Working Group report

__Progress Report, 16 September 2021__

WG number : 3

Targeted Societal Outcome : Sustainably Productive Ocean

WG chair(s) : Javier A. Arata

Ocean Decade Definition of the Outcome : The ocean is the foundation for future global economic development and human health and wellbeing, including food security and secure livelihoods for hundreds of millions of the world's poorest people. Knowledge and tools to support the recovery of wild fish stocks, deploy sustainable fisheries management practices, and support the sustainable expansion of aquaculture, while protecting essential biodiversity and ecosystems, will be essential. The ocean also provides essential; goods and services to a wide range of established and emerging industries including extractive industries, energy, tourism, transport and pharmaceutical industries. Each of these sectors has specific, priority needs in terms of increased knowledge, and support to innovation, technological development and decision support tools to minimize risk, avoid lasting harm, and optimize their contribution to the development of a sustainable ocean economy. Governments also require information and tools, for example via national accounts that incorporate ocean indicators, to guide development of sustainable ocean economies and promote marine sectors.

References:
- 1st SOUTHERN OCEAN REGIONAL WORKSHOP, 16 February 2020, San Diego, CA USA. Prepared by E Hofmann, L Biddle, T de Bruin, C Brooks, S Corney, A Haumann, N Johnston, M Mazloff, E Murphy, C Reiss, J Russell, H Rosenthal, E Sikes
  - ☐ 30 participants, representing 11 countries

- Southern Ocean Task force [2021] Review of identified priorities for the Southern Ocean in the context of the UN Ocean Decade 2021. DOI: 10.5281/zenodo.4784227

Background information:
- UNESCO-IOC (2021). The United Nations Decade of Ocean Science for Sustainable Development (2021-2030) Implementation Plan. UNESCO, Paris (IOC Ocean Decade Series, 20.)

WG3 seminars:
WG3 videoconference, 10 & 13 September 2021.

Priorities Identified during the previous workshop:

I. Increase the suite, types, and reliability of measurements, including those focused on ecosystem change, needed to inform management and policy
    ● Identify and develop relevant ecological indicators to evaluate risks to the Southern Ocean and services it provides, and to monitor health and rates of ecosystem change and its interactions with human activities
    ● Improve the understanding of the consequences of human-induced change on polar ecosystem services
    ● Create guidelines for sustainable monitoring and regular assessments that enable us to assess our progress towards the desired states
    ● Improve our understanding of key mechanisms regulating the ecosystem in the winter
    ● Assess how much ecosystem services the Southern Ocean contribute to the global budget, and whether they will change in space and time

II. Achieve sustainable management of fisheries based on an ecosystem approach, including the recovery of overexploited species and the effect of climate change on ecosystems.
    ● Improve understanding of fish stock sustainability and resilience integrating oceanographic, climate, ecosystem structure and functioning, connectivity and harvesting interactions
    ● Identify new methods to effectively integrate both quantitative and qualitative data, fill critical data gaps, and analyse the likely effects of crossing thresholds that are likely to be irreversible in the near term
    ● Develop integrated stock assessments which take into consideration the ecosystem where the fishery operates.
    ● Develop models considering the functional connectivity among ecosystem elements, including drivers in all cardinal directions (e.g., circumpolar, Subtropical effect on polar regions)
    ● Identify thresholds or abrupt or irreversible changes
    ● Develop Decision Support Tools (DSTs) for the timely managing fishing quotas.
    ● Develop recovery strategy plans for overexploited species, considering the ecological role and current and future status of the ecosystem (which may affect they realized recovery abundance)
    ● Understand the role of Myctophid for consumers, producers and as an extractable resource
    ● Understand the role of Mackerel icefish for consumers, producers and as an extractable resource
    ● Progress on the understanding and managing of toothfish species
    ● Progress on the understanding and managing of Antarctic krill
        − Improve knowledge on Antarctic krill's resilience to climate change.
        − Get a mechanistic understanding of seasonal krill flux in relation to currents, bottom topography, and endogenous control via geophysical forcing.
        − Develop an integrated, spatially explicit, stock-recruitment population model for Antarctic krill

III. Ensure science-based and effective spatial planning process, including MPAs, with consideration of sustainable fisheries management and tourism development
    ● Assess the success of existing Southern Ocean Marine Protected Areas in meeting their conservation objectives, including as scientific references areas, and determine additional requirements for the achievement of regional conservation and research objectives

- Develop a framework for effective Southern Ocean spatial planning, including new MPAs, considering effects on ecosystem processes, sustainable use of resources, historical changes and future projections on species distribution, and climate-driven change
- Develop informed strategies for management adaptation and conservation priorities at different time-scales
- Identify mechanisms to harmonize Southern Ocean conservation priorities and the sustainable management of human activities across competing organizations
- Develop a framework to assess responsible and sustainable marine transport and navigation in harmony with the spatial planning of the Southern Ocean
  - Investigate how to transport and other marine activities can be developed to avoid disturbing current and future functions of marine protected areas
  - Identify what social (e.g., xx) and environmental risks vessels and infrastructure development pose
  - Determine the scope for consistent and dedicated monitoring of tourism and related activities at hotspot areas

IV. Ensure a sustainably harvested and productive Southern Ocean by working towards a stronger interface between science, industry and policy
- Determine how the complexity and uncertainty in our understanding of the functioning of these ecosystems should be reflected in the preparation and delivery of management advice
- Assess the need for sustainable resource utilization in light of changing environments and expanding human needs
- Determine how the Southern Ocean can contribute to blue growth and a low carbon energy transition
- Investigate what ways research and policy can effectively tackle the whole extraction cycle, from exploration to the final stage of closure of operations, and related remediation and reclamation activities
- Identify the institutional, political and practical obstacles to adopting and implementing ecosystem-based management on a larger scale
- Assess how external pressures and changes in the geopolitical configurations of power affect Antarctic governance and science
- Knowledge enabling Antarctic operators to be leading contributors in developing a responsible strategy for, achieving economic gains with sustainable solutions and inclusive benefit from a green economy

Research challenges (purely scientific)

<u>Priority I</u>. Increase the suite, types, and reliability of measurements, including those focused on ecosystem change, needed to inform management and policy

This priority will strongly benefit from progress on other SO Decade WGs and initiatives in place (SOOS, ICED, among others), but focusing on specific areas and variables that best described the past, current and future status of exploited resources, and other ecosystem services vital for the development of sustainable economic activities.

- *Challenge R1:* Identify and develop relevant ecological indicators to evaluate risks to the Southern Ocean and services it provides and to monitor health and rates of ecosystem change and its interactions with human activities
    - R1.1. Identify key indicators for each particular ecosystem (trophic web) where the target species participate, including the spatial and temporal scale at which the indicators must be measured.
    - R1.2. Develop predictive models of the target ecosystem (communities/trophic web)
    - R1.3. Assess the status of the indicators and evaluate the current, past, and future states of the target ecosystems (communities/trophic web)
    - R1.4. Develop benchmarks to assess the health of target ecosystems.
    - R1.5. Identify and assess the ecosystem services provided by the Southern Ocean [cross-cutting] [WG2]
    - R1.6. Assess the status of the ecosystem services and evaluate the current, past, and future states of key services provided by the Southern Ocean [cross-cutting] [WG2]

- *Challenge R2:* Improve the understanding of the consequences of human-induced change on polar ecosystem services
    - R2.1. Develop and integrate relevant approaches to explore life history of exploited species and its interactions with environmental dynamics and human activities
    - R2.3. Develop new technologies, able to integrate with existing ones, to improve the understanding of the life history of target species and their responses to the changing habitats
    - R2.4. Develop predictive models to help explain the habitat suitability of target species and its contribution to the structure and function of target ecosystems described in Challenge R1.
    - R2.5. Assess the impacts of human activities on sustainability of target species
        - R2.5.1. Develop models that incorporate direct and indirect impacts of human activities <u>to inform</u> decision making and the evaluation of management strategies
        - R2.5.2. Understand cumulative effects and extended causal relationships that play out over temporal and spatial scales, particularly interactions between people and nature
        - R2.5.3. Better knowledge of the effects of operations on natural and <u>social environments[?]</u>, with a focus on integrated effects, involving different environmental and social factors

- *Challenge R3:* Create guidelines for sustainable monitoring and regular assessments that enable us to assess our progress towards the desired states
    - R3.1. Identify key approaches to reveal and monitor key life-history processes of target species
    - R3.2. Determine what principles are required to utilize data from ecosystem monitoring programmes as part of management

- ○ *Challenge R4:* Improve our understanding of key mechanisms regulating the ecosystem in the winter
  - ■ R4.1. Lack essential information on zooplankton biology, trends, and how seasonal sea-ice influences these patterns and the ecosystem as a whole.

- ○ *Challenge R5:* Assess how much ecosystem services of the Southern Ocean ecosystem contribute to a global budget, and whether they will change in space and time

<u>Priority II</u>. Achieve sustainable management of fisheries based on an ecosystem approach, including the recovery of overexploited species and the effect of climate change on ecosystems

This priority will strongly benefit from collaboration with regional organizations, such as CCAMLR, existing initiatives undertaken by ICED and SKAG, among others, for improving our understanding of the krill-centred ecosystem, and the work of IWC to monitor whale populations.

The krill fishery
The Southern Ocean is one of the last almost pristine environments. In the pelagic realm at the Peninsula, the ongoing environmental changes (warming, ice-loss) are accompanied by large biomass shifts of the most important microzooplankton grazers in the Southern Ocean Antarctic Krill (*Euphausia superba*) and Salps (*Salpa thompsoni*). On the other hand, cetacean populations are currently recovering (10% increase of humpbacks and 2-8% increase of Antarctic blue whales over the past decade) and rely almost exclusively on krill as food source. We have only started to comprehend how this shift in key organisms impacts the ecosystem structure and functioning with an emphasis on the effectiveness of the biological carbon pump in terms of carbon sequestration of the Southern Ocean, which is one of the most important carbon sinks on our planet. The effect of sea-ice changes on cryo-pelagic coupling, especially on krill, is still poorly constrained. In addition, economic interests in terms of fisheries and tourism are steadily increasing at the Peninsula and pose a threat not only to cetacean but to all secondary consumers in the krill-based food web.

Toothfish fisheries
…

- ○ *Challenge R6:* Improve understanding of fish stock sustainability and resilience integrating oceanographic, climate, ecosystem structure and functioning, connectivity and harvesting interactions
  - ■ R6.1. Determine the spatial and temporal relationship between spawning and recruitment sections of the stocks for all exploited species
  - ■ R6.2. Develop a timely, responsive strategy for estimating stock distribution, abundance and connectivity

- ○ *Challenge R7:* Identify new methods to effectively integrate both quantitative and qualitative data, identify critical data gaps, and analyse the likely effects of crossing thresholds that are likely to be irreversible in the near term
  - ■ R7.1. Estimate the long-term effects of fishing on the trophic web structure and functioning; in particular, the effect of reducing target stocks to 50% or 75% of B0 (as per CCAMLR targets)

- ○ *Challenge R8:* Develop integrated stock assessments which take into consideration the ecosystem where the fishery operates, considering the following elements:
  - ■ *R8.1.* Multispecies approach

- ■ R8.2. Spatial planning
- ■ R8.3. Ongoing ecosystems change due to climate change and recovery of overexploited species (see R10)
- ■ R8.4. Develop a projection of the development of the fishery in the next 10 years, so management systems being developed are responsive to changes in fishing capacity

- ○ *Challenge R9:* Develop models considering the functional connectivity among ecosystem elements, including drivers in all cardinal directions (e.g., circumpolar, Subtropical effect on polar regions)

- ○ *Challenge R10:* Identify thresholds or abrupt or irreversible changes
  - ■ R10.1. Estimate impacts of ongoing climate change on exploited species and the ecosystem they depend upon
  - ■ R10.2. Develop predictive models to assess ecosystem change [cross-cutting] [WG2]

- ○ *Challenge R11:* Develop Decision Support Tools (DSTs) for the timely managing fishing quotas.

- ○ *Challenge R12:* Develop recovery strategy plans for overexploited species, considering the ecological role and current and future status of the ecosystem (which may affect they realized recovery abundance)
  - ■ R12.1. Determine the effects of past removal of whales on food web structure and functioning, and estimate the effect of their incipient recovery
  - ■ R12.2. Determine the effects of past overfishing (i.e., icefish and Notothenioid species) on food web structure and functioning, and estimate the effect of their potential recovery

- ○ *Challenge R13:* Understand the role of Myctophid for consumers, producers and as an extractable resource

- ○ *Challenge R14:* Understand the role of Mackerel icefish for consumers, producers and as an extractable resource

- ○ *Challenge R15:* Progress on the understanding and managing of toothfish species

Priorities specific to Antarctic krill: Krill is a key species in - drive the functional biodiversity of - and is the target species of the largest fishery in tonnage caught in the Southern Ocean. Up to now, we have almost no knowledge on krill's resilience to climate change, which is a prerequisite to make reliable predictions of krill population shifts under different climate change scenarios in the future (according to IPCC predictions). The following process studies on krill are needed to generate appropriate data, embedded in individual and ecosystem models to understand population shifts of krill that is important for krill fishery management decisions.

- ○ *Challenge R16:* Progress on the understanding and managing of Antarctic krill
  - ■ R16.1. Improve knowledge on Antarctic krill's resilience to climate change.
    -To assess the resilience of krill to climate change, we must understand first how basic life function traits (reproduction, lipid accumulation, growth etc.) are controlled by geophysical cycles (photoperiod -, tide - and lunar cycle), which will not shift in a changing environment. It is established that krill has an endogenous clock, but our molecular understanding of how this clock mediate physiological functions and behaviour via geophysical cycle sis far from clear
  - ■ R16.2. Get a mechanistic understanding of seasonal krill flux in relation to currents, bottom topography and endogenous control via geophysical forcing.

-Relate process-orientated studies to long-term seasonal data from the field, such as obtained from gliders
- ■ R16.3. Develop an integrated, spatially explicit, stock-recruitment population model for Antarctic krill
-Unravel the control on recruitment success
-Investigate if only a small part of the population is responsible for replenishing the krill stock (as long-term data on krill sex and ontogenetic stage distribution assume).

Priority III. Ensure science-based and effective spatial planning process, including MPAs, with consideration of sustainable fisheries management and tourism development

○ *Challenge R17:* Assess the success of existing Southern Ocean Marine Protected Areas in meeting their conservation objectives, including as scientific references areas, and determine additional requirements for the achievement of regional conservation and research objectives

○ *Challenge R18:* Develop a framework for effective Southern Ocean spatial planning, including new MPAs, considering effects on ecosystem processes, sustainable use of resources, historical changes and future projections on species distribution, and climate-driven change.

○ *Challenge R19:* Develop informed strategies for management adaptation and conservation priorities at different time-scales

○ *Challenge R20.* Identify mechanisms to harmonize Southern Ocean conservation priorities and the sustainable management of human activities across competing organizations

○ *Challenge R21:* Develop a framework to assess responsible and sustainable marine transport and tourism industries in harmony with the spatial planning of the Southern Ocean
  - ■ R21.1. Investigate how transport and other marine activities can be developed to avoid disturbing current and future functions of marine protected areas
  - ■ R21.2. Identify what social (e.g., ??) and environmental risks vessels and infrastructure development pose
  - ■ R21.3. Determine the scope for consistent and dedicated monitoring of tourism and related activities at hotspot areas

Priority IV. Ensure a sustainably harvested and productive Southern Ocean by working towards a stronger interface between science, industry and policy

○ *Challenge R22:* Determine how the complexity and uncertainty in our understanding of the functioning of these ecosystems should be reflected in the preparation and delivery of management advice

○ *Challenge R23:* Assess the need for sustainable resource utilization in light of changing environments and expanding human needs
  - ■ *R23.1.* Agree on the level of food security that can come from the Southern Ocean, taking into account ecosystem variability and climate change.

○ *Challenge R24:* Determine how the Southern Ocean can contribute to blue growth and a low carbon energy transition

- ○ *Challenge R25:* Investigate what ways research and policy can effectively tackle the whole extraction cycle, from exploration to the final stage of closure of operations, and related remediation and reclamation activities

- ○ *Challenge R26:* Identify the institutional, political and practical obstacles interfering in the decision-making process at CCAMLR [review]

- ○ *Challenge R27:* Assess how external pressures and changes in the geopolitical configurations of power affect Antarctic governance and science

- ○ *Challenge R28:* Knowledge enabling Antarctic operators to be leading contributors in developing a responsible strategy for, achieving economic gains with sustainable solutions and inclusive benefit from a green economy

Logistical and technical challenges (funding, infrastructure, data accessibility, etc.)

- ○ *Challenge L1:* Securing the long-term commitment from funding agencies to carry on the Southern Ocean Decade Action Plan. This will require −
  - ■ L1.1. Long-term funding of existing programs and develop programs for organismic studies in the Southern Ocean
  - ■ L1.2. Cross-national funding opportunities
  - ■ L1.2. Funding of new sampling sites, particularly in remote areas, to cover a range of environmental conditions
  - ■ L1.3. Funding, including in-kind from responsible operators, to access sampling sites; access costs for logistics to conduct research
  - ■ L1.4. Funding of workshops, symposia, and similar
  - ■ L1.5. Funding of new technological development

- ○ *Challenge L2:* Improve international collaboration on logistics, such as platform-sharing, and incorporate vessels of opportunity from various industries that operate in the Southern Ocean (i.e., fishing vessels, tourism vessels)
  - ■ L2.1. Need to increase spatial and temporal coverage to seasons other than summer.
  - ■ L2.1. Improve alternatives/availability of platforms for deployment and retrieving of sensors, including moorings, UAVs, etc

- ○ *Challenge L3:* Technical
  - ■ L3.1. Maintain year-round, high-resolution data, sampling sites while providing prompt delivery of data and samples
  - ■ L3.2. Develop a new generation of sensors for remote collection of data and near-real time data delivery [cross-cutting] [WG6]
  - ■ L.3.3. Develop a reliable and affordable network for data transfer

- ○ *Challenge L4:* Generate a specific platform to identify key data gaps by compiling existing observations for different spatial and temporal scales
  - ■ L4.1. Identify how best to overcome current limitations
  - ■ L4.2. Instigating a community-wide, coordinated effort to design year-round sampling operations which takes advantage of new marine technology.
  - ■ L4.3. Create a Mooring networking to coordinate at the international level the deployment and recovery of moored platforms

- *Challenge L5:* Develop data-sharing protocols that foster cooperation between different stakeholders, and official (government) and non-official (universities) scientists.
  - L5.1. Data accessibility outside respective management organizations [cross-cutting] [WG6]

- *Challenge L6:* Develop a support system for transmitting, handling and storing relevant information for the Decision Support Tools (DSTs).

- *Challenge L7: Priorities specific to Antarctic krill*
  - L7.1. Develop a network of Antarctic stations to implement process studies on krill in Antarctica
  - L7.2. Develop programs to get funding for field work at Antarctic Stations
  - L7.3. Develop an infrastructure to perform scientific work on krill fishing vessels

Uptake challenges (effective communication between stakeholders, engaging the public)

- *Challenge U1:* Improving collaboration and communication among different scientific disciplines and expertise
  - U1.1 Need to collide existing information and identify data gaps, including the incorporation of new experts into the discussion
  - U1.2 Agree with partners which data gaps are most urgent and most feasible to address
  - U1.3 Gain experience from Arctic management of resource

- *Challenge U2:* Engage business operators in the collection of long-time series of ecosystem monitoring data. These should be utilized to their maximum and expanded with greater spatial coverage, engaging operators in using mobile, comparative, and complimentary measurement platforms.

- *Challenge U3:* Disentangle science from management.

- *Challenge U4:* Improve collaboration with RFMO and national fisheries managers adjacent to the CCAMLR area.

- *Challenge U5: Priorities for improving understanding of fishing resources*
  - U5.1. Coordinate communication between scientists working on collecting long-term data via gliders and scientists focusing on process-oriented studies
  - U5.2. Effective communication between scientist and fishery regarding data collection (to close knowledge gaps)

- *Challenge U6:* Ensure new research/findings are included to define adopted MPA boundaries (with boundaries modified if required - e.g., new important foraging areas included)

- *Challenge U7:* Engage constructively and iteratively with policymakers at all stages of the research, with a focus on the existing and likely future threats to target ecosystems

- *Challenge U8:* Understanding the decision-making process for managing resources, from basic science to policy making.

- *Challenge U9:* Provide relevant and timely scientific advice to decision-makers for sustainable management of the Southern Ocean under a changing climate

○ *Challenge U10:* Achieve an open, nurturing discussions between different stakeholders (scientists, economists, industry, and policymakers), within an interdisciplinary and inter-cultural environment, with consideration of gender, racial and economic inclusion

Identify tangible actions that would be able to address these challenges. Delineate the scope of suggested actions (leading organization, involved stakeholders, funding, timeline, implementation).

Action 1

Name of Action	Southern Ocean Decade Funding Program
Related challenge	ALL
Short description	Exploring different funding agencies to launch national and multinational funding programs in support of the SO Decade
Key stakeholders to consider	National Funding Agencies, EU Agencies, International Cooperation Agencies
Timeline	Ongoing; need to develop first calls for grants in the near time (2022-2023)
Potential resources	
Other comments	

Action 2

Name of Action	Workshop to Identify and Develop relevant ecological indicators to evaluate risks to the Southern Ocean and the services it provides
Related challenge	R1, R5, L1, L2, L3, L5, U1, U2, U5
Short description	Initial WS to assemble existing capacities, identify relevant indicators, knowledge, and technological gaps, and set a roadmap to develop R1 *Cross-theme in coordination with WG2, WG4*
Key stakeholders to consider	Coordinators of monitoring programs, such as CEMP, LTERs; ICED, SOOS (modellers);
Timeline	Short term (e.g., 2022)
Potential resources	
Other comments	

Action 3

Name of Action	SO UN DECADE WORKSHOP - NEW TOOLS for MONITORING

Related challenge	R2.3, R3, R4, R5, L1.1, L1.2, L1.4, L2, L3, L4, U1, U2
Short description	Thematic workshop on new methods for long-term Oceans monitoring. Much of the Southern Ocean is under observed. A number of actions can be undertaken to address this, including: 1. Improve observation under the sea-ice 2. Development of a coordinated global effort that delivers circumpolar observations with effort more evenly distributed in space and across seasons. 3. Increase the use of fishing vessels (and other ships of opportunity) as observing platforms. Investigate possibilities to use such platforms for sampling (which is critical). 4. Firming up and expansion of animal-borne sensor network 5. New technologies that allow better and more measurements *Cross-cutting WS in collaboration with WG2, WG4*
Key stakeholders to consider	Commission for the Conservation of Marine Living Resources (CCAMLR), BEPSII, SCAR, Managers, UNEP, IAATO, the Southern Ocean Observing System (SOOS), the Integrated Climate and Ecosystem Dynamics (ICED) modelling community, National Antarctic Programs (COMNAP), COLTO, ARK
Timeline	Short term (2022-2023)
Potential resources	
Other comments	

Action 4

Name of Action	WS for developing a framework for a new sampling regime for key elements of the ecosystem
Related challenge	R2.3, R3, R4, R5, L1.1, L1.2, L1.4, L2, L3, L4, U1, U2
Short description	Generate a framework providing recommendations for the design of future sampling operations. Could be in parallel to Action 3 (WS on NEW TOOLS for MONITORING) *Cross-cutting WS in collaboration with WG2, WG4*
Key stakeholders to consider	Commission for the Conservation of Marine Living Resources (CCAMLR), the Polar Data Centre, the Southern Ocean Observing System (SOOS), the Integrated Climate and

	Ecosystem Dynamics (ICED) modelling community, National Antarctic Programs
Timeline	Short term (2022-2023)
Potential resources	
Other comments	

Action 5

Name of Action	PROGRAM: Fishing through ecological indicators
Related challenge	R1, R5, L1, L2, L3, L5, U1, U2, U5
Short description	Development and assessment of a set of indicators for assessing Southern Ocean ecosystem services, based on SOOS eEOV
Leading organisation	
Key stakeholders	SOOS, ICED, CCAMLR, SKAG,
Timeline	Short term (2022-2023)
Resources	
Other comments	

Action 6

Name of Action	PROGRAM: Increased observing program across trophic levels
Related challenge	R3, R6 R13, R14, R15, R16, R17, L1, L2, L3, L4, L5, U1, U2
Short description	We currently have observational programs for the environment (ocean and sea ice) and a number of top predators, however a significant gap exists in observing between these ends of the trophic ecosystem. We need more observations of the trophic levels between these extremes. This could include 1. Targeted sampling programs across trophic levels 2. Closing the gap between statistical and dynamical/mechanistic models of biology (statistical models are empirically derived from observations, whereas dynamical and mechanistic models require understanding of key, driving processes) 3. Improve our understanding and estimates of mid-trophic levels 4. Increase observations of predators in winter

	5. Improve battery technology and decrease weight of animal borne tags (to allow tagging of more species)
	6. Improve autonomous vehicles to allow them to observe biology
	Cross-cutting theme in collaboration with WG2, WG4, WG6
Key stakeholders to consider	National Antarctic programs, long term monitoring programs, ecosystem management bodies (CCAMLR, IWC), SCAR programs,
Timeline	SO Decade (ongoing)
Potential resources	
Other comments	

Action 7

Name of Action	WS to develop responsive sampling strategy for Antarctic krill
Related challenge	R1.2, R16, L1, L2, L3, L5, L7, U1, U2, U5
Short description	Initial Workshop to assemble existing capacities, identify relevant indicators, knowledge, and technological gaps, and set the decade's roadmap.
Key stakeholders to consider	National Programs with current research on krill, SKAG, CCAMLR, ARK, IAATO
Timeline	Short term (e.g., 2022)
Potential resources	
Other comments	

Action 8

Name of Action	Working Group on Regional Model Integration
Related challenge	R1.2, R2.4, R4, R6, R7, R9, L1, L4, L5, U1
Short description	Progress in most sectors of Antarctica has been made in developing some degree of Minimally Realistic Models (ROMS NPZD, EwE, Atlantis, qualitative networks etc). Formalizing and connecting these models (even if only qualitatively) to provide a start-point for considering circum-Antarctic connectivity and linkages north of the SO boundary are going to be needed to stimulate conversations about characterizing knowledge gaps and giving policy the ability to evoke the precautionary approach to management where needed.

	Cross-cutting theme in collaboration with WG2, WG4
Key stakeholders to consider	SOOS (as good as any to define the geography of each regional MRM). SCAR SRP's (draw in research groups that are «inwardly focussed' on their own regions). ICED (technical integration).
Timeline	Throughout the Decade. 2022-2030. This initiative will be an ongoing/never-ending process. The goal should be a « straw man » model before the end of the decade.
Potential resources	Regional funding (ERC / NSF scale)
Other comments	

Action 9

Name of Action	Summit to Assess the past and future contribution of the SO to the global budget
Related challenge	R2, R5, R23, R24, L1, L5, U1, U10
Short description	*Cross-cutting theme in collaboration with WG2, WG4*
Key stakeholders to consider	
Timeline	2028-2029
Potential resources	
Other comments	

Action 10

Name of Action	Importance of the Southern Ocean for food security [and other ecosystem services] (Outreach activity)
Related challenge	R5, R23, R24, L1, U10
Short description	Outreach activity for the general public, about the importance of the SO in providing ecosystem services worldwide *Cross-cutting theme in collaboration with WG2, WG4, WG7*
Key stakeholders to consider	National Antarctic Programs (COMNAP), CCAMLR, SCAR, IAATO
Timeline	Medium to long term (2024-2029)
Potential resources	
Other comments	

Action 11

Name of Action	WS to develop *in situ* experimental krill research
Related challenge	R16, L1, L2, L9
Short description	Initial Workshop to assemble existing capacities, identify relevant indicators, knowledge, and technological gaps, and set the decade's roadmap
Key stakeholders to consider	CCAMLR members states who have the infrastructure for experimental krill work, fishery, krill scientists SKAG
Timeline	Short term (e.g., 2022)
Potential resources	
Other comments	

Action 12

Name of Action	Data Limited Fisheries Working Group
Related challenge	R6, R7, R8, L1, L4, L6, U1, U4, U5
Short description	There is considerable experience in data-limited fisheries science and management that resides outside the typical CCAMLR arena. None of the other key science bodies in the Southern Ocean (SCAR, SOOS, ICED etc) focus on fisheries management. A <u>dedicated Working Group of fisheries scientists</u> to be established to provide advice into existing management bodies would provide an inlet for external science and integration across geographic boundaries (i.e. between RFMO and CCAMLR).
Key stakeholders to consider	Initial outreach through RFMO and national fisheries research organisations to collate key individuals / groups.
Timeline	Should be started in line with Action #1, to ensure functional connectivity is incorporated into data limited fisheries science.
Potential resources	Regional funding (ERC / NSF scale)
Other comments	

Action 13

Name of Action	Establish a Myctophid fisheries research Working Group
Related challenge	R9, R13, L1, L4, U4
Short description	Coarse biomass estimates of Myctophid in the SO are an order

	of magnitude greater than for Antarctic krill, yet very little is known about their basic role within the foodweb. Fisheries techniques under development to harvest myctophids are likely to be trawl-based, and once the economic hurdles to extraction are overcome, there will likely be calls to develop exploratory fisheries for them. Mapping the functional role of myctophids to the rest of the foodweb, as well as understanding their movement and distribution in time and space (seasonality, hotspots, etc) will be a prerequisite to such exploratory fisheries being approved. <u>Developing a WG to synthesise and direct myctophid fisheries-related research in the SO</u> would provide a focal point for responsible management authorities in the SO (CCAMLR, EEZ national managers, etc).
Key stakeholders to consider	RFMO, nation-states with trawl fisheries, SCAR, CCAMLR.
Timeline	Should be started in line with Action #1, to ensure a key marine biomass and potential resource is fully considered in developing sustainable management options.
Potential resources	Regional funding (ERC / NSF scale)
Other comments	

Action 14

Name of Action	SO UN DECADE WORKSHOP - Science into POLICY
Related challenge	R20, R22, R25, U7, U8, U10
Short description	Thematic workshop on promoting best practises for science-based evidence for Antarctic policy making *Cross-cutting theme in coordination with WG2, WG4, WG7*
Key stakeholders to consider	Scientific community, SCAR, CCAMLR, Managers, ATCM Parties, IAATO, COLTO, ARK
Timeline	to be implemented during UN Decade (long-term)
Potential resources	
Other comments	

Action 15

Name of Action	Science-management education
Related challenge	R22, L1, U7, U8, U9, U10
Short description	The key management organization in the SO (CCAMLR) is becoming paralyzed, with scientists increasingly discussing management options as opposed to providing scientific

	knowledge to managers. At the same time, delegate Members are inserting individuals with no scientific credentials into scientific working groups in order to promote management discussions. Given that managers must incorporate other (sometimes competing) interests into their decision-making process (social, economic, political etc), a method of continuing education of the role of scientists in the provision of advice to managers would seem helpful.
Key stakeholders to consider	National-level scientific and management agencies involved in Southern Ocean resource management.
Timeline	Throughout the SO Decade
Potential resources	Governmental
Other comments	

Action 16

Name of Action	Role of SO in the global economy
Related challenge	R5, R23, R24, L1, U7, U10
Short description	Round of discussions on the significance of the SO for global budget, climate change resilience, resource productivity, and capacity to contribute to the global blue economy
Key stakeholders to consider	National-level scientific and management agencies involved in Southern Ocean resource management.
Timeline	Midterm
Potential resources	Governmental
Other comments	

Action 17

Name of Action	PROGRAM: A win for all: Understanding the management of Antarctic resources
Related challenge	U9, U10
Short description	Develop an outreach plan for engaging and communicating the science behind the management of Antarctic resources. The plan must include differential activities for different public : – General awareness activities for the general public – Seminars and Workshops for fellow scientists from other regions/disciplines – Webinar and media material for engaging Early Career

	Scientists Examples include celebrating a « Krill Day » to communicate role of krill in the ecosystem and our daily lives. *Cross-cutting theme in coordination with WG2, WG4, WG7 (see* SO UN DECADE WORKSHOP - Science into EDUCATION & OUTREACH, WG2)
Key stakeholders to consider	National-level scientific and management agencies involved in Southern Ocean resource management. Educators, PEI, Scientific community, ATCM Parties interested in Education and outreach, IAATO, COMNAP, APECS
Timeline	Throughout the SO Decade
Potential resources	Governmental
Other comments	

Action 18

Name of Action	PROGRAM: Knowledge enabling Antarctic operators
Related challenge	R20, R21, R24, R28, U2, U10
Short description	Develop a framework to assess responsible and sustainable marine transport and tourism industries
Key stakeholders to consider	IAATO, ATS, UNCLOS, CCAMLR
Timeline	Throughout the SO Decade
Potential resources	
Other comments	

Describe already-existing activities and stakeholders who are presently working towards resolving these challenges.

Name of Action	Science-Industry Forum (krill)
Related challenge	R1.1, R16, L2, L7.3, U1, U2, U5
Short description	Communication between scientists and fishery
Leading organisation	SKAG, ARK, CCAMLR
Key stakeholders	CCAMLR members, scientists, fishery
Timeline	Short term (2022-)

Resources	
Other comments	

Name of Action	Due South
Related challenge	L2
Short description	SOOS initiative to share and coordinate surveys. https://www.soos.aq/activities/duesouth Coordination across multiple national-run programs and incorporate vessels of opportunity from various industries that operate in the southern ocean
Leading organisation	
Key stakeholders	
Timeline	
Resources	
Other comments	

Name of Action	Ant-ICON (SCAR)
Related challenge	
Short description	The Ant-ICON SRP will answer fundamental science questions (as identified by the SCAR Horizon Scan), relating to the conservation and management of Antarctica and the Southern Ocean and focus on research to drive and inform international decision-making and policy change.
Leading organisation	SCAR
Key stakeholders	
Timeline	
Resources	
Other comments	

Name of Action	SKAG (SCAR)

Related challenge	
Short description	The SCAR Krill Action Group (SKAG) provides a forum to guide research directions, promote collaboration, improve understanding of krill biology and ecology, and provide a forum for information exchange.
Leading organisation	SCAR
Key stakeholders	
Timeline	
Resources	
Other comments	

Rank suggested actions in order of priority while taking into account feasibility and timeline. The highest ranking actions will be included in the Southern Ocean Action Plan and will most likely require additional notes.

Order of priority	Action number & name
1	ex: Action 2
2	
3	
...	