Strategic plan for the Marine Working Group of the International Arctic Science Committee: Research priorities for transdisciplinary research in the changing Arctic Ocean

Version: 2024-10-11

Over the last two years, members of the Marine Working Group (MWG) of the International Arctic Science Committee (IASC) have developed a new strategic plan for the group by hosting several in-person workshops and by correspondence, see details in Appendix 1. The main outcome of the process is the identification of the most pressing research priorities in the field of marine science that can be achieved over the next decade (2025 – 2035).

In this document, the MWG outlines 15 key research priorities grouped under six main pillars: Disturbances, Connectivity and Borealization, Sea Ice and Stratification, Biogeochemical Cycles, Marine Life, and Humans. The table below summarizes the main research priorities along with their relevance to the seven Research Priority Teams (RPTs) of the International Conference on Arctic Research Planning (ICARP IV) 2025. Each research priority aligns with one or more of the seven RPTs, the majority being relevant to RPT2 "Observing, Reconstructing, and Predicting Future Climate Dynamics and Ecosystem Responses". Details and elaboration on each point are provided in the following chapters.

This document is intended to guide, inspire, and accelerate research, scientific cooperation, and international research planning in times of rapid change in Arctic marine waters.

Pillars & Research Priorities	Research Priority Team (RPT)						
	1	2	3	4	5	6	7
Disturbances							
More temporal and spatial data on the occurrence of disturbances, and how seasonality and local processes affect these		X					X
Better understanding of the impact of disturbances on species and ecosystem health, and identification of particularly vulnerable species and areas		X	X				
Insight into how climate change affects the distribution, fate, and effects of disturbances globally		X					
Connectivity and Borealization							
Understanding how and how rapidly climate change will propagate through the Arctic Ocean gateways in a scenario of sea ice loss, Arctic warming and change in the subpolar circulation (AMOC slowdown)	X	X	X				
Assessing the response of coastal systems to increased fluxes of particulate and dissolved constituents, including propagation further into the Arctic Ocean interior		X	X				
Sea Ice and Stratification							
Assessing the changes associated with a state shift in (a) perennial to seasonal sea ice conditions and (b) seasonal sea ice to sea ice-free conditions		X					
Determining how changes in freshwater sources/sinks and enhanced coupling of the ocean-ice-atmosphere system will impact stratification		X					
Biogeochemical Cycles							
Increase the resolution of biogeochemical *in situ* rate measurements using standardized methodologies through coordinated international efforts, with improved linkages between organism biomass, omics, and quantitative biogeochemical measurements		X					X
Enhance our understanding of sink and source processes for greenhouse gases, carbon, and	X	X					

nutrients in the Arctic Ocean to facilitate the integration of biogeochemical data into regional and global models							
Increase efforts to enable the prediction of biogeochemical consequences of abrupt changes such as the disappearance of perennial sea ice	X	X					
Marine Life							
Elucidate changes in sympagic-pelagic-benthic coupling brought by phytoplankton changes, altered bloom phenology and carbon flux in the water column across systems		X					
Improve the taxonomic resolution and biomass estimations as well as seasonal and spatial patterns of pan-Arctic community structure		X					X
Clarify future risks of biodiversity loss and changes in ecosystem functionality, impacts of borealization, and the effects of environmental changes on biological conditions		X	X				
Humans							
The impact of climate change and disturbances on local Arctic communities' livelihood and their existence must be better understood			X	X	X		
Integrated risk assessment methodologies and combined risk management strategies for marine ecosystem conservation need to be developed at a global, national and community level, that includes local adaptive knowledge in the decision-making process and implementation of Arctic marine ecosystem conservation strategies.	X		X	X	X		
Recommendations for implementation							
Establishing key research initiatives	X	X	X	X	X	X	X
Building robust research infrastructure				X			X
Promoting international collaboration				X			
Supporting early-career researchers						X	
Enhancing public engagement and policy integration				X	X	X	
Fostering technological and methodological innovation				X			X

Table of Contents

1. Introduction

The *Strategic Plan for the Marine Working Group of the International Arctic Science Committee* is a document to guide the research priorities of Marine Working Group (MWG) members and the wider Arctic research community. It is also intended as input to larger transdisciplinary research planning and collaboration efforts, such as the fourth International Conference on Arctic Research Planning (ICARP IV) and the 5th International Polar Year. Furthermore, the Strategic Plan is aligned with the research priorities of other important international initiatives (Fig. 1) and expands on the consequences of climate change and human activities for the Arctic Ocean, and the research priorities that arise from the most pressing knowledge gaps.

Figure 1. The IASC MWG Strategic Plan is embedded in and aligned with larger international initiatives and agreements as presented here. UN DOS: UN Decade of Ocean Science for Sustainable Development (https://oceandecade.org). ICARP IV: International Conference on Arctic Research Planning IV (https://icarp.iasc.info). RPT: Research Priority Team within ICARP IV (https://icarp.iasc.info/engagement/research-priority-teams).

The changing Arctic marine system

i. Physical-chemical change

The central Arctic Ocean, its shelf seas, and subarctic seas are experiencing significant changes in response to anthropogenic warming, with important consequences for the Arctic, the Northern Hemisphere, and on a global scale (Fig. 2, Fig. 3). Rising temperatures in the ocean, melting glaciers and ice caps, a dramatic reduction of the sea ice cover, and changing hydrography and light availability are strongly influencing the Arctic Ocean. Eustatic sea level is rising and the volume of freshwater in Arctic surface waters is increasing. Freshwater sources include riverine discharge, precipitation, increased inflow of fresher Pacific water, meltwater from sea ice and glaciers in response to an accelerated hydrological cycle, atmospheric moisture transport, and atmospheric and oceanic warming.

ii. Feedback to the ecosystem

Primary productivity, which forms the base of the marine food web, is fundamentally driven by prevailing hydrography, including freshwater input, stratification, ocean currents, and temperature in combination with light and nutrient availability, and grazing pressure. A decrease in sea ice and snow cover is associated with increasing light availability for Arctic marine ecosystems. However, in nearshore areas, sediment load and turbidity derived from rivers, coastal erosion, glacial discharge, and transformation of marine-terminating to land-terminating glaciers, can cause coastal darkening. Nutrient dynamics in the Arctic Ocean are regionally heterogeneous. The central Arctic Ocean is typically well-stratified and oligotrophic, with nitrogen being the limiting nutrient. Regionally, the upwelling of nutrient-rich subsurface waters, such as along the sea ice edge, and the inflow of Pacific and Atlantic waters increase the nutrient budget. The shelf seas, and increasingly also the central Arctic Ocean, are additionally influenced by nutrient input from rivers and coastal erosion. The changing freshwater budget has altered the halocline in different areas, in turn affecting primary productivity. These fundamental drivers of primary productivity in the Arctic Ocean can trigger a cascade affecting other trophic levels.

iii. Human/local/Indigenous

The changing Arctic Ocean will also affect human communities in the Arctic area in various ways, including shifts in physical conditions, changes in biological resources and ecosystems, and consequences for culture, subsistence, or infrastructure. In addition, a warmer, more accessible, ice-free, resource-rich Arctic Ocean will be very attractive for different countries and companies to increase their anthropogenic activities in this area (potentially more industry, more tourism, increasing populations, and growing cities at the coasts). Therefore, Arctic communities may experience increased international interest in its marine waters and economic as well as political influence.

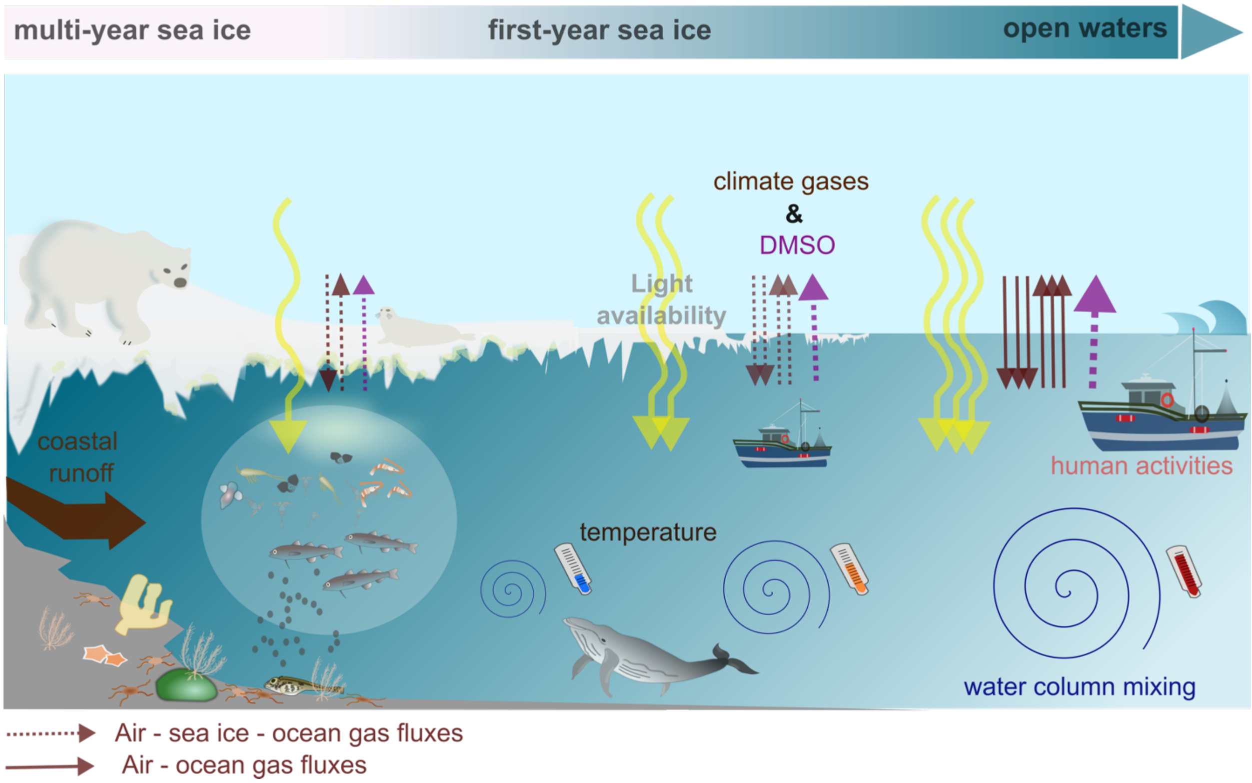

Figure 2. Schematic infographic of ongoing processes as the Arctic Ocean transforms from a white to a blue system (from ice-covered to seasonally ice-free as the perennial ice cover disappears). DMSO: dimethyl sulfoxide. Graphic by Laura Ghigliotti

Global connections

i. Borealization

Current marine observations indicate that the narrow and shallow passages linking the Arctic Ocean to adjacent seas are undergoing significant physical and biological alterations as a result of sea ice decline and rising temperatures. According to model projections, these changes are expected to intensify in the future. At the same time, paleoclimate data show that the Arctic Ocean has experienced comparable shifts in the past (potentially going back several million years), underscoring the importance of viewing contemporary climate change within a broader historical and geological-time context. While both the Atlantic and Pacific sectors are experiencing important modifications, contrasting regional responses can be observed across the Arctic Ocean. Warm and salty Atlantic water flowing through the Atlantic gateway, which extends from the southern Barents Sea and Fram Strait to the eastern Eurasian Basin, is a major contributor to the Arctic Ocean's heat budget, controlling sea ice loss and physical water column structure by reducing the upper-ocean halocline and promoting winter mixing. This has significant implications for albedo, fueling polar amplification, coupled with the northward expansion of boreal species and subsequent disruptions to the marine food chain. At the other gateway, the "Pacification" of the Arctic Ocean, particularly evident in the Amerasian Basin, is characterized by the anomalous influx of Pacific waters. This influx has led to elevated heat and freshwater content within the Beaufort Gyre halocline, facilitating the expansion of Pacific species into the Arctic interior. In the upper layers of the Amerasian Basin, local Arctic atmospheric processes have driven changes, resulting in intensified wind-ice-ocean coupling, increased convergence within the Beaufort Gyre, a thicker fresh surface layer, and a deeper nutricline and chlorophyll maximum.

ii. Global impacts

The global implications of, for instance, Arctic sea ice loss are far-reaching, encompassing both energy balance disruptions through the ice-albedo feedback and perturbations to the carbon cycle that can release carbon into the atmosphere, further accelerating climate change. As the Arctic Ocean becomes increasingly ice-free in summer, enhanced solar absorption by the ocean is expected to lead to a gradual accumulation of stored ocean heat. Conversely, regions previously covered by sea ice can now fully exchange with the atmosphere during the cold seasons, promoting deep water convection and releasing heat to the atmosphere, which further increases winter atmospheric temperatures. While deep-water formation in subpolar regions is predicted to decrease by the end of the century due to freshwater discharge from Greenland, changes in the halocline thickness and ventilation degree will affect the general formation of intermediate water contributing to the global conveyor belt with still unknown consequences. Such changes in oceanic circulations can also influence subtropical and tropical climates, including monsoons. In addition, sea ice loss contributes to longer ice-free seasons along coastal regions, stimulating storm activity. In combination with a warmer ocean and atmosphere, this intensified swell action accelerates coastal erosion of permafrost deposits. In parallel, increased runoff and thermal disruption of permafrost in the watersheds further release dissolved organic carbon, contributing to the reactivation of the frozen-carbon pool and its downstream release to the atmosphere further increasing the global radiative forcing.

iii. Intra-Arctic connections

As the Arctic Ocean continues to warm, exchanges of heat, salt, and particulate and dissolved matter will be significantly altered within the coastal region and at the shelf-ocean interface. Monitoring data indicate that river runoff in the Arctic has been increasing and is projected to rise further with continued warming. Concurrently, changes in water table depth, active layer deepening, and thermokarst formation will influence the composition of dissolved and particulate elements released into the coastal region, alongside the effects of coastal erosion on permafrost in response to ice-free and warmer conditions. Changes in the freshwater, nutrient, and carbon fluxes will ultimately affect water column physical properties, primary productivity, food chain, and Arctic Ocean alkalinity (i.e., acidification) in the coastal zone. Perturbations can further echo towards the Arctic interior with the shelf-basin exchange by shelf-break morphometry, wind, and ice concentration. In a scenario of reduced sea ice and intensified wind forcing and cyclones, it is expected that the shelf break exchange (upwelling) will intensify further fueling nutrient supply and primary productivity. In parallel, higher energy events over the shelf will intensify the crossshelf transport of particulates that can ultimately reach the deep Arctic Ocean interior through the slope conduits such as submarine canyons.

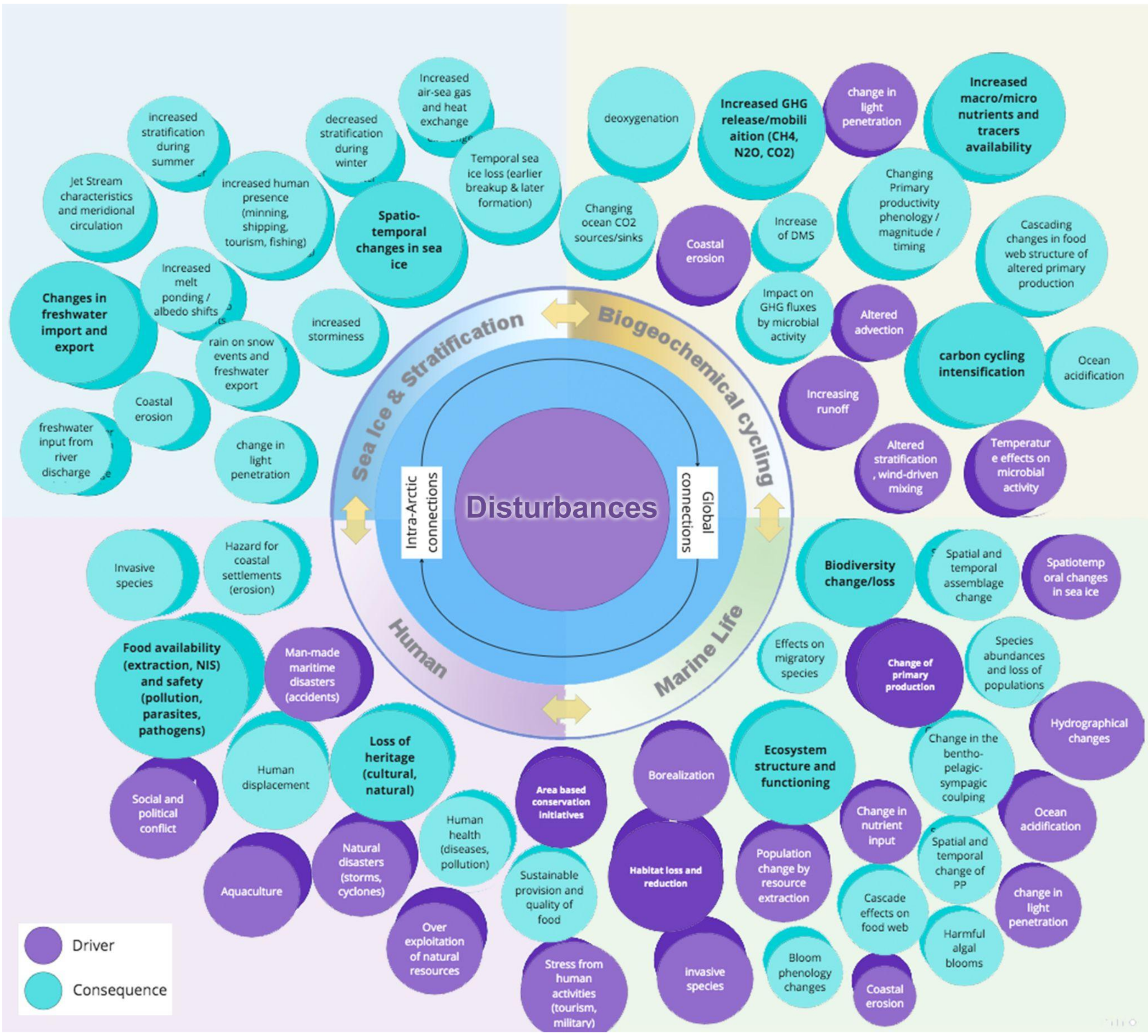

Figure 3. Overview of the main drivers of change (purple) and their potential consequences (turquoise) in the four pillars Sea ice & Stratification, Biogeochemical cycling, Marine Life, and Human.

2. Research priorities

The Strategic Plan endorsed by the MWG in 2022, identified five marine-related themes that address major unknowns and that contribute to an integrated and predictive understanding of the Arctic System and its interactions with the overall Earth System (https://iasc.info/images/working-groups/marine/IASC_MWG_Stragegic_Plan_2023.pdf). Here, the theme "Humans" is added addressing the interactions between marine physical/ecological processes and social dynamics.

The six pillars, in no specific order of importance, are: Disturbances, Connectivity and Borealization, Sea Ice and Stratification, Biogeochemical Cycles, Marine Life, and Humans.

To improve the document readability, a standard format is applied to each theme by including the following sections:

- *Main outcomes*, key priorities for research over the next decade (2025-2035);
- *Background information*, overview of the main drivers of change and potential consequences;
- *Key questions*, outline of the main knowledge gaps, and definition of future research priorities.

Disturbances

Main outcomes

The processes and impacts of individual and cumulative disturbances in the Arctic marine environment are not fully understood. Therefore:

- Further attention and data are needed on the temporal and spatial occurrence of disturbances, and on how seasonality and local processes affect the fate of these disturbances (e.g. pollutants).
- Urgent studies are required on the impact of disturbances on species and ecosystem health, and to identify particularly vulnerable species and areas.
- A better understanding of how climate change affects the distribution, fate, and effects of disturbances globally is necessary.

Background information

Human activities such as vessel transport, resource exploration and extraction, tourism, scientific research, construction of ports, and aquaculture have been increasing in the Arctic region in the past few decades, yet their consequences for marine ecosystems and humans are not well-understood. These disturbances include for instance chemical pollution (e.g. mercury and PFAS), marine litter, noise and light pollution, and the introduction of invasive species, which can have physical, chemical, and pathological impacts on marine life. Other important but not well-understood aspects include the effects of climate change on the fate, distribution, and effects of these disturbances.

Key questions

i. Occurrence and impacts of disturbances on Arctic ecosystem health

D-Q1: How will increased human activity (local and long-range) influence marine life?

D-Q2: How will changes in exposure to ocean acidification, pollutants, marine litter and (micro)plastics, noise, light, and invasive species impact Arctic ecosystem health?

Spatial and temporal data on disturbances in the marine Arctic region is currently limited, particularly in remote areas. This includes knowledge on sources and sinks of contaminants, litter, and non-indigenous species, and whether these are coming from local activities or result from long-range transport via air and ocean currents. Furthermore, there is a lack of understanding of how vulnerable Arctic species are to disturbances, what their thresholds for effects are, and which species are particularly sensitive to (certain) disturbances. Data from other, lower latitude areas may guide if enough knowledge is available to translate the sensitivity of these species to those of Arctic species. Altogether, these knowledge gaps hamper a good understanding of which locations and species are particularly vulnerable to disturbances.

Future research priorities should especially include:

- Assessing the spatial and temporal occurrence of disturbances such as pollution (chemical, noise, light), litter, and invasive species in the Arctic marine region, and identifying the sources of these disturbances [RPT-2, RPT-7]
- Identifying the impacts of disturbances on marine life and in particular assessing the thresholds of species for disturbances, as well as the most vulnerable (key) species and areas for disturbances [RPT-2, RPT-3]

ii. Cumulative effects of climate change and disturbances

D-Q3: How will changing physical conditions influence the distribution and levels of pollutants?

The fate of pollutants is influenced by changes in global patterns and local environmental conditions. Global atmospheric and seawater circulation (including sea ice transport and riverine discharges) affect pollutant transport pathways, direction, and strength, which is further influenced by local geographical settings, such as open sea versus closed fjord areas, the bottom depth and structure, the presence of pycnoclines, as well as influences from land (glacier melt, permafrost thawing, coastal erosions and changes in riverine outflow and precipitation patterns). Moreover, the physio-chemical seawater properties (oxygen content, pH and redox potential, temperature, suspended matter and salinity, etc.) are important factors shaping the ultimate fate of pollutants. All these changes will also affect the transfer and bioaccumulation potential of pollutants in marine food webs, the vulnerability of species to these combined stressors, and ultimately the ecosystem response to cumulative effects of climate change drivers and disturbances.

Future research priorities should especially include:

- Assessing how changes in conditions influence the discharge and fate of pollutants in the Arctic marine system, such as changes in global transport, local environmental conditions, and seawater properties [RPT-2].
- Determining what the consequences of those changes are, in particular the pollutant transfer in biota and food chains, the vulnerability of the ecosystem in a changing environment, and the ecological response to cumulative effects of climate change drivers and disturbances [RPT-3].

Connectivity and Borealization

Main outcomes

The boundary regions of the Arctic Ocean are particularly susceptible to climate change and are already showing clear evidence of their vulnerability. Key boundaries include the Arctic Ocean gateways in the Atlantic and Pacific regions, as well as the wide land-ocean interface (Fig. 4).

Rapid modification of characteristics of these dynamic areas is anticipated, therefore the following priorities have to be highlighted:

- Understanding how and how rapidly climate change will propagate through the Arctic Ocean gateways in a scenario of sea ice loss, Arctic warming and change in the subpolar circulation (slowdown of AMOC, the Atlantic Meridional Overturning Circulation) is a pressing priority.
- Assessing the response of coastal systems to increased fluxes of particulate and dissolved constituents is crucial, including how these changes may propagate further into the Arctic Ocean interior.

Background information

As an enclosed ocean basin, the Arctic Ocean is significantly affected by the interactions with neighboring southern regions and exchange with shelf seas and coastal waters. In a scenario of polar amplification, as regional atmospheric circulation patterns change, along with sea ice cover, the lateral-vertical distribution of heat and salt at the gateways of the Arctic Ocean is anticipated to rapidly shift. Warming temperatures and changing precipitation patterns will lead to increased melting of glaciers, ice caps, and frozen soils resulting in higher river discharge, delivering fresh water and dissolved as well as particulate material to the coastal regions with unknown consequences for the Arctic Ocean interior. Collectively, the rapid loss of the terrestrial and marine cryosphere will profoundly change the Arctic Ocean including marine biota, ecosystem services, biogeochemical cycles, as well as human life. At the same time, internal dynamics and ocean-cryosphere interactions will echo outside the Arctic influencing the global energy balance and thermohaline circulation and, consequently, the global climate.

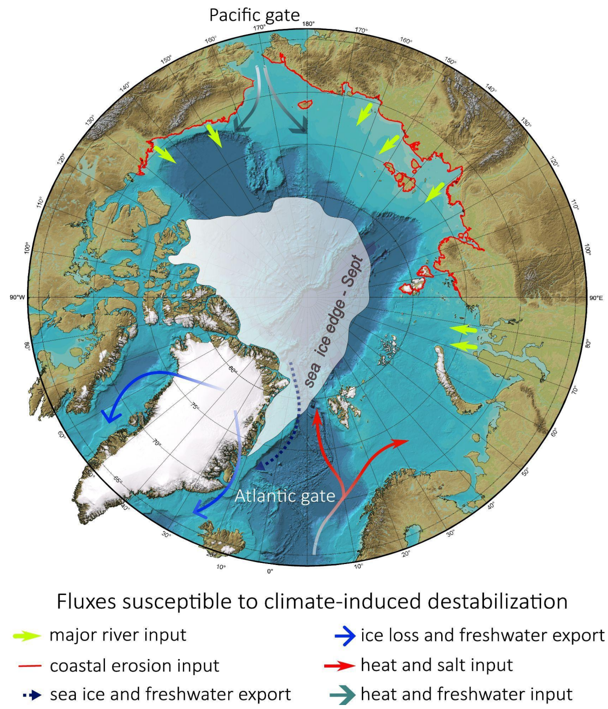

Figure 4. The Arctic Ocean bathymetry chart (IBCAO, version 4.0, Scientific Data 7.1 (2020): 176) with gateways (Atlantic and Pacific) and key regional boundaries (land-coastal regions and shelves-ocean interior).

Key questions

i. Global connections

C&B-Q1: How will the exchange of heat and freshwater in and out of the Arctic Ocean change over time in response to the AMOC *slowdown and North Pacific freshening and warming?*

C&B-Q2: How does modern and future borealization compare with past climate variability, and which regions of the Arctic Ocean are less or more resilient to Atlantification and Pacification?

Rapid changes in response to human-induced climate change are already visible today at the gateways to the Arctic Ocean where water masses, previously covered by sea ice and a thick halocline, are becoming relatively saltier and warmer, a phenomenon known as Atlantification or Pacification, depending on the geographic domain. Numerical models suggest that sea ice loss will likely continue in the next decade regardless of the climate scenario. At the same time, the AMOC is predicted to slow down as the Greenland ice sheet releases freshwater into the subpolar ocean while the Northern Pacific is expected to become warmer and fresher. However, how this ultimately affects the exchange of heat and salt remains elusive. For instance, some models predict a general decrease of the heat transport towards the north in response to the AMOC weakening which will slow down the sea ice loss. Others, instead, predict that the ocean heat transport to the Arctic will increase as the AMOC decreases because the reduced surface heat loss at subpolar latitudes will leave more heat in the northern sector of the Atlantic Ocean.

Future research priorities should especially include:

- Resolving ocean-cryosphere dynamics: monitoring and forecasting the interactions between the Arctic and Sub-Arctic, with a focus on how freshwater and heat exchange will decrease or increase in a global change scenario [RPT-1, RPT-2]
- Establishing a baseline for borealization using climate archives (*i.e.,* going beyond instrumental measurements), monitoring changes over time at the pan-Arctic scale, and predicting how it will evolve spatially and temporally with Earth System Models (ESM) in the warming Arctic Ocean due to human-induced climate change [RPT-2, RPT-3].

ii. Land-shelf-ocean interactions

C&B-Q3: How will changes to land-ocean interactions alter the physical, chemical, and biological characteristics of coastal waters?

C&B-Q4: How much of the anticipated changes in the water properties of continental shelves will be echoed within the Arctic Ocean interior?

Arctic coastal ecosystems are areas of increased complexity, being under the constant influence of marine, terrestrial, and atmospheric forces. These processes are multi-directional, making both the observation of current status and the prediction of future trajectories a challenging task. Coastal and shelf areas are, thus, highly susceptible to changes that occur in any of these categories (e.g., changes to seasonality in discharge from the catchment, glacial retreat, or wave dynamics in the nearshore zone). However, knowledge about land-shelf-ocean interactions is limited and necessitates interdisciplinary research. Arctic coastal ecosystems are also providing essential ecosystem services and are areas of high productivity. However, benthic responses to changes in the coastal zone will have to be better understood to better predict productivity developments of nearshore ecosystems.

Future research priorities should especially include:

- Detailed and holistic representation of coastal systems in Earth-System-Models (ESM) and evaluation of how Arctic regional models compare with ESM [RPT-2]
- Understanding how the rapid changes in the chemical and physical properties of water masses in Arctic coastal and shelf areas will ultimately affect the Arctic Ocean interior [RPT-3]

Sea Ice and Stratification

Main outcomes

Arctic sea ice is changing both spatially (with reductions in areal extent and thickness) and temporally (with earlier seasonal sea ice breakup and later sea ice formation) resulting from anthropogenic emissions and internal variability. Shifts in freshwater availability are contributing to important changes in stratification across the Arctic as well. There are numerous cascading implications of such changes (Fig. 2), eliciting two main pressing questions:

- What are the changes associated with a state shift in (a) perennial to seasonal sea ice conditions; and (b) seasonal sea ice to sea ice-free conditions?
- How will changes in freshwater sources/sinks and enhanced coupling of the ocean-ice-atmosphere system impact stratification?

Background information

Sea ice represents a physical barrier influencing light penetration and fluxes of gas and energy at the ocean-atmosphere interface and provides habitat for several ice-associated species with functions such as feeding grounds, refuges from predation, and hatching and nursery grounds. Reduction in the sea ice areal extent and thickness, as well as earlier breakup and later sea ice formation, are leading to changes in the ocean-atmosphere exchange of light, heat, freshwater, and gases, with repercussions on the sea ice-associated marine biota. Furthermore, changes in the sea ice annual cycle, epitomized 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 meltwater delivery, thus altering the strength and seasonal timing of stratification across the Arctic Ocean.

Key questions

i. Sea ice reductions

SI&S-Q1: What are the changes associated with a state shift in (a) perennial to seasonal sea ice conditions; and (b) seasonal sea ice to sea ice-free conditions?

Arctic sea ice is changing both spatially (with reductions in areal extent and thickness) and temporally (with earlier seasonal sea ice breakup and later sea ice formation) resulting from anthropogenic emissions and internal variability. As we are now (and even more so during the 5th IPY) moving into the realm of the possibility of occasional to consistent ice-free conditions (<1 million km^2), especially during September, this results in broad regions across the Arctic experiencing fundamental system-state changes (i.e., transitions from perennial sea ice cover to seasonal sea ice cover, as well as transitions from seasonal sea ice cover to sea ice-free conditions). This will have significant consequences for the biogeochemical and physical systems of the Arctic Ocean, with the latter including changes in stratification, the radiation balance, ocean-atmosphere energy and gas fluxes, and coastal erosion. This may also influence subtropical/tropical climates, including monsoons, through various teleconnections. Internal variability and spatiotemporal heterogeneity in sea ice loss, however, complicate straightforward interpretations of the drivers and consequences, posing a key challenge to the scientific community over the next decade. This involves large-scale studies of spatiotemporal shifts in sea ice and the development of coherent definitions, approaches, and best practices to reduce the uncertainties in sea ice projections and our understanding of the ongoing and future consequences of regional and pan-Arctic sea ice loss at the interface of the coupled ocean-atmosphere system.

Future research priorities should especially include:

- Developing coherent definitions of regional and pan-Arctic sea ice states (i.e., seasonal, ice-free, marginal ice zone, etc.) and innovative approaches to enable holistic real-time studies of the consequences of regional and pan-Arctic sea ice loss and state-shifts (i.e., seasonal to ice-free, perennial to seasonal), given both the overall rapidity and heterogeneity in spatiotemporal sea ice changes [RPT-2].
- Understanding drivers of internal variability and their effect on sea ice extent/area on multiple timescales, integrating essential knowledge from models, observations, and paleo studies [RPT-2].
- An understanding of the physical aspects of sea ice decline (decreases in sea ice extent/thickness; increases in sea ice mobility, melt ponding, leads, freshwater input/stratification, coastal erosion) [RPT-2]
- Investigating how sea ice reductions impact ocean-atmosphere exchange of light, heat, freshwater, and climate-relevant gases [RPT-1, RPT-2]

ii. Drivers and strength of stratification

SI&S-Q2: How will changes in freshwater sources/sinks and enhanced coupling of the ocean-ice-atmosphere system impact stratification?

Arctic Ocean stratification is salinity driven, with sea ice melting/freezing, glacial melt, riverine input, precipitation, and the exchange with Pacific and Atlantic water masses setting the halocline strength. In addition to the salinity budget, changes in sea ice cover also affect surface ocean wind stress, internal wave dynamics, and ocean-atmosphere heat exchange – all important factors in Arctic Ocean stratification. Changes in the upper-ocean stratification affect vertical fluxes, the efficiency of air-sea gas exchange, and the upper-ocean supply of heat and nutrients from below, thus also affecting marine ecosystem properties including biogeochemical cycling, primary productivity, and food web maintenance. Additionally, Arctic Ocean stratification is involved in climate feedback mechanisms, with changes in vertical heat transport as a result of stratification weakening/strengthening affecting sea ice formation and melting processes.

Future research priorities should especially include:

- Assessing changes in river discharge, precipitation/atmospheric moisture transport, freshwater transport by sea ice, freshwater flux from glaciers and the Greenland ice sheet, and freshwater transport through gateways into and out of the Arctic Ocean [RPT-2]
- Understanding how the enhanced coupling of the ocean-ice-atmosphere system (through sea ice reductions and enhanced ocean-atmosphere mixing) impacts stratification [RPT-2]
- Seasonal changes in stratification and their impacts on the coupled climate-ecosystem [RPT-2].

Biogeochemical cycles

Main outcomes

It is poorly known how biogeochemical cycles are impacted by small- and large-scale alterations of the rapidly transforming Arctic Ocean. Therefore, it is crucial to:

- Increase the resolution of biogeochemical *in situ* rate measurements using standardized methodologies through coordinated international efforts, with improved linkages between organism biomass, omics, and quantitative biogeochemical measurements [RPT-2, RPT-7]
- Enhance our understanding of sink and source processes for greenhouse gases, carbon, and nutrients in the Arctic Ocean to facilitate the integration of biogeochemical data into regional and global models [RPT-1, RPT-2]
- Increase efforts to enable the prediction of biogeochemical consequences of abrupt changes and tipping points such as the disappearance of perennial sea ice [RPT-1, RPT-2]

Coordinated, interdisciplinary efforts using tools from different fields are essential to understanding the impact of the changing Arctic Ocean on biogeochemical cycles, as well as how these altered cycles influence the Arctic Ocean.

Background information

Profound changes in the Arctic physical system, including summer sea ice disappearance, rising temperatures, increased freshwater inputs from terrestrial and glacial sources, enhanced stratification, and advancing Atlantification are already impacting biogeochemical cycles. Understanding how these changes affect source/sink dynamics of climatically active gases, carbon sequestration, nutrient availability with the subsequent ecosystem productivity, and the associated implications for both marine ecosystems and humans are of high importance.

Key questions

i. Climate gases

BC-Q1: How are changing conditions influencing the source and sink of climate gases?

The Arctic Ocean plays a critical role in the global climate system, acting both as a source and a sink for climate gases such as carbon dioxide, methane, and nitrous oxide, with complex and heterogeneous regional responses to ongoing change. Thawing permafrost releases greenhouse gases through the intensification of microbial metabolic activities (e.g. denitrification, organic matter remineralization). Changes in ice cover alter gas flux between the ocean and atmosphere by increasing sea-to-air ventilation. Changing primary productivity impacts biologically regulated air-sea CO_2 exchange and increases dimethyl sulfide emissions (DMS) - a volatile compound affecting cloud formation and thereby radiative balance.

Future research priorities should especially include:

- Improving spatiotemporal coverage of greenhouse gas flux rate measurements including the poorly sampled winter and shoulder seasons and remote regions to enable large-scale modeling to predict future trends in Arctic greenhouse gas emissions and uptake [RPT-2]
- Understanding key processes affecting greenhouse gas emissions and uptake, such as primary productivity, sea ice decline, permafrost thaw, river discharge, and changes in water mass properties [RPT-1, RPT-2]

ii. Carbon cycling

BC-Q2: How is the Arctic carbon cycle responding to the increase of anthropogenic inorganic carbon and regional changes in biological pump functioning?

Changing sea ice presence and associated phytoplankton bloom phenology changes will reorganize the tight pelagic-benthic coupling that has historically characterized productive Arctic shelf environments. Evidence of a shift toward more pelagic conditions on Arctic shelves has already been noted, with implications for the cycling of carbon (and associated nutrients) on shelves and coastal carbon burial. Meanwhile, increased loading of terrestrial carbon, particularly associated with permafrost thaw in the Siberian Arctic, and warming temperatures and associated effects on microbial respiration rates, has intensified carbon cycling between dissolved and inorganic carbon pools and led to pronounced outgassing. Anthropogenic CO_2 contributions, both from inflowing Atlantic and Pacific waters and through absorption of atmospheric CO_2 under reduced ice cover, contribute to ocean acidification, with some regions already crossing important thresholds that indicate unfavourability for biotic calcification.

Future research priorities in this subject area should include:

- Quantifying the transformations between inorganic and organic carbon pools and associated rates (microbial respiration, photolysis) [RPT-2]
- Quantifying how changes in the biological pump (e.g. Arctic “greening” associated with declines in sea ice and potential nutrient advection at Arctic gateways) are associated with carbon export and burial including proportions of new and regenerated production [RPT-1, RPT-2]

- Quantifying rates of ocean acidification, particularly in coastal regions where impacts to subsistence resources are likely to be significant [RPT-2, RPT-3]

iii. Macro- and micronutrients

BC-Q3: How are gradual and abrupt physicochemical and/or biological changes spatiotemporally altering the distribution and availability of nutrients and trace elements?

The availability of macro- and micronutrients are the main drivers for primary productivity and pelagic-benthic coupling, and as such are key aspects of the Arctic Ocean's role in the global carbon cycle. Nutrient availability is rapidly changing in multiple, often element-specific, ways, including increased influx/advection and mobilization from adjacent subpolar and terrestrial regions, altered vertical water column mixing, and changing biological conversions due to temperature, oxygen or substrate availability (e.g., denitrification). Nitrogen limits primary production in much of the Arctic Ocean, yet there are significant gaps in our understanding of its availability, utilization, and microbial transformations. Addressing the impacts of abrupt changes is crucial for better predicting and modeling the Arctic's role in the global nitrogen cycle. Other elements (e.g., phosphate, silicate, iron and other trace metals, vitamins) are additional regulators of biological processes, but poorly constrained in their availability, environmental driving factors, and potential to limit primary production.

Future research priorities should especially include:

- Quantifying how changes in the availability of nitrogenous species impact the balance between new and regenerative production on varying spatiotemporal scales [RPT-1, RPT-2]
- Better understanding of the mass balance, cycling, and biological availability of inorganic and organic macro- and micro-nutrients [RPT-2]

Marine life

Main outcomes

Arctic marine life is still understudied. To better understand the responses of marine life to rapid changes that are occurring in the Arctic region, it is key to:

- Improve the taxonomic resolution and biomass estimations as well as seasonal and spatial patterns of pan-Arctic community structures
- Elucidate changes in sympagic-pelagic-benthic coupling brought by phytoplankton changes, altered bloom phenology, and carbon flux in the water column across systems.
- Clarify future risks of biodiversity loss and changes in ecosystem functionality, impacts of borealization, and the effects of environmental changes on biological conditions.

A deep knowledge of Arctic ecological patterns and processes is crucial to support conservation measures tailored to manage and regulate emerging activities.

Background information

The Arctic Ocean is experiencing significant changes with cascading effects on marine life. Among others, increased coastal erosion and glacial discharge promote turbidity and coastal darkening in nearshore areas, while sea ice thinning and reduction translate into increasing brightness. Growing meltwater input, as well as altered inflows from the Pacific and Atlantic, are affecting stratification and nutrient dynamics. Consequently, alteration of biodiversity, microbially mediated steps of biogeochemical cycles, and the spatiotemporal distribution of primary production are expected to cause changes in the food availability and quality for secondary producers, with cascade effects in marine food webs up to higher trophic levels. Additional stressors deriving from human activities are altering habitat integrity, local biodiversity, ecosystem resilience, and function.

Key questions

i. Primary productivity

ML-Q1: How and where will the net primary production (PP) change?

Pelagic, sympagic, and coastal benthic PP form the base of Arctic marine food webs, and feed material and energy through the system. PP is regulated by the availability of light and macronutrients, which in turn are affected by hydrography and the distribution and properties of sea ice. During the last decades, phytoplankton biomass has increased in particular on the inflow shelves of the Barents and Chukchi seas, and declined in the inner and outflow shelves that are affected by increased riverine outflow, which underlines the importance of interactions between the Arctic Ocean and adjacent seas or internal nutrient flows as regulators of PP. The overall productivity is increasing but projected complex changes in sea ice and hydrography imply significant uncertainty in future spatiotemporal PP distribution with cascading consequences.

Future research priorities should especially include:

- Systemic changes or tipping points and resilience in PP, as a function of sea ice change and ocean acidification [RPT-2]
- Changes in coastal benthic PP and habitat formation by macroalgae e.g. due to lower ice scouring, increased turbidity, and nutrient input [RPT-2]

ii. *Sympagic/Pelagic/Benthic Community Structure*

ML-Q2: How will changes in community structure of sympagic/pelagic/benthic Community Structure impact biodiversity and the food web?

Sympagic communities, depending on sea ice as a habitat for food provision, shelter, resting, and reproduction, play an important role in the food supply for ice-associated top predators and for transmitting carbon from the ice-water interface to the pelagic and benthic food webs. Different drivers can impact sympagic communities with consequences for species composition and culminating effects on energy transfer to higher trophic levels. Pelagic secondary producers include zooplankton and heterotrophic microbiotes. Especially zooplankton, consisting of herbivores, carnivores, and omnivores, are linking primary producers to higher trophic levels. Zooplankton provides a relevant contribution in terms of biomass, biodiversity, and serves as an indicator of ecosystem health. Changes can alter pelagic secondary production and affect diversity patterns, with consequences for higher trophic organisms. Benthic communities inhabiting the bottom substrates, composed of macro- and meiofauna, are strongly influenced by the sediment composition, the physical-chemical gradients inside the sediment, and bottom-water conditions/currents. They are connected by bentho-pelagic-sympagic coupling, which plays a crucial part in turnover rates, carbon remineralization, and carbon processing. The central Arctic Ocean is an oligotrophic system, causing slow growth rates and high age of the benthos. But PP and other drivers are changing, with far-reaching consequences.

Future research priorities should especially include:

- Improvement of taxonomic resolution, biomass estimations, and understanding of seasonal and spatial patterns of pan-Arctic community structures, including species composition, biodiversity, connectivity, abundance, productivity, and timing of blooms and reproduction. Identifying key habitats and climate refugia in support of biodiversity conservation efforts. [RPT-2, RPT-7]
- Response of ecosystems to changing conditions, changes in the bentho-pelagic-sympagic coupling, altered bloom phenology and carbon flux, new species, and anthropogenic influence. [RPT-2, RPT-3]

iii. *High Trophic Level Species*

ML-Q3. How will higher trophic level species abundance and distribution change?

In Arctic marine ecosystems, higher trophic level species include secondary consumers (fish, whales, seals, and sea birds) as well as top predators, such as the polar bear. Those animals all show distinct ecological features (e.g. foraging strategies, reproductive habits, migratory behavior, and population structuring), often connected to sea ice and resulting in a degree of complexity. Nevertheless, dominant drivers, including human activities (shipping, fishing, hunting, contaminants, etc.), can be recognized which particularly affect the higher trophic level community.

Future research priorities should especially include:

- Effects of changes in the community of predators on the food web and impact of human activities on high trophic level species. [RPT-2, RPT-3]
- Impacts of borealization and environmental change on their biological status, distribution, interaction, foraging, and reproduction as well as their resilience to disturbances. [RPT-2, RPT-3]

Humans

Main outcomes

Climate change and disturbances in the marine and coastal systems also affect the people living along the Arctic marine coast. Mitigation of disturbances that are affecting the Arctic marine system including humans, is required at a global, national, and community level. Therefore:

- The impact of climate change and disturbances on local Arctic communities' livelihood and their existence need to be better understood
- Integrated risk assessment methodologies and combined risk management strategies for marine ecosystem conservation need to be developed at a global, national, and community level, including local adaptive knowledge in the decision-making process and implementation of the Arctic marine ecosystem conservation strategy.

This is needed to safeguard a sustainable Arctic marine future.

Background information

Disturbances in the marine system also affect the people living along the Arctic marine coast at different levels. There is a strong connection with the marine system for food provision, transport, and cultural value. The quality and availability of local marine food are influenced by contaminants, coming from local sources and long-range transport, and by pathogens and parasites as a consequence of borealization, the introduction of non-indigenous species (NIS), and aquaculture. Furthermore, the arrival of new species (non-indigenous species and through borealization) is likely to affect the natural system for instance through competition. Besides this, climate change is strongly affecting the Arctic coastal system by changes in weather patterns (increased storms and rainfall), erosion, permafrost thaw, glacier melting, and increased run-off of sediments, nutrients, and contaminants from all these processes into the sea.

As the Arctic marine ecosystem is a complex socio-ecological system, multidisciplinary research is essential to comprehensively understand the interactions between physical, ecological processes, and social dynamics. By combining expertise from various fields, researchers can identify risks evolved by the disturbances and ways to develop more effective and holistic strategies for managing those risks for marine ecosystems and the connecting human society. Moreover, active local community involvement in risk mitigation policies is of utter importance. The Indigenous knowledge on how to manage and explore the resources from the ecosystem in a sustainable way should therefore be considered in bottom-up approaches rather than top-down. Any Arctic risk management strategy to mitigate risks due to natural and human disturbance needs to be user-friendly, flexible, and practical. As the Arctic marine ecosystem will be affected by both intra-Arctic and global factors, the implementation of risk management policies should also be well-coordinated at local, national, and international levels.

Key questions

i. Impact of disturbances on local coastal communities

H-Q1: How are local coastal communities affected by disturbances in the Arctic marine system?

With the rapid changes occurring in the Arctic marine system, there is a need to know how various stakeholders and local communities perceive the natural and human-induced risks in the Arctic marine socio-ecological system, and what strategies should be adopted to mitigate the vulnerabilities by increasing resilience capacities of the ecosystem and society.

Future research priorities should especially include:

- Determining the combined impacts of various disturbances (e.g., physical, chemical, biological, biogeochemical), on the Arctic marine ecosystems, local Arctic communities' livelihood, and their existence. This includes topics such as food availability (due to fisheries, invasive species), migration patterns of economically important marine species, and food quality (contaminants, pathogens, parasites) for local coastal communities that are dependent on the sea for their food supply (natural and cultural heritage, social security, and socio-economic consequences) [RPT-3, RPT-5]
- Assessing the impact of sea ice melting on the movement of Indigenous communities (e.g., Inuit) across the Arctic region and the preservation of their cultural heritage [RPT-3, RPT-5]

ii. Mitigation management of disturbances

H-Q2: What knowledge is needed for a sustainable Arctic marine future?

Traditional marine resource management policies often separate ecological and human aspects, failing to recognize their interconnectedness and interdependence. Climate change, increased resource extraction, and other anthropogenic activities are posing multidimensional risks to the fragile Arctic ecosystem and increasing conflicts among resource users. Therefore, a holistic management approach that considers the interplay between ecological systems and human needs is crucial for the sustainable management of the Arctic marine ecosystem. In this regard, the following research is needed.

Future research priorities should especially include:

- Assessment of environmental and social sustainability under increased anthropogenic activity in the intra-Arctic and connected oceans [RPT-3, RPT-5]
- Mapping of risks, consequences, and strategies to mitigate those risks for the sustainability of the Arctic socio-ecological system [RPT-3, RPT-4]
- Development of integrated risk assessment methodologies and combined risk management strategies for marine ecosystem conservation at a global, national, and community level. Mitigation measures should also include monitoring strategies to assess their effectiveness. Local adaptive knowledge in the decision-making process and implementation of the Arctic marine ecosystem conservation strategy is key [RPT-3, RTP-4, RTP-5]

3. Recommendations for implementation

In light of the evolving challenges posed by climate change and the urgent need for transdisciplinary research in the Arctic Ocean, the MWG has in this document outlined several key research priorities and strategic pillars to guide scientific collaboration until the 5th International Polar Year 2032/33. This implementation section builds on the identified priorities and focuses on establishing the necessary infrastructure, promoting international cooperation and research alliances, and fostering an environment for early-career researchers to thrive.

Establishing key research initiatives [All RPTs]

The research pillars identified (Disturbances, Connectivity and Borealization, Sea Ice and Stratification, Biogeochemical Cycles, Marine Life, and Humans) form the backbone of future Arctic research. To effectively implement these research priorities, the MWG recommends:

- Initiate targeted research projects: Each research pillar must be supported by specific projects that address the knowledge gaps identified in the strategic plan. For example, studying disturbances in Arctic ecosystems requires advanced monitoring of pollution and invasive species, combined with predictive models to forecast the impacts of climate change.
- Coordinate with international partners: The alignment of these research initiatives with broader international frameworks, such as the UN Ocean Decade, the EU-Network for Polar Research Infrastructures (POLARIN), and the Global Ocean Observing System (GOOS) will ensure the MWG's research contributes to global climate models and oceanic systems.

Building robust research infrastructure [RPT-4, RPT-7]

To achieve the outlined research goals, it is essential to implement cutting-edge infrastructure to support Arctic research in both ice-covered and open-water regions. Key areas of focus include:

- Modular measurement platforms: The development of modular platforms with state-of-the-art sensor technology will allow for comprehensive data collection on and beneath the ice, throughout the water column, and on and below the seafloor. These platforms should be scalable, allowing for deployment in various Arctic environments, and capable of adapting to seasonal and environmental changes.
- Robotic systems and artificial intelligence (AI): The integration of robotic systems equipped with standardized sensor technology, advanced telemetry, hydroacoustics, and AI-driven navigation will dramatically improve the speed, economy, and sustainability of measurements. Autonomous underwater vehicles and drones with standardized sensors should be deployed to increase coverage and precision in data collection, particularly in the deep ocean and under-ice environments.

- Real-time communication and interactivity: By developing systems that allow robots to communicate with each other and with human observers, real-time data analysis and decision-making will be enhanced. This will allow for more efficient large-scale data collection and improve the response time in critical situations.

Promoting international collaboration [RPT-4]

Given the scale and complexity of Arctic research, cooperation between Arctic and non-Arctic nations is crucial. The MWG calls for:

- Strengthened global partnerships: Collaborating with international initiatives like POLARIN, GOOS, Synoptic Arctic Survey (SAS), and the Distributed Biological Observatory (DBO) will enhance the scope and impact of Arctic research. Shared data, methodologies, and technologies will ensure that research efforts are complementary and reduce redundancy.
- Standardize data collection and sharing: The MWG should work with its international partners to ensure that Arctic data is collected using standardized protocols, allowing for seamless integration into global climate models and enhancing cross-disciplinary utilization.

Supporting early-career researchers (ECRs) [RPT-6]

The success of Arctic research hinges on the next generation of scientists. To build a competent and diverse research community, the MWG recommends:

- Training and capacity building: Allocating funding for fieldwork training, transdisciplinary workshops, leadership training, and chief scientist programs will equip ECRs with the skills necessary to study a rapidly changing Arctic. This training should emphasize an interdisciplinary approach, preparing researchers for the complexities of future Arctic research.
- Knowledge transfer and mentorship: Facilitating opportunities for ECRs to collaborate with senior researchers through joint projects, workshops, and conferences will ensure the transfer of critical knowledge and foster a collaborative research culture.
- Establishment of solid support networks: Fostering a healthy, safe, and diverse academic work environment is of high importance for safeguarding knowledgeable polar scientists with long-term sustainable work ethics.

Enhancing public engagement and policy integration [RPT-4, RPT-5, RPT-6]

It is essential that Arctic research findings are effectively communicated to the public, policymakers, and other stakeholders. This requires:

- Science communication: Researchers should be trained in outreach techniques, enabling them to convey complex scientific ideas to non-experts. This will promote public understanding of the significance of Arctic research and its global implications.
- Policy action: Arctic research must inform and shape policies that aim to conserve marine ecosystems, establish marine protected areas, and develop risk management strategies for Arctic communities. Ensuring that scientific findings are incorporated into decision-making processes will support the sustainable management of the Arctic.

Fostering technological and methodological innovation [RPT-4, RPT-7]

To keep pace with the changing Arctic environment, the MWG recommends to continue to innovate in both technology and methodology:

- AI and digital tools: AI should, in alignment with its further development, be integrated into Arctic research to process large datasets and predict future changes in ecosystems, ice coverage, and biogeochemical cycles. This will improve the accuracy and efficiency of research efforts.
- Sustainable technologies: The development of green technologies, such as solar-powered sensors and renewable energy solutions for research platforms, will ensure that data collection can be sustained over long periods without harming the environment.
- Utilization of archives: The development of technology also enables the utilization of sample archives in new ways (e.g. museum collections). It should be acknowledged that the use of already collected samples is in some instances an efficient way of accelerating scientific knowledge, as well as being a record of the old Arctic (e.g. before sea ice disappearance).

Conclusive remarks

The IASC MWG is positioned to lead transformative Arctic research that will significantly contribute to global scientific knowledge and policy. By prioritizing research initiatives, investing in cutting-edge infrastructure, fostering international collaboration, and supporting the development of early-career researchers, the MWG will play a pivotal role in addressing the pressing environmental changes affecting the Arctic. As the strategy aligns with the upcoming 5th International Polar Year 2032/33 (IPY), it will contribute to closing critical knowledge gaps by facilitating globally coordinated research efforts. The IPY presents an unparalleled opportunity for the MWG to collaborate with polar researchers, knowledge holders, rightsholders, and stakeholders worldwide to achieve breakthroughs in the knowledge required to protect both polar and global environments. This coordinated action will help in developing effective national and local strategies for mitigating and adapting to environmental changes, ultimately contributing to the acceleration of progress towards the UN Sustainable Development Goals.

Appendix 1

The Marine Working Group (MWG) of the International Arctic Science Committee (IASC) has developed this strategic plan through a series of in-person and online workshops and meetings between 2022 and 2024. The work was initiated and first outlined at an in-person workshop at the Technical University of Denmark, Lyngby, Denmark November 15 - 17, 2022. It was followed by a second in-person workshop focusing on the pillar "Marine Life" hosted at the Department of Paleontology in Vienna, Austria 11-12 December 2023. Four online workshops were held in May 2024 on the pillars "Disturbances", "Connectivity and Borealization", "Sea ice and Stratification", and "Biogeochemical cycles". A final in-person workshop was held at the National Research Council of Italy, Bologna, Italy 12-13th June 2024 where this report was drafted. The report was finalized after being open to input from the whole MWG in September 2024. This report also constitutes the main contribution of the MWG to the ICARP IV process. All members of the IASC Marine Working Group were given the opportunity to review and approve the final version of the report. The table below presents a list of the authors associated with the different sections of this document.

Name	*Affiliation*
Introduction	
Henrieka Detlef	Aarhus University, Denmark
Tommaso Tesi	CNR, Italy
Martine van den Heuvel-Greve	Wageningen University & Research, the Netherlands
Laura Ghigliotti	CNR, Italy
Daniela Walch (IASC fellow)	Université du Québec à Rimouski, Canada
Disturbances	
Martine van den Heuvel-Greve (chair)	Wageningen University & Research, the Netherlands
Neelu Singh (co-chair)	IASC MWG (Secretary)
Agata Zaborska	Institute of Oceanology Polish Academy of Sciences, Poland
Dewan Ahsan	University of Southern Denmark, Denmark
Lisa W. von Friesen (IASC fellow)	Linnaeus University, Sweden
Connectivity and Borealization	
Tommaso Tesi (chair)	CNR, Italy
Daniela Walch (co-chair, IASC fellow)	Université du Québec à Rimouski, Canada
Anna H. Ólafsdóttir	Marine and Freshwater Research Institute, Iceland
Arild Sundfjord	Norwegian Polar Institute, Norway
Laura Ghigliotti	CNR, Italy
Sea Ice and Stratification	
Karen Frey (chair)	Clark University, USA
Henrieka Detlef (co-chair)	Aarhus University, Denmark
Marie-Noelle Houssais	CNRS, France
Arnab Mukherjee	NCPOR, India

Tommaso Tesi	CNR, Italy
Arild Sundfjord	Norwegian Polar Institute, Norway
Agnieszka Beszczynska-Möller	Polish Academy of Sciences, Poland
Mark Inall	SAMS, United Kingdom
Jinyoung Jung	KOPRI, Republic of Korea
Biogeochemical cycles	
Lauren Juranek (chair)	Oregon State University, USA
Lisa W. von Friesen (co-chair, IASC fellow)	Linnaeus University, Sweden
Catarina Magalhaes	CIIMAR, Portugal
Karen Frey	Clark University, USA
Adam Ulfsbo	University of Gothenburg, Sweden
Jinyoung Jung	Korea Polar Institute, Korea
Marine Life	
Petra Heinz (chair)	Austrian Polar Research Institute, Austria
Laura Ghigliotti (co-chair)	CNR, Italy
Henrieka Detlef	Aarhus University, Denmark
Hermanni Kaartokallio	Finnish Environment Institute, Finland
Neelu Singh	IASC Marine Working Group
Martine van den Heuvel-Greve	Wageningen University & Research, the Netherlands
Lisa W. von Friesen	Linnaeus University, Sweden
Humans	
Dewan Ahsan	University of Southern Denmark, Denmark
Martine van den Heuvel-Greve	Wageningen University & Research, the Netherlands
Neelu Singh	IASC Marine Working Group
Agata Zaborska	Institute of Oceanology Polish Academy of Sciences, Poland
Recommendations for Implementation	
Heidemarie Kassens (MWG outgoing chair)	GEOMAR, Germany
Lisa W. von Friesen (IASC fellow)	Linnaeus University, Sweden
Daniela Walch (IASC fellow)	Université du Québec à Rimouski, Canada
Martine van den Heuvel-Greve	Wageningen University & Research, the Netherlands