

Final Report of the Fifth Meeting of Scientific Experts on Fish Stocks in the Central Arctic Ocean

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List of Acronyms and Abbreviations

AIS	Automatic Identification System
AUV	Autonomous Underwater Vehicles
AZFP	Acoustic Zooplankton and Fish Profilers
CAFF	Conservation of Arctic Flora and Fauna
CLIVAR	Climate Variability and Predictability
CTD	Conductivity Temperature Depth
DBO	Distributed Biological Observatory
eDNA	Environmental DNA
ELOKA	Exchange for Local Observations and Knowledge of the Arctic
FISCAO	Scientific Experts on Fish Stocks of the Central Arctic Ocean
IASC	International Arctic Science Committee
ICC	Inuit Circumpolar Council
ICES	International Council for the Exploration of the Sea
JAXA	Japanese space agency
LME	Large Marine Area
MOSAIC	Multidisciplinary drifting Observatory for the Study of Arctic Climate
NAFO	Northwest Atlantic Fisheries Organization
NOAA	U.S. National Oceanic and Atmospheric Administration
PAME	Protection of the Arctic Marine Environment
PI	Principle Investigator
PICES	North Pacific Marine Science Organization
RDA	Research Data Alliance
SAON	Sustaining Arctic Observing Networks
SUIT	Surface and Under Ice Trawl
ToR	Terms of Reference
USA	United States of America
WGIBAR	Working Group on the Integrated Assessments of the Barents Sea
WGICA	ICES/PICES/PAME Working Group on Integrated Ecosystem Assessment for the Central Arctic Ocean
WMO	World Meteorological Organization

Executive summary

This report provides a summary of the 5th meeting of scientific experts on Fish Stocks in the Central Arctic Ocean (FiSCAO) on October 24-26, 2017, in Ottawa, Canada.

At the request of the 10 parties negotiating on an agreement to prevent unregulated commercial fishing in the High Seas portion of the Central Arctic Ocean (CAO), participants of the 5th FiSCAO meeting were tasked with addressing four Terms of Reference, summarized below:

- ToR 1. Design a 1-3 year long mapping program.
- ToR 2. Design a monitoring program.
- ToR 3. Identify human, financial, vessel/equipment resources needed for mapping and monitoring.
- ToR 4. Develop data collection, sharing, and hosting protocols that outline the details of what and how data shall be collected, shared, and hosted for consideration by the Parties.

The 5th FiSCAO meeting included scientific representatives from seven states including Canada, the People's Republic of China, the European Union, Iceland, the Republic of Korea, the Kingdom of Norway and the United States of America. The meeting also included representatives from the International Council for the Exploration of the Sea (ICES), the North Pacific Marine Science Organization (PICES) and the Arctic Council's Protection of the Arctic Marine Environment (PAME) and Conservation of Arctic Flora and Fauna (CAFF) working groups.

The report summarizes the elements for collecting baseline data (i.e., a mapping program) in the high seas CAO to achieve the goals of documenting species distributions, relative abundances and key ecosystem parameters (ToR 1). The mapping program describes the priority areas to sample, the types of data to collect and possible data collection approaches to employ. Participants emphasized that existing planned surveys are very limited, and that significant dedicated resources will be required to implement the mapping program.

The report outlines a strategy for monitoring indicators of fish stocks and ecosystem components (ToR 2). The report includes a list of existing monitoring programs and a prioritized list of indicators to detect environmental change in the high seas CAO. Further refinement of a monitoring program will use information from the mapping program (ToR 1). Participants emphasized the need to begin monitoring as soon as possible and that additional research is required to operationalize monitoring indicators.

The report summarizes the preliminary cost estimates (ToR 3) to implement a mapping program to collect data in the high seas portion of the CAO using a vessel of opportunity and in the Pacific Gateway region of the CAO using an independently-organized survey. Cost implications for the monitoring program and other scientific activities are also listed (e.g., data analysis, data management).

The report includes a draft data sharing policy as the foundation for a future data sharing protocol, including the technical specifications for data sharing (ToR 4). The development of the data sharing protocol will require negotiation and legal review among the participating states. A data management and data sharing pilot study on a CAO fish database is suggested to test a framework.

1 Introduction

Scientific experts on fish stocks in the Central Arctic Ocean (CAO) met from October 24-26, 2017, in Ottawa, Canada to develop a scientific program supporting the participating states (Canada, the People's Republic of China, the Kingdom of Denmark in respect of the Faroe Islands and Greenland, the European Union, Iceland, Japan, the Republic of Korea, the Kingdom of Norway, the Russian Federation and the United States of America) negotiating on an agreement to prevent unregulated commercial fishing in the High Seas portion of the CAO. The diplomatic negotiations build on the [2015 Oslo Declaration](#) in which the five nations with waters adjacent to the High Seas portion of the CAO agreed to interim measures for the prevention of unregulated commercial fishing in the High Seas. In November 2017, the [delegations successfully concluded negotiations](#) on the draft *Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean*.

At the direction of the participating states, and building on the outcomes of four previous meetings of scientific experts on Fish Stocks of the Central Arctic Ocean (FiSCAO), participants at this 5th FiSCAO meeting were tasked with addressing four [Terms of Reference](#) (ToRs), summarized below:

- ToR 1. Design a 1-3 year long mapping program.
- ToR 2. Design a monitoring program.
- ToR 3. Identify human, financial, vessel/equipment resources needed for mapping and monitoring.
- ToR 4. Develop data collection, sharing, and hosting protocols that outline the details of what and how data shall be collected, shared, and hosted for consideration by the Parties.

In total, 24 participants attended the 5th FiSCAO, with representation from 7 of the 10 participating states including Canada, the People's Republic of China, the European Union, Iceland, the Republic of Korea, the Kingdom of Norway and the United States of America, and representatives from the International Council for the Exploration of the Sea (ICES), the North Pacific Marine Science Organization (PICES) and the Arctic Council's Protection of the Arctic Marine Environment (PAME) and Conservation of Arctic Flora and Fauna (CAFF) working groups ([Appendix A](#)).

Representatives from the Inuit Circumpolar Council were not able to attend the 5th FiSCAO meeting. As a result, this report only includes limited considerations for the inclusion of indigenous and local knowledge but this important component will be expanded in further refinements of the mapping and monitoring programs.

This report summarizes the discussions and conclusion of the 5th FiSCAO meeting in relation to each of the four ToR.

2 ToR 1: Mapping Program

2.1 Background

During the 4th FiSCAO meeting, participants drafted a schematic framework for a joint scientific research and monitoring plan program that included two survey elements, 1) a mapping phase and 2) a monitoring phase (FiSCAO 2017). In general, the mapping phase is designed to provide a snapshot of species distributions and relative abundances in relation to biotic and abiotic factors. The mapping program can also lay the groundwork for determining population structure, trophic linkages and environmental drivers. At the conclusion of the mapping phase, if no potentially harvestable stocks are identified, efforts will focus on monitoring the High Seas CAO and adjacent areas for temporal variability or trends in species distribution or ecosystem productivity using a set of indicators.

During the 4th FiSCAO meeting, participants also created a list of detailed scientific questions that need to be addressed to fully assess the potential for sustainable commercial fishing in the High Seas CAO (FiSCAO 2017).

Of those questions, the following could be addressed during the mapping phase:

- What are the distributions of species with a potential for future commercial harvests in the High Seas CAO?
- What fish species are currently present in the High Seas CAO?
 - What are their distribution and relative abundance patterns?
 - What are their local life-history strategies, habitat associations, and demographic patterns?
 - Do these strategies, associations or patterns differ among regions in the Arctic?
- What are the trophic linkages among fishes and between fishes and other taxonomic groups (i.e. quantify food web(s))?
- What are the likely key ecological linkages between potentially harvestable fish stocks of the High Seas CAO and adjacent shelf ecosystems?
 - What are the connections between fish in the High Seas CAO and those in the adjacent regions?
 - What are the mechanisms that establish and maintain these linkages?

For the 5th FiSCAO meeting, ToR 1 tasked participants with developing the mapping program to document the current physical, chemical and biological oceanographic conditions and the distributions of marine invertebrates, fishes, mammals and birds in the High Seas portion of the CAO and surrounding waters (Figure 1) to determine where invertebrate or fish populations of potential commercial interest currently exist in the CAO and identify drivers of population productivity. Fishery sustainability is considered within an ecosystem context, therefore interactions between species and ecological drivers of changes in populations of harvested species are equally important as assessments of their standing stocks and life history parameters.

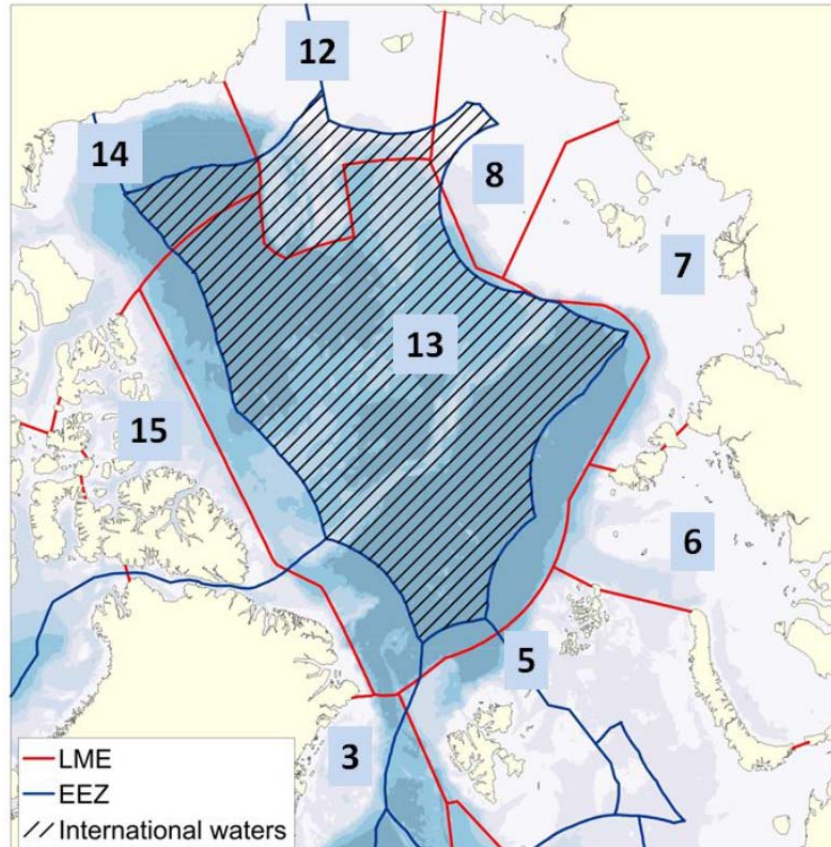


Figure 1. National boundaries (blue) and boundaries of Large Marine Areas (LMEs; red). The High Seas area (international waters) is hatched. Numbers refer to LMEs defined by red boundaries: 13 Central Arctic LME, 5 Barents Sea LME, 6 Kara Sea LME, 7 Laptev Sea LME, 8 East Siberian Sea LME, 12 Northern Bering- Chukchi Seas LME, 14 Beaufort Sea LME, 15 Canadian High Arctic – North Greenland LME, 3 Greenland Sea LME (northern portion only). Source: FiSCAO 2017.

2.2 Sampling areas

The High Seas CAO covers 2.8 million km², and given that sampling periods and resources will be limited, subareas of the High Seas CAO will need to be prioritized for sampling. Areas of particular interest for the mapping program can be identified based on the relative availability (or lack) of information, degree of sea ice loss and water depth. Areas in the High Seas CAO with little existing information, the greatest degree of sea ice loss, and where depths are fishable (e.g., less than 2000 m for demersal species), such as the East Siberian Sea including the Chukchi Borderlands and waters northwest of Wrangel Island, are of particular interest for demersal species. There is virtually no knowledge about the existence and distribution of pelagic fishes in the deep-sea areas of the CAO, e.g., redfish *Sebastes spp.*, lanternfishes (myctophidae) and polar cod *Boreogadus saida*. Filling this knowledge gap sets an important baseline for future management of fisheries and associated ecosystem impacts in the CAO. Gaining the best possible knowledge about the presence and distribution of pelagic fishes in the CAO is therefore considered a priority of the mapping program. Surveys should also be conducted in areas where there have been documented, observed or expected northward range expansions by potentially harvestable species (for a list of potential species, see FiSCAO 2017). Surveys should also include areas where environmental changes have been documented or are expected to occur. Refuge areas for polar fishes from climate

change effects, both physical and biological, within which species can complete their lifecycles are of particular ecological importance (e.g., ice-covered CAO for *Boreogadus saida*). Additional research beyond the scope of the mapping program is required to identify areas within which individual polar fishes can complete their life cycles to identify candidate refuge areas.

2.3 Field program

The mapping program should occur over as short a time period as possible (i.e., within 1-3 years) to capture the current state of the High Seas CAO ecosystem, adjacent ecosystems and potential commercial species therein. To the extent possible, this program should make use of existing surveys and monitoring programs in territorial waters or the High Seas CAO, vessels of opportunity and indigenous and local knowledge. Synoptic mapping surveys should be conducted over as much of the High Seas CAO as possible.

The mapping program will require collection of a wide suite of data and multiple vessels to complete. Sets of vessels will undertake mapping in different regions of the High Seas CAO (see section [2.2 Sampling areas](#)). All participating countries should contribute vessels, with vessels tasked in waters nearest to their homeport, to the extent possible. All vessels will follow standardized sampling protocols and use consistent data formats; internationally agreed best-practices will be followed, when available. Sampling will occur in sympagic, pelagic and benthic habitats to fully characterise the communities and environmental conditions throughout the water column, particularly in areas that have never been surveyed before. Vessel-based sampling should occur when the sea ice extent is at its lowest, allowing the largest possible area to be surveyed, with a primary focus on fish sampling.

The resulting mapping data will be suitable for identifying species distributions and relative abundance patterns. The timeframe will not be long enough to generate estimates of total abundance or replacement rates. The mapping program will focus on capturing spatial variability in populations and, if sufficient resources are available and the program includes multiple years of sampling, it may be possible to capture temporal variability through repeated sampling of a subset of stations within and across years.

Target survey locations may contain sensitive benthic habitats or species (e.g., corals and sponges). To minimize the impact of scientific surveys on these habitats and species, to the extent possible, sampling locations for bottom trawls and other bottom contacting gears should be visually surveyed using Autonomous Underwater Vehicles (AUV) or drop cameras prior to gear deployment. If sensitive benthic habitats or species are observed, the sampling location will be moved to an adjacent area.

2.4 Prioritization of data types

To achieve the fundamental goals of the mapping program, to document species distributions, relative abundances and key ecosystem parameters, certain data are essential. Additional data could be collected at minimal costs to provide complete fundamental datasets for fishery monitoring and assessment programs.

Three data tiers were identified as follows:

Data essential for identifying fish species distributions and relative abundances include the following:

- Information on the vessel, gear and fishing practices that affect fishing effort (i.e., fishing gear specifications, fishing effort metrics (e.g., length of time fishing, speed of fishing), fishing vessel details (e.g., vessel size, horse power, IMO number), net mensuration). These data are required to have confidence that the sampling methods were appropriate and the data are reliable for the mapping goals.
- To document and analyse patterns in species distributions and relative abundances, data need to be recorded regarding the date, latitude, longitude, fishing depth and water column depth for each sampling event, as well as species binomials (scientific name) and total number and total weight for each species captured or acoustic data (target strength converted to biomass) collected during the sampling.

Data essential for understanding population structure and the factors affecting species distributions and productivity include:

- Characteristics of individual fishes (i.e., length, weight, age, sex and maturity) and habitat conditions (i.e., temperature and salinity profiles, substrate type and composition, sea ice concentration and nutrient concentrations).
- For acoustic surveys, net collection or video observations of acoustic targets is critically important.

Data needed to manage fisheries in an ecosystem context include:

- Trophic dynamics (i.e., phytoplankton abundance and composition, zooplankton abundance and composition, marine mammals, sea birds, lipid content, stable isotope composition, fatty acid contents, stomach contents and community composition).
- Data on animal health (i.e., condition, growth via examination of RNA/DNA), CO₂-carbonate-alkalinity, O₂, currents and light levels would provide insights into drivers of fish productivity and stressors.
- Genetic sequencing data are important for assessing stock structure and connectivity. Understanding the relative contributions of local reproduction and immigration to the maintenance of fish stocks in the High Seas CAO is particularly important when considering potential commercial fisheries.
- Environmental DNA (eDNA) provides an alternative method for assessing species presence and may identify species not available to fishing gears.
- Assessments of catchability (e.g., trawl cameras to observe escapement) are important for integrating catch data across surveys.

2.5 Vessels of opportunity

Vessels and other platforms of opportunity should be used to the extent possible to supplement data collected by the dedicated mapping program. Several types of platforms of opportunity exist, including:

- Planned scientific missions (e.g., Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC)) and supply ships supporting the mission
- Icebreakers on other missions
- Passenger cruise ships
- Satellites (e.g., Japanese satellite by Japanese space agency (JAXA), launched December 2017)
- Ice camps (e.g., Russia North Pole ice camp)
- Critter cams and electronic animal tagging programs
- Gliders
- Submarines

Additional vessels of opportunity can be identified by contacting the shipping industry, examining Automatic Identification System (AIS) data from previous years and consulting regulatory authorities.

Within the next 5 years (i.e., until 2023) the following research icebreakers will potentially be operating in the CAO. The coordinators of these vessels should be contacted to verify the likelihood that they will be operating in the CAO and to evaluate the possibility of using the ship as a vessel of opportunity.

- Polarstern (Germany; MOSAiC project)
- Support vessels for the MOSAiC project
- Oden (Sweden)
- Kronprins Haakon (Norway)
- Xuelong (China)
- Arctica (Finland)
- Araon (Korea)
- Russian icebreakers

Research programs operating on icebreakers should be asked to collect as much of the following data as possible. Within the list, data types identified as “direct observations” have the greatest potential for giving information to address the objectives of the mapping program.

- Passive data collection:
 - Sonar profile data for fish (direct observations)
 - Soundings giving bathymetric information (some level of benthic habitat characterization)
 - Acoustic Doppler Current Profiler (ADCP)
- Active data collection:
 - Marine mammals/bird observers
 - Conductivity Temperature Depth (CTD)
 - Rosette
 - Fluorescence, chlorophyll *a*
 - Drop cameras – fish focused protocols (direct observations)
 - Plankton tows including ichthyoplankton (direct observations)
 - Environmental DNA (eDNA; direct)
 - Fish sampling including various types of methods (direct observations)

2.6 Indigenous and local knowledge

Historic and contemporary baseline data on species distributions and abundances, and environmental conditions in waters adjacent to the High Seas CAO, and to a lesser extent within the High Seas CAO, may be available through indigenous and local knowledge holders. The Inuit Circumpolar Council will be consulted and sources of information may include existing regional programs such as the Nunavut Coastal Resource Inventory in Nunavut, Canada. Participation by Indigenous knowledge holders will be important to the success of this effort, and participants recommended continued engagement and continued development of the mapping and monitoring programs with Indigenous representation.

3 ToR 2: Monitoring Program

3.1 Background

For the 5th FiSCAO meeting, ToR 2 tasked the participants to design the monitoring program. This included the identification and definition of potential areas for monitoring and appropriate indicators to measure. The design of the monitoring program is to make use of existing programs to the extent possible, including government, community-based and academic programs as well as indigenous and local knowledge. Participants agreed the best approach was to begin by developing a monitoring strategy that would inform future refinement of the monitoring program. Recommending a strategy was determined to be more valuable than developing a program until available resources are committed by the participating states. Additionally, the identification of indicators and selection of triggers will likely depend on what is learned during the mapping phase.

The monitoring strategy was developed with the assumption that the FiSCAO monitoring program would primarily rely on existing monitoring activities. Participants also recognized that new research programs are being or may be developed by various governments, academic or industrial bodies, and the FiSCAO monitoring program could leverage these new activities. Where possible, advice on the type of data collected should be given to existing and developing monitoring programs to improve alignment with the FiSCAO monitoring program.

Resources will be required for both data collection and data analysis. Although this monitoring strategy was developed to leverage existing monitoring programs, any requirements for new monitoring activities in the High Seas CAO or in waters adjacent to the High Seas CAO would significantly increase resources requirements. For data analysis, various options are possible, including forming a new working group or leveraging existing analytical groups that are conducting relevant assessments (e.g., the ICES/PICES/PAME Working Group on Integrated Ecosystem Assessment for the Central Arctic Ocean (WGICA)).

Although the mapping phase will generally be followed by monitoring, there is a strong need to begin collecting monitoring data immediately. The collection of time series data is essential for ecosystem-based management of fisheries. Therefore, it is essential that monitoring begin well in advance of the start of any potential commercial fishing in the High Seas CAO, in part to provide a baseline against which any changes observed can be interpreted. Participants also noted that seasonal aspects in the High Seas CAO and adjacent waters are not well documented and that information collected outside the open water months would be highly valuable.

The monitoring strategy presented in this report includes an inventory of existing monitoring programs maintained by the participating states or bodies, a prioritized list of geographical areas for implementing a monitoring program and a list of potential indicators to monitor. In addition, this monitoring strategy includes considerations for identifying triggers that would indicate that or where a change in productivity has occurred, at least within a localized area, and when a new targeted survey should be conducted (i.e., repeat the mapping phase in a localized area).

3.2 Current and planned monitoring by participating states

Prior to the 5th FiSCAO meeting, participants provided metadata on existing activities that could support a monitoring program for the High Seas CAO to develop an inventory of monitoring programs ([Appendix B](#)). The inventory includes programs that take (or plan to take) regularly scheduled observations in the High Seas CAO, adjacent and contiguous Larger Marine Ecosystems (LMEs) or the four major gateways to the Arctic (i.e., Bering Strait, Fram Strait, the Barents Sea and the Canadian Arctic Archipelago).

The intent was to create a preliminary list of the existing programs that might provide information relevant to the FiSCAO monitoring program. Given the ecosystem-based approach of the FiSCAO research program, the inventory includes programs that collect data on oceanographic conditions, productivity, invertebrates, fishes, marine mammals and birds to assess fish populations, their drivers and other species that could be affected by commercial fishing.

The resulting inventory is not exhaustive and is biased towards fisheries survey programs relative to other types of surveys (e.g., physical and biological oceanography, marine mammals, and seabirds). The monitoring programs in the inventory are primarily undertaken by governments, but monitoring programs by academia or other organizations may also be relevant and should be considered.

The inventory includes information from 8 countries including Canada, China, Germany, Greenland (Denmark), Iceland, Korea, Norway and the USA. During breakout sessions, the participants identified the main types of monitoring programs included in the inventory.

The main types of monitoring programs are:

- Fish and/or invertebrate surveys
- Ecosystem surveys (biological components with oceanographic and environmental data)
- Physical oceanographic surveys
- Moorings and ice buoys (physical, chemical, geological and biological data collection)
- Marine mammal surveys/satellite tagging
- Seabird surveys/satellite tagging
- Remote sensing

The inventory also identifies various levels of data availability for the different programs. Some programs reported that data are publically available with access through an online data repository while data from other programs can only be found in published reports or by request. Data sharing is further discussed as part of ToR 4.

3.3 Monitoring areas

Three geographical subareas were identified as priorities for the monitoring program; the High Seas CAO, the Atlantic gateway and the Pacific gateway. For the purpose of this monitoring strategy, the Atlantic gateway includes the Barents Sea LME and the northern portion of the Greenland Sea LME. The Pacific gateway encompasses Bering Strait and the northern Bering-Chukchi Seas LME, excluding the High Seas CAO (Figure 1). A fourth generalized subarea was included as the other waters adjacent to the

High Seas CAO that are under the jurisdictions of states, to capture areas that are not covered by the gateways. Further refinement of the geographic areas will be dependent on the outcomes of the mapping program.

The joint monitoring program would greatly benefit from data collection in the High Seas CAO; however, because few programs exist in the High Seas CAO, data regularly collected from both the Atlantic and Pacific gateways were identified as critical for detecting potential changes in the High Seas CAO. Other waters adjacent to the High Seas CAO and under the jurisdictions of states were also seen as important to include in a monitoring program.

The Atlantic and Pacific gateways were recognised as priority subareas to monitor because of their strong influences on the Arctic Ocean through the transport of water, heat, nutrients and plankton from subarctic to Arctic waters. Both gateways may also be important conduits for fish movement and northward distributional shifts. Due to the importance of the gateways, monitoring activities are already well established and assessments are conducted regularly.

Key aspects of the four geographic subareas include:

- High Seas CAO
 - Overall, very limited monitoring occurs in the High Seas CAO.
 - Fish survey data suitable for monitoring are not available in the High Seas CAO. New resources would be required to fill this gap, e.g., using autonomous sonars connected to sea-ice buoys.
 - Limited acoustic data have been collected to examine fish presence and distributions. Through vessels of opportunity, new acoustic data could be collected and, where possible, advice should be given for the methodology (ideally the data would include sampling fish to support acoustic data).
 - Some aspects of the CAO ecosystem can be monitored using satellite data, vessels of opportunity and marine mammal/seabird surveys and remote tracking data.
 - Analyses of these data could be potentially conducted by the WGICA (or a similar body), if added to their terms of reference.
- Atlantic gateway (Barents Sea LME and the northern portion of the Greenland Sea LME)
 - Due to the increasing influx of Atlantic water into the area this is considered a region where species extensions into the CAO are likely to occur as environmental conditions change.
 - The Atlantic gateway is already being monitored for changes and assessed by ICES working groups and by monitoring programs, such as the Barents Sea Ecosystem Survey (Norway, Russia) and the Hausgarten LTER (Germany).
- Pacific gateway (Northern Bering- Chukchi Seas LME)
 - Some species in the Pacific gateway will expand northward to the CAO as environmental conditions change.
 - Parts of the Pacific gateway is monitored for changes and assessed by management agencies (e.g., NOAA conducts regular stock assessments and other work in portions of the Bering Sea).

- Other waters under the jurisdictions of states
 - Data from existing monitoring programs should be included and can contribute relevant information.
 - Indigenous and local knowledge from coastal communities in these subareas can contribute valuable information.

3.4 Indicators

In the context of the FiSCAO monitoring program, indicators are quantitative variables that can be used to detect changes (e.g., increases) in the availability and viability of species of commercial interest in the High Seas CAO and ecosystem state. Indicators can include both direct measures of fish and invertebrates and indirect ecosystem variables (e.g., physical, biological) of fish and ecosystem productivity.

A prioritized list of potential indicators that could be used in a monitoring program to detect changes in fish stocks of the High Seas CAO is included below. The indicators were also selected based on the types and availability of measurements collected by existing monitoring programs. Priority was determined based on the usefulness of the indicator for providing information on changes to fish species presence, productivity or distribution.

Although monitoring should continue in parallel with the mapping phase, a more refined set of indicators will need to be developed based on data collected during the mapping phase. In addition, the extent of monitoring may be scaled according to what is found during the mapping phase. For example, if significant abundances of a fish species of potential commercial interest is discovered in the High Seas CAO, dedicated data collection for stock assessment purposes will be required. Conversely, if the presence/relative abundances of fishes do not suggest potential commercial interest, a minimal monitoring program could be implemented based upon continued environmental monitoring and infrequent fish surveys.

Further research will be required to allow quantitative comparisons and assessments of indicators and to operationalize scientifically sound monitoring indicators. Also, when operationalizing the monitoring program, examinations of individual indicators in isolation have limited value; inferences about the status of fish stocks in the High Seas CAO should only be made based on a combination of indicators.

3.5 Prioritization of indicators

1. Distributions of potential commercial fishes and invertebrates.
 - a. Northward expansion of the distribution range of commercial fishes and invertebrate species would give a direct measure of changes.
 - b. Observations can focus on existing lists of species that have the potential to move northward into the Arctic Ocean and into the High Seas CAO.
 - c. A list of target species can be developed from the following select sources:
 - i. Primary literature: Hollowed et al. 2013; Fossheim et al. 2015; Ingvaldsen et al. 2015; Frainer et al. 2017; Haug et al. 2017; Mueter et al. 2017.

- ii. FiSCAO 2017 - Appendix B of the 4th FiSCAO report includes a list of fish and invertebrate species reported in the literature in the High Seas CAO and in adjacent waters with potential for future commercial harvests.
- 2. Fishing vessel activity in waters adjacent to the High Seas CAO.
 - a. Expansion of existing fisheries as indicated by fishing vessel activities towards waters adjacent to the High Seas CAO. This would be indicative of resource movement.
 - b. Data could be sourced from AIS.
- 3. Marine mammal and seabird abundance, distributions, diets, condition or foraging behaviours.
 - a. Changes in fish and ecosystem productivity can be inferred from changes in predators such as marine mammals and seabirds. Several types of observations and measurements can provide useful information (e.g., foraging behaviour based on satellite-tagging data, monitoring of population parameters in select breeding colonies).
 - b. For some species, long time series exist (e.g. several decades) and observations are likely to be ongoing.
 - c. Information sources include existing regional research groups and inter-governmental observation networks (e.g. the North Atlantic Marine Mammal Commission).
- 4. Zooplankton transport and potential establishment into the High Seas CAO.
 - a. Changes in the distribution of zooplankton can be an indicator of changes in the ecosystem and food web structure. Additionally, detection of ichthyoplankton (eggs and larvae of fish) provides direct observation of potential changes in fish populations.
- 5. Deep scattering layer.
 - a. Acoustics surveys can be used to estimate fish and invertebrate presence, distribution and relative abundance. This data source is an indirect measure of fishes or invertebrates and requires direct observations (e.g. using trawls or cameras) to identify species.
- 6. Primary productivity and associated variables.
 - a. Primary productivity can be used to detect changes in the lower food web and may indicate changes in productivity of fishes and invertebrates and other ecosystem components.
 - b. Relevant measures and analyses by existing monitoring programs include:
 - i. Primary production in sea ice and water.
 - ii. Nutrient concentrations.
 - iii. Chlorophyll-*a* concentrations in sea ice and water (by field measurements or satellite images).
 - iv. Phytoplankton community composition.
- 7. Sea ice.
 - a. Changes in sea ice extent (volume), thickness and other parameters (e.g., age of sea ice) will affect marine ecosystems.
 - b. Changes in sea ice may affect ecosystem components such as primary producers and potentially result in altered food webs. In addition, fish species may be directly affected by changes in sea ice (e.g., sea ice importance as feeding and spawning habitat).
 - c. Sea ice can be monitored by direct observations and by remote sensing (e.g., satellite).

8. Currents in the gateways.
 - a. Changes to fluxes and water masses northward through the Atlantic and Pacific gateways may be linked to species range expansions either by affecting environmental conditions or by entrainment of individuals.
 - b. Moorings in various locations in the gateways can monitor changes in currents.
9. Temperature.
 - a. Water temperature is an important driver of ecosystem processes. Additionally, changes in water temperature can be used to infer changes in fish and invertebrate distributions based on species-specific thermal tolerances.
 - b. Water temperature can be measured by:
 - i. Deployed instruments, such as CTDs.
 - ii. Moorings with temperature sensors.
 - iii. Satellite-based estimates of surface water temperature.
10. Ocean acidification.
 - a. Increasing levels of ocean acidification may lead to adverse effects in food webs.
 - b. Linkages between ocean acidification and impacts to fishes and invertebrates are not fully understood and ocean acidification is not routinely measured across monitoring programs.

3.6 Relative availability of indicator data

Participants assessed the availability of the listed indicators in each of the three priority subareas, the High Seas CAO, the Atlantic gateway and the Pacific gateway. Based on the knowledge of meeting participants, scores were assigned for the present relative sampling intensity/frequency of each indicator variable for each subarea (Table 1). The method of data collection was also noted. This exercise was undertaken to determine if the subareas were well represented for the listed indicators and to identify data gaps. It should be cautioned that high scores for indicators in the gateways do not necessarily mean that existing data collections are sufficient. These high scores must be taken in context with the relatively low survey coverage reported for the High Seas CAO.

Overall, survey coverage was found to be highest in the gateways relative to the High Seas CAO. In the High Seas CAO, data collection generally does not occur or is very infrequent, especially for biological and ecosystem variables (e.g., marine mammals, zooplankton). In the Atlantic and Pacific gateways there is moderate to good coverage of fish surveys. In the gateways, ecosystem variables are surveyed with moderate to good coverage; however, the Pacific gateway has relatively less coverage for marine mammal observations and zooplankton. In both gateways, physical variables have moderate to good coverage and are measured by moorings, satellites and oceanographic surveys.

Table 1. Relative assessment of survey coverage of indicator variables within each monitoring subarea. 0=no ongoing sampling; 1=poor; 2=moderate; 3=good. Methods of data collection are included in brackets next to each score: as = acoustic surveys; is = ice stations; ns = net surveys; m = moorings; o = observers; os = oceanographic surveys; r = radio; s = satellite.

Type	Indicator	Monitoring Areas		
		High Seas CAO	Atlantic Gateway	Pacific Gateway
Direct	Fish observations	0	3 (as, ns)	2 (as, ns)
Indirect	AIS	1 (s with poor coverage)	3 (r, s)	3 (r, s)
Indirect	Mammals/birds	1	3 (o)	3 (o)
Indirect	Zooplankton	1 (is, ns)	3 (ns)	2 (ns, m)
Indirect	Deep scattering	1 (os)	3 (as)	2 (as)
Indirect	Productivity*	2 (is, m, s)	3 (os, s)	3 (m, os, s)
Indirect	Sea ice	3 (o, s)	3 (o, s)	3 (o, s)
Indirect	Currents	1 (os)	2 (m, os, s)	3 (m, os, s)
Indirect	Temperature	2 (is, m, os, s)	3 (m, os, s)	3 (m, os, s)
Indirect	Acidification	0	2 (os)	3 (m, os)

*PP, Chl-a, nutrient concentrations, phytoplankton

3.7 Triggers

A trigger refers to the value (relative or absolute) of an indicator that would suggest a potential change has occurred in the availability of fish and invertebrate stocks or in ecosystem productivity in the High Seas CAO. Triggers would be used to determine when to repeat the mapping phase or to re-sample select areas. As noted above, indicators should not be evaluated in isolation but in combination with other indicators.

For the selection of appropriate triggers, participants emphasized the need for greater understanding of the sensitivity of indicators and their relationships with fish and invertebrate stocks. Information gathered during the mapping phase would be used to develop appropriate triggers, and additional research will probably be necessary. For example, additional work is required to understand natural variability in order to select trigger values. Similar to discussions during the 4th FiSCAO meeting, participants suggested that a working group of scientists would be needed to set appropriate threshold values for the indicators.

3.8 Indigenous and local knowledge

Indigenous and local knowledge is a valuable source of information for understanding and monitoring changes in Arctic fisheries. During the monitoring phase, it is expected that indigenous and local knowledge, particularly from coastal communities in regions adjacent to the High Seas CAO would greatly enhance an ecosystem-based understanding of potential changes. The amount of Indigenous and local knowledge that has been directly collected in the High Seas CAO is likely to be minimal given the significant distance between High Seas waters and communities.

Participation by Indigenous knowledge holders will be important, and participants recommended continued engagement and continued development of monitoring programs with Indigenous Peoples. This important element of the monitoring program is expected to be expanded during its further

development. In addition, existing organizations or programs were identified that may contribute relevant information including: the Inuit Circumpolar Council (ICC); the [Exchange for Local Observations and Knowledge of the Arctic \(ELOKA\)](#); and the Alaska Native Organizations that work cooperatively with U.S. federal government agencies through Marine Mammal Protection Act cooperative agreements (e.g., [Alaska Eskimo Whaling Commission](#), [Eskimo Walrus Commission](#)).

3.9 Development of methods and data assessment

Detailed methods and data assessment techniques need to be developed. Several options for the data assessment were suggested, including the option of leveraging activities by other analytical groups, such as the Working Group on the Integrated Assessments of the Barents Sea (WGIBAR). However, it was noted that other analytical groups may not use metrics that are most relevant to address the objectives of the FISCAO monitoring program. An alternative option is to create a new working group supported by all participating states.

A working group of scientists could undertake further refinement of indicators and develop appropriate triggers, develop methods and perform assessments. The following are potential items that may be considered by a working group:

- Define key areas where potential changes are anticipated in commercial fish and invertebrate species (e.g. Chukchi borderlands, Russian shelves).
- Determine appropriate methods for data collection and what data to request from surveys including considerations for:
 - Sampling locations.
 - Fishing gear.
- Determine appropriate data analyses including considerations for:
 - Analyses using multivariate indices to combine information from multiple survey sources.
 - Region-level analyses of all surveys instead of survey-level analyses.
 - Statistical techniques to identify changes in the distribution of a species and changes in the geographic centre of a species (e.g., FishStat; ICES FishDish workshop).
 - Statistical techniques to detect regime changes.
- Improve understanding of inter-relationships between indicators and fish/invertebrate species and ecosystems including considerations for:
 - Examining how fish distribution may change with temperature and sea ice.
 - Identifying limiting oceanographic factors (including nutrients) for production.
 - Evaluating ocean acidification as an indicator.
 - Determine or develop means of understanding how much primary production would be required in the High Seas CAO to support higher fish productivity.
- Determining appropriate triggers including considerations for:
 - Assessing multiple years of data (>5 years) to understand the influence of inter-annual variability, which is necessary to set appropriate values for triggers.
 - Determining appropriate timeframes for change.

4 ToR 3: Preliminary cost estimates for mapping and monitoring

4.1 Introduction

ToR 3 called for the identification of resource needs (human, vessel and equipment) for the mapping and monitoring components of the joint scientific research and monitoring plan. In this section of the report, the goals of mapping and monitoring are briefly reviewed and example budgets based on participants' experience with similar programs in the Pacific Gateway and in the High Seas CAO are provided.

4.2 Resources related to mapping

Baseline information, especially on fish populations, is lacking for many parts of the CAO and most notably for the High Seas region, hence a substantial mapping effort is initially required. Here, mapping refers to the initial data collection and analysis in the area with the aim of creating an initial snapshot of the system to assess what species reside in the High Seas CAO, their spatial variability, and their relative abundance. A synoptic mapping survey should be carried out, covering as much of the High Seas CAO as possible in order to characterize fish and invertebrate communities and their spatial variability.

Ideally, the initial mapping phase should consist of ecosystem-based synoptic surveys that sample as much of the High Seas CAO (2.8 million km²) as possible. These surveys should characterize the presence of demersal and shellfish stocks in the region but should also collect ecosystem related information consistent with three data tiers described under ToR 1. In addition to sampling fish resources, data collection should include oceanographic observations, primary production measurements, zooplankton abundance and species composition, seabird and marine mammal observations, etc. that will collectively help identify environmental drivers, food-web interactions, and key ecosystem linkages.

4.3 Existing mapping efforts

The 10 participating states in the Arctic fisheries negotiations have conducted relevant Arctic research for at least the past six decades, as was described in presentations from the [3rd FiSCAO meeting](#). A variety of physical and biological observations relevant to mapping have been taken recently from a variety of platforms (ships, moorings, AUVs, remote sensing) in the High Seas CAO and adjacent areas.

4.4 Areas to map

To achieve the goals of the mapping program, three general regions of the CAO were identified because of the different resources and platforms that will be needed to accomplish the goals of the program:

- Ice-covered and ice-free zones of the High Seas CAO.
- Ice-covered and ice-free zones of the High Seas CAO adjacent to the Pacific Gateway.
- Ice-free zones of the High Seas CAO adjacent to the Atlantic gateway.

Costing case studies were developed for the first two regions to provide contrasts between the resources and costs associated with surveying an area using a vessel of opportunity or a dedicated vessel, and between surveying ice-covered and ice-free zones. Because of the vastly different resources and approaches needed to sample in ice-covered High Seas areas compared to the Pacific Gateway region, the resources required for each area are treated separately below. In addition, research in the

High Seas CAO and in the High Seas CAO adjacent to the Pacific Gateway would generate significant amounts of data that will require data management, analysis and storage; accordingly, resource needs for those activities are combined (see section [4.9 Resource needs for data analysis, coordination and management associated with the mapping and monitoring phases](#)).

4.5 Interpretation of cost estimates and contrasting approaches

Caution should be applied when reviewing the preliminary cost estimates provided in this document. The cost estimates provided for work in the High Seas CAO rely on accessing a vessel of opportunity with additional support from a supply vessel that will be undertaking a research project in the High Seas CAO in 2019-2020 (i.e., Germany's MOSAiC project using the RV *Polarstern* icebreaker and resupply vessels). In contrast, the cost estimates provided for working in the High Seas CAO adjacent to the Pacific Gateway do not leverage a planned research project and therefore reflect the full costs of undertaking a mapping survey.

There are also significant differences in the type of research and data that can be generated by the two approaches. Work on vessels of opportunity must balance the priorities of multiple partners and the research capabilities can be limited to the vessel design, number of project-dedicated staff onboard and access and operability of gear and equipment. For the mapping program in the High Seas CAO, using a vessel of opportunity such as the RV *Polarstern* will provide limited coverage relative to the large area of the High Seas CAO (2.8 million km²). Independently organized surveys have fewer competing priorities to address, can generally cover a larger area and can plan to include the use of more appropriate vessels and gear for fish and ecosystem research. However, independently organized surveys are challenged by limited availability of appropriate vessels and significantly higher resource costs.

4.6 Ice-covered and ice-free portions of the High Seas CAO

Large parts of the High Seas CAO are presently ice-covered year-round. It is therefore necessary to use research icebreakers equipped with fish echosounders and pelagic trawls. The backbone of the sampling will be hydroacoustic profiles of the water column, with pelagic fish detected based on their acoustic signatures and subsequent estimation of biomass. This sampling will be complemented by under-ice trawling for species such as *Boreogadus saida*, pelagic target trawls to calibrate hydroacoustic targets where possible, and the collection of physical and ecosystem parameters, such as temperature and salinity profiles, algal biomass in sea ice and water column, and zooplankton abundance.

Constraints:

- Since there are no regular survey programs in the High Seas CAO, vessels of opportunity must be used out of the very limited pool of icebreaking vessels suitable to fulfill this task.
- Due to the widespread ice coverage, sampling with conventional fishing gear is logistically challenging. Development of suitable ice-adapted gear to sample fish in the ice-covered oceans may therefore be necessary.
- The entirety of the CAO cannot be covered by a single survey because of the vast area (2.8 million km² – larger than the Mediterranean). To significantly extend the spatial and seasonal coverage of the mapping program, Acoustic Zooplankton and Fish Profilers (AZFP) equipped to

autonomously collect and transmit hydroacoustic data would need to be deployed in combination with autonomous bio-physical sea ice observatories on free drifting ice floes.

4.6.1 Focus area and timing of a limited survey in the High Seas CAO by MOSAIC

The target area of the mapping survey is the High Seas CAO, an area mostly situated in deep-sea waters north of 80°N. The survey should be conducted as soon as possible, i.e., in the next 2-3 years.

Information about seasonal changes in fish distributions is desirable. The international year-long drift expedition MOSAiC with the RV *Polarstern* in 2019-2020 would serve as an excellent and cost-effective basis for a limited mapping survey. Since trawling cannot be conducted during MOSAiC, data collection should be supplemented with a trawl survey using one of the supply vessels visiting the RV *Polarstern*, e.g., RV *Oden*. Alternatively, an independently-organised mapping survey in the CAO using a ship of opportunity cannot realistically be achieved before 2020 and to obtain a comparable level of mapping for the high Seas CAO as outlined for the High Seas CAO adjacent to the Pacific Gateway (see below), substantial higher resources than outlined in Table 2 would be needed.

Table 2. Estimated resources (\$K USD) needed for a survey in the High Seas CAO in conjunction with MOSAIC.

	Trawl survey	MOSAIC
Number of berths		
Fish	3	1
Ecosystem	1	-
Physical	1	-
Total	5	1
Time requirement (days)		
Fish	3	180*
Ecosystem	1	-
Physical	1	-
Transit	15	-
Total survey duration	20	180
Salaries costs		
~3 FTEs estimated at \$112K/year	224	112
Total salaries	224	112
Equipment and logistics costs		
Surface and Under-Ice Trawl (SUIT)	178	-
Logistical costs and consumables	12	12
Field equipment (pelagic trawl, AZFP, sensors, sampling tools)	107	487
Berth fee	178	320
Development of ice-suitable sampling gear	178	-
Travel costs	14	18
Total equipment and logistics costs	667	837
Total trawl survey including salaries	891	949
Total survey (\$K USD)	1840	

*Assuming a commitment to 6 of the 12 months of the drift project

4.7 Regions of the High Seas CAO adjacent to the Pacific Gateway

Sampling in ice-free zones should follow methods currently used by many fisheries oceanography surveys. Intensive sampling efforts can effectively sample data from all three data tiers identified in ToR1. Once resources and sampling capabilities are identified, sampling effort can be spread across the prioritized regions of the Pacific Gateway either through a systematic grid design, random sampling or mutually agreed upon “hotspot” stations similar to the Distributed Biological Observatory (DBO) approach. Regardless of the design used, instituting a sampling regime that effectively samples the three data tiers will need to be integrated at the station level and requires extensive sampling effort. Time required to accomplish these goals will likely reduce the number of stations to very low numbers, likely 2-3 stations per day. Considering the short window of sampling time and vessel endurance, this may require extensive prioritization of sampling effort in the ice-free zones.

For sampling in ice-covered zones, it is likely that much of this effort would occur on vessels of opportunity. Most of these vessels are used primarily for geophysical research and therefore are not configured for deploying common types of fishing gear. Adapting fishing methods such as trawling and longlining for use from icebreaker platforms would require development of innovative technologies to achieve these types of sampling. Determining a sampling design may be difficult if the research cruise has competing objectives. Due to issues such as the on deck foot print of sampling gear, and the total length of time required to deploy, fish and retrieve fishing gear, the use of gears such as under ice trawls (i.e., Surface and Under Ice Trawl (SUIT)) will likely need to receive top priority. Preferred sampling methods would need to compliment and not impede other cruise objectives. Alternatives such as longline deployment may accomplish this balance because setting and retrieval are relatively quick and the gear can actively sample while other cruise sampling objectives are being carried out.

4.7.1 Resources required for the high seas CAO adjacent to the Pacific Gateway

Sampling platforms are likely the most significant resources required. In the ice-free zones, vessel charter costs will be significant, as most vessels capable of operating in these regions will have high daily operating costs. Vessel size will likely be >200 ft and vessels will likely have an operational endurance of over 45 days, be able to deploy multiple scientific sampling gear types, and carry a minimum of 15 people. Fuel costs will be high as transit time from deep water ports must be included in all survey estimates. Additionally, operating in the High Seas CAO may limit the available vessels as many licenses are issued by countries and some vessels and captains may not be licensed to operate in international waters.

For operations in ice-covered zones, vessel costs can be extreme and exceed \$50,000 (USD)/day, and markets for suitable vessels is limited. Because of these constraints, and due to limitations on funding, survey operations may need to be conducted on vessels of opportunity and on scientific survey vessels that are designated for multiple sampling objectives. Under these scenarios, it is likely the number of scientists onboard that are dedicated to fish surveys may be reduced due to other mission interests and vessel capabilities. If the mission is dedicated to fishing, it is likely that up to 15 scientists would be needed to collect the full suite of fish and ancillary biological and abiotic data identified in ToR 1. Seasonal timing is important and surveys will need to be conducted in summer months, but because ice-

capable vessels are being used, the sampling timeframe may be slightly greater compared to work done in ice-free zones. As was noted above, sampling gear will need to be modified from commercially available sources or newly developed through research efforts to effectively sample from ice-capable vessel platforms. Equipment costs in ice-covered zones are likely to be much higher than for research cruises in ice-free zones where traditional sampling gear can be used.

4.7.2 Focus area and timing of survey of the high seas CAO adjacent to the Pacific Gateway

Shallow areas in and near the Pacific Gateway are expected to be more biologically productive than deeper waters. Therefore, increased sampling effort in shallower depths where fish resources and fishing activities may occur should be prioritized. Focusing on depths less than 1500 m provides a general guide for choosing survey areas in the Pacific Gateway. Further refining of these areas to depths <500 m, <1000 m, and <1500 m provides smaller scale geographical regions where prioritized sampling efforts should occur. While sampling efforts across the entire region are desired, these sub-regions provide focus areas that can be used to prioritize limited resources for conducting mapping efforts.

4.7.3 Survey timing and access to the High Seas CAO adjacent to the Pacific Gateway

Survey timing and seasonal ice extent in the Arctic are major considerations for establishing successful mapping operations. Because of the remote locations and transit times required by vessels, research operations will likely be limited by either the vessel's operational endurance or environmental conditions and ice extent. Ice extent in the Pacific Gateway region is variable and sampling time frames are limited and may be as short as 30 days in a year, likely in late summer or early fall (August-September). For research operations that do not use ice-capable vessels or under-ice sampling gear, the areas sampled can be defined as "ice-free zones", which would correspond to areas that experience ice-free conditions for a minimum of one month per year to allow sufficient time for sampling to occur. When accounting for transit times from the nearest deep water port, cruise duration will likely be 30-45 days, including on 25-30 days of sampling effort. For "ice-covered zones", ice hardened hull research vessels and innovative under ice sampling equipment will be required which may allow a broader time frame for sampling, but will also increase costs (Table 3). For these areas, vessels of opportunity are critical as platforms to conduct mapping operations. Research objectives will need to be prioritized since accomplishing the full complement of sampling goals may not be possible when using a vessel of opportunity.

Table 3. Estimated sampling plan requirements and associated costs (\$K USD) for conducting research in both ice-free zones and ice-covered zones in the High Seas CAO adjacent to the Pacific Gateway.

	Ice-free Zone	Ice-covered Zone
Survey timing	August – October	May – November
Sampling components: fish, ecosystem, oceanography	30 days needed for each component, best with simultaneous operations if vessel is compatible	35 days needed for each component, best with simultaneous operations if vessel is compatible
Survey duration (includes port call and transit)	50 days	60 days
Equipment costs	750	1500
Vessel/platform costs (fuel and moorage included)	1500 (30K/day)	4500 (75K/day)
Supplies/salaries/consumable costs	260	300
Sampling team number (on vessel)	12	15
New technology (under ice work or towed vehicles)	350	750
TOTALS (\$K USD)	2860	7050

4.8 Additional resource implications associated with the mapping and monitoring phases

Participants noted there are additional resource implications associated with mapping and monitoring. Resources would be needed for:

- Costs associated with a working group to plan scientific activities (secretariat support, travel, meeting logistics).
- Development and testing methods to collect and integrate data.
- Support for staff to develop a proof of concept for using existing survey data to develop a suite of indicators that are stable, informative and responsive.
- Costs to support the inclusion of indigenous and local knowledge, as appropriate.
- Collecting data on parameters and in areas that are not regularly assessed and reported by existing monitoring programs.¹
- Costs associated with a working group to develop data protocols and agreements.²
- Support for staff to coordinate data sharing, data management, data assessments and reporting.³

¹ ToR 2 includes a monitoring program strategy developed with the assumption that most of the data would be collected as part of existing monitoring programs in waters adjacent to the High Seas CAO. If new monitoring activities in the High Seas CAO or in waters adjacent to the High Seas CAO were required, resources needed would significantly increase

² See section on ToR 4 for activities associated with a data protocols and agreement working group.

³ Cost estimates for these activities have been incorporated into the next section “Resource needs for data analysis, coordination and management associated with the mapping and monitoring phases”.

4.9 Resource needs for data analysis, coordination and management associated with the mapping and monitoring phases

Ecosystem research requires extensive post-sampling support to process samples, catalog data, conduct laboratory experiments, and maintain and provide data through a data sharing agreement. Extensive laboratory time and raw data analysis is customary for ecosystem-based fieldwork because of the diverse data collected. Arctic research incurs particularly high time and costs because harsh field conditions limit processing in the field therefore samples need to be shipped to laboratories.

For the mapping phase, data analysis and reporting in a timely manner is critical, as this information needs to be synthesized and made available for decision making during the monitoring phase. From existing ecosystem studies, it is estimated that up to 25 people are needed to process raw data and make data available following a single survey (including laboratory work, data processing, modelling and data management). The preliminary cost estimate for labour and support related to data analysis and management requirements is \$250K (USD) per survey. In the short term, there would be requirements for group work space for data sharing while the project underway. In the long term, there would be requirements for data archiving and metadata record storage and, for meetings associated with data analysis, housing and synthesis. The costs may rise significantly depending on the data sharing, storage and management approaches that have yet to be decided and depending on the final design of the mapping program.

For the monitoring phase, estimated costs for data analysis, coordination and management are not provided in this document but there will be resources required for these activities on an ongoing basis. The details of the costs will need to be developed when refining the monitoring program.

5 ToR 4: Data collection, sharing, and hosting protocols

5.1 Purpose

A framework of data collection, sharing and hosting protocols is needed to ensure that data collected during the FiSCAO mapping and monitoring programs are available in a timely manner for the initial post-mapping analysis and ongoing monitoring. The framework needs to strike a balance between making data available to FiSCAO for assessments and protecting the intellectual property rights of primary investigators, organizations, institutions and countries.

Various examples of existing data sharing and hosting protocols are available from international groups, including ICES, Northwest Atlantic Fisheries Organization (NAFO) and the DBO. The DBO provides an excellent example framework for connecting databases from multiple countries and agencies, and is supported by the Sustaining Arctic Observing Networks (SAON) program. Adoption of similar protocols and frameworks would streamline integration of data collected during the FiSCAO mapping and monitoring programs with existing Arctic datasets.

A distributed database is preferred over a single hosted database. A distributed database combines metadata on existing data sets and data collection programs within a small hosted database, simplifying data discovery. Data records are hosted by member data centers, allowing data owners to maintain greater control over data access. Clear protocols for data sharing, use and publication are essential.

5.2 Proposed FiSCAO Data Policy and Release Guidelines

A draft data policy and release guideline was developed prior to the 5th FiSCAO meeting. The development of the draft document was largely based on the [DBO data policy and release guidelines \(Final Version, Feb. 20, 2015\)](#) and was further reviewed with participants of the meeting. The proposed FiSCAO data policy and release guideline document is found in [Appendix C](#).

5.3 Recommended next steps

Development of data sharing protocols will require legal discussions, negotiations and agreement among the participating states. This legal framework needs to be finalized before the sharing and analysis of data. A data protocol committee should be established as soon as possible after an agreement in principle among the participating states is reached. Recommended next steps include:

- Explore options for data archiving and data management of the FiSCAO data including:
 - Contacting the DBO data archive developers (e.g. Jacqueline Grebmeier) and managers to discuss the possibility of establishing a FiSCAO data archive and to discuss the successes and difficulties encountered with their data policies and protocols.
 - Contacting the CCAMLR to discuss data management options and to learn about the data sharing framework established for Southern Oceans.
- Develop an agreement with an existing organization to help data providers develop DOIs if their institutional or national data archive cannot provide the service.
- Conduct joint NOAA/ICES/PICES pilot study on data hosting and sharing protocols using the fish distribution dataset developed during the 4th FiSCAO meeting.

6 General conclusions

With respect to the design of a mapping program (ToR 1), participants agreed that filling knowledge gaps in the understanding of fish distribution in key areas in the High Seas CAO is the highest priority, and the mapping program should begin as soon as possible. Participants emphasized that existing planned surveys are very limited, and new resources will be required to implement the mapping program.

With respect to the design of a monitoring program (ToR 2), participants developed an inventory of existing monitoring programs that are critically important for detecting potential changes in the High Seas CAO, identified areas in which reliable monitoring would need to be implemented and agreed that further research is required to operationalize scientifically sound monitoring indicators.

With respect to resources needed to implement the mapping and monitoring programs (ToR 3), participants noted that a coordinating body will be required to effectively implement and oversee the mapping and monitoring programs and to carry out analyses of resulting data and reporting. Mapping of fish species in the High Seas CAO will require dedicated resources (either new or reallocation of existing resources), including vessels, personnel and sampling equipment. Vessels of opportunity could be used for some mapping and monitoring; these opportunities will also require some new resources. Data management and scientific analysis will require personnel and infrastructure investments.

With respect to data sharing and management (ToR 4), participants developed a draft data sharing policy as the foundation for a future data sharing protocol, including the technical specifications for data sharing. A data sharing protocol needs to be developed; this will require negotiation and legal review among the participating states. The data sharing protocol needs to be operational before the mapping program starts. A data management and data sharing pilot study should be undertaken building upon the FiSCAO fish inventory database that was initially developed for the 4th FiSCAO meeting. Representatives from NOAA, ICES and PICES expressed interest in collectively undertaking this pilot study.

With respect to the consideration of Indigenous and local knowledge, especially regarding ToR 1 and ToR 2 which make explicit reference to indigenous and local knowledge, participants recognized that indigenous and local knowledge is an important source of information but also noted that indigenous and local knowledge holders were not available to participate in the meeting. It is critically important that indigenous and local knowledge holders be involved during the operationalization of the joint program of scientific research and monitoring.

7 References

- Distributed Biological Observatory (DBO). <https://www.pmel.noaa.gov/dbo/>
- Fish Stock Experts of the Central Arctic Ocean (FISCAO). (2017). Final Report of the Fourth Meeting of Scientific Experts on Fish Stocks in the Central Arctic Ocean 2017. 1-82. https://www.afsc.noaa.gov/Arctic_fish_stocks_fourth_meeting/pdfs/FourthFISCAOreportfinalJan26_2017.pdf
- Fossheim, M., Primicerio, R., Johannesen, E., Ingvaldsen, R. B., Aschan, M. M., & Dolgov, A. V. (2015). Recent warming leads to a rapid borealization of fish communities in the Arctic. *Nature Climate Change*, 5 (7), 673-677.
- Frainer, A., Primicerio, R., Kortsch, S., Aune, M., Dolgov, A. V., Fossheim, M., & Aschan, M. M. (2017). Climate-driven changes in functional biogeography of Arctic marine fish communities. *Proceedings of the National Academy of Sciences*, 201706080.
- Haug, T., Bogstad, B., Chierici, M., Gjøsæter, H., Hallfredsson, E. H., Høines, Å. S., Hoel, A. H., Ingvaldsen, R. B., Lindal Jørgensen, L., Knutsen, T., Loeng, H., Naustvoll, L.-J., Røttingen, I. & Sunnanå, K. (2017). Future harvest of living resources in the Arctic Ocean north of the Nordic and Barents Seas: a review of possibilities and constraints. *Fisheries Research*, 188, 38–57.
- Hollowed, A. B., Planque, B., & Loeng, H. (2013). Potential movement of fish and shellfish stocks from the sub-Arctic to the Arctic Ocean. *Fisheries Oceanography*, 22 (5), 355-370.
- Ingvaldsen, R.B., Bogstad, B., Dolgov, A.V, Ellingsen, K.E., Gjøsæter, H., Gradinger, R., Johannesen, E., Tveraa, T., & Yoccoz, N.G. (2015). Sources of uncertainties in cod distribution models. *Nature Climate Change*, 5, 788-789.
- International Arctic Science Committee (IASC). Iceland: Arctic Portal; [accessed 2018 Feb 15]. <http://www.iasc.info/>
- Mueter, F. J., Weems, J., Farley, E. V., & Sigler, M. F. (2017). Arctic Ecosystem Integrated Survey (Arctic Eis): Marine ecosystem dynamics in the rapidly changing Pacific Arctic Gateway. *Deep Sea Res. II*, 135,1-6.
- Oslo Declaration. (2015). Declaration Concerning the Prevention of Unregulated High Seas Fishing in the Central Arctic Ocean. 1-2. <https://www.regjeringen.no/globalassets/departementene/ud/vedlegg/folkerett/declaration-on-arctic-fisheries-16-july-2015.pdf>
- Sustaining Arctic Observing Networks (SAON). <http://www.arcticobserving.org/>
- Third Meeting of Scientific Experts on Fish Stocks in the Central Arctic Ocean. 2015. https://www.afsc.noaa.gov/Arctic_fish_stocks_third_meeting/default.htm

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Appendix B: Inventory of monitoring programs in the High Seas CAO and adjacent waters

#	Country	Organization	Contact person	Geographic location of monitoring	Type of monitoring (physical/chemical/biological/trophic level, etc.)	Temporal span of monitoring (range of seasons, years or ongoing)	Likelihood of continuing	Availability of data
1	Canada	Fisheries and Oceans Canada	Kevin Hedges	Baffin Bay	<ul style="list-style-type: none"> Benthic fish and invertebrate community structure, physical oceanography, trophic interactions 	1999 and ongoing	high	Publicly available via OBIS (annual data uploads)
2	Canada	Environment and Climate Change Canada	Carina Gjerdrum	Eastern Arctic	<ul style="list-style-type: none"> opportunistic (ships of opportunity) observational surveys for seabirds (and other marine wildlife) 	Since 2007 and ongoing	Medium – based on year to year funding	Publicly available via OBIS (annual data uploads)
3	Canada	Fisheries and Oceans Canada	Marianne Marcoux	Eclipse Sound	<ul style="list-style-type: none"> Telemetry of narwhals, sharks, seals Acoustic tags for fish Zooplankton Water temperature and salinity Passive acoustic monitoring of marine mammals 	2017-ongoing	For a couple of years	Available on request
4	Canada	Fisheries and Oceans Canada	Marianne Marcoux	East Baffin (Clyde River and Qikiqtarjuaq)	<ul style="list-style-type: none"> Passive acoustic monitoring of marine mammals 	2012-ongoing	For a couple more years	Available on request
5	Canada	Fisheries and Oceans Canada	Humfrey Melling	Canadian High Arctic	<ul style="list-style-type: none"> Thickness & movement of multi-year ice Sea ice features (ridges, leads, floes, etc.) Ocean circulation Ocean temperature & stratification 	2003 and ongoing	Very low	In DFO data archive, Pacific Region, at IOS
6	Canada	Fisheries and Oceans Canada	Humfrey Melling	Eastern Beaufort Sea	<ul style="list-style-type: none"> Thickness & movement of sea ice at the periphery of the Beaufort Gyre Sea ice features (ridges, leads, floes, etc.) Ocean circulation Ocean temperature & stratification 	1990 and ongoing	Low	In DFO data archive, Pacific Region, at IOS

#	Country	Organization	Contact person	Geographic location of monitoring	Type of monitoring (physical/chemical/biological/ trophic level, etc.)	Temporal span of monitoring (range of seasons, years or ongoing)	Likelihood of continuing	Availability of data
7	Canada	Fisheries and Oceans Canada	Clark Richards	Barrow Strait/Lancaster Sound	<ul style="list-style-type: none"> physical oceanography, including: moored temperature, salinity, oxygen, water currents, ice draft, ice velocity Ship based CTD surveys Under-ice profiles (Icycler): CTD plus oxygen, fluorescence. Data available for 2003-2004 and 2007-2008, with plans for future deployments Opportunistic chemical/biological in situ samples 	1998 and ongoing	High	Publicly available through ODIS/MEDS
8	Canada	Fisheries and Oceans Canada	Les N. Harris	Cambridge Bay region on Southern Victoria Island (commercial ARCH stocks)	<ul style="list-style-type: none"> Monitoring of commercial catch since the 1960s Fishery-dependant sampling (collection of biological data) of commercially harvest ARCH since the 1970s Periodic fishery-independent sampling (on and off since the 1970s). More frequent monitoring as of late. Effort (CPUE) data has been monitored/collected since 2011 	1970s and ongoing	high	CPUE data are publicly available through the Nunavut General Monitoring Plan (annual uploads) All other data are summarized in reports but data are not publicly available
9	Canada	Fisheries and Oceans Canada	Andy Majewski	Beaufort Sea	<ul style="list-style-type: none"> Benthic/pelagic fish and invertebrate community structure, Ship and mooring-based oceanography and hydroacoustics, Marine productivity Trophic interactions 	Ship – 2012-2014, 2017 and ongoing Mooredings – 2017 and ongoing	Ship – high in short-term (1-2 years), medium in longer-term (3 years +) Mooredings - high	Metadata via Polar Data Catalogue Subset of datasets via published reports
10	China	Polar Research Institute of China	wulizhong@pric.org.cn	Canada Basin	<ul style="list-style-type: none"> Physical, chemical, biological oceanography Chlorophyll, PP, plankton community structure 	Summer, 2003, 2008, 2010, 2012, 2014, 2016, 2017	High (each year since 2017)	Via Chinese national Arctic and Antarctic Data Center, according to data sharing policy

#	Country	Organization	Contact person	Geographic location of monitoring	Type of monitoring (physical/chemical/biological/trophic level, etc.)	Temporal span of monitoring (range of seasons, years or ongoing)	Likelihood of continuing	Availability of data
11	China	Polar Research Institute of China	wulizhong@pric.org.cn	Chukchi Sea	<ul style="list-style-type: none"> Physical Oceanography Chemical Oceanography Biological Oceanography (Chlorophyll, PP, plankton community structure, benthic fish and invertebrate community structure) 	Summer, 1999, 2003, 2008, 2010, 2012, 2014, 2016, 2017	High (each year since 2017)	Via Chinese national Arctic and Antarctic Data Center according to data sharing policy
12	Germany	Alfred Wegener Institute	thomas.solt@awi.de	Fram Strait	<ul style="list-style-type: none"> Physical Oceanography Chemical Oceanography Biological Oceanography (Chlorophyll, PP, plankton community structure, benthic fauna) Vertical fluxes 	Annually, since 1999	High	Via PANGAEA data repository
13	Germany	Alfred Wegener Institute	martina.loebel@awi.de	Eurasian Arctic	<ul style="list-style-type: none"> Autonomous buoys and moorings: Physical Oceanography Chemical Oceanography Vertical fluxes 	Permanent, since 2014	High	Via PANGAEA data repository and FRAM data portal
14	Greenland	Greenland Institute of Natural Resources	Helle Torp Christensen	Disco Bay up to Upernavik	<ul style="list-style-type: none"> Net survey targeting Greenland Halibut (inshore) 	(2011)2014 - present	High	Data can be found in yearly reports from NAFO and ICES Data can be requested by contacting Greenland Institute of natural Resources
				Greenland west coast up to Upernavik	<ul style="list-style-type: none"> West Greenland shallow water trawl survey targeting fish and shrimp West Greenland deep water trawl survey targeting Greenland halibut 	1992 - present 1997 - present		
				Southern part of the Greenland East coast up to 66°N	<ul style="list-style-type: none"> East Greenland shallow water trawl survey targeting fish and shrimp 	Present time series 2008 and ongoing (Earlier time series targeting shrimp 1989-1992 and 1994-1996)		
					<ul style="list-style-type: none"> Deep water trawl survey targeting Greenland halibut 	1998 - present		

#	Country	Organization	Contact person	Geographic location of monitoring	Type of monitoring (physical/chemical/biological/trophic level, etc.)	Temporal span of monitoring (range of seasons, years or ongoing)	Likelihood of continuing	Availability of data
15	Iceland	Marine and Freshwater Research Institute	Hedinn Valdimars-son	Shelf and oceanic waters around Iceland	<ul style="list-style-type: none"> Physical oceanography, plankton, carbon 	1960 and ongoing (carbon since 1983)	high	At request from MFRI, partly also from ICES
16	Iceland	Marine and Freshwater Research Institute	Thorsteinn Sigurdsson Asta Gudmunds-dottir	Shelf and oceanic waters north of Iceland (to ca 70 N)	<ul style="list-style-type: none"> Capelin 	1980 and ongoing (plankton since 1965)	high	At request from MFRI, partly also from ICES
17	Iceland	Marine and Freshwater Research Institute	Gudmundur Thordarson Asta Gudmunds-dottir	Icelandic shelf area to 500 m	<ul style="list-style-type: none"> Demersal fish and invertebrates 	1985 and ongoing	high	At request from MFRI
18	Japan	Japan Agency for Marine-Earth Science and Technology	Takashi Kikuchi Shigeto Nishino	Pacific sector of the Arctic Ocean	<ul style="list-style-type: none"> Physical, chemical, and biological (lower trophic levels) oceanography, Meteorology Physical and chemical moorings and sediment traps 	1998 and ongoing	high	Publicly available via DARWIN
19	Japan	Faculty of Fisheries Sciences, Hokkaido University	Toru Hirawake	Bering Sea, Chukchi Sea	<ul style="list-style-type: none"> Physical, chemical, and biological oceanography, Bottom trawl survey Gill net survey 	Since 1957 and ongoing	middle	Data Record of Oceanographic Observations and Exploratory Fishing (Hokkaido University)
20	Republic of Korea	Korea Polar Research Institute	Hyoung Chul Shin Sung-Ho Kang	Some portion of Bering Strait, Chukchi Sea, waters off East Siberia	<ul style="list-style-type: none"> routine oceanographic measurements nutrient, pCO₂, chlorophyll lower trophic level sea ice buoy deployment (via cooperation) 	2010 and ongoing	high	metadata available (detailed data upon quest and consultation)

#	Country	Organization	Contact person	Geographic location of monitoring	Type of monitoring (physical/chemical/biological/ trophic level, etc.)	Temporal span of monitoring (range of seasons, years or ongoing)	Likelihood of continuing	Availability of data
21	Norway	Institute of Marine Research	Geir Odd Johansen Randi Ingvaldsen	Barents Sea and adjacent Arctic Ocean	<ul style="list-style-type: none"> Physical and chemical oceanography Phyto- and zooplankton Pelagic and demersal fish abundance, biomass, community structure Benthos abundance, biomass, community structure Marine mammal observations (absence/presence) Acoustic registrations trophic interactions 	Annual (August-September) since 2004. Ongoing.	High	Available at Norwegian Marine Data Centre
22	Norway	Institute of Marine Research	Elvar Hallfredsson	Eastern slope of Norwegian Sea/Fram Strait (68-80°N - 400-1500 m depth)	<ul style="list-style-type: none"> Greenland halibut and other deep-sea fish species Physical oceanography and acoustic registrations (from 2009) trophic interactions 	Autumn Annual 1994-2009 Biennial since 2009	High	Available at Norwegian Marine Data Centre
23	Norway	UIT/The Arctic University of Norway	Jørgen Schou Christiansen TUNU-Programme	Northeast Greenland fjords and shelf (70°N - 79°N)	<ul style="list-style-type: none"> Biodiversity and food webs – fishes (2002–2017) Biodiversity and food webs – plankton & benthos (2015 & 2017) Acoustics (2017) and seabed mapping (2010-2017) Physical and chemical oceanography (2002–2017) 	2002–2017	2019	Oceanography – data partly available at Norwegian Marine Data Centre. Biodiversity and food webs – data need “quality checks” before released
24	Norway	Institute of Marine Research	Asgeir Aglen	Barents Sea south of ice edge	<ul style="list-style-type: none"> Demersal fish abundance, biomass, community structure Physical oceanography 	1981	High	Available at Norwegian Marine Data Centre
25	Norway	Institute of Marine Research	Randi Ingvaldsen Espen Bagøien	Barents Sea – standard sections	<ul style="list-style-type: none"> Physical, chemical and biological oceanography Zooplankton biomass and abundance 	4-6 times each year, since 1977	High	Available at Norwegian Marine Data Centre

#	Country	Organization	Contact person	Geographic location of monitoring	Type of monitoring (physical/chemical/biological/trophic level, etc.)	Temporal span of monitoring (range of seasons, years or ongoing)	Likelihood of continuing	Availability of data
26	Norway	Institute of Marine Research	Randi Ingvaldsen	Southern Barents Sea	<ul style="list-style-type: none"> Volume flux of Atlantic Water - moorings 	1997 (continuous – replaced once a year)	High	Available at Norwegian Marine Data Centre
27	Norway	Institute of Marine Research	Randi Ingvaldsen	North of Svalbard	<ul style="list-style-type: none"> Volume flux of Atlantic Water - moorings 	2011 (continuous – replaced every second year)	High	Available at Norwegian Marine Data Centre
28	Norway	Institute of Marine Research	Nils Øien	West and north of Svalbard	<ul style="list-style-type: none"> Sighting surveys of common minke whales and other whales 	Summer, every 6 year	High	
29	Norway	Institute of Marine Research	Tore Haug	West Ice and East Ice	<ul style="list-style-type: none"> Aerial surveys to assess the abundance of harp seals 	March/April, every 5 year	High	
30	Norway	Norwegian Polar Institute		Barents Sea and north of Svalbard	<ul style="list-style-type: none"> Surveys to assess endemic seal and whale species 			
31	USA	Alaska Fisheries Science Center (NOAA/NMFS) RPA Program	Janet-Duffy Anderson	Chukchi Sea	<ul style="list-style-type: none"> Larval fish distribution and abundance Zooplankton distribution and abundance Physical oceanography 	2010 and ongoing	High	Publically available in compliance with NOAA PARR requirements (contact Janet Duffy-Anderson)
32	USA	Alaska Fisheries Science Center (NOAA/NMFS) EMA Program	Ed Farley	Chukchi Sea (US EEZ) and Beaufort Sea coast	<ul style="list-style-type: none"> Benthic, pelagic, and surface fishes; invertebrate community structure Physical oceanography Biological oceanography Food web/trophic interactions Fish life history 	Intermittent late summer surveys (2003, 2007, 2012, 2013, 2017, and 2019)	High through 2019	Data through 2013 publically available
33	USA	Alaska Fisheries Science Center (NOAA/NMFS) EMA Program	Ed Farley	Northeastern Bering Sea	<ul style="list-style-type: none"> Pelagic and surface fishes distribution and relative abundance Physical oceanography Biological oceanography Food web/trophic interactions Fish life history 	2002 and ongoing (September)	High	Data through 2015 publically available

#	Country	Organization	Contact person	Geographic location of monitoring	Type of monitoring (physical/chemical/biological/trophic level, etc.)	Temporal span of monitoring (range of seasons, years or ongoing)	Likelihood of continuing	Availability of data
34	USA	Alaska Fisheries Science Center (NOAA/NMFS) RECA Program	Ron Heintz	Pt. Barrow	<ul style="list-style-type: none"> Fish (midwater trawl, beach seine) Oceanography (CTD, moorings, ADCP, zooplankton) Energetics Food web/trophic interactions 	2013-2015	None	Publically available in InPort
35	USA	Alaska Fisheries Science Center (NOAA/NMFS) Groundfish Program	Bob Lauth	Northern Bering Sea	<ul style="list-style-type: none"> Benthic fish and invertebrate distribution and abundance Food web/trophic interactions Fish life history 	2010; biennial in odd years	Moderate	Publically available
36	USA	University of Alaska Fairbanks	Seth Danielson	NE Chukchi Sea (Hanna Shoal region) 71.6N, 161.5W	<p>Mooring-based measurements with annual turn-around via research vessel</p> <ul style="list-style-type: none"> Temperature Salinity Pressure Wave Height and Direction Current Speed and Direction Ice Draft Acoustic Backscatter Photosynthetically Available Radiation Particle Size Spectra Particle Concentrations Optical Backscatter Chlorophyll-a Fluorescence Colored Dissolved Organic Matter Dissolved Oxygen pH Partial Pressure of Carbon Dioxide Nitrate Underwater noises (marine mammal Vocalizations, vessel traffic, and other sounds) 	2014-present and ongoing	High	Publically available via the Alaska Ocean Observing System (AOOS) and from http://chukchiecosystemobservatory.org/

#	Country	Organization	Contact person	Geographic location of monitoring	Type of monitoring (physical/chemical/biological/trophic level, etc.)	Temporal span of monitoring (range of seasons, years or ongoing)	Likelihood of continuing	Availability of data
37	USA	US Geological Survey (USGS)	Vanessa von Biela	Beaufort Sea, Simpson Lagoon to Kaktovik	<ul style="list-style-type: none"> Nearshore fish assemblage with fyke nets, temperature, and salinity 	2017-2019 2003-2005 1988-1991	Low	Will be public at study completion
38	USA-Canada (Marine Arctic Ecosystem Study)	24 entities including BOEM, USARC, ONR, US and Canadian Coast Guards, DFO, IOS, Stantec, ASL, WHOI, VIMS, UAF, ODU, NSB, AOOS, Shell, Kavik-Stantec and others.	Guillermo Auad	Eastern Beaufort Sea (near international border)	<ul style="list-style-type: none"> Ecosystem structure and function Variables: biological, physical, chemical Carbon cycling 	2015-present	Funded through 2018 at least	Not yet available

Appendix C: Proposed FiSCAO Data Policy and Release Guidelines

[Based on: DBO DATA POLICY AND RELEASE GUIDELINES---Final Version (Feb. 20, 2015)]

Introduction

The FiSCAO group was established to answer the following questions:

- What are the distributions and abundances of species with a potential for future commercial harvests in the Central Arctic Ocean?
- What other information is needed to provide advice necessary for future sustainable harvests of commercial fish stocks and maintenance of dependent ecosystem components?
- What are the likely key ecological linkages between potentially harvestable fish stocks of the central Arctic Ocean and adjacent shelf ecosystems?
- Over the next 10-30 years, what changes in fish populations, dependent species, and the supporting ecosystems may occur in the central Arctic Ocean and the adjacent shelf ecosystems?

To answer these questions the FiSCAO group has developed mapping and monitoring plans for the High Seas region of the Central Arctic Ocean (CAO) and adjacent territorial waters (ToR 1 and ToR 2 of this report). The mapping program will collect baseline data on marine fishes, phytoplankton, zooplankton, benthos, marine mammals, seabirds and oceanography in the High Seas CAO. Data from the mapping phase will be used for initial assessments of species distributions and abundances, and to quantify trophic linkages. Monitoring programs in the High Seas CAO and adjacent territorial waters will collect data to support regular reassessments of populations and ecosystem status; detected changes could trigger new surveys in targeted areas in the CAO to re-evaluate potential commercial harvesting opportunities.

Coordinated multi-national mapping and monitoring programs will require the establishment of an agreement on a data management policy and protocols that permit the sharing of monitoring and research data related to the FiSCAO program (see FiSCAO 2017). The FiSCAO group noted that several international bodies have already developed data management policies (e.g., DBO, SAON and the International Arctic Science Committee (IASC), ICES and the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR)) that might address the FiSCAO group's needs for data standards and protocols for metadata, quality assurance and data sharing. Development of a distributed data management system is encouraged, in which each nation is responsible for the storage and maintenance of the data it collects, while software provides search and query capabilities across the individual databases. Establishment of a FiSCAO data network could be facilitated by leveraging existing networks, such as the DBO. Furthermore, CCAMLR has a long tradition of fishery- and ecosystem-related data sharing and data management, which may serve as an example and may offer expertise. The need for public data sharing limitations and protocols was identified as an important component of any data sharing agreement and policy.

Definition of the FiSCAO data archive

The FiSCAO distributed data archive will consist of a series of distributed data centers, combining data from multi-national FiSCAO and national sampling programs. A single site (website) will need to be developed for the submission of metadata that meet the standard FiSCAO metadata profile (see list of potential metadata profile in Table 1).

FiSCAO data (see list of potential data fields in Table 2) will need to be available to FiSCAO researchers in a timely manner for analysis, and to the larger community once initial analyses are completed. The first step in submitting FiSCAO data will be the completion of a metadata profile for the dataset. The data will then be submitted to a national or institutional data archive that is part of the FiSCAO distributed data archive. Metadata should be submitted as soon as possible (i.e. within one month) after completion of a sampling program. Data should be made available as soon as possible after collection and completion of quality assurance programs. A common, password protected shared data archive may be established (e.g., Circumpolar Biodiversity Monitoring Programme, SAON data portals) to facilitate analyses upon completion of the mapping phase of the FiSCAO program and repeated analyses throughout the monitoring phase.

Data centers that are part of the FiSCAO distributed data archive will need to coordinate their data management activities, including developing consistent metadata generation, curation and interoperability. When data submitted directly to an institutional or national archive are deemed ready for long term storage and distribution, a final version of the data and metadata will be uploaded or linked to the shared-archive, if one has been created.

Fish distribution dataset

A dataset of fish observations in the CAO and adjacent waters was created during the 4th FiSCAO meeting. This database is continuing to be maintained by the U.S. National Oceanic and Atmospheric Administration (NOAA)⁴ and researchers are encouraged to contribute new observations from the High Seas CAO and adjacent waters to the database. At a minimum, records need to include the species binomial (i.e. scientific name; genus and species), data and location of collection. Ultimately, use of this database will be governed by the proposed FiSCAO data policy and protocols.

Data policy in compliance with IASC and other collaborative Arctic activities

Any policy for the dissemination of FiSCAO data should be consistent and compliant with international standards and agreements such as the IASC Statement of Principles and Practices for Arctic Data Management. That is, free, timely, and unrestricted exchange of essential data and products to the maximum extent possible. The proposed FiSCAO data policy approach is fully compatible with the World Meteorological Organization (WMO) Climate Variability and Predictability (CLIVAR) Data Policy. The

⁴ Contact Chris Lunsford, Chris.Lunsford@noaa.gov

FiSCAO data archive will follow the WMO Core Profile of the ISO 19115: Geographic Information --- Metadata standard.

This FiSCAO policy is not meant to conflict with or supersede any national or international agency policy related to public access to these data.

Broad community access to data

Final FiSCAO data products should be made publicly available on the internet. It is in the best interests of both data providers and potential users to maintain only the latest version of fully audited data and metadata in FiSCAO archives. This will allow the FiSCAO archives to alert users of data revisions or updates. Unrestricted copying of original data from sources outside FiSCAO archives may lead to the propagation of errors in data analyses, confusion regarding data versions, incomplete metrics and loss of recognition of FiSCAO as the data source. The sharing of data through a common password protected FiSCAO shared archive would allow for the distribution of preliminary data among the FiSCAO group before it is submitted to national or institutional archives and made fully accessible to the broader community.

The resulting distributed database will follow the standards of the international community on data sharing (e.g., the Arctic Data Committee).

Acknowledgement and citation

Whenever FiSCAO data are downloaded from the archive and used in publications, the data's origin should be acknowledged and referenced. Every user is responsible for referencing the Principle Investigator (PI) responsible for creating the dataset that is used and identifying that the dataset was obtained through the FiSCAO data archive. If multiple sources have been used, acknowledgement must be provided for each dataset used.

International agencies, professional societies and research organizations are moving towards the formal citation of data and sources that led to a given analytical result or conclusion. Consequently, there has been increased use of DOIs (Digital Object Identifiers) as a simple, standard way to reference datasets. DOIs allow for linkages between datasets and respective publications, providing the ability to track the use of individual datasets in the literature and to provide metrics of their use or influence. DOIs are considered perpetual and provide proper attribution, even if a dataset is moved between archives. Standards have been established for the creation of data DOIs and have been supported by international coordination groups such as the Research Data Alliance (RDA).

Co-authorship for FiSCAO Principal Investigators

Research programs that contribute data to FiSCAO use sophisticated, state-of-the-art instrumentation and comply with strict requirements for maintenance, exposure of instruments, calibration, quality assurance procedures and the like, in order to achieve the highest attainable standards of measurement, accuracy, representativeness, stability and repeatability. To ensure that this goal is

reached, PIs who are leading experts for their instruments will take responsibility for individual instruments operated on the respective research program.

Users of FiSCAO data are encouraged to establish direct contact with the FiSCAO Scientific Point of Contact for each data set used; this contact is included in the metadata for each data set. The FiSCAO Scientific Point of Contact will discuss the planned use of the dataset and, if necessary, put the data user in contact with the data set PI as the data provider for the purpose of complete interpretation and analysis of data for publication purposes. Co-authorship of FiSCAO PIs on publications that make extensive use of FiSCAO data is warranted if their work has contributed to the study in question, or if the PI has directly contributed to the publication in other ways. It is highly recommended that any data user contact the responsible PI and discuss whether the PI's data collection and Quality Assurance (QA) or Quality Control (QC) work warrants co-authorship or an acknowledgement.

FiSCAO publication list

Users of FiSCAO data are strongly encouraged to submit citations for any publications or products that make use of FiSCAO data to the FiSCAO shared archive. The FiSCAO shared archive will develop a citation list of FiSCAO publications from the submitted citations. Whenever possible, the FiSCAO archive will use DOIs to link to a publication to its data source(s). The FiSCAO shared archive will make the FiSCAO citation list public via the archive website to provide a continuous record of applications and analyses of FiSCAO data and FiSCAO scientific achievements.

References

Arctic Data Committee (ADC). <https://arcticdc.org/>

Circumpolar Biodiversity Monitoring Programme (CBMP). <https://www.caff.is/monitoring>

Distributed Biological Observatory (DBO). <https://www.pmel.noaa.gov/dbo/>

Fish Stocks in the Central Arctic Ocean (FiSCAO). (2017). Final Report of the Fourth Meeting of Scientific Experts on Fish Stocks in the Central Arctic Ocean 2017. 1-82. https://www.afsc.noaa.gov/Arctic_fish_stocks_fourth_meeting/pdfs/FourthFiSCAOreportfinalJan26_2017.pdf

International Arctic Science Committee (IASC). Iceland: Arctic Portal; [accessed 2018 Feb 15]. <http://www.iasc.info/>

Research Data Alliance (RDA). <https://www.rd-alliance.org/>

Sustaining Arctic Observing Networks (SAON). <http://www.arcticobserving.org/>

World Meteorological Organization, Climate and Ocean: Variability Predictability and Change Data Policy <http://www.clivar.org/resources/data/data-policy>

Table 1: FiSCAO metadata profile

	Metadata Field Name	Definition
General	title	A name given to the data set.
	dataset authors	The person(s) receiving credit for the data set, as in a citation (usually the PI).
	FiSCAO scientific point of contact	The person(s) to contact when using the data, to make link with dataset authors, for data requests and interpretations.
	organizations	The organization(s) for which the PIs worked at the time of data collection
	description	A summary of data set content
	language	Language of the data set (e.g. English, Japanese, Korean)
Dataset Details	cruise number	Cruise ID or Number
	funding agency	The Agency providing funding (e.g. JAMSTEC, NSF, NOAA)
	grant, project or award number	Agency assigned Grant or Award number
	temporal coverage start	Begin date of full data set
	temporal coverage end	End date of full data set
	continuation	Likelihood that the data collection will continue and be useful for ongoing monitoring (categorical)
	temporal resolution	The sampling or reporting frequency of an instrument or platform
	northernmost latitude	Northern extent of data collection in decimal degrees
	southernmost latitude	Southern extent of data collection in decimal degrees
	westernmost longitude	Western extent of data collection in decimal degrees
	easternmost longitude	Eastern extent of data collection in decimal degrees
	regions occupied	List of large marine ecosystems in which data were collected.
	Contact Info	point of contact
principal investigator		The PI responsible for leading the project
publisher		The Institution where the data resides and responsible for distributing the data set (e.g. KOPRI, JAMSTEC, PRIC, UCAR/NCAR, CCIN)
weblink to dataset		Electronic link to location of dataset (e.g., KOPRI, JAMSTEC, AOOS, EOL)
Data Details	platform	The vessel or vehicle from which instruments are deployed, or name of ice station
	instrument	The name of the instrument used to acquire the data
	keywords	Suite of data type collected, with pull down menu of parameters from FiSCAO data matrix: e.g., CTD, ADCP, bottle data for chlorophyll, nutrients; abundance, biomass and composition of Ice algae, phytoplankton, zooplankton, benthic fauna (infauna and epifauna) and fish; seabird and marine mammal surveys; Mooring data (T, S, Currents, fluorescence, nutrients, sediment trap); Satellite data (surface T, S, wind)
	science keywords	GCMD Science Keywords
	data version	Version number of the data set available
	dataset last revision date	Date the data set was last revised
	distribution format	Distributed file format of the data set (e.g. excel, ascii, multiple)
	data set progress	Amount of progress through to data publication (i.e ongoing, complete)
	access restriction	Password protection required
	Citation	
DOI		List if known

Table 2: FiSCAO data fields

Data category	Data field
Oceanographic conditions	conductivity
	temperature
	depth
	current direction
	current speed
	turbidity
	fluorescence
	chlorophyll
Sea ice observations from ships	dissolved nutrients
	sea ice concentration
Species specific abundance and biomass	Sea ice thickness
	ice algae
	phytoplankton
	zooplankton
	benthic in fauna
	benthic epifauna
	fishes
	sea birds
Measurements and biological samples collected from individuals	marine mammals
	morphometrics
	ageing structures
	organ weights and volumes
	stable isotope samples
	genetics samples
Sediment	sample storage location
	grain size
	organic carbon content
Satellite data	chlorophyll <i>a</i> content
	chlorophyll pigment concentration
	sea surface temperature
	sea ice concentration
	cloud fraction
Analytical results	winds
	sea level pressure
	stable isotope values
	fatty acid values
	genetic sequences