A Strategic Plan for the Marine Working Group of the International Arctic Science Committee (IASC): priorities to support implementation of the UN DOS Arctic Action Plan and transdisciplinary research cooperation in the Arctic

Public Summary

The Marine Working Group (MWG) of the International Arctic Science Committee (IASC) has developed a strategic plan to guide research and monitoring priorities that are aligned with international science planning goals such as those identified by the ICARP process and the UN Decade of Ocean Science for Sustainable Development. The strategic plan includes research priorities that are practical areas for international cooperation and consistent with the pillars of IASC and the science programs of its 24 member countries. The priorities listed include transdisciplinary collaborations that involve other IASC Working Groups, integration of Indigenous knowledge, and a thematic consideration of current research problems. The five themes identified by the MWG are Marine Life, Sea Ice and Stratification, Disturbances, Biogeochemical Cycles, and Connectivity and Borealization. The research questions within each theme aim to contribute to an integrated and predictive understanding of the Arctic System and its interactions with the overall Earth System. The MWG's strategic plan will facilitate addressing key unknowns about the Arctic System and ecosystem-based management as well as the pressing research needs that are driven by climatic change impacts on the Arctic marine system.

Introduction

The overarching goal of the Marine Working Group's (MWG) strategic planning process is to guide research and monitoring priorities that are aligned with international science planning goals such as those identified by the ICARP process and the UN Decade of Ocean Science for Sustainable Development. An additional requirement is that research priorities identified are practical areas for international cooperation and consistent with the pillars of IASC[1] and the science programmes of its 24 member countries. It must also be guided by the global and regional measures that are in place for protection of the Arctic marine environment and supported by national governments and the Arctic Council. Much of the funding that is driving Arctic marine research is best understood as addressing the imperative risks associated with climate change. The fate of polar icesheets, the presence of invasive species in the Arctic Ocean, the outputs of permafrost thaw reaching the marine environment, and changes in the

[1] Pillar 1: Facilitating Arctic Research Cooperation; Pillar 2: Promoting Engagement; Pillar 3: Ensuring Knowledge Exchange.

hydrographic system are examples of some of the pressing research needs that are in whole or in part driven by climatic change impacts on the Arctic marine system.

Within this context, appropriate elements for research coordination include transdisciplinary collaborations that involve other IASC Working Groups, integration of Indigenous knowledge, and a thematic consideration of current research problems. Ultimately, these elements can be used for practical objectives such as ecosystem-based management as well as facilitate addressing key unknowns about the Arctic System. The priorities listed here are not intended to represent an exhaustive list of specific priorities, but rather high-level themes which align with and encompass a broad range of topic areas that need to be addressed.

Research Priorities

The MWG identified the following five themes that address major unknowns that remain to be resolved in order to contribute to an integrated and predictive understanding of the Arctic System and its interactions with the overall Earth System. These themes, in no specific order of importance are:

- Marine Life,
- Sea Ice and Stratification,
- Disturbances,
- Biogeochemical Cycles, and
- Connectivity and Borealization.

Marine Life

- How and where will the net primary production change?
- How will changes in sympagic, pelagic and benthic community structure impact food web and biodiversity?
- How will higher trophic level species abundance and distribution change?

Key ecological research questions in the Arctic revolve broadly around changes in primary and secondary production patterns that have implications for all components of marine life. This includes the timing and species composition of blooms, and the resulting impacts on cryo-pelagic-benthic coupling in various parts of the Arctic Ocean characterized by different water mass predominance, sea ice cover seasonality and water column depth (e.g. shelf versus slope versus deep basin). Understanding the impacts of environmental conditions (e.g. temperature, light, nutrients, sea ice water masses, and sediments), and resulting changes in quantity/quality of available organic carbon, on the species composition and community structure of lower trophic organisms (sympagic fauna, zooplankton benthic organisms) and abundance and distribution of higher trophic organisms (fish, birds, marine mammals) is also of importance. Filling these knowledge gaps would be crucial for understanding and predicting past, current, and future marine ecosystem functioning.

Sea Ice and Stratification

- How will the changing length of the freezing season, thickness of sea ice, surface state (e.g. melt ponds) and drift pattern influence freshwater distribution, light penetration and habitat for ice associated organisms?
- How will changes in the drivers and strength of stratification affect nutrient availability, heat and momentum exchange and carbon fluxes?

Changes in the sea ice annual cycle, epitomised by shorter freezing seasons and changes in the onset and length of the melting period, are expected to affect the timing and geographical distribution of sea ice melt water delivery, thus altering the strength and seasonal timing of stratification across the Arctic Ocean. Besides representing a physical barrier influencing light penetration and fluxes of gas and energy at the ocean-atmosphere interface, sea ice provides habitat for a number of ice associated species with functions such as feeding grounds, refuges from predation, and hatching and nursery grounds.
Changing upper-ocean stratification also affects vertical fluxes, efficiency of air-sea gas exchange and the upper-ocean supply of heat and nutrients from below will also change, thus also affecting marine ecosystem properties including biogeochemical cycling, primary productivity, and food web maintenance.
Large-scale studies of the annual cycles of sea ice and stratification are required to understand the ongoing future changes in this important interface in the coupled ocean-atmosphere system. Similarly, research should be undertaken on the effect of sea-ice loss and changing stratification on sea ice associated biota.

Disturbances

- How will increased human activity influence marine life?
- How will changing physical conditions influence the distribution and levels of pollutants?
- How will changes in exposure to ocean acidification, pollutants, marine litter and (micro) plastics, noise, light and invasive species impact Arctic ecosystem health?

Human activities such as shipping, resource extraction, tourism and scientific activities, construction of port facilities, energy installations and domestic sources have been increasing in the Arctic region during the past few decades, yet their consequences for marine ecosystems are not well-recognized. The introduced disturbances include pollutants, litter and (micro) plastics, noise, light, and intrusion of invasive species which can have physical, chemical and pathological impacts on marine life. Increasing ship traffic also introduces the potential for ship-strikes on vulnerable Arctic animals, including threatened and endangered species. Other important but not well-understood aspects include effects of climate change on the distribution of pollutants, litter, microplastics. Loss of sea ice, permafrost thawing, ice melting, glacier reduction, soil destabilization, weather pattern changes, and ocean current alterations should be investigated along with the effects of seasonality on the impacts of disturbances.

Biogeochemical Cycles

- How are Arctic carbon, oxygen, nutrient and trace metal biogeochemical cycles and distributions responding to changing conditions?
- How are the changing conditions in the Arctic Ocean influencing its role as a sink of CO_2 and source of potent greenhouse gases such as methane and nitrous oxide?

Key biogeochemical research questions in the Arctic revolve broadly around elemental cycles, resolving the sources, sinks and exchange pathways, as well as their influence on ecosystem function. This includes such diverse topics as the impacts of sea ice coverage and duration on productivity, as well as the impacts of coastal erosion, denitrification, increasing runoff, and changes in oxygenation. Sources and fluxes of greenhouse gases and the extent of exchange with the atmosphere, including ocean acidification are also of importance. In addition to ongoing changes, the MWG recognizes the role of biogeochemical cycles through earth history, combined with the use of appropriate proxies.

Connectivity and Borealization

- How is the transport of heat, water masses, nutrients and plankton to and from, and within the Arctic changing?
- How are the migratory patterns, distributions, feeding strategies and phenology of marine organisms changing in response to habitat contraction and expansion?

The Arctic Ocean is strongly influenced by inflow from adjacent southern areas and exchanges with shelf seas and coastal waters. With changing regional atmospheric circulation as well as sea ice cover and dynamics, ocean current pathways, volumes, and lateral redistribution such as eddies will change. Along with the concurrent warming of the atmosphere and ocean, this sets the stage for primary production levels and habitats to be altered within the Arctic Ocean, as exemplified by the observed ongoing borealization in some areas. Research and long-term monitoring should target key gateways and baseline locations to monitor and understand ongoing change and provide the system understanding for prediction of further downstream changes.

Implementation Tools

Different types of research are needed in order to achieve the goals set as part of this strategy. This includes discovery research, leading to new knowledge and frontiers in the Arctic, mechanistic and process-oriented research, with the focus on understanding the physical, chemical, biological, and societal processes in the coupled system, and sustained observations. The latter includes modern observations using state-of-the-art technologies, projections of future changes using climate models, and reconstructions of past climates, environments, and societies in the Arctic. Together these three aspects of sustained observations will provide a comprehensive spatiotemporal pattern of Arctic changes needed to address the goals set in this strategy.

Collaboration across disciplines, nations, generations, and approaches is needed in order to achieve the goals of the strategic planning process. This is already embedded in the three central pillars of IASC which strive to facilitate Arctic research collaboration, promote engagement and ensure knowledge exchange. Fulfilment of the strategy is particularly dependent on the principles of FAIR and CARE[2] for data sharing and management (Pillar 1). Additionally, the promotion of involvement of early career and Indigenous scholars through effective and developed mentoring plans is essential for the future development of partnerships across the IASC community (Pillar 2). International collaboration and exchange of knowledge between researchers, decision makers, and the broader community of member states (Pillar 1) are also necessary for the success of this strategy (Pillar 3).

From a practical standpoint, research to address the research questions identified cannot be mounted everywhere all of the time. However, one approach to these comprehensive questions is for the international community to identify and agree on a limited number of focal areas to study more closely and collectively; e.g. biological hotspots, baseline locations and key transport gateways. Similarly, sets of prioritised variables that together allow characterization and understanding should be agreed upon. On-going projects and networks that are working towards this, such as the Synoptic Arctic Survey and the Distributed Biological Observatories, could be models, if not vehicles for increased collaboration and improved cost-efficiency across nations, disciplines and methods.

Alignment with the United Nations Decade for Ocean Sciences for Sustainable Development (UNDOS)

The Arctic Action Plan (AAP), published in 2021, identified a list of barriers for progress towards achieving the Decade's goals; as well as Research, Organisational and Uptake challenges for the region.

The research priorities and implementation tools outlined above contribute directly to resolving Barrier 1 "A disconnected Arctic" and Barrier 4 "Inadequate management of Arctic marine ecosystems". Furthermore, Barrier 3 "Inadequate Knowledge of the value and distribution of resources", and Barrier 5 "Inadequate support to the Arctic regions" are partially overcome.

Due to the broad and inclusive nature of the Decade, not all the challenges highlighted in the AAP are directly relevant for the marine research community to address. The scope of the challenges outlined in the AAP span across several research disciplines and cover the interest of a wide range of stakeholders. A summary of how the MWG strategy aligns with the UN Ocean Decade overarching Challenges and selected challenges of the AAP is shown in Figure 1.

[2] Findability, Accessibility, Interoperability, and Reuse (FAIR) and Collective benefit, Authority & Control, Responsibility, and Ethics (CARE)

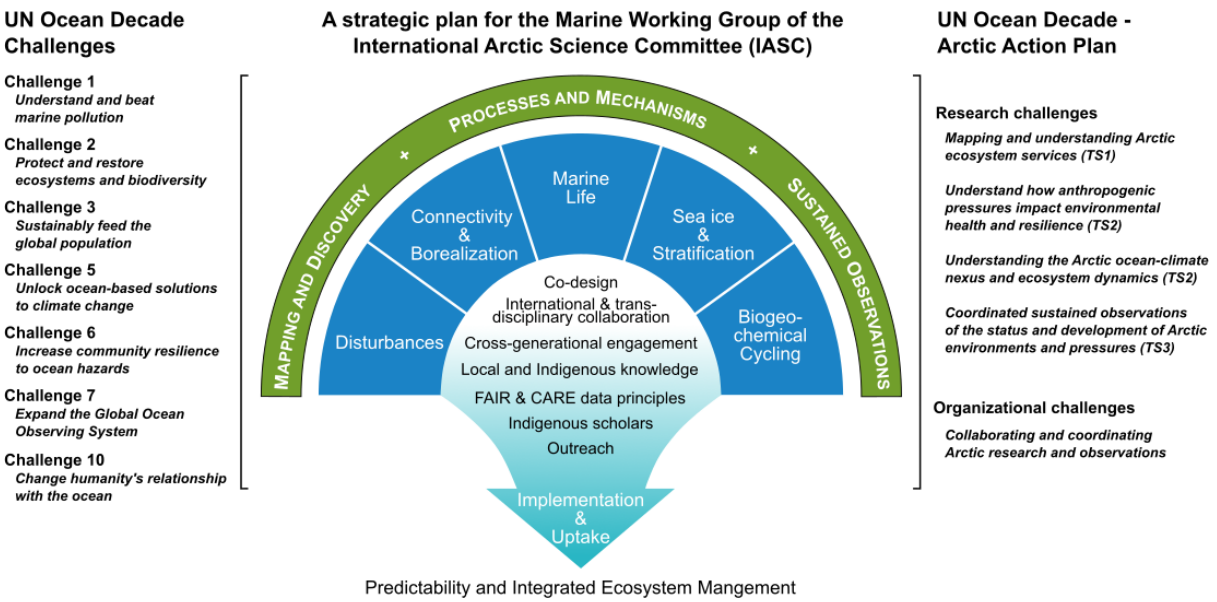

***Figure 1**: Alignment between the Marine Working Group strategy and the UN Ocean Decade. On the left the Decade Challenges are listed. To the right the challenges from the Arctic Action Plan that are addressed by the strategic plan are listed. The green area indicates the three approaches to be employed, while the dark blue indicates the five overarching research themes identified.*

The three approaches and the five science themes (and their underlying questions) outlined in the MWG strategy contribute to elements of selected Transformative Solutions (TS) identified in the AAP. In particular, “Mapping and understanding Arctic ecosystem services” (TS1), “Understand how anthropogenic pressures impact environmental health and resilience” and “Understanding the Arctic ocean-climate nexus and ecosystem dynamics” (TS2), “Coordinated sustained observations of the status and development of environment and pressures” (TS3). The fourth TS “Predict and forecast Arctic ecosystem and climate dynamics” is not explicitly addressed, but the science developed according to the present strategic plan is implicitly contributing to the development of better tools for prediction and forecasting of this complex, coupled system.

The Organisational and Uptake challenges described in the AAP are not specifically addressed in this document, but the IASC goals and activities across all work groups are well aligned with them. In particular, the IASC MWG will provide support for coordination of new, large-scale, and sustained, internationally co-funded programmes as well as ongoing and future Arctic research, management and observation programmes. Successful co-design of actions will link people across local, national and regional and international communities, and contribute to increasing global awareness of Arctic issues and ocean literacy globally (points 2, 3, 5 and 6 under Organisational challenges).