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# Science for Management Advice in the Arctic Ocean: The International Council for the Exploration of the Sea (ICES)

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## Abstract

The International Council for the Exploration of the Sea was established in 1902 and is one of the oldest marine science institutions in the world. It has aged well – today it provides scientific advice for the management of the marine environment and the natural resources there to governments and regional commissions for fisheries and environment in the Northeast Atlantic. It has 20 member nations and a network of 6000 scientists and 700 institutes as the foundation of its activities, spanning from basic marine science via data management to the provision of scientific advice on marine management. The purpose of this chapter is to provide an overview of the ICES organization and its functions, discuss its provision of scientific advice and thereby its role at the science-policy interface in the North Atlantic and the Arctic, including how this role is changing with the development of integrated, ecosystem based management of the oceans. The final part of the chapter addresses the current governance of Arctic marine science and its science – policy AQ1 interfaces.

## 25.1. Introduction

The fate of the oceans and their governance is a major issue of our times. A number of international commissions, task forces, and expert groups have assessed the state of marine environments, identified problems, and proposed solutions (Independent Commission on the Oceans, 1998; Global Ocean Commission, 2016; High Level Panel, 2020). A critical issue running through these initiatives is how scientific knowledge can be effectively communicated to policymakers and put to use in marine management. Also, the UN General Assembly has proclaimed a Decade of Ocean Science[1] during 2021–2030 to address the UN 2030 agenda and support the Sustainable Development Goals.

The Arctic Ocean can be loosely defined as the central Arctic ocean (CAO) above the continents and the marginal seas surrounding it (see map). This is a huge area – the Arctic above the Arctic Circle is some 20 million $km^2$. The CAO alone is more than seven million $km^2$ – an area almost three times the size of the Mediterranean - consisting of the waters of the five

coastal states (USA, Russia, Norway, Denmark/Greenland, and Canada) as well as an area beyond national jurisdiction. The area covered by sea ice in the wider Arctic Ocean is about 15 million $km^2$ at its maximum in early spring, and less than five million $km^2$ in early fall.[2]

While there is little human activity in the CAO, the surrounding marginal seas (the Bering Sea, the Barents Sea, waters around Iceland and Greenland, Russia's and Canada's northern waters),[3] have substantial economic activities in fisheries (Hoel, 2018), shipping (Hildebrand et al., 2018), petroleum development (Baker, 2020), aquaculture, and others. Over time, the amount and diversity of human activity is also increasing (ACIA, 2005), a trend that is expected to continue with declining sea ice in the CAO and warming waters. All of these issues, including climate change, and their combined effects call for massive investments in science for societies to understand and adapt to these on-going changes. The science-policy interface is therefore of particular interest when discussing the future of Arctic marine stewardship.

The science-policy interface is an important aspect of environmental politics (Andresen et al., 2000; SAPEA, 2019), not least in the marine realm. In the case of ICES, the science-policy relationship has evolved over more than a 100 years (Holland & Pugh, 2010), and science is a critical factor in decision-making in international fora dealing with marine issues (Miles, 1987) as well as at the domestic level of governance (Sakshaug et al., 2009).

The International Council for the Exploration of the Sea – ICES – is one of the oldest and most important marine science organizations in the world, with 20 member countries and a network of some 6000 scientists and 700 marine science institutes.[4] It has a special role in the Arctic, as all Arctic coastal states are members, a large part of its work is related to Arctic and sub-arctic marine ecosystems, and its scientific advisory function is critical to marine governance in the Northeast Atlantic part of the Arctic in particular and increasingly also Arctic-wide.

The purpose of this chapter is first to describe the role and functions of ICES in marine science and its advisory functions, including an account of how the organization has evolved to address ecosystem-based and integrated oceans management. We then proceed to discuss its role in Arctic marine management, drawing on the author's experience, conversations with colleagues and practitioners, and academic publications as well as grey literature.

## 25.2. ICES History and Organization

ICES was established in 1902, following international conferences in 1899 and 1901 on promotion of international cooperation in marine science (Nature, 1902). It has evolved considerably over the years (Rozwadowski, 2002),[5] becoming a formal international intergovernmental organization (IGO) with the adoption of the ICES convention in 1964.

The ICES convention sets out the purposes of ICES to promote and encourage research for the study of the marine systems, "particularly those relating to the living resources", to draw up programs for this purpose, and to disseminate the results of research.[6] It also defines its geographical scope to encompass the Atlantic Ocean and its adjacent seas, provides for relations with other organizations, and commits member countries to supply ICES with the information needed to fulfill its mission. The convention furthermore sets out organizational arrangements.

Following the increasing uses and pressures on the oceans, developments in international ocean law and other initiatives as well as the increasing use of ICES advice in fisheries management, the Copenhagen Declaration on Future ICES strategy was adopted on its 100 year anniversary in 2002.[7] The declaration reaffirms a commitment to maintain ICES as an independent science organization and stresses the need for ICES to strengthen relations with the users of marine science.[8] Since then, ICES has developed its strategy through several cycles, the latest being adopted in 2019 (ICES, 2019a). Over time the ICES strategy has placed increasing emphasis on an ecosystem approach to the study and management of the oceans. The 2019 strategic plan represents a further step in this direction, reflecting also an increasing concern with the human dimension. Another long-term development in the evolution of the organization is increased attention to the needs and wishes of the users of ICES advisory products.

The mission of the current ICES organization is to "advance and share scientific understanding of marine ecosystems and the services they provide and to use this knowledge to generate state-of-the-art advice for meeting conservation, management, and sustainability goals" (ICES, 2019a). The 2019–2024 ICES Strategic Plan sets out science priorities (see below) and outlines steps to address them.

The ICES Council is the organization's key decision-making body, led by an elected president and consisting of two

representatives from each member country. A Bureau acts as the executive committee of the Council and a Finance Committee oversees the organization's budget and finances. The 60+ person secretariat, led by a General Secretary, is located in Copenhagen, Denmark.[9]

The scientific work of ICES is governed through its Science Committee (SCICOM) and Advisory Committee (ACOM). The SCICOM drives the ICES science program, links science, data and advice, and organizes the annual science conference as well as meetings and workshops.[10] A number of steering groups under SCICOM address "broad and enduring areas of science and advice" such as aquaculture, fisheries resources, and integrated ecosystem assessments, drawing on the work of around 200 expert groups. The expert groups address a wide range of issues, including a strategic initiative on the human dimension.[11]

The ICES annual science conferences are major events in the world of marine science, gathering participants from all over the world. Also, in cooperation with other marine science organizations, such as the Pacific Marine Science Organization (PICES), ICES organizes global conferences on topical issues such as climate change.[12] In keeping with its Convention, ICES is also engaged in the dissemination of marine research and hosts the *ICES Journal of Marine Science*, a prominent marine science journal published by Oxford University Press.[13]

Another important part of ICES is its role in the management of marine data in the North Atlantic and the Arctic. The ICES Data Centre[14] is directed by a Data and Information Group which works to ensure the alignment of data policies and processes. Data are collected by its members, and work on methods, quality checks, and submission of data to ICES also relies on inputs from members. ICES has established a data pipeline from collection of data to advice products, supported by a set of best practices intended to ensure quality and consistency as well as transparency. Data services are delivered via various web services; AI, cloud services, and machine learning are increasingly important in this respect (ICES, 2019b).

While ICES has been in existence for more than 100 years, a number of other regional organizations concerned with the marine environment and associated natural resources have emerged over the last decades. ICES has established working relationships through MoUs or similar documents with, among others, the Northeast Atlantic Fisheries Commission (NEAFC), the North Atlantic Marine Environment Organization (OSPAR), the HELCOM which addresses the marine environment in the Baltic, the North Atlantic Marine Mammals Commission (NAMMCO) as well as the European Union. The relationship with NEAFC is particularly close, as the NEAFC convention requires NEAFC to seek scientific advice from ICES.[15]

Also, relationships are developing beyond the North Atlantic. ICES has recently been granted observer status in the UN General Assembly, providing it with the opportunity to participate in oceans- and science-related meetings there. It also participates in other UN bodies such as the Intergovernmental Oceanographic Commission of UNESCO. And it has a working relationship with Arctic Council working groups PAME and AMAP as well as its sister organization in the North Pacific, the North Pacific Marine Science Organization PICES.

## 25.3. ICES Science

Use of ocean space and its natural resources requires an understanding of the nature and dynamics of marine ecosystems. Nowhere is this more evident than in fisheries management, where assessments of abundance, distribution, and other characteristics of fish stocks subject to harvest are critical for decision-makers to be able to establish regulatory measures to ensure a sustainable harvest (Pitcher & Hart, 1982). This was recognized as a key function of ICES already at the outset,[16] and remains a central area of work.

The science agenda of ICES has evolved considerably since then, in response to scientific developments as well as to increasing uses of and pressures on the oceans. The current ICES Strategic Plan outlines seven interrelated science priorities (ICES, 2019a):

- Ecosystem science
- Impacts of human activities
- Observation and exploration
- Emerging techniques and technologies
- Seafood production

Conservation and management science

Sea and society

Each of the science priorities is accompanied by a set of tasks designed to address it. The ecosystem science priority is foundational in the sense that it addresses the need to understand the dynamics, structure, and functions of marine ecosystems as a basis for scientific advice as well as for marine management (Wilson 2009, Walther and Møllmann 2013). It also reflects a long-term evolution in ICES's organizational focus (Ballesteros et al., 2018). Similarly, with increasing impacts if climate change, pollution and human uses of the oceans, understanding the impacts of human activities, including cumulative effects, becomes critical.

The next two priorities relate to collection of data and technologies for monitoring and analysis of data. This is a rapidly expanding field where our capacity to collect and assimilate data is increasing exponentially (European Marine Board, 2020). The seafood production priority is a traditional core area for ICES, providing scientific advice for marine capture fisheries as well as aquaculture. A more recent priority is conservation and management science, which is concerned with providing options for managers to set and meet objectives for management. The final priority on sea and society reflects ICES's intent to address issues relating to culture, recreation and human livelihoods.

All these endeavors rely on the science institutions in member states and beyond to provide the data and the resources needed to address the priorities.

## 25.4. ICES Advice

Providing scientific advice for fisheries has been a raison d'être for ICES since its inception. Its work in this respect has contributed significantly to the evolution of fisheries management, a development that was reinforced with the law of the sea negotiations (UNCLOS III) during the 1970s. UNCLOS III resulted in the 1982 UN Convention on the Law of the Sea,[17] conferring sovereign rights over natural resources in 200 nautical mile Exclusive Economic Zones on coastal states (Churchill & Lowe, 1989). This provided coastal states with a strong incentive to invest in marine science and to manage fisheries through regulating access to and utilization of resources (Juda, 1996).

The convention proved deficient when it came to regulating fisheries beyond national jurisdiction (Burke, 1994), and another UN conference produced the 1995 UN fish stocks agreement (Balton, 1996).[18] Both treaties have a number of provisions regarding marine science. The 1982 convention defines maximum sustainable Yield (MSY) as an objective of fisheries management, which has proved important to subsequent developments in marine science (Hoel, 2017). By making the application of a precautionary approach mandatory under international law, the 1995 agreement spurred a significant change in how scientific advice was to be developed and communicated to policymakers (Kvamsdal et al., 2016). The 1995 agreement also requires states to address ecosystems and biodiversity in their management of fisheries, which requires additional scientific inputs. The 1995 agreement has wide ranging requirements regarding data collection and transparency. These provisions have had a significant impact on the work and practices of ICES (Lassen et al., 2013).

While the initial mission as well a large part of ICES history has been weighted towards fisheries science and advice, this has changed in recent years, bringing changes to how its advisory functions are organized and work. Three advisory bodies for fisheries (Advisory Committee on Fisheries Management), environment (Advisory Committee for the Marine Environment), and ecosystems (Advisory Committee on Ecosystems) were collapsed into the Advisory Committee for Ocean Management (ACOM) in 2008, reflecting the increasing emphasis on understanding marine ecosystems and addressing them holistically (Strange et al., 2012).

The current mission of ACOM, therefore, is to translate "…ICES science into advice on the sustainable use and protection of marine ecosystems".[19] ACOM has a representative from each of the member countries. It provides scientific advice to its clients who are the member countries, the European Union, and regional commissions such as OSPAR and NEAFC.

An advisory plan (ICES, 2019c) sets forth the framework for advice, where various types of requests for advice from clients are addressed through a process starting with the formulation of a request. Requests in many cases will be recurrent, as in the scientific advice provided on the status of fish stocks and options for management including total quotas. A second step in the advisory framework is the role of expert groups synthesizing knowledge syntheses using data that conforms to ICES standards.[20] The products of expert groups are subject to independent peer review (the third step), before ACOM formulates the actual advice as the fourth and final step. The advice is published on the ICES Website.[21]

Fisheries-specific advice is supported by other advisory products such as Ecosystem Overviews and Fisheries Overviews, intended to complement and provide context for fisheries-specific advice. Such overviews are based on the ICES ecoregions.

A new framework for ICES advice – a "more appropriate framework that incorporates the ecosystem approach in all sectors" – specifically addresses EBM. The framework was adopted in 2020, reflecting a further evolution in the organization's thinking about the science-policy interface and its emphasis on an ecosystem approach. The Guide explains how ICES provides advice based on ten principles:

1. Document openly
2. Formulate request iteratively
3. Clarify objectives & risks
4. Deliver knowledge timely
5. Use best available science
6. Apply data FAIR principles
7. Undergo peer review
8. Develop clear & consistent advice
9. Agree by consensus
10. Explain without advocacy

Principles 1–3 are guidelines for advice and refer to the first step in the framework for advice. Principles 4–6 deal with the second step of the framework (the knowledge syntheses), and 7 refers to peer review. The fourth step is addressed by principles 8–10 and focuses on the formulation of advice.

A pertinent question is what happens after ICES advice is provided. It is widely recognized that this advice is not always acted upon and that disentangling the causal path from scientific advice to policy outcomes is complex (Stokke, 2012). A case in point is the situation with regard to pelagic species in the Norwegian Sea, where controversies related to allocation of fish quotas have prevented lasting agreement on management (Bjørndal & Ekerhovd, 2014). It is beyond the scope of this chapter to address this issue in depth.

## 25.5. ICES and the Arctic

ICES has a long standing engagement with the Arctic. Its Arctic Fisheries Working Group (its oldest expert group) has existed for more than 50 years. This group plays a critical role in developing the scientific basis for management advice for the fisheries of the Barents Sea (Kovalev & Bogstad, 2011), a globally significant fishing ground with the world's largest cod fisheries. The recipient of advice in this case is the Norway-Russia Joint Fisheries Commission, which manages five shared fish stocks in the Barents Sea.[22]

The Northeast Atlantic has a large number of fish stocks that are shared between two or more countries and/or extend into waters beyond national jurisdiction. ICES therefore also provides advice to a number of other sub-Arctic cooperative arrangements, including those between Norway and Iceland, Norway and Greenland, Norway and the Faroes, and Norway and the EU.[23] It also coordinates scientific cooperation on Norwegian Sea surveys of pelagic fish stocks. ICES provides advice directly to coastal states and the EU, and this is the basis for management of the fish stocks in the waters of Greenland, Iceland, Norway and Russia.

The Northeast Atlantic has three areas of waters extending beyond EEZs: in the Norwegian Sea and the Barents Sea, in the sub-Arctic, and in the central Arctic Ocean. The sub-Arctic waters are home to significant fisheries, while the European wedge of the high seas portion of the CAO is ice-covered and does not have any fisheries.[24] These areas are Regulatory Areas of the Northeast Atlantic Fisheries Commission.[25] NEAFC regulations apply to all regulatory areas, including the European wedge of the high seas in the CAO, specifically the scheme on control and enforcement, protection of vulnerable marine ecosystems, deep sea fisheries, and annual regulations on a series of fish stocks.[26]

While most other regional fisheries management organizations (RFMOs) have an in-house mechanism to provide for scientific advice (FAO, 2020), NEAFC relies on ICES for this purpose. The 1980 NEAFC convention explicitly requires that it "... shall seek information and advice from the International Council for the Exploration of the Sea."[27] NEAFC and ICES have established an MoU for this arrangement.[28] Thus, NEAFC gets scientific advice that is independent of NEAFC and its members.

ICES involvement in the Arctic is also significant in the context of the 2018 agreement to prevent unregulated fishing in the high seas portion of the central Arctic Ocean. This ten-party[29] agreement, which establishes a 16-year moratorium on fishing (Balton, 2019), has been more than a decade in the making. A number of scientific meetings since 2011 have been important to its development and conclusion. ICES contributed substantively to these meetings by providing advice on how to organize the functions of a science mechanism to be established when the agreement enters into force (Hoel 2020).[30] When such a mechanism eventually is set up,[31] ICES is likely to be important by virtue of its central role in scientific cooperation and provision of scientific advice in the Northeast Atlantic, the fact that all coastal states are ICES members, and its special relationship with NEAFC, which has a Regulatory Area in the European wedge of the high seas portion of the Central Arctic Ocean.

ICES also has working relationships with the Arctic Council[32] and with ICES's sister organization PICES in the North Pacific. This is the basis for a 3-way cooperation on developing an integrated ecosystem assessment of the central Arctic Ocean. Integrated ecosystem assessments (IEAs) are critical elements in the development of ecosystem-based management (Levin et al., 2009), and ICES is currently engaged in producing several such assessments in the Arctic and sub-Arctic, including for the Central Arctic Ocean, the Barents Sea, and the Norwegian Sea. The working group established for the conduct of an integrated ecosystem assessment of the Central Arctic Ocean (WGICA) has met since 2016, and has recently embarked on its second three-year mandate period.[33] The first WGICA IEA report and the first Ecosystem Overview of the CAO will be published by ICES in 2021.

Ecosystem Overviews are priority action areas for ICES have become advisory products along with Fisheries Overviews,[34] complementing the regular scientific advice for fisheries management. Ecosystem Overviews follow a human activity – pressures – states conceptual scheme,[35] and are already published for the subarctic ecoregions[36] in the Barents Sea, the Norwegian Sea, the Greenland Sea, and Icelandic waters. ICES ecoregions are the spatial units for ecosystem-based scientific advice.[37]

With the increasing impacts of climate change in the Arctic and its ramifications affecting Arctic marine ecosystems (Haug et al 2017), along with increasing human activity, the role of science and scientific advice for management will become ever more important. ICES is not the only game in town. An assessment of its future role in the Arctic needs to factor in other organizations and initiatives and how they relate to each other.

## 25.6. The Wider Context of Science and the Arctic Ocean

While commercial activities are the dominant human presence in the sub-Arctic, marine scientific research is probably the most significant human activity in the Central Arctic Ocean today. The conduct of marine scientific research in the Arctic Ocean is governed by global norms as well as regional and domestic institutions.

As for the global norms, the 1982 UN Convention on the Law of the Sea provides the legal framework for all activities in the oceans globally, including science (Churchill & Lowe, 1989). Within national jurisdictions, marine scientific research by entities from other nations requires the consent of the coastal state. In areas beyond national jurisdiction, marine scientific research is one of the freedoms of the high seas. The Intergovernmental Oceanographic Commission (IOC) of UNESCO is the global marine science body tasked with promoting marine science and implementing global marine science programs[38]; it is the coordinator and driver of the 2021–2030 UN Decade of Ocean Science for Sustainable Development.[39]

A number of regional organizations and arrangements are engaged in Arctic marine science. The International Arctic Science Committee (IASC) was established in 1990 to encourage and facilitate cooperation in all aspects of Arctic research (Rogne et al., 2015).[40] IASC, an NGO, has members from 23 countries and can be viewed as the science community's own organization, relying on bottom-up processes to identify cutting-edge research topics (Smieszek, 2015). It has a marine

working group dealing with basic science.

Another, more recent, regional initiative features the Arctic Science Ministerial Meetings, which have been held in 2016, 2018 and 2021. The 2018 meeting was attended by 26 countries. The main goal of the ministerial meetings is to shape the course of future Arctic research. The outcomes of the meetings is a set of conclusions setting out priorities for research, such as increased international cooperation.[41] The main themes for cooperation are observations and data, regional and global dynamics, and vulnerability and resilience.

Still another regional arrangement is the 2018 Agreement on Preventing Unregulated Fishing in the High Seas Portion of the Central Arctic Ocean. It is the outcome of negotiations, first among the five coastal states, subsequently expanded to include potential distant water fishing nations (Japan, China, Republic of Korea, the EU, and Iceland). Interactions over several years between science and policy actors was critically important for the conclusion of the agreement, which contains provisions for the establishment of a Joint Program of Scientific Research and Monitoring. Given that a 16-year moratorium will commence when the agreement enters into force, to be continued beyond the initial 16 years in five-year increments as long as no party objects, scientific research is likely to constitute a large part of this body's agenda in the coming years (Hoel 2020).

The Arctic Council was established in 1996 as a high-level intergovernmental forum to provide a means for promoting cooperation, coordination and interaction among the Arctic States (Young, 2010). While not a scientific body, its various working groups (AMAP,[42] CAFF,[43] PAME,[44] EPPR,[45] ACAP,[46] and SDWG[47]) are users of scientific research, focusing on monitoring and assessments. A significant legacy of the Arctic Council is therefore that our understanding of the Arctic is greater than ever before, resulting inter alia from the Arctic Climate Impact Assessment (ACIA) (ACIA, 2005), the Snow, Water, Ice and Permafrost in the Arctic (SWIPA) (AMAP, 2017), the State of the Arctic Marine Biodiversity Report 2017 (CAFF, 2017), the Arctic Marine Shipping Assessment (PAME, 2009), and the Arctic Human Development Report II (SDWG, 2015). ICES acquired observer status in the Arctic Council in 2017, a relationship the encourages enhanced collaboration.

Under the auspices of the Arctic Council, an agreement on international scientific cooperation in the Arctic was signed in 2017 and entered into force in 2018. The purpose of this agreement is to enhance cooperation in scientific activities in order to improve scientific knowledge about the Arctic by providing access to areas, data, and infrastructure (Smieszek, 2017). While it has the potential to boost cooperation (Berkman et al., 2017), so far there appears to have been little activity under this agreement.

With respect to Arctic-wide coordination of observations and data, the Arctic Council and the International Arctic Science Committee established the Sustaining Arctic Observations Network (SAON) in 2011 in the wake of the International Polar Year (2007–2009).[48] The mission of SAON is to strengthen pan-Arctic observing, and its 2018–2028 strategy sets out the principles for this.[49] ICES is a SAON partner organization.

In a larger perspective on Arctic marine stewardship, a significant recent development is the establishment of the SAO-based Marine Mechanism (SMM) in the Arctic Council, aiming to provide a high-level coordination and steering function for the marine activities of the Arctic Council. The outcome of a 2015–2018 Task Force on Arctic Marine Cooperation, the SMM will likely be an important arena for discussion of marine scientific research. Its first meeting took place in October 2020, and ICES contributed with an introduction to ecosystem-based management. With the establishment of the SMM, the Arctic Council has created a focal point for Arctic marine issues at a strategic level, an important development when viewed in a wider, global perspective and in relation to the on-going negotiations of an international legally binding instrument for the conservation and use of biodiversity in the areas beyond national jurisdiction (Balton, 2019).

## 25.7. Discussion

The International Council for the Exploration of the Sea (ICES) has a long history; it was established more than a century ago, at the beginning of the twentieth century. With a network of 6000 scientists and 700 institutes, it has a large pool of intellectual capital for marine science. It is an Intergovernmental Organization (IGO) based on its 1964 convention and has evolved from a body mainly concerned with fisheries science and advice to a broad-based marine science organization now having marine ecosystems as its organizational focus. In this respect it represents a broad, international development over recent decades where ecosystem science and the need for integrated ocean management has become broadly accepted (Winther et al., 2020), if not yet widely implemented.

The advisory function of ICES is unique. It is the only international marine scientific organization with such a strong mandate for provision of scientific advice to its clients – coastal states and regional marine management organizations in the North

Atlantic. Its sister organization PICES in the North Pacific has a similar mandate but does not perform the same advisory functions.

ICES is also an independent scientific organization, and an IGO in its own right where scientific integrity is valued highly and where a number of safeguards and procedures are in place to protect the scientific work from undue political influence. With the growing threats to the oceans and their resources, the growth in interest in marine issues, and the proliferation of private initiatives to influence marine governance, the need for impartial scientific advice for marine management is more important than ever.

With the onset of the International Decade on Ocean Science[50] in 2021, a pertinent question is whether and how the ICES can represent a model for the organization of marine science and provision of scientific advice to other regions in the world. A number of features of ICES are of interest in this respect, such as the organization of its work, the data pipelines and their governance, and the protection of scientific integrity.

While ICES as an organization represents a cutting-edge approach to the provision of scientific advice to management authorities, an important question is "what happens next"? Is the advice listened to and followed by its clients? A full answer to that question is beyond the scope of this chapter and would require a major effort to address fully. Also, the quality and role of scientific advice in marine management is but one of several factors explaining the status of marine ecosystems and the natural resources they encompass. The overall development in the status of fish stocks in the Northeast Atlantic is however generally improving, as can be seen for example in the Barents Sea or the North Sea (Hilborn et al., 2020) and indeed in regions where modern fisheries management plans are implemented (Melnychuk et al., 2021). Increases in the quality and influence of scientific advice obviously play some role in this development. Regarding the current preoccupation with ecosystem-based management and advice, it could be asked how ICES can advance the implementation of the ecosystem approach to fisheries management, so long as clients primarily ask for advice on single species management (Ramirez-Monsalve et al., 2021).

As regards the Arctic specifically, ICES has a mandate for the Northeast Atlantic up to the North Pole. Its historical as well as current engagement in the Arctic includes both its traditional preoccupation with fisheries and its more recent emphasis on ecosystem science. The first is amply illustrated by its critical role in providing scientific advice for fisheries management in the Northeast Atlantic, a role that is set to become more important as climate change drives fish stocks north (Hastings et al., 2020, Fossheim et al., 2015). As regards ecosystem science and management, the cooperation with PICES and the Arctic Council's working group PAME on an integrated ecosystem assessment for the Central Arctic Ocean (WGICA)[51] is a significant initiative in several ways. It represents a new and important foundation for subsequent development of ecosystem advice; it is also a novel model of cooperation among key scientific bodies in that region (ICES 2020). ICES performs such integrated ecosystem assessments also in the seas surrounding the Central Arctic Ocean, such as the Barents Sea and the Norwegian Sea.[52] In addition, ICES is connected to other recent initiatives of importance to marine science in the Arctic, such as the Sustaining Arctic Observation Networks (SAON) and the scientific work under the 2018 agreement to prevent unregulated fishing.

The Arctic marine science landscape is a complex work in progress. Also, it evolves in the context of increasing geopolitical tensions (Stavridis, 2017), a development that could have major repercussions for science (Nature, 2020). Still, it seems safe to conclude that ICES will remain a core part of the fabric of Arctic marine science in the future.

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1 https://oceandecade.org/assets/The_Science_We_Need_For_The_Ocean_We_Want.pdf

2 See the Se Ice Index of the National Snow and Ice Data Center: https://nsidc.org/data/seaice_index/

3 See the Arctic Ocean Review phase I report for a discussion of which ocean areas that constitute the Arctic Ocean.

4 http://www.ices.dk/about-ICES/who-we-are/Pages/Who-we-are.aspx

5 See also the ICES website at http://www.ices.dk/about-ICES/who-we-are/Pages/Our-history.aspx

6 The convention text can be found here: http://www.ices.dk/about-ICES/who-we-are/Documents/ICES_Convention_1964.pdf

7 http://www.ices.dk/about-ICES/who-we-are/Documents/CPH_declaration_2002.pdf

8 http://www.ices.dk/about-ICES/who-we-are/Documents/CPH_declaration_2002.pdf

9 The ICES convention specifies its location to be in Copenhagen.

10 http://www.ices.dk/community/groups/Pages/SCICOM.aspx

11 http://www.ices.dk/community/groups/Pages/SIHD.aspx

12 Cfr the Effects of Climate Change on the World's Oceans quadrennial conference series. https://meetings.pices.int/meetings/international/2018/climate-change/Background

13 https://academic.oup.com/icesjms

14 http://admin.ices.dk/Submissions/index.aspx?t=1

15 Article 14 of the NEAFC Convention. https://www.neafc.org/system/files/Text-of-NEAFC-Convention-04.pdf

16 In a report of the first meeting of ICES in 1902, it was noted that the funding from governments was conditioned by the need for knowledge for fisheries management. "Practical results of direct value to the fisheries are sought for" (Nature, 1902).

17 https://www.un.org/Depts/los/convention_agreements/texts/unclos/closindx.htm

18 https://www.un.org/Depts/los/convention_agreements/texts/fish_stocks_agreement/CONF164_37.htm

19 http://www.ices.dk/community/groups/Pages/ACOM.aspx

20 https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/Guide_to_ICES_Advice.pdf

21 https://www.ices.dk/advice/Pages/default.aspx

22 Cod, haddock, capelin, Greenland halibut, and redfish.

23 These agreements are subject to annual review in reports to Parliament in Norway.

24 The world's northernmost fisheries are on the Northern flank of Norway's Svalbard archipelago, well inside its 200-mile zone.

25 NEAFC has seven contracting parties: The European Union, the Faroe Islands, Iceland, Greenland, Norway, the Russian Federation, and the United Kingdom. The UK became a contracting party in 2020 following Brexit.

26 Statement by NEAFC regarding the conclusion of the negotiations on the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean. https://www.neafc.org/system/files/NEAFC-statement_Central-Arctic-Ocean-Agreement.pdf

27 NEAFC Convention article 14.

28 https://www.neafc.org/system/files/ices_mou-2019.pdf
29 Canada, Denmark/Greenland, Norway, the Russian Federation, USA, China, the Republic of Korea, Japan, Iceland and the EU.
30 The agreement requires that all 10 parties have ratified for it to enter into force. By the end of 2020 nine out of 10 signatories have ratified.
31 Currently, a Provisional Scientific Coordination Group has held one meeting.
32 Observer status, as well as functions in relation to working groups.
33 http://www.ices.dk/community/groups/Pages/WGICA.aspx . The mandate of WGICA is here: http://www.ices.dk/community/Documents/Science%20EG%20ToRs/IEASG/2019%20-%202020/WGICA%20resolution%202019-2021.pdf
34 http://www.ices.dk/advice/Fisheries-overviews/Pages/fisheries-overviews.aspx
35 https://www.ices.dk/advice/ESD/pages/preview.aspx?diagramid=52
36 http://www.ices.dk/advice/ESD/Pages/Ecosystem-overviews.aspx
37 http://www.ices.dk/advice/ICES%20ecoregions%20and%20advisory%20areas/Pages/ICES-ecosystems-and-advisory-areas.aspx
38 https://ioc.unesco.org
39 https://oceandecade.org
40 https://iasc.info
41 https://www.arcticscienceministerial.org/files/ASM2_Joint_Statement.pdf
42 Arctic Monitoring and Assessment Programme.
43 Conservation of Arctic Flora and Fauna.
44 Protection of the Arctic Marine Environment.
45 Emergency Prevention and Preparedness and Response.
46 Arctic Contaminants Action Programme.
47 Sustainable Development Working Group.
48 https://www.arcticobserving.org/images/pdf/Board_meetings/5th_tromso/nuuk_declaration_final.pdf
49 https://www.arcticobserving.org/images/pdf/Strategy_and_Implementation/SAON_Strategy_2018-2028_version_16MAY2018.pdf
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