Working Group 2 report)

WG number : 2 Healthy & Resilient Ocean

Targeted Societal Outcome : How to achieve a healthy and resilient ocean where marine ecosystems are understood and managed

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Ocean Decade Definition of the Outcome
Degradation of marine ecosystems is accelerating due to unsustainable activities on land, atmosphere and in the ocean. To sustainably manage, protect or restore marine and coastal ecosystems, priority knowledge gaps of ecosystems, and their reactions to multiple stressors, need to be filled. This is particularly true where multiple human stressors interact with climate change, including acidification and temperature increase. Collecting sustained core physical, biological and biogeochemical observations to better understand the structure and function of an ecosystem are important to develop tools to implement management frameworks that build resilience, recognise thresholds and avoid ecological tipping points, and thus ensure ecosystem functioning and continued delivery of ecosystem services for the health and wellbeing of society and the planet as a whole. To achieve a healthy and resilient Southern Ocean, such information must be used in development of projections in support of regional and global protection and management/conservation strategies, and policy advice.

Identify regional challenges that need to be overcome to achieve Southern Ocean priorities (*cfr* report) over the next 10 years in the context of your appointed Societal Outcome.

Research challenges (purely scientific)

Challenge R1: Improve understanding of key drivers of change and their impacts on Southern Ocean (SO) species and ecosystems (across a range of spatial temporal and organisational scales)

- Improve our basic knowledge of the biodiversity, biology and ecology of Antarctic marine organisms across a range of spatial and temporal scales (e.g. ice associated, mesopelagic, deep-sea and benthic communities at the regional and circumpolar scales)
    - Determine life histories and life history strategies of key species
    - Understand the interactions of various life stages of plankton species with other food web components (including microzooplankton and phytoplankton, ice algae) and the potential consequences for energy flow and biogeochemical cycling
- Determine the structure and functioning of Southern Ocean ecosystems
- Determine the key drivers of change and their impacts on Southern Ocean species and ecosystem structure and functioning. This should include emphasis on the effects of changing sea ice conditions on key species (e.g., Antarctic krill, upper trophic level species)
- Distinguish the impacts of physical climate change due to anthropogenic processes/stressors on Southern Ocean food web structures from natural variability
- Investigate the potential changes in Southern Ocean systems occurring from influences of climate change and direct and indirect human activities (e.g., marine traffic, tourism, fishing,

pollutants (including emerging pollutants and plastics), invasive species, parasites and diseases)
    - Understand the impacts of invasive species and range shifts of native species on ecosystems and human well-being
    - Identify which pathways for alien species introductions present the greatest risks and which locations are most vulnerable to invasion
    - Assess the origin, fate and effects of Southern Ocean pollution (e.g. plastics, trace metals, POP´s) in Antarctic ecosystems (cross-cutting theme with WG1)
    - Identify biosecurity techniques to reduce introduction risk and develop methods to respond to existing invasions and a program of disease surveillance/detection
- Understand the role of microbiomes in Antarctic ecosystems
- Improve our understanding of cryo-pelago-benthic coupling and and the impacts of multiple drivers on different ecoregions (e.g., shallow, deep, off- and in-shore, high and low latitudes, bays, canyons, exposed shelf areas etc.)
- Understanding bacteria-algae coupling under potential future impacts scenarios
- Identify marine biogeographic regions of biodiversity and related processes and their importance in maintaining ecosystem structure and functioning, ecosystems services and conservation
- Understand how changes in environmental factors will manifest in population-, community- and ecosystem-level changes
- Understand the impacts of changing ocean circulation and water mass properties on early life history stage dispersal and colonisation
- Understand co-evolution between species or disruption of key marine interactions
- Determine the key factors for speciation
- Assess the spatio-temporal impacts of ocean acidification and deoxygenation on upper ocean biogeochemical processes and food web dynamics
- Understand the role of iron (and other trace metals) in shaping the environment: address sources (e.g. hydrothermal, sedimentary, glacial, sea-ice), role on microbial and micro-algal growth and in food web recycling, the impact of microbial ligands-EPS, siderophores, and microbes in regulating trace metal availability for biogeochemically important processes like nitrification, denitrification and silica assimilation.
- Understand how deep-sea ecosystems respond to modifications of deep-water formation, and their interactions with shallow water ecosystems
- Investigate the physiological limitations, thresholds and tipping points of Antarctic marine organisms and their consequences in Antarctic ecosystems
- Determine the resilience of zooplankton species to change
- Assess the role of Antarctic endemism in coping with multiple stressors
- Identify the potential of biological and genetic adaptation of organisms to environmental change that may provide resilience
- Determine thresholds leading to extinction & collapse
- Assess the vulnerability of Southern Ocean ecosystems to combined, multi-stressor human and natural influences
- Identify key marine species as biomonitors of trophic interactions, food web structure and environmental change, and develop a system of “ecosystem health”
- Evaluate long-term trends of change in Southern Ocean ecosystems (e.g., using use of long-term monitoring programmes and historical data)
- Impact of changes in the Southern Ocean physical characteristics on the functioning and adaptations of the microbial loop, and the coupled rates of carbon transfer across trophic levels
- Improve modelling tools to predict future change in the Southern Ocean in the context of the IPCC framework (cross-cutting theme with WG4)

- Identify how the uniqueness and endemism of Southern Ocean species and ecosystems (and their intrinsic value) respond to global change
- Determine how fast mutation rates are and how extensive gene flow is
- Identify and develop metrics or indicators to monitor the status and resilience of Antarctic social-ecological systems
- Identify molecular and cellular adaptations and understand the functioning of cells at low temperatures
- Understand how proteins function at low temperatures and how they interact differently with other cell components (e.g. water, osmolytes) from warmer water species
- Assess genetic/genomic biodiversity status of Antarctic marine organisms in relation to their resilience and adaptation
- Evaluate how Antarctic marine food webs compare to other food webs elsewhere in terms of resilience and adaptation
- Promote the future development of conservation of Southern Ocean ecosystems under different protection scenarios, including networks of Marine Protected Areas, assess actual strategies and propose new concepts, being eventually more efficient and being adapted to recent and future developments
- Assess how changes in Southern Ocean biodiversity will affect global marine biodiversity (at both the species and functional level)
- Improve understanding of the high benthic patchiness (hot and cold spots in terms of biodiversity, endemism and ecosystem functions) to identify key processes and vulnerable communities and support ecosystem management and conservation
- Determine anti-microbial resistance levels in Antarctic marine organisms (cross-cutting theme with WG1)
- Understand how diseases spread between Antarctic invertebrate and vertebrate species (cross-cutting theme with WG1)

Challenge R2 : Improve understanding of Southern Hemisphere ice (sea ice, land ice and subsea permafrost), including its role in ecological processes of the Southern Ocean

- Understand the differences between various ice types for ecosystem structure and functioning
- Evaluate the impact of sea-ice variability on the base of the Antarctic food web and the consequences for ecosystem structure and functioning
- Define the uniqueness of sea-ice species in terms of their intrinsic value and role in ecosystem services (e.g. genetic and medicinal resources)
- Understand ocean circulation, properties and processes beneath Antarctic sea ice and ice shelves
- Understand how the sea-ice ecosystem is linked to the pelagic and benthic ecosystem
- Understand influences of changes in freshwater fluxes from iceberg melting, sub-ice shelf melting, subglacial discharge and sea ice on ocean circulation, biogeochemistry and marine ecosystems
- Quantify sea ice-ocean-atmosphere characteristics and biological processes including floe-size distribution, wave-ice interaction and deformation processes at the ice edge/marginal ice zone. This is critical to understand processes that drive change and variability in the volume, properties, floe-size and distribution of Antarctic sea ice and consequent impacts on atmospheric and oceanic properties, and circulation in marine biogeochemistry and ecosystems (cross-cutting with WG4)
- Understand dynamics of the Antarctic fast-ice belt and its role in protecting glacier/ice shelf fronts, polynya formation/maintenance and water-mass modification

- Evaluate the contribution of seasonally ice-covered areas to greenhouse gases and aerosols fluxes, carbon uptake and export
- Assess the spatial, seasonal and interannual distribution of essential climate variables in the sea-ice-impacted SO to decrease uncertainty on air-sea-ice fluxes
- Evaluate the contribution of seasonal variability of sea ice to heat budgets, considering turbulent fluxes at the ocean-atmosphere interface
- Explore the differences in sea ice processes between the Arctic and Antarctic
- Understand the role of fast ice for the ecosystem at the end of winter/start of summer and if there is environmental risk if broken out early by shipping
- Understand ocean circulation properties and processes beneath Antarctic sea ice and ice shelves
- Understand dynamics of the Antarctic fast-ice belt and its role in protecting glacier / ice shelf fronts, polynya formation/maintenance and water-mass modification relevant to Antarctic ecosystems
- Assess the spatial, seasonal and interannual distribution of essential climate variables in the sea ice-impacted SO to decrease uncertainty on air-ice- sea fluxes

Challenge R3: Improve understanding of biogeochemical processes of the Southern Ocean linked to the influence of sea ice, glaciers and ice shelves

- Evaluate how sea level rise may provide changes or create new habitats
- Understand the importance of sea ice for the life history of polar species
- Understand the wider impact of ice retreat on carbon and sulfur fluxes into the ocean and the atmosphere
- Understand influences of changes in freshwater fluxes from iceberg melting, sub-ice shelf melting, subglacial discharge and sea ice on ocean circulation and marine ecosystems
- Improve subglacial and continental shelf bathymetry to understand how it affects Antarctic ice sheet, and related ecosystems, response to climate change
- Understand the impact of climate change on Antarctic subsea permafrost and its effects on ecosystems and biogeochemical cycles
- Develop a comprehensive approach to study the hydrology-ice-ocean interactions

Challenge R4: Improve understanding of Southern Ocean biogeochemical cycling. The Southern Ocean plays a key role in biogeochemical cycling, particularly in regulating air-sea exchange of carbon dioxide in the global carbon cycle and the generation of various climate-active gases, including dimethylsulfide and halogens

- Understand patterns and variations in nutrient dynamics and biogeochemical processes at various spatial and temporal scales, and their interactions with physical and biological processes
- Understand the role of metabolic diversity and evolution in Southern Ocean biogeochemical cycling and ocean ecosystem processes
- Understand the feedbacks between Southern Ocean circulation, water masses, biogeochemical cycling and the cryosphere, including the role of coastal and open ocean polynyas
- Assess the spatial, seasonal and interannual distribution of climate-active gases (e.g. dimethylsulfide) and halogens in ice-covered and ice-free waters
- Understand the fluxes of climate relevant components (e.g. aerosols, gases) between the ocean, ice and atmosphere

- Determine the key drivers of primary productivity and the Biological Carbon Pump - light, predation and nutrient supply - and assess ongoing changes in these parameters
- Quantify the impact of recycling and remineralization, including via the Microbial Carbon Pump, on nutrients and carbon cycling in the water column and by macro- meio- as well as microbenthic communities
- Understand the role of physical processes such as upwelling, mixing and lateral oceanic advection on nutrient and CO_2 distributions and fluxes
- Understand impacts of the combined changes in ocean physics and marine ecosystems on the Southern Ocean sink for CO_2
- Identify the effects of Westerly winds on ocean circulation, carbon uptake and global teleconnections
- Prioritise understanding of the role of Antarctic krill, salps, and other organisms, such as cetaceans, in the role of carbon uptake, storage and long-term sequestration
- Estimating the efficiency of biological pump of C, S and N using sediment traps, being an insight into microbes associated with sinking particles and composition of aggregates

Challenge R5: Improve understanding of the Southern Ocean's role within the Earth Climate System (Cross-cuts Outcome 4)

- Understand how the recovery of the ozone hole will affect regional and global atmospheric circulation, climate and ecosystems
- Understand the processes controlling the polar ecosystems (i.e. Antarctic and Arctic), including the climate system, the socio-ecological system structure and functioning, and the different knowledge systems and their multiple interactions
- Understand the ocean's role in determining/modulating natural modes of climate variability at both global and regional scales
- Understand the specific role of sea-ice (dominated) areas in determining climate variability
- Determine and understand the mechanisms of regional variation in climate regulation
- Enhance understanding of processes controlling, and feedbacks resulting from, the interactions between the polar climate system components using data acquisition and long-term observation
- Identify key interaction and feedback processes across spatio-temporal scales and improve the description of these processes in coupled earth system models and in coupled regional models
- Improve understanding of greenhouse gas climate sensitivity and climate forcing, through improved inclusion of interactions between atmosphere, ocean, cryosphere and biogeochemical cycles in models
- Understand the role of human impacts on the Southern Ocean, particularly the impact of anthropogenic heat and carbon on water mass properties, formation and circulation, and the changes in surface fluxes and freshwater input from the cryosphere
- Understand what the regional and coastal impacts of a changing climate are upon sea level, ocean heat content, ocean-cryosphere interactions and the water cycle
- Understand what processes control coastal dynamics and upwelling systems, including the impacts of a changing climate
- Understand what the oceanic constraints on transient climate sensitivity are, including air-sea exchange, ocean heat uptake and transport, and the Earth's energy budget
- Understand how volcanic activity affects the global atmosphere, the stability of cryospheric components (i.e., glaciers and ice sheets) and marine ecosystems

- Investigate whether greenhouse gases stored in Antarctic and Southern Ocean clathrates, sediments, soils, and permafrost will be released as climate changes
- Understand how the Southern Ocean regulates Southern Hemisphere clouds and climate
- Advance the understanding of ecological feedbacks in the Earth System

- *Logistical and technical challenges (funding, infrastructure, data accessibility, etc.)*
    - *Challenge L1:* Develop a global ocean ecosystem observational and modelling network that provides essential ecosystem ocean variables (eEOVs) and improve marine data and information management, supported by data quality control

    - *Challenge L2:* Improve current monitoring and observation tools and assess the potential for the development of new tools, including marine *in situ* (e.g. gliders, animal born ocean sensors) or space (e.g., new satellite imagery) tools, to assess and improve assessments of physical, biogeochemical and biological processes at a circumpolar scale

    - *Challenge L3:* Promote international collaborations and facilitate access to logistical science facilities (e.g., vessels, research bases) to conduct SO research following the Antarctic Treaty (cross-cutting theme with all WGs)

    - *Challenge L4:* Further improve the accessibility and sharing of ecological (and related) data and databases (e.g., develop and build on existing quality-controlled storage solutions) (cross-cutting theme with all WGs)

    - *Challenge L5:* Support more data collection on Antarctic seafloor, both physically and ecologically, as well as promote the improvement/development seafloor mapping technologies relevant to conservation and management

    - *Challenge L6:* Improved funding support for sustained long-term observations under a multi-national effort (as well as in kind, e.g. ARK, IAATO), as well as expanding the network of ocean sensors, support data quality centres and assistance for specific activities needed to advance our knowledge (e.g. key workshops/conferences; see Actions List below)

    - *Challenge L7:* Improve logistical support to understand sea ice conditions to better estimate repeated accessibility (e.g., relevant to logistical operations, industry, MPAs)

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

    - *Challenge U1:* Develop tools and improve links between the scientific community and decision makers to accelerate science-policy making mechanisms in the creation of evidence-based relevant decisions on management of the Southern Ocean ecosystems under the Antarctic Treaty framework (making use of ongoing research programs/organizations (e.g., ICED, SCAR, CCAMLR))

    - *Challenge U2:* Advance and improve the use of social sciences research/data for ocean management, decision making and policy development

- *Challenge U3:* Compare changes in Antarctic ecosystems functions and biodiversity in fished and non-fished areas to support management decision making (e.g. to aid regulations in Marine Protected Areas and fishing areas) (cross-cutting theme with WG3)

- *Challenge U4:* Assess how present and future changes in Antarctic biodiversity may affect Antarctic ecosystem services and evaluate/implement remediation measures (cross-cutting theme with WG3)

- *Challenge U5:* Review bioprospecting in the Southern Ocean (cross-cutting theme with WG3)

- *Challenge U6:* Assess of future conditions of sea-ice to improve Antarctic Treaty and other international legislation (Eg. POLAR CODE)(cross-cutting theme with WG1 + WG5)

- *Challenge U7:* Define areas of uniqueness in terms of ecosystem-services (habitat/supporting, provisioning, regulating and cultural), in both the marine and sea-ice domain of the Southern Ocean

- *Challenge U8:* Promote and facilitate more local, regional, national and international education and outreach programs and initiatives showing the relevance of an healthy and resilient Southern Ocean to the rest of the World (cross cutting theme with WG7)

- *Challenge U9:* Develop a system of ecosystem health that can be used to combine and communicate complex scientific knowledge to a broader audience

- *Challenge U10:* Promote multidisciplinary and interdisciplinary approaches, particularly the inclusion of social scientists in all aspects of Southern Ocean research, from conception to completion. This will facilitate the exchange of knowledge and expertise, an appreciation of the challenges we face in addressing globally important research questions in the Southern Ocean, and enhance policy uptake (cross cutting themes group)

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

Proposed tangible actions in the future (to be updated over the course of the Decade)

- RESEARCH GROUPS

. Set up a multi-national long-term observational site to integrate information from observing tools (e.g. ARGI profilers, ships, gliders, animals, satellites, etc…) (check with OCEANOPS)

- WORKSHOPS (addressing specific Antarctic ecosystems issues (e.g.CCAMLR-SCAR-ATCM-ICED-SOOS- MEASO - IPCC, IPBES, UNEP and related programmes thematics workshops), for both sea-ice/glacial dominated and marine ecosystems)

- Status of Antarctic Ecosystems, biodiversity and functioning

- Effects of climate change and human activities in the Southern Ocean
- Towards biogeographic regions relevant to conservation
- Life history and long term trends of key Southern Ocean species
- Modelling and predicting Southern Ocean foodwebs and biogeochemical cycles
- Evolutionary linked to biological processes in the Southern Ocean
- Science evidence-Based policies development for the Southern Ocean (e.g. links to SCAR SCATS + Antarctic Environments Portal)
- Worlds Biodiversity Monitoring: potential of new tools in the Southern Ocean
- Present and future of invasive species in the Southern Ocean
- Thresholds and tipping points of Antarctic ecosystems
- Genetics/genomics biodiversity status for the Southern Ocean
- Bioprospecting
- Status of Southern Ocean circulation and sea-ice variability in Antarctic biological processes
- Present and future of Southern Ocean biogeochemical cycling in the global carbon cycle
- Southern Ocean's role in Earth Climate System
- Southern Ocean as a case-study for World education and outreach on Oceans

ONGOING/PLANNED INITIATIVES

. Join UN DECADE OCEANS CONFERENCE 2022 (https://www.un.org/en/conferences/ocean2022)
. Science (and policy & outreach) sessions within SCAR research programs (and UN/POLAR/ thematic conferences) (E.g SCAR OSC 2022 - India)
. Education & Outreach (E & O) Polar Educators International (PEI) workshops
. E & O Association of Polar Early Career Scientists (APECS) + SCAR CBET Capacity Building Workshops

Examples of endorsed actions for the Decade… https://www.oceandecade.org/resource/166/Announcement-of-the-results-of-the-first-endorsed-Decade-Actions-following-Call-for-Decade-Actions-No-012020

EXAMPLES:
Action 1

Name of Action	SO UN DECADE WORKSHOP - Science towards an healthy and resilient Southern Ocean
Related challenge	R1 - R4, L1-L2, U8
Short description	Thematic workshop on the Status of Antarctic science
Key stakeholders to consider	Scientific community, SCAR, Policy makers,
Timeline	to be implemented during UN Decade (Short-term)
Potential resources	
Other comments	

Action 2

Name of Action	SO UN DECADE WORKSHOP - NEW TOOLS for MONITORING towards an healthy and resilient Southern Ocean
Related challenge	L1-L2, L4
Short description	Thematic workshop on new methods for long-term Oceans monitoring
Key stakeholders to consider	Scientific community, BEPSII, SCAR, Managers, COMNAP, UNEP, SOOS, IAATO
Timeline	to be implemented during UN Decade (Short-term)
Potential resources	
Other comments	A **"sea-ice in-situ technology and monitoring workshop" is foreseen in association with the IGS on Sea Ice in Bremen in 2023 (for more info Klaus.Meiners@aad.gov.au)**

Action 3

Name of Action	SO UN DECADE WORKSHOP - Science into POLICY towards an healthy and resilient Southern Ocean
Related challenge	U1-U5
Short description	Thematic workshop on promoting best practises for science-based evidence for Antarctic policy making
Key stakeholders to consider	Scientific community, SCAR, CCAMLR, Managers, ATCM Parties, IAATO
Timeline	to be implemented during UN Decade (long-term)
Potential resources	
Other comments	

Action 4

Name of Action	SO UN DECADE WORKSHOP - Science into EDUCATION & OUTREACH towards an healthy and resilient Southern Ocean
Related challenge	U6
Short description	Thematic workshop on education and outreach

Key stakeholders to consider	Educators, PEI, Scientific community, ATCM Parties interested in Education and outreach, IAATO, COMNAP, APECS
Timeline	to be implemented during UN Decade (Short-term)
Potential resources	
Other comments	

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

Name of Action	UN OCEANS CONFERENCE 2022
Related challenge	
Short description	
Leading organisation	UN - Portugal and Kenya as hosts
Key stakeholders	
Timeline	2022 (short-term)
Resources	
Other comments	WG2 may contribute to it

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	
...	

If you have any further comments/suggestions, please describe them below.

****** Don't forget to have a look and comment on the reports of other Working Groups. ******