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Marine Ecosystem Assessment for the Southern Ocean (MEASO) - Key Findings and Recommendations

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Information Paper submitted by SCAR

Summary

The Marine Ecosystem Assessment for the Southern Ocean (MEASO)¹ is a core program of Integrating Climate and Ecosystem Dynamics of the Southern Ocean (ICED), which is co-sponsored by IMBeR and SCAR. It has been an open participatory, multidisciplinary up-to-date assessment of status and trends in Southern Ocean ecosystems for use by policy makers, scientists and the wider public. To date, it has involved over 200 scientists from across the Antarctic and Southern Ocean scientific community (18 countries, >50% female, >40% early career), contributing to 25 research articles published in a special research topic in *Frontiers* journals (greater than 200,000 views, 38,000 downloads). The international network and outputs of MEASO have direct relevance for a number of priorities and actions in the CEP in relation to its Climate Change Response Work Program and the Five-Year Plan. This paper presents key findings from MEASO on how Southern Ocean species and ecosystems are already being affected by climate change and what the future looks like; where to find fuller explanations behind these conclusions; options for managers to protect these ecosystems and enhance their resilience; suggested processes for a wider participation in protecting the Southern Ocean; and priorities for scientific research to support management into the future.

Introduction

- Global interest in Antarctica and the Southern Ocean and the desire for its protection are demonstrated by the development of the Antarctic Treaty System and its emphasis on conservation and protection.
 - Global policy and action is required to safeguard Southern Ocean ecosystems from the effects of climate change and ocean acidification caused by greenhouse gas emissions.
 - Regional pressures on Southern Ocean species and ecosystems have been dominated by fisheries, with human presence (science and tourism) and pollution having only localised effects at this stage.
 - The Marine Ecosystem Assessment for the Southern Ocean (MEASO) has demonstrated the array of existing knowledge, data, tools and approaches available for informing decisions on conserving and sustaining marine ecosystem services in the region, and how their implementation could be improved.
 - MEASO contributes to the CEP Climate Change Response Work Program (CCRWP) on the following issues:
 - Issue 3) Change to marine near-shore abiotic and biotic environment
 - Issue 4) Ecosystem change due to ocean acidification
 - Issue 6) Marine and terrestrial species at risk due to climate change
 - Issue 7) Marine, terrestrial and freshwater habitats at risk due to climate change
- and to the 2022 CEP Five-year Work Plan on the following issues:

¹ Contact: measo.2020@utas.edu.au

- Climate change implications for the environment
 - Action: Consider implications of climate change for management of Antarctic environment.
- Monitoring and state of the environment reporting
 - Action: Identify key environmental indicators and tools
 - Action: Establish a process for reporting
- Marine spatial protection and management
 - Action: Identify and apply processes for spatial marine protection
 - Action: Consider connectivity between land and ocean
- The first section of this information paper provides key policy-relevant findings for the CEP and recommended research priorities, and is followed by three sections underpinning those recommendations – key findings on the value and change in marine ecosystems of the Southern Ocean, the background to MEASO, and, finally a list of peer-reviewed MEASO journal articles that will be published as an eBook in 2023 and used as the basis for the Summary for Policy Makers to be released in 2023.
- This paper focuses on MEASO findings and recommendations that are relevant to the CEP; additional information was presented to CCAMLR in 2022 (SC-CAMLR-41/BG/25).

1. Key policy-relevant findings and recommended research priorities

Managing for change

- Human interventions to facilitate adaptation of Southern Ocean marine ecosystems to the effects of greenhouse gas emissions are not available.
- Strategies for conserving Southern Ocean marine biodiversity, including in managing fisheries, need to be developed based on current knowledge to ensure resilience of Southern Ocean ecosystems into the future.
- Managing local human activities in the Southern Ocean will benefit from assessments of the risks of different scenarios along with improved socio-ecological modelling and stakeholder engagement.

Measuring change

- Directly measuring the state of Southern Ocean ecosystems requires greater investment in research than current levels, because of the complexity of food webs and biodiverse communities, the size of the areas to be covered, and the remoteness of the region.
- A greater spread of comprehensive, long-term ecosystem studies across all Southern Ocean regions is needed to assess spatial variability in the structure of Southern Ocean ecosystems and the relative importance of different ecological processes in different areas.
- Systematic and sustained measurements of biological sentinel variables in all relevant MEASO areas are needed to underpin assessments of ecosystem change in the Southern Ocean and for projecting future changes.

Projecting change to support risk assessments

- Projecting future changes of species needs improved models that relate change in habitats, food webs and human activity to change in the survival and/or dynamics of those species.
- Projecting change of ecosystems in different MEASO areas needs dynamic food web and ecological community models coupled to models of Earth's ice-ocean-atmosphere (physio-chemical models) scaled to relevant ecological processes.

2. Key findings from MEASO on state, variability and change

Value and importance of Southern Ocean ecosystems in the Earth System

- Southern Ocean ecosystems are an integral part of the Earth System; changes in Southern Ocean ecosystems will have impacts throughout the world's oceans and climate system and vice versa.
- Once thought to be isolated, the Southern Ocean exchanges water with oceans to the north in some locations through surface eddies driven by wind as well as deep water convection driven by temperature and salinity. Such connectivity enables movement of pelagic organisms (plankton and fish) and biological material into and out of the Southern Ocean.
- The Southern Ocean provides important feeding and breeding grounds for migratory whales, pinnipeds and seabirds; migratory species transport important nutrients to and from the Southern Ocean each year and can contribute to the transport of pollutants and invasive species.
- Globally, people have a deep, often unacknowledged, connection with the Southern Ocean and value it greatly, despite not living there.
- Human activities in the region (science operations, fisheries, tourism) involve the large-scale transfer of people and material north and south each year linking communities and social systems elsewhere to the Southern Ocean but also potentially contributing to unexpected effects in the region through transport of non-native species/diseases, direct disturbance and pollution.
- The demand for, and global importance of the role of, ecosystem services from the Southern Ocean, is expected to increase during the 21st century.

Changing habitats in the Southern Ocean

- The Southern Ocean is warming, but to varying extents around Antarctica.
- Sea ice, a key habitat and defining feature of the Southern Ocean, is changing but in different ways around Antarctica; prognoses for sea ice are amongst the greatest uncertainties on the future of marine ecosystems in the region.
- The Southern Ocean is freshening and becoming more windy.
- The light environment in the Southern Ocean is changing, therefore affecting blooms of phytoplankton.
- Nutrients (iron, silicic acid, phosphate and nitrate) that are required for primary production are changing but supply is dependent on local conditions.
- Absorption of large amounts of atmospheric CO₂ by the Southern Ocean is causing the water to become more acidic.
- The melting and retreat of glaciers and the collapse of ice shelves due to increased oceanic and atmospheric temperatures affects coastal ecosystems.
- Globally-generated pollutants, including micro-plastics, are increasingly detected in the environment and in biota of the Southern Ocean, and local effects of pollution are altering environments adjacent to stations.

Biological changes and vulnerabilities

- Sea ice supports productivity in the spring, autumn and winter, and provides habitat for feeding, breeding and refuge for many species.

- Coastal and shelf systems of the Southern Ocean in waters shallower than 2000 m are among the most productive ecosystems in the global ocean and drive production locally and downstream.
- Primary production by phytoplankton and carbon export to deeper water around Antarctica are changing but the outcomes are complex because of multiple factors affecting iron supply, mixed layer depth, light availability and export efficiency.
- Warming will alter seasonal patterns in production (phenology) and the relative abundances of different types of phytoplankton (particularly diatom vs. non-diatom).
- Individual sensitivities of benthic and pelagic species to change in habitat conditions is determined by their morphology, ability to regulate their physiology, and ability to move if the conditions are inhospitable.
- Evidence for individual tolerances of species and the measured contraction in the northward extent of the range of Antarctic krill indicates that the Antarctic (polar) ecosystem is contracting towards Antarctica; tolerant species and species from more northern areas may become more abundant in southern areas.
- Seals, penguins and flying birds dependent on sea ice for breeding and haul-out resting are negatively impacted by declining sea ice conditions.
- Shore-based colonies will be impacted by shifting of the primary locations of their prey, particularly for subantarctic predators, and in changing conditions at their colonies.
- Foraging success of migratory seabirds, seals and whales may be disrupted should there be a change in timing of productivity in the coupled ocean-ice ecosystems.
- Pollution and pathogens are emerging as factors impacting species in the Southern Ocean, including fish, marine mammals and birds.
- Benthic systems will be negatively impacted by warming, freshening and acidifying habitats and, on the Antarctic continental shelf, by increased iceberg scour.
- Change in Southern Ocean food webs is dependent on the energy pathways prevalent in an area and the sensitivity of species (either as predators or as prey) to the abundance of those species affected by changes in their habitats.
- Reduced dominance of Antarctic krill may arise in the Atlantic sector of the Southern Ocean due to sea ice loss, warming and acidification, thereby impacting higher trophic levels and the energetic efficiency of the ecosystem.

3. Background to MEASO

MEASO is the first circumpolar assessment of Southern Ocean ecosystem status and trends, beginning its activities in 2018. This section outlines the key features of MEASO and important outputs and events since 2018.

Key Features

- A spatially-structured circumpolar ecosystem assessment.
- A 5-year inclusive international program providing a forward-looking assessment of trends in Southern Ocean ecosystems. To date, it has involved over 200 scientists from across the Antarctic and Southern Ocean scientific community (18 countries, >50% female, >40% early career), contributing to 25 research articles published in a special research topic in *Frontiers* journals (greater than 200,000 views, 38,000 downloads).
- A key output of the program Integrating Climate and Ecosystem Dynamics of the Southern Ocean (ICED), which is a regional program of the Integrated Marine Biosphere Research (IMBeR) project and a co-sponsored program of SCAR.

Outputs and events

- 2018 Hobart International Conference on the Marine Ecosystem Assessment for the Southern Ocean, including a one-day Policy Forum.
- 2019 Working Workshop on progressing the first MEASO.
- 2019-21 Delivery of the Marine Ecosystem Assessment e-book published in *Frontiers: Contributions to Intergovernmental Panel on Climate Change: Special Report on Oceans and Cryosphere in a Changing Climate* (Ch 3: Polar Regions), Working Group II (Ch 3: Oceans and Coastal Ecosystems and their Services; Cross- Chapter Paper 6: Polar Regions).
- 2021 UN Framework Convention on Climate Change, Conference of Parties 26 (UK) - Cryosphere Pavilion Polar Oceans Day: Antarctic marine ecosystems under pressure: protection needs action locally and globally.
- 2022 UN Framework Convention on Climate Change, Conference of Parties 27 (Egypt) - Cryosphere Pavilion Polar Oceans Day: Southern Ocean ecosystems: need for augmented understanding, research efforts and protection; Presentations to SCAR Open Science Conference and to the Challenger 150 Symposium, among others.

4. Publications

Research Topic in *Frontiers* (to be made into an eBook in 2023) with participating journals: *Frontiers in Ecology and Evolution* (Conservation & Restoration Ecology), *Frontiers in Environmental Science* (Conservation & Restoration Ecology), and *Frontiers in Marine Science* (Global Change and the Future Ocean). The research topic can be accessed at:

<https://www.frontiersin.org/research-topics/10606/marine-ecosystem-assessment-for-the-southern-ocean-meeting-the-challenge-for-conserving-earth-ecosys#overview>

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