NZ Hub**		**UK Hub**		**Plenary**	
4-Sep-23	Online	47	Online	69	Online	55
	NZ Hub	10	UK Hub	13	NZ	10
			China Sub-hub	5	UK	13
			French Sub-hub	7	China Sub-hub	5
					French Sub-hub	7
	Subtotal	57		94		90
5-Sep-23	Online	46	Online	67	Online	58
	NZ Hub	8	UK Hub	15	NZ	8
			China Sub-hub	5	UK	15
			French Sub-hub	7	China Sub-hub	5
					French Sub-hub	7
	Subtotal	54		94		93
6-Sep-23	Online	46	Online	43	Online	57
	NZ Hub	6	UK Hub	14	NZ	6
			China Sub-hub	5	UK	14
			French Sub-hub	7	China Sub-hub	5
					French Sub-hub	7
	Subtotal	52		69		89
8-Sep-23					Online	82
					NZ	6
					UK	9
					China Sub-hub	5
					French Sub-hub	7
	Subtotal					109

Attachment II

List of Participants

Co-conveners	Dr Rachel Cavanagh British Antarctic Survey
	Mr Enrique Pardo Department of Conservation
Argentina	Dr Dolores Deregibus Instituto Antártico Argentino/CONICET
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	Dr María Mercedes Santos Instituto Antártico Argentino
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	Dr Nat Kelly Australian Antarctic Division, Department of Climate Change, Energy, the Environment and Water
	Mr Dale Maschette Institute for Marine and Antarctic Studies (IMAS), University of Tasmania
	Dr Cara Masere Australian Antarctic Division, Department of Climate Change, Energy, the Environment and Water

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	Ms Anaelle Durfort Université de Montpellier
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	Dr Sara Labrousse Sorbonne Université
	Dr Sylvain Lenoir TAAF
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	Ms Clara Beauvoir Ministry for Primary Industries
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	Mr Jack Fenaughty Silvifish Resources Ltd
	Mr Simon Lamping Department of Conservation
	Dr Matt Pinkerton NIWA
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	Mr Nathan Walker Ministry for Primary Industries
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	Dr Otis Brunner British Antarctic Survey
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	Ms Olivia Lassaline Fisheries and Oceans Canada

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	Professor Catherine Iorns Victoria University of Wellington, NZ
	Dr Aurélie Spadone Ocean Team, Centre for Conservation Action, IUCN
IWC	Mr Mark Simmonds University of Bristol
	Dr Iain Staniland International Whaling Commission
SCAR	Dr Cassandra Brooks University of Colorado Boulder
	Dr Andrew Constable University of Tasmania
	Dr Susie Grant British Antarctic Survey

	Dr Chandrika Nath Scientific Committee on Antarctic Research
	Dr Kirsten Steinke Oregon State University
SCOR	Dr Alyce Hancock Southern Ocean Observing System (SOOS)

Observers – Non-Governmental Organisations

ARK	Dr Javier Arata Association of Responsible Krill harvesting companies (ARK)
ASOC	Dr Ricardo Roura Antarctic and Southern Ocean Coalition
COLTO	Mr Rhys Arangio Coalition of Legal Toothfish Operators
	Mr Richard Ball SA Patagonian Toothfish Industry Association
Oceanites	Mr Steven Forrest Oceanites, Inc.
	Professor Philip Trathan Oceanites, Inc.

Attachment III

Agenda

Workshop on Climate Change
(Cambridge, UK and Wellington,
New Zealand, 4 to 8 September 2023)

1. Expected effects and risks of climate change on Antarctic Marine Living Resources

   1.1 Workshop opening: welcome, workshop structure, housekeeping, adoption of agenda
   1.2 Invited presentation: Climate change and Antarctic Marine Living Resources (Dr Jess Melbourne-Thomas and Dr Tom Bracegirdle)
   1.3 Climate change effects on harvested species
   1.4 Climate change effects on dependent and related species
   1.5 Summary of the discussion
   1.6 Close

2. Spatial management approaches to ensure objective of the Convention is met

   2.1 Day 1 plenary report summary
   2.2 Invited presentation: Climate change and management approaches for marine living resources (Dr Anne Hollowed)
   2.3 Climate change considerations for CCAMLR's management approach
   2.4 Specific climate change considerations for spatial management
   2.5 Summary of the discussion
   2.6 Close

3. Information, including monitoring and metrics, needed to support management decisions, and mechanisms to develop and integrate these

   3.1 Day 2 plenary report summary
   3.2 Climate change information needed to support management decisions
   3.3 Mechanisms to improve input, and use of, relevant scientific information and advice on climate change throughout CCAMLR's work program
   3.4 Summary of the discussion
   3.5 Close

4. Report drafting

5. Report adoption

Attachment IV

List of Documents

(Cambridge, UK and Wellington,
New Zealand, 4 to 8 September 2023)

WS-CC-2023/01	Evaluating climate change risks to Patagonian and Antarctic toothfish Cavanagh, R., O. Brunner, M.A. Collins, T. Earl, J. Freer, S. Hill, O. Hogg, P. Hollyman, H. Peat, M. Soeffker, S. Thorpe, C. Waluda and M. Whitelaw
WS-CC-2023/02	Adaptation of fisheries management to climate change Handbook Fulton, E.A. , E.I. van Putten, L.X.C. Dutra, J. Melbourne-Thomas, E. Ogier, L. Thomas, R.P. Murphy, I. Butler, D. Ghebrezgabhier, A.J. Hobday, N. Rayns
WS-CC-2023/03	An exploratory evaluation of forecasted changes in sea surface temperature and sea ice in the Domain 1 Marine Protected Area Krüger, l., F. Santa Cruz, L. Rebolledo and C.A. Cárdenas
WS-CC-2023/04	Climate change impacts vary with depth: what can be the consequences for pelagic ecosystems and for conservation ? Examples from the Southern Indian Ocean Azarian, C., L. Bopp and F. d'Ovidio
WS-CC-2023/05	Potential implications of climate change on the Patagonian toothfish fisheries management Azarian, C., L. Bopp and F. d'Ovidio
WS-CC-2023/06	Summary of recent climate change science discussions within CCAMLR (2015-present) Cavanagh, R. and E. Pardo
WS-CC-2023/07	Turning the page on CCAMLR’s response to climate change ASOC
WS-CC-2023/08	Predicting future fishable distribution of Antarctic toothfish (Dissostichus mawsoni), with implications for Marine Protected Areas in the Southern Ocean Konijnenberg, R., C. Nissen, C. Kraan, J.A. Caccavo, C.A. Cárdenas, M. Collins, T. Okuda, R. Sarralde Vizuete, P. Yates, Ziegler, P. and K. Teschke
WS-CC-2023/09	Carbon sink fishery: a climate change perspective in CCAMLR ecosystem based fishery management Ying, Y., L. Liu, X. Mu and X. Zhao

WS-CC-2023/10	The crabeater seal as a candidate species for climate change monitoring and the CCAMLR Ecosystem Monitoring Program (CEMP): East Antarctica monitoring program Labrousse, S., J-B. Charrassin, M. LaRue, L. Huckstadt and M. Eleaume
WS-CC-2023/11	SCAR affiliated research activities relevant to the integration of climate change information into CCAMLR's work program SCAR
WS-CC-2023/12	Outcomes of the first Marine Ecosystem Assessment for the Southern Ocean (MEASO) useful to CCAMLR in developing science to support managing the effects of climate change SCAR
WS-CC-2023/13	Potential effects of climate variability and change on bycatch using Antarctic skates as a case study Finucci, B. and M. Pinkerton
WS-CC-2023/14	Summary of the IWC Climate Change Workshop Report related to the Southern Ocean and CCAMLR IWC
WS-CC-2023/15	Taking climate change effects on benthos into account in CCAMLR Cummings, V., D. Lohrer et al.
WS-CC-2023/16	A Risk Assessment of Changing Climate on Antarctica and the Southern Ocean Bertler N.A.N. and I. Hawes
WS-CC-2023/17	Anticipating environmental and biogeochemical changes in the Southern Ocean using Earth System Models: the importance of evaluation Rickard, G., E. Behrens, A. Bahamondes Dominguez and M. Pinkerton
WS-CC-2023/18	Effects of climate variability and change on the recruitment of Antarctic toothfish in the Ross Sea region: the impact of sea-ice drift, ocean circulation, and prey resources Behrens, E., M. Pinkerton, G. Rickard, A. Grüss, C. Collins and I. Blixt
WS-CC-2023/19	Environmental change in the Southern Ocean: observations, trends, bioregions and species-distribution models Pinkerton, M. and S. Halfter
WS-CC-2023/20	Monitoring the effects of environmental variability and climate change on toothfish assessments Pinkerton, M., J. Devine, A. Dunn and S. Mormede

WS-CC-2023/21	Approaches to incorporating climate change considerations into fisheries management in CCAMLR Earl, T., J. Pinnegar and M. Soeffker
WS-CC-2023/22	Climate Genomics of Antarctic Toothfish (ClimGenAT) Caccavo, J.A., F. d'Ovidio and M. Gehlen

Other Documents

WS-CC-2023/P01	Antarctic Extreme Events Siegert, M.J., M.J. Bentley, A. Atkinson, T.J. Bracegirdle, P. Convey, B. Davies, R. Downie, A.E. Hogg, C. Holmes, K.A. Hughes, M.P. Meredith, N. Ross, J. Rumble and J. Wilkinson. 2023. Antarctic Extreme Events. *Front. Environ. Sci.*, 11:1229283, doi: 10.3389/fenvs.2023.12292.
WS-CC-2023/P02	Climate drives long-term change in Antarctic Silverfish along the western Antarctic Peninsula Corso, A.D., D.K. Steinberg, S.E. Stammerjohn and E.J. Hilton 2022. Climate drives long-term change in Antarctic Silverfish along the western Antarctic Peninsula. *Commun. Biol.,* 5:104, doi: 10.1038/s42003-022-03042-3
WS-CC-2023/P03	Managing for climate resilient fisheries: Applications to the Southern Ocean Chavez-Molina, V., S.L. Becker, E. Carr, R.D. Cavanagh, D. Dorman, E. Nocito, Z. Sylvester, B. Wallace, C. White and C.M. Brooks. 2023. Managing for climate resilient fisheries: Applications to the Southern Ocean. *Ocean Coast. Manag.*, 239:106580, doi: 10.1016/j.ocecoaman.2023.106580

Attachment V

Terms of Reference for the Climate Change Workshop

Objective

To improve the integration of scientific information on climate change and ecosystem interactions throughout CCAMLR's work program.

Draft Terms of Reference

1. Review information on climate change in the Southern Ocean relevant to CCAMLR objectives and how climate change effects are being addressed by management both inside and outside the Convention Area.

2. Use the information from (1) to:

   (i) review the effects/risks of climate change to Antarctic marine living resources (including disentangling the effects of climate change and fishing)

   (ii) review the effects of harvesting activities on key Antarctic marine living resources as well as the ecosystem services they provide (inter alia carbon sequestration)

   (iii) identify and prioritise issues that should be considered by CCAMLR

   (iv) identify further research needs, including the use of novel platforms for data collection (inter alia vessels of opportunity) and the enhancement of CEMP.

3. Identify mechanisms to improve input, and use, of relevant scientific information and advice on climate change into the Commission.

4. Provide advice to Scientific Committee and it's working groups on adaptive management approaches available to CCAMLR to address climate change impacts on marine living resources.