Miscellanea: Notes

Syn-Arctic Comprehension

Envisaging a Holistic Understanding of the Contemporary and Future Arctic Ocean

ABSTRACT The relatively small, but extremely resource-rich Arctic Ocean is under considerable pressure from a resource-hungry world. Our scientific approach is often characterized by national, sectorial approaches. However, the Arctic Ocean cannot be understood, let alone managed, without an all-encompassing, pan-Arctic perspective. In natural science, first steps have been taken to achieve such a holistic understanding of the contemporary Arctic Ocean, but to support a sustainable and wisely managed Arctic Ocean in the future, the integrative work has to be carefully and wholeheartedly expanded. Suggestions, such as the integration of national investigations and the education of a future generation of scientists can improve the indispensable understanding of the entire Arctic, resulting in adequate comprehension and management.

Introduction

The Arctic Ocean is small and comprises only 1% of the world ocean volume, 3% of the world ocean area and 0.05% of the human population lives in the Arctic (as defined by AMAP, the Arctic Monitoring & Assessment Program). Why should the world pay attention to such a small fraction of the world ocean and so few people? One reason is that nowhere else is global warming and its effects greater than in the Arctic, with consequences for the world, as we will see. Since 1850 global warming worldwide has been about 0.06°C per decade, i.e. about 1.1°C up until today. Arctic amplification accelerates global warming, in particular north of 60°N (the latitude of Stockholm) and increases towards the North Pole. Here we find more than 4 °C warming, i.e. three times more than the world average. Global warming has significantly changed the environment of the Arctic. To point out some of the processes we can mention sea-ice loss, melting glaciers and permafrost, increasing melt of the Greenland ice cap, invasion of boreal species and changes in fisheries. These processes (and more to be mentioned below) have not only local impacts, but also a significant influence on the entire world, in particular the two thirds of humanity that live in the Northern Hemisphere. The gigantic landmass of the Arctic, the Arctic Ocean and changes taking place in the entire Arctic region (Fig. 1A) are therefore of substantial importance for humanity. This is easily demonstrated if we focus upon sea level rise caused by the melt of the Greenland ice cap, which increases the global sea level by 0.5 millimeters per year. Throughout the world, communities have to face the challenges for their population and infrastructure, even in Scandinavia. By the year 2100, sea level rise alone may turn 240–400 million people into climate refugees. Equally distributed over the world population, this implies about 40 million *additional* refugees in Europe (or roughly 0.5 million new arrivals per year). What takes place in the remote Arctic, "where nobody lives," is thus of eminent significance for humanity as

a whole and thus needs particular attention. In recent decades, research, economic and political interest in the region has increased, but the efforts (as compared to the challenges) are still limited and they came late.

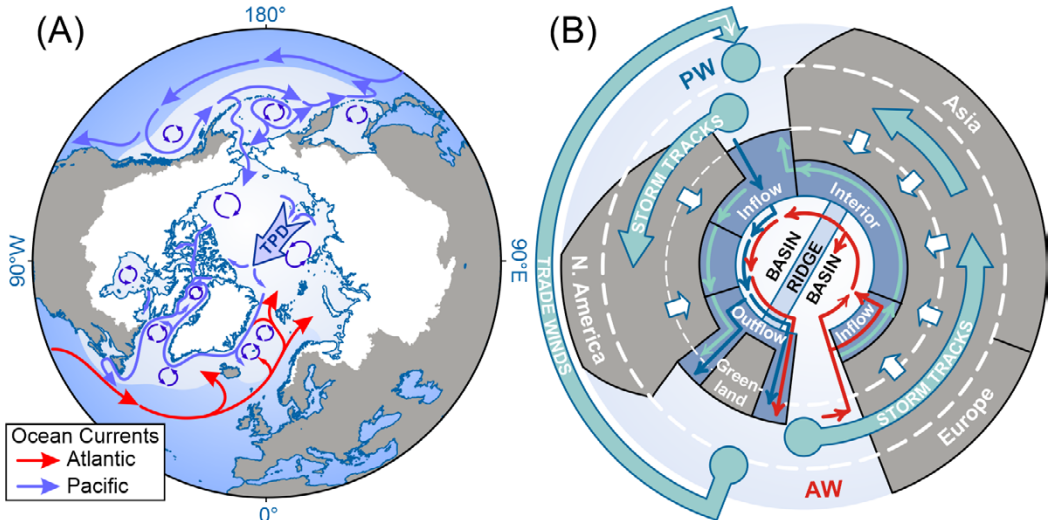

Fig. 1. A. The northern ocean circulation: major ocean currents (long arrows), subarctic fronts that separate the thermally stratified subarctic oceans (darker blue) from the salt-stratified Northern Ocean (lighter blue) in both the Atlantic and Pacific Oceans, the four Arctic Ocean gateways in Fram Strait, the Barents Sea Opening, Davis Strait, and Bering Strait (thick bars with red denoting inflow and blue denoting outflow), the gyral circulation patterns (circular arrows). The salt-stratified ocean domains are shown in light blue, and the terrestrial drainage areas in white.

Fig. 1. B. Regional components of the high-latitude system. Moisture is transported from the subtropical and tropical Atlantic Ocean to the Pacific Ocean via the trade winds over Central America. It is then transported from the Pacific and Atlantic Oceans to the Arctic catchment basins by the midlatitude (westerly winds) storm tracks, which subsequently drain into the Arctic Ocean (thick white arrows) where the moisture spreads initially within the Riverine Coastal Domain (dashed green arrows). Warm, salty Atlantic origin waters (thin red arrows) enter the Arctic Ocean through Fram Strait and through the Barents Sea Opening and circulate within the Arctic Basins as subsurface, counterclockwise, topographically steered boundary currents. Internally modified Atlantic waters exit the Arctic Ocean southward through Fram Strait along eastern Greenland. Cooler and fresher Pacific origin waters (thin blue arrows) enter the Arctic Ocean through the Bering Strait and exit through the Canadian Arctic Archipelago and Fram Strait along eastern Greenland. Within the Arctic Ocean a topological distinction is made between inflow, interior, and outflow shelves. (From chapter 2 by Carmack, Rudels, Polyakov and Itoh in Wassmann 2024.)

Does Research in the Arctic Receive Adequate Attention?

The Arctic was for lengthy periods of time an inaccessible and hostile region, somewhere far north and remote from human civilization. From the late sixteenth century and onwards it became the place for expeditions trying to find a shorter sea route to the lucrative east Asian markets. However, the midnight sun did not melt the sea ice, as assumed. A navigable path was not detected until recent global warming provided new opportunities. Instead, after a short, but intensive whaling frenzy, Arctic explorers dominated the scene with their attempts to sail through the Northeast (Adolf Erik Nordenskiöld, 1880–1882) and Northwest passages (Roald Amundsen, 1903–1906)

and to get to the legendary North Pole (who came first is still debated). After the Second World War and the Cold War, the Arctic region became a domain for military confrontation (e.g. submarines, atomic weapons and the DEW line—the Distant Early Warning Line, a series of radar stations in the Arctic operated during the Cold War by the USA, Canada, Greenland and Iceland). As a consequence, limited attempts were made to carry out scientific investigations. The few attempts prior to the 1980s were, for the most part, carried out by Arctic nations that focused upon their national waters (but also other countries participated, in particular Germany and Sweden).

The Arctic Ocean remained a *mare incognita*. The main focus of polar research was directed towards Antarctica. This situation continues. Even today, when the Arctic is exposed to the wide-ranging consequences of global warming (extreme summer heat, burning peat, melt of permafrost, atmospheric rivers hitting the Arctic more often, increased ice melt) the number of oceanographic and marine biological publications on Antarctica is almost twice that of publications on the Arctic Ocean (Brandt, Wassmann & Piepenburg 2023). Also, the numerical difference in publications increase: oceanographic and marine biological publications on Antarctica is increasing far more than those on the Arctic Ocean. We may ask if we are giving adequate priority to understanding the region that is by far the most challenged by global warming, the Arctic Ocean?

Because the Arctic Ocean is the most climate change-impacted region, we might expect this to be reflected in research. National and international authorities continually challenge scientists that research should address the most prominent questions in support of human wellbeing, economic prosperity and political stability. In research applications, scientists continually argue for the connection between society's needs and the anticipated science. This is truly also the case for polar research. One might expect prosperous countries in the Northern Hemisphere to pay particular attention to the challenges in the Artic because of the increasing regional impacts on human wellbeing and economic prosperity. Astonishingly, this seems not to be the case. Relative to Antarctica, Arctic research obtains decreasing scientific attention as reflected in absolute and relative numbers of scientific publications (Wassmann et al. 2011; Brandt, Wassmann & Piepenburg 2023). Is science subjected to political demands that result in greater interest in the international waters of Antarctica (and a forthcoming negotiation of the Antarctic Treaty), as compared to the Arctic with its legitimate, territorial claims of Arctic coastal states (regulated by the Law of the Sea)?

There are serious knowledge gaps in the Arctic Ocean region. The political consequences of Russia's invasion of Ukraine makes a large sector of the Arctic inaccessible for non-Russian research, and the publishing of Russian scientific data internationally is in rapid decline. Also, we are facing a lack in pan-Arctic understanding and thus a solid base for indispensable pan-Arctic management. In conclusion, marine science in the most impacted ocean of the world is not given the priority that it deserves.

Socioeconomic Relevance of the Arctic

The Arctic Ocean plays an important role for global climate regulation. It accounts for about 10% of the global atmospheric annual marine CO_2 uptake. It is also important for the global freshwater balance. 20% of the world's 100 largest rivers flow into the Arctic Ocean, comprising 11% of global river runoff. It has wide shelves: 25%

of world continental shelf area is found in the Arctic Ocean and comprises 35% of world coastline. The world's longest coastline is often missing when littoral ecology overviews are presented. While only 0.05% of human population live in the Arctic, it has 15% of global petroleum production (mainly on the Yamal Peninsula), and we expect that large amounts of oil and gas reserves, and 20% or more of many metal and non-metal resources (for the green transition) will be found in the region. Some of the most important fisheries take place in the Arctic (e.g. in the Barents and Bering Seas). In summary, the socioeconomic role of the Arctic is enormous. How much emphasis will be given to ecological and environmental concerns when so few people live in such a rich region? When humanity needs essential supplies and sees rich resources, how much consideration will the world pay to the pristine ecosystems and the people that live in the Arctic? The future Arctic is thus increasingly of immense interest for the remaining 99.95% of humanity.

To illustrate how the future Arctic matters for the world, we can add a few examples. Most of us are concerned by the increasing variability in weather. Torrential rain, flooding, heat waves, snowstorms, icing etc., give rise to significant economic implications and loss of human life (drowning, hypothermia due to heat waves, increasing insurance costs or ineligibility to obtain property insurance). Many of these demanding phenomena are caused by the decreased ice-cover in the Arctic Ocean. More open water impacts storm tracks and increases the north–south range of the Jet Stream (Lindsey 2021). Warmer air from the south is drawn further northward, while cold Arctic air is drawn further southwards. Increasingly, this results in climate anomalies. Before, we had a more stable and uninterrupted Polar Vortex (a persistent, large-scale cyclone found near the poles of the middle and upper troposphere and in the stratosphere) and a closed ice cap. Now the Polar Vortex is disrupted, the ice cap is reduced and we face more open water (Lindsey 2021). This is the main cause for the increasing frequencies of records of "too hot, too cold, too dry, too wet." The undulation of the Jet Stream results in extreme warmth and intense winter weather, resulting in record deviations that can be felt as far south as the Mediterranean region. Thus, these regions, too, should engage in intense Arctic research.

In the hitherto ice covered central Artic Ocean, the harvestable marine production of the future will increase because of increased radiation entering the water column, but decrease by 20–40% in regions where fishery today is significant (Slagstad, Wassmann & Ellingsen 2015). This may have implications for fisheries and human food provision. Increased freshwater discharge from the melting Greenland ice cap will impact the vertical stability of the northeastern North Atlantic and increase stratification. This in turn may reduce the Atlantic Meridional Overturning Circulation (AMOC), currents that are carried in the "global conveyor belt" which circulates water from north to south and back in a long cycle within the Atlantic Ocean. A slowing AMOC will reduce the global CO_2 uptake of the Arctic Ocean and thus promote the accumulation of climate gasses in the atmosphere (stimulating global warming). Changes in primary production, increased spread of boreal species and a decrease in the "cool pool" in the Bering Strait (Kinney et al. 2022) will result in unforeseen changes in one of the world's most important fisheries.

The environmental strain on the Arctic Ocean is thus increasing. Significant interests in marine oil and gas production, transport of cargo, oil and gas to and from

Asia (and soon across the North Pole), new industries (such as petrochemical plants), mining, fisheries (cod, halibut and shrimps, king and snow crab) and ever-increasing tourism ("Experience pristine nature, polar bears and the Arctic, before it is 'too late'") expose the Arctic increasingly to pollution. It is unknown how to deal with oil pollution events in ice-covered waters and at low temperatures.

In summary, global warming makes the Arctic Ocean accessible, and a resource-hungry world population takes advantage to increase their economic interests in the Arctic. The cool Arctic is indeed a hot issue! How can we use the rich resources and possibilities in the Arctic in a sustainable manner, both for the people living in the Arctic (four million) and the peoples of the Arctic (the indigenous population comprises about 10% of the total population)? To contribute to wise solutions, we obviously need far more research, caution and improved multidisciplinary and multiethnic understanding of the Arctic, for which we are not well prepared, despite increased research.

Basin-Wide Management and Geographic Perspectives

In order to understand the impact the Arctic has upon the northern hemisphere we have to understand the entire Arctic, not only sections of it. The Arctic Ocean does not consist of separate meteorological systems or ecosystems. It is one circular system with minor subsystems (Fig. 1B). We must focus upon how the interests of the five Arctic Ocean states (often along sectorial south–north directed research strategies) support not only their sectorial interest, but the entire, circular space of the Arctic Ocean. The geographic and political settings of the Arctic Ocean result in serious challenges for a holistic understanding. Like any mediterranean type ocean (engirdled by land masses, see Fig. 1A), the circular Arctic Ocean has to be understood and managed as one ecosystem.

The Arctic Ocean is divided by national interest and often characterized by several internationally non-recognized borders. Each of the five Arctic states that share coastlines along the Arctic Ocean (from the zero meridian to the west: Greenland/Denmark, Canada, USA, Russia and Norway) looks at the Arctic Ocean from a local, south–north perspective. Each country has its own geographic center of gravity. The Arctic perspective of Greenland/Denmark focusses on the largest island of the world, the deep Fram Strait with its out-flowing Arctic water to the east, the deep Arctic Ocean basins to the north, and its enormous ice cap (Fig. 2A). Canada's focus is on its extensive archipelago and its narrow shelf towards the Beaufort Sea (Fig. 2B). The USA focusses on the Alaska Peninsula, the Bering Strait, the inflowing Pacific water and the oligotrophic Beaufort Sea (Fig. 2C). Russia focusses upon the extensive and wide shelf regions north of Siberia, the Kara and Barents seas and its many islands (including Novaya Zemlya and Franz Josef Land), and Norway upon the Svalbard archipelago, the highly productive waters of the Barents Sea, the inflow of Atlantic water, the deep Fram Strait and the adjacent Nansen and Amundsen basins (Fig. 2D). The scientists and politicians of these five Arctic nations thus have completely different perspectives of the Arctic Ocean. They take the local peculiarities as a sign of the whole ("The Arctic Ocean"), resulting in misconceptions. The four perspectives in Fig. 2 need to be geographically and oceanographically combined. For the comprehension and sustainable management of the Arctic Ocean, a pan-Arctic or meta-

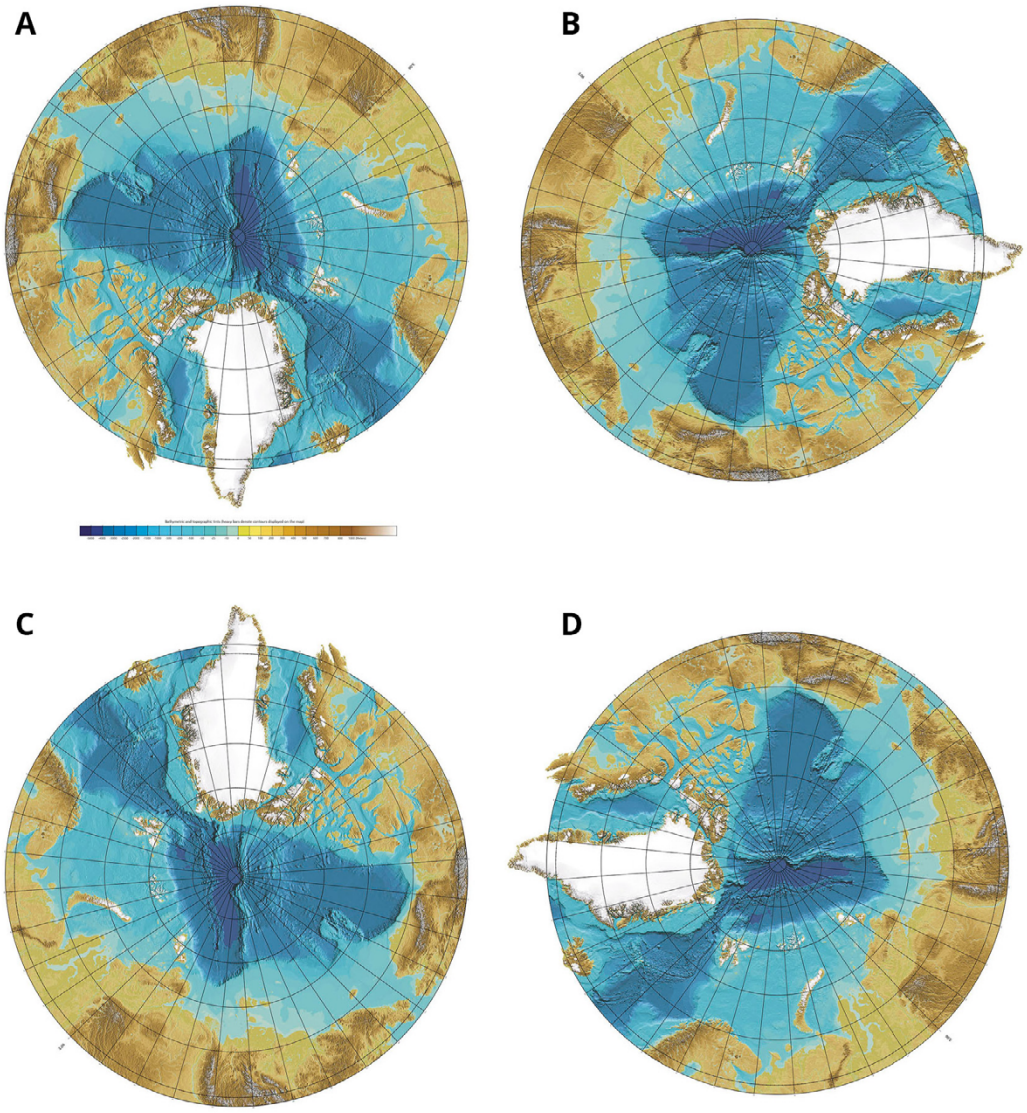

Fig. 2. A pan-Arctic map composite, illustrating four perspectives: from Greenland (A), Canada/USA (B), Russia (C) and Europe (D). Take note that the impression of the Arctic Ocean and its adjacent seas and shelves is widely different, easily supporting skewed generalisations of "how the Arctic Ocean" is functioning. (From chapter 1 in Wassmann 2024.)

perspective is imperative. Only a united perspective can create a base for sustainable ecosystem management.

Like the Baltic Sea, another mediterranean type ocean, the impact of all states engirdling the sea need to present their "point of view," their environmental impact and contribution. This is reflected by The Baltic Marine Environment Protection Commission—also known as the Helsinki Commission (HELCOM)—which is a successful and well-working intergovernmental organization and a regional sea convention in the Baltic Sea area. Politically, work is carried out by the Council of the Baltic Sea States (CBSS) founded in 1992 with the participation of the nine Baltic Sea States.

Nothing similar is in place in the Arctic, but for wise and sustainable management, the development of similar organizations is crucial. In concert, such organizations could support an indispensable, multidisciplinary understanding of the Arctic. The question can be raised how a sustainable management of the Arctic Ocean could be achieved. Without comprehensive participation by Russia, such an endeavor is hardly possible. What can be done? One may ask if the political firmness following the unlawful attack upon the Ukraine is so important that a sustainable management of the Arctic Ocean is out of reach. Are there possibilities to combine both our political and environmental goals?

The Pan-Arctic Perspective Is Indispensable

Why is the author preoccupied with pan-Arctic approaches? He lives so far north that he can almost "see" the pan-Arctic region as a curved, two-dimensional region, the "calotte" that covers the entire top of the Northern Hemisphere.[1] Northerners do not observe the Arctic from outside. They live in it. Tromsø is situated less than 36 ship hours away from the ice edge in spring and it takes only two days to reach Greenland. It would only take eight hours by plane to travel to Fairbanks, Alaska. Also, the population of the northern Fenno-Scandic Peninsula consists of a highly diverse, multiethnic conglomerate that is characteristic of the entire Arctic: mountain and coastal Sami, Kven (people of Finnish origin), local ethnic Fenno-Scandians (who had lived in the north for hundreds of years) and non-local Fenno-Scandians, foreigners and refugees. Today the people of the Arctic do not need to include indigenous perspectives: they all live together in their daily life (increasingly so after decades of discrimination of minorities). In concert, it is easier to envision the obvious, which is so often forgotten "in the south": that the Arctic is *one system*, including all the people presently living in the Arctic. To enjoy sociologically, politically and environmentally adequate perspectives, our perspective needs to be pan-Arctic. The Arctic exhibits essential traits that are more difficult to detect with traditional intradisciplinary strategies. The pan-Arctic meta-perspective tells us that the Arctic Ocean is *one system*, a fully functional "nucleus" on top of the world that influences the entire Northern Hemisphere. By combining the spatial dimensions of our knowledge and by paving the ground for "more than there is in isolation", we can create opportunities for a new, systemic dimension. A system is *not* merely the sum of the parts, but something more. Unless we approach the Arctic in a systemic manner, our current strategy may be inadequate to grasp the essentials of the Arctic Ocean. We need to look for the patterns of the pan-Arctic "calotte," not just the parts. However, even among geographically, politically and sociologically close nations, such as Finland, Norway and Sweden, "calotte" cooperation in the High North is challenging (although improving). The reason for that may be the fact that the capitals of the Nordic countries are all situated in the south.

As an example of how looking for parts, reflects our inadequate attitudes with regard to the Artic Ocean, I use the frequently applied term "Western Arctic," a term often applied by researchers from the USA and Canada investigating the Bering Sea, Bering Strait and the Chukchi Sea. "Western" implies west from the perspective of the North American continent, and suggests that the scientists consider their continent as the cultural center of gravity in the north. Similarily, a Russian may talk about the Barents Sea as the "Western Arctic" while what the Canadian and US scientists call

the "Western Arctic" would be the Russian "Eastern Arctic." The ambivalent term "Western Arctic" is so entrenched that it cannot be omitted in the literature, but it is hopelessly geographically and culturally inaccurate. Thus, only specific geographic terms should be applied to the Arctic Ocean. By giving up the term "Western Arctic," Canadian and US scientists would indicate that they do not consider themselves as the cultural center of gravity, but offer their contribution to the whole.

In a two-dimensional, circular system on the "top of the world," the terms east and west only have a navigational meaning: the coordinates. Cultural centers of gravity only surface when we omit to consider the Arctic Ocean as one, circular system. If we, in the future, address the pan-Arctic region through our local, south–north transects or our political endeavors,[2] we are faced with the question of how to visualize the Arctic Ocean. Which part of the Northern Hemisphere should be at the bottom of our maps (Fig. 2)? A general standard based upon a compromise must be acquired. It is suggested that the lower center of all two-dimensional presentations of the entire Arctic Ocean is Greenland or the zero meridian (similar to Fig. 1A). In this manner, the large-scale impact of the Greenland ice cap and the inflow and outflow of Atlantic and Arctic water, respectively, upon the Arctic Ocean and the North Atlantic will become the focus. The political east and west will be clearly separated, clearly separated, without claims by the big Arctic nations such as Canada, USA and Russia to be centers of gravity.

Towards a Meta-Perspective of the Arctic Ocean

Having in mind these challenges and knowledge gaps, we may ask how far we have come to understand the Arctic Ocean as one system, or if we have already obtained some holistic understanding of the contemporary and future Arctic Ocean? In recent decades, significant work in natural science has been carried out internationally. Knowledge has been exchanged across the pan-Arctic region since 2002 when a set of pan-Arctic integration symposia were initiated by UiT – The Arctic University of Norway. Over the years these endeavors have resulted in four volumes with dedicated publications (Wassmann 2006; Wassmann 2011; Wassmann 2015; Wassmann et al. 2021). On this basis, an invitation by the Interagency Arctic Research Policy Committee (IARPC) and Bureau of Ocean Energy Management (BOEM), Office of Naval Research, USA (ONR), US Arctic Research Commission (USARC) was directed to UiT – the Arctic University of Norway to lead efforts to formulate a unifying perspective of the ecological function of the entire Arctic Ocean. In 2016 this invitation was picked up by the research groups Seasonal Ice Zone Ecology (ArcticSIZE) and Arctic Marine Ecosystem Research Network (ARCTOS) who initiated the workshop "Towards a Unifying Pan-Arctic Perspective: Concepts and Theories," led by P. Wassmann, C.M. Duarte and E. Carmack. In turn, this workshop resulted in a comprehensive publication (Wassmann et al. 2020) where the basic features, functions and biological players of the Arctic Ocean were adequately summarized. Also, the work of AMAP and Conservation of Arctic Flora and Fauna (CAFF) must be considered, paving the road for recent integrating programs such as the Multidisciplinary Drifting Observatory for the Study of Arctic Climate Change (MOSAiC) expedition, Pan-Arctic Observing System of Systems (Arctic PASSION) and the Nansen and Amundsen Basins Observational Systems (NABOS).

The oceanography and basic biological and ecological players, and how the Arctic Ocean is embedded into the Northern Hemisphere, are already reasonably well known (Fig. 1). This implies that the most important ice flora and fauna, phyto- and zooplankton and many benthic species are known. In particular, the fish fauna is well known and overviews and distribution maps for most species exist. Less known is the gelatinous zooplankton and the deep sea fauna. We have also started to become familiar with basic biological processes such as primary production, ice edge blooms, succession of key organisms, vertical migration of zooplankton, vertical flux regulation of biogenic matter and sea ice related organisms and their succession. The traditional phenology of phytoplankton blooms as a function of ice and snow cover and nutrient limitation, and the effects of the Polar night on multiannual life cycles of several organisms are also known. Estimates of the harvestable production have been launched. We also understand the one-to-multiyear life cycle strategies of major zooplankton species in permanently and seasonally ice-covered as well as ice-free regions (for a comprehensive overview, see Wassmann 2024). Even the footprints of climate change in the Arctic have been extensively investigated (Wassmann et al. 2011) and revised for the effects of climate change during the last decade (Brandt, Wassmann & Piepenburg 2023).

In summary, although pan-Arctic integration is not a highly prioritized aspect of scientific investigations in the Arctic, organizations such as AMAP, CAFF, a multitude of expeditions by the Swedish Polar Research Secretariat, Arctic Net, the Tukavik Laboratory, the pan-Arctic Distributed Biological Observing network, regular Russian expeditions by the Institute of Oceanology, a wide range of Danish projects, MOSAiC, The Nansen Legacy, Arctic PASSION and others have paved the ground for today's rudimentary comprehension (Fig. 1). Recently, the coordination activities by UiT – the Arctic University of Norway have resulted in the first pan-Arctic textbook in marine ecology (Wassmann 2024), creating the foundation for educating new generations of scientist in a fully pan-Arctic perspective. In decades to come, these will not start from four sectorial perspectives (Fig. 2), but will start immediately from the only adequate one: that of the pan-Arctic.

Future Endorsement of the Indispensable Pan-Arctic Challenge

It is more than timely that scientists working in the Arctic discuss the demand for further and realistic investigations that support the indispensable need to understand and, last but not least, manage the expanse of the Arctic Ocean, since these inter- and multidisciplinary studies, beyond the procedures, elements and proportions that have dominated so far are imperative. In many respects, natural science has already applied "interdisciplinary" investigations in the Arctic Ocean. Meteorology, physical, chemical and biological oceanography, paleontology, fishery science and modeling can be seen as disciplines. However, the combination of these science fields, often promoted by the isolation and confinement during icebreaker expeditions, have provided us with an understanding of the elements and basic function of the nature of the pan-Arctic Ocean (e.g., Wassmann 2024).

In the author's opinion, some of the multidisciplinary work in the Arctic, carried out with noble and timely intentions, lack adequate and balanced scientific knowledge. We need more knowledge on the complex social-ecological dynamics, the implica-

tions for resilience of coastal communities (tourism, transport, mineral exploration, or biological resource exploitation) and how climate change challenges ecosystems that have significance for indigenous populations (cf. Arctic Council 2016). Scientific research in the Arctic Ocean started relatively late, during a period when the ecosystems were already exposed to climate change. Natural science research is so strongly impacted by climate change and Arctic amplification that the basic function of the Arctic Ocean, prior to global warming, is difficult to establish. Considering complex social-ecological dynamics can thus not be based on a sound natural science base, and climate change will increasingly challenge the living conditions of the people living in the Arctic, in particular, the indigenous peoples. The advice, predictions and projections made by natural scientists are not as detailed as desired.

Natural scientists have been accused of trying to force their vision of future climate change upon indigenous populations, without involving the knowledge of the elders (e.g., Karetak et al. 2017). It is highly critique-worthy that it took so long for natural scientists to listen to indigenous knowledge, and for governments to respect indigenous rights (Gaski 2013). Climate is talked about and represented as having the power to influence our lives in ways we have never before experienced or imagined, suggesting something transformative, and disruptive. In doing so, the complexity of human future is explained in terms of scientific models that suggest a return to climatic and environmental determinism that oversimplifies our understanding of human–environment relations (e.g., Nuttal 2012). However, climate change predictions do not primarily reflect a lack of respect by natural scientists for the choices humans make. Nor do they try to represent a form of "benevolent dictatorship." They address the challenge for all people of the Arctic to respond to the rapidity and harshness of climate change that exceeds by far hitherto accumulated knowledge by science as well as traditional knowledge. The advice of natural scientists may address environmental and climatic challenges that have never been experienced before, such as the loss of sea-ice during the hunting season, loss of housing and parts of the taiga due to permafrost melt, or ice layers under the snow that prevent reindeer from reaching fodder. Knowledge of the Arctic of yesterday is thus not a safe pathway into a sustainable future; essential tipping points are notoriously difficult to predict (Wassmann & Lenton 2012). For sociologists, anthropologists, economists and natural scientists alike, more modesty, openness and intense dialogues between researchers and with Arctic locals are mandatory.

The limited availability of adequate education for future experts points at a lack of dedication to achieve balanced, joint solutions. Institutions of higher education appear to struggle with educating researchers who can deal with integrated and multidisciplinary solutions and thus they fail to meet society's expectations for the ever-increasing need for these solutions. Being afraid that they have to make scientific sacrifices that will weaken their specific research fields, faculties are often reluctant to contribute wholeheartedly to such education. The multidisciplinary students need to convene on a regular basis, they must get exposed to a wide range of different research fields and they have to include specialists of the respective faculties. By doing so, they will not contribute exclusively to the particular research goals of their faculties. Overarching integrated and multidisciplinary approaches have to become a dedicated research goal of institutions of higher education.

Also, there are excellent graduate school courses in the pan-Arctic region that offer international short-term participation (e.g. on icebreakers). Due to the traditional dedication to support national research, it is notoriously difficult to obtain national funding for course participation abroad, as well as acceptance of study credits from other countries. In this manner, nations refrain from doing what is needed to comprehend the challenges facing the Arctic: multidisciplinary and pan-Arctic research and understanding. We clearly need to improve two issues: 1) universities need to live up to expectations and educate experts that can solve complex climate change challenges; 2) we need international, recognized umbrellas that promote and partly fund international courses for doctoral students in the pan-Arctic region. The Arctic Ocean requires a new generation of researchers who, from the start, adopt pan-Arctic and multidisciplinary, rather than sectorial and single faculty, perspectives. We also need patience to achieve adequate solutions; there is a tendency towards counting our chickens before they are hatched.

Arctic Science Meetings and the International Polar Year

Under the pressure and interests of national policies, an increasing number of Arctic science meetings that originally were based upon science have turned into politically and economically dominated venues where any type of basic science plays an increasingly peripheral role. That leaves less time to increase the basic knowledge foundation of the future Arctic. However, there are venues that can contribute to increased pan-Arctic understanding in all relevant science fields. The annual Arctic Science Summit Week (ASSW) is one of these fora that indeed promote pan-Arctic integration. However, ASSW tends to promote a maximum number of talks and posters. To accommodate as many sessions as possible, less coherent sessions are fused, with the result that presentations fit badly together. More than several hundred short talks in a three-day period ensure a rich numerical accumulation of knowledge, but prevent integration or comprehensive understanding of the Arctic system. Systems are *not* merely the sum of the parts, and the lack of discussions prevent deeper comprehension. To promote a holistic understanding we need fewer, longer and more integrated presentations, and fora for longer discussions that focus upon integration, process understanding, multidisciplinary approaches and planning of future research.

An important event for pan-Arctic and interdisciplinary comprehension was the 4th International Polar Year (IPY 2007–2008). An enormous, unprecedented, synchronized endeavor of simultaneous investigations took place over the entire Arctic. But almost no money was set aside to work up and compare data in an international, pan-Arctic perspective. Thus, the 4th IPY failed to become more than a suite of national endeavors, inside an international framework. Despite its great success, IPY failed to obtain its ultimate goal: an international meta-analysis across polar regions for holistic comprehension. A real pan-Arctic integration milestone was in reach, but the option was regrettably missed; preference was given to traditional national endeavors, rather than all-compassing international ones.

The 5th International Polar Year (2032–2033) is already in the planning. In order to use this new IPY in the best possible way for promoting pan-Arctic integration and endorse interdisciplinarity, we should plan to organize the next IPY out of a truly pan-Arctic spirit. To achieve inter- and multidisciplinary, as well as pan-Arctic, inte-

gration after the two-year field campaign, an indispensable ten-year meta-data campaign should follow. Also, an internationally accessible archive or portal for IPY data must be in place. A new generation of researchers needs to be recruited by working on pan-Arctic IPY data. Therefore, pan-Arctic and pan-Antarctic integration needs to be placed at the top of future IPY agendas right from the start. The scientific community needs to be committed to fostering interdisciplinary progress, across the natural and social sciences and humanities. The mutual dependence of inter- and multidisciplinary progress is a precondition for making sufficient progress. This can be compared to the second floor of a building. The social-ecological dynamics that lead to sustainable ecosystem management represent the third floor. Both these floors depend on the first floor, which is pan-Arctic integration, and a solid basement made up of a multitude of sciences. Focussing on the second and third floor of a house before planning a substantial basement and a solid first floor results in a fragile building. Without such endeavors our good intentions turn into pipe dreams.

Concluding Outlook

In Norse mythology the ravens Hugin (thought) and Munin (memory), couriers for Odin's thirst for knowledge, represent symbols of our generic endeavors to learn both from and about the past and the future. They symbolize our indispensable desire for knowledge upon which wise decision-making and a sustainable development need to be based. They have a particular mission for UiT – The Arctic University of Norway, the alma mater of the author, as they constitute the university's symbol. The past and future knowledge of the northern realms, including the Arctic Ocean, is continuously brought back to UiT and any Nordic stronghold of learning where knowledge for wise assessments accumulates. The Arctic Ocean is a crucial region for our existence in the Northern Hemisphere and needs adequate attention. The research institutions in the North have a particular mission which should be far more highlighted. By focusing upon the Arctic, Nordic research institutions will make a significant contribution to the living conditions in the Northern Hemisphere, preferably out of a pan-Arctic and multidisciplinary perspective. Above all, we must achieve a solid base for sustainable and wise ecosystem management that includes all people living in the Arctic region and those who are impacted by climate change and rely on resources from the region. We have to make sure that the ravens Hugin and Munin fly every day, now and in the future. And Odin—or we—must listen carefully to be able to comprehend how to act in the future.

In addition to good information, humanity needs terms, concepts and models that inspire, unify and excite contributors. We believe that pan-Arctic integration can serve this purpose. A poem by Joseph von Eichendorff (translated by Walter A. Aue) illuminates the attraction of the term *pan-Arctic integration*.

Magic Wand

Sleeps a song in things abounding
that keep dreaming to be heard:
Earth's tunes will start resounding
if you find the magic word.

Inspired by Dobzhansky's famous dictum, we conclude that nothing in the High North makes sense except in the light of a pan-Arctic vision and a shared history. The magic wand to find this appropriate perspective is the term *pan-Arctic*. It resounds the tunes of the earth on the "calotte" of the High North. If we finally achieve the pan-Arctic vision throughout, we will enter a new, highly desired and ultimate phase in the High North: syn-Arctic comprehension (*syn* = 'acting or considered together; united'). Syn-Arctic comprehension translates into a full, wide-ranging and encompassing strategy, the ultimate base for pan-Arctic Ocean decision making. Getting there is a long process, but we are on our way.

NOTES

[1] The Norwegian and Swedish term *Nordkalotten* and the Finnish *Pohjoiskalotti* ['Cap/Calotte of the North'] is the region of Norway, Sweden, and Finland located north of the Arctic Circle.

[2] Already under Stalin, the Soviet Union/Russia claimed that the country is an Arctic nation and that the sectors from the North Pole and between the Franz Josef Land, the date line through the Bering Strait, were Russian territorial waters. In 2007 this view found support when a Russian expedition, financed privately by a Swede, descended in a pair of submersible vessels more than two miles under the ice cap to "claim" the North Pole by depositing a Russian flag on the seabed. From an international point of view, this was only a demonstration as it is the Law of the Sea, coordinated by the United Nations, that defines borders outside the 200 nautical mile zones.

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