Framework of the CAOFA Joint Program of Scientific Research and Monitoring (JPSRM)

Central Arctic Ocean Fisheries Agreement (CAOFA)
Scientific Coordinating Group (SCG)

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1 Background

1.1 Introduction

A landmark international agreement was established to promote effective stewardship of Arctic marine living resources: the *Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean* (Appendix 1). The Agreement (also known as the "Central Arctic Ocean Fisheries Agreement" or CAOFA) entered into force on June 25, 2021 after ratification by all ten of the Signatories (Canada, the People's Republic of China, the Kingdom of Denmark in respect of the Faroe Islands and Greenland, Iceland, Japan, the Republic of Korea, the Kingdom of Norway, the Russian Federation, the United States of America, and the European Union).

The objective of the Agreement (Article 2) is to prevent unregulated fishing in the high seas portion of the central Arctic Ocean through the application of precautionary conservation and management measures as part of a long-term strategy to safeguard healthy marine ecosystems and to ensure the conservation and sustainable use of fish stocks.

By providing time for the collection of scientific knowledge, Indigenous Knowledge, and local knowledge before the commencement of commercial fishing, the CAOFA creates a rare opportunity to understand the structure and dynamics of central Arctic Ocean (CAO) ecosystems. This understanding is crucial for development of long term management strategies that support sustainable fishing in the CAO high seas and safeguard healthy marine ecosystems that support subsistence resources. As sea ice coverage continues to decline in the CAO and other anthropogenic activities, increase in extent and frequency, assessment of multiple, interacting stressors will be important to support the sustainability of CAO ecosystems in accordance with the objective of CAOFA.

1.2 Objectives, development, and timeline

Article 4 of the Agreement calls for the creation of a Joint Program of Scientific Research and Monitoring (JPSRM) as follows:

1. The Parties shall facilitate cooperation in scientific activities with the goal of increasing knowledge of the living marine resources of the central Arctic Ocean and the ecosystems in which they occur.
2. The Parties agree to establish, within two years of the entry into force of this Agreement, a Joint Program of Scientific Research and Monitoring with the aim of improving their understanding of the ecosystems of the Agreement Area and, in particular, of determining whether fish stocks might exist in the Agreement Area now or in the future that could be harvested on a sustainable basis and the possible impacts of such fisheries on the ecosystems of the Agreement Area.

3. The Parties shall guide the development, coordination and implementation of the Joint Program of Scientific Research and Monitoring.
4. The Parties shall ensure that the Joint Program of Scientific Research and Monitoring takes into account the work of relevant scientific and technical organizations, bodies and programs, as well as indigenous and local knowledge.
5. As part of the Joint Program of Scientific Research and Monitoring, the Parties shall adopt, within two years of the entry into force of this Agreement, a data sharing protocol and shall share relevant data, directly or through relevant scientific and technical organizations, bodies and programs, in accordance with that protocol.
6. The Parties shall hold joint scientific meetings, in person or otherwise, at least every two years and at least two months in advance of the meetings of the Parties that take place pursuant to Article 5 to present the results of their research, to review the best available scientific information, and to provide timely scientific advice to meetings of the Parties. The Parties shall adopt, within two years of the entry into force of this Agreement, terms of reference and other procedures for the functioning of the joint scientific meetings.

At its inaugural meeting in November, 2022, the CAOFA Conference of Parties (COP) highlighted the need for the CAOFA Scientific Coordinating Group (SCG) to conclude its work to develop the JPSRM in a timely manner so that the COP may consider the JPSRM for approval and adoption by the Agreement deadline of June 25, 2023 (Appendix 2). The COP emphasized that the initial document describing the JPSRM should be considered as a framework for the future work of the SCG. That framework may be revised and updated from time to time as new information requires. An associated JPSRM implementation plan will be developed following the COP's approval of the JPSRM framework presented in this document.

The JPSRM comprises an initial mapping phase that is envisioned to occur over a short time period (e.g., three-year duration) followed by a monitoring phase (FiSCAO 2015). The major goals of the mapping phase are to develop an understanding of baseline conditions and to test and evaluate different approaches, biological and ecological indicators, protocols, methods, Indigenous Knowledge, and local knowledge to be used during the monitoring phase. The appropriate threshold values (triggers) for the indicators need to be developed to determine when to repeat the mapping phase or to re-sample targeted areas during the monitoring phase.

As noted above, the Agreement stipulates that as part of the JPSRM, a data sharing protocol shall be adopted to share relevant data, directly or through relevant scientific and technical organizations, bodies and programs. Two working groups within the SCG were established to help develop the JPSRM: the Mapping and Monitoring Working Group (MM-WG) and the Data Sharing Protocol Working Group (DSP-WG).

1.2.1 Terms of reference: Mapping and Monitoring Working Group

The Mapping and Monitoring Working Group (MM-WG) was established to develop the mapping and monitoring plans for the JPSRM to achieve its aim, building on the draft plans from the 4th and 5th FiSCAO meetings and the 1st PSCG meeting and based on the questions and discussions from the 2nd PSCG meeting with the following Terms of Reference:

a. The MM-WG will consist of multiple representatives from each Party with expertise, including scientific, Indigenous Knowledge, and local knowledge, as well as appropriate external experts,

of ecosystem components of the JPSRM (e.g., fish, marine mammals, oceanography, ecosystem production, birds, and lower trophic level species).

b. The MM-WG will meet on a timeline determined by the working group with draft plans available for review and discussion.
c. The MM-WG may form smaller teams to meet separately with similar objectives and products to contribute to the overall draft plans.
d. The MM-WG will focus efforts on scientific, Indigenous Knowledge, and local knowledge activities concerned with:
    i. Mapping requirements in the Agreement Area, Atlantic, and Pacific gateways.
    ii. Monitoring requirements consistent with Article 4 of the Agreement.
    iii. Data collection (e.g., gear type) and data format standardization.
    iv. Prioritization of mapping and monitoring parameters as well as spatial and temporal sampling scales.

1.2.2 Terms of reference: Data Sharing Protocol Working Group

The Data Sharing Protocol Working Group (DSP-WG) was established to develop a data management policy and sharing protocols as part of the JPSRM, for consideration by the SCG and approval by the Parties, building on the draft plan from the 5th FiSCAO meeting and based on the discussions from the 2nd PSCG meeting with the following Terms of Reference:

a. The DSP-WG will consist of no more than three representatives from each Party including a technical expert, and no more than two representatives from any one external group, as appropriate.
b. The DSP-WG will meet on a timeline determined by the working group with a data management policy and sharing protocols plan available for review and discussion at the fall 2022 Provisional Science Coordinating Group (PSCG).
c. The DSP-WG will meet in two phases to: 1) identify the framework and specific policy components to be developed and 2) identify appropriate technical requirements.
    i. The DSP-WG will draft a hybrid framework that recognizes
    ii. A centralized data management system collected specifically for the JPSRM, and
    iii. A distributed data management system for relevant accessible data collected in the JPSRM area.
d. The DSP-WG will consider other international data management policies and sharing protocols to benefit from state-of-the-art agreements already in use.

In summary, the JPSRM will follow an ecosystem approach to assess: 1) the status of knowledge regarding marine ecosystem structure and function in the Agreement Area and adjacent waters, and identify gaps in knowledge of ecosystem components and functions, 2) the prospects and potential sustainability of commercial fisheries in the Agreement Area, 3) the potential impacts of such commercial fisheries on the marine ecosystems linked to the central Arctic Ocean, and 4) the potential impacts of commercial fisheries on Arctic Indigenous communities and local communities that depend on marine ecosystems for sustainable subsistence harvests. The JPSRM mapping and monitoring phases will enable the SCG to acquire and evaluate the information needed to make decisions that support the goals of CAOFA with respect to the management, sustainable use, and conservation of marine living resources in the central Arctic Ocean.

1.3 Geography

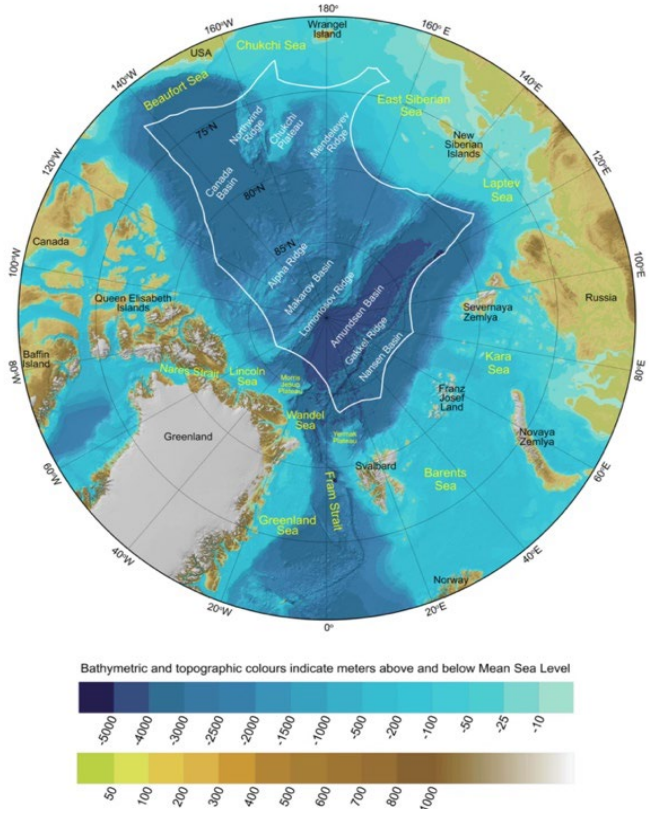


Figure 1. Bathymetric map of the central Arctic Ocean. The Agreement Area is situated within the white line, i.e., the high seas border extending 200 nautical miles from coastal baselines. The background map was extracted from the International Bathymetric Chart of the Arctic Ocean.[2]

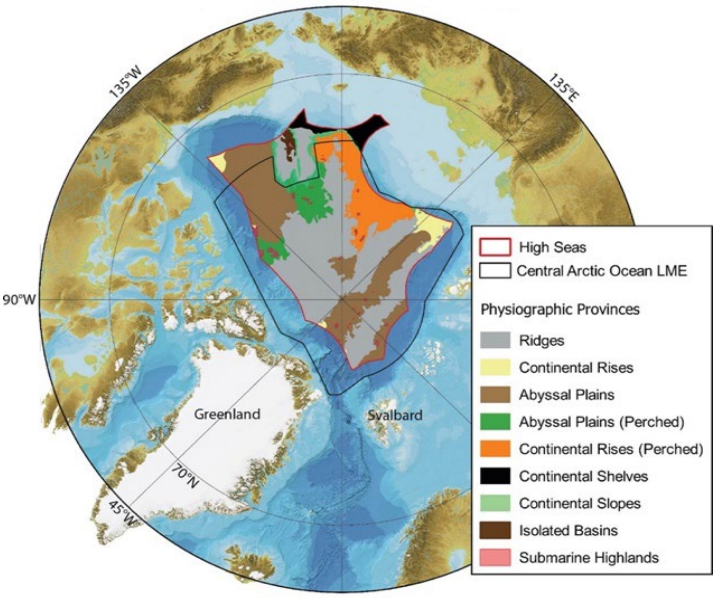


Figure 2. Map of the physiographic provinces in the Agreement Area. The red line is the high seas border cf. Figure 1. The black line is the Central Arctic Ocean Large Marine Ecosystem (CAO-LME) as defined by the Arctic Council.[3] The Physiographic Provinces were calculated by Martin Jakobsson.[4]

Because the issues to be addressed by CAOFA require information about marine ecosystems distributed broadly across the central Arctic Ocean as well as nearby areas, the JPSRM focuses on three ecologically linked zones: 1) the waters within the Agreement Area boundaries, 2) the continental shelf/slope areas peripheral to the Agreement Area, and 3) the Pacific and Atlantic marine gateways. The gateways are defined as the regions of substantial oceanographic flux between marginal seas of the Arctic Ocean and neighboring basins.

The Agreement Area itself comprises the high seas of the central Arctic Ocean, a 2.8 million km^2 area around the North Pole, that is surrounded by waters within which Canada, the Kingdom of Denmark in respect of Greenland, the Kingdom of Norway, the Russian Federation and the United States of America exercise fisheries jurisdiction. (Figure 1). The Agreement Area is characterized by several oceanic physiographic provinces (e.g. Figure 2). It mainly consists of permanently (winter and summer) ice-covered deep ocean (33.3% abyssal plains, 43.5% submarine ridges, 14.8% continental rises), but also some shallower areas that are not permanently ice-covered (3.3 % continental shelves, 3.2% continental slopes, 1.2% submarine highlands, 0.7% isolated basins). The latter areas could be expected to contain more living marine resources (e.g. fish, squid, crabs, marine mammals, and seabirds) than the permanently ice-covered deep ocean area. For clarity, the Agreement Area is not the same as the

Central Arctic Ocean Large Marine Ecosystem (CAO-LME) as defined by the Arctic Council based on ecosystem parameters (Figure 2).

The sea ice cover in the Agreement Area is gradually decreasing as a result of climate change. Today the major effect of warming in the central Arctic Ocean is that the ice is thinning and becoming more dynamic as winds can move thinner ice more easily. Within decades, most of the Agreement Area is expected to be accessible by non-icebreaking vessels, including fishing vessels, in late summer (August-October), but will likely still be covered by sea ice during the rest of the year.

The Agreement Area is not isolated. Its ecosystems are ecologically linked to peripheral Arctic shelf/slope ecosystems (visible as lighter marine zones in Figure 1) and Atlantic and Pacific gateways through physical, chemical, and biological processes intrinsic to ecosystem functioning. Climate change will likely alter the nature of those linkages (e.g., by northward transport of heat and changing distributions of species neighboring subarctic and Arctic areas into the Agreement Area). Such aspects should be covered by the JPSRM as well if they are relevant for the ecosystems of the Agreement Area. The Atlantic and Pacific gateways (and adjacent shelves and slopes) are recognized 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 area. These regions are also important seasonal and long-term migration corridors supporting distributional shifts of fish, marine mammals, birds, and crustaceans.

The Agreement recognizes the importance of involving Indigenous peoples and local peoples who live in coastal communities that depend on the bordering seas of the Agreement Area. Their involvement together with the science community promotes a holistic approach to incorporating coastal communities into the understanding the Arctic Ocean ecosystems and decisions made under the Agreement. A large portion of the bordering seas of the Agreement Area are offshore of the Inuit Homeland in Greenland, Canada, United States, and Russia (Figure 3). Figure 4 illustrates the distribution of Indigenous peoples in the Russian Federation.

Figure 3. Proximity of the Inuit Homeland to the CAOFA Agreement Area and boundary. Dark gray line indicates the boundary of the CAOFA Agreement Area. Dark green terrestrial areas show the Inuit Homeland as described by the Inuit Circumpolar Council.[1]

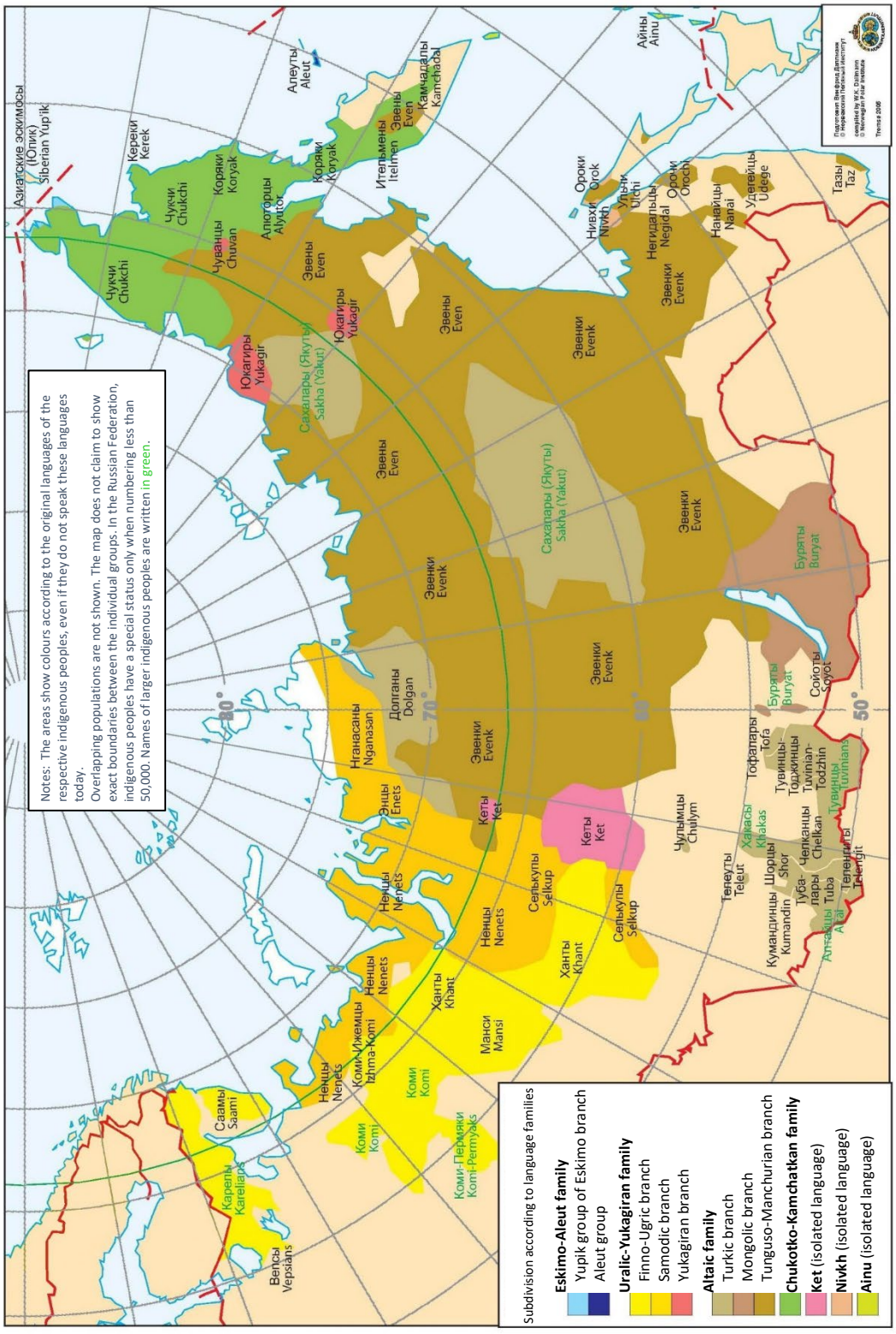


Figure 4. Indigenous peoples of the North, Siberia, and Far East of the Russian Federation. [This figure is based on information compiled by W.K. Dallmann and published by the Norwegian Polar Institute, Tromsø (2005), but modified here to show only the distribution of Indigenous peoples in the Russian Federation.]

2 Information Needs

2.1 Research and monitoring questions of the JPSRM

To guide the development of the JPSRM with a view to achieve its aim, the PSCG drafted a list of questions that were presented to the COP in November 2022 and detailed in the Report of the Third Meeting of the PSCG (Appendix 7). Those questions were developed and refined building on the work of two meetings of the Scientific Experts on Fish Stocks in the Central Arctic Ocean (FiSCAO) (Appendices 3, 4), three meetings of the Provisional Science Coordinating Group (PSCG) (Appendices 5, 6, 7). During its meeting in November 2022, the COP endorsed the two meeting reports of the PSCG report, indicating support for the work of the PSCG on the JPSRM, including the list of questions for the JPSRM developed and revised (Table 1), while also recognizing that different views existed on some questions. In particular, there was not consensus regarding the relevance of some human activities (e.g., ship noise, ship traffic, industrial activity, and pollution) to sustainable fisheries. Some delegations also expressed the need to prioritize the work of the SCG, on the objectives of the Agreement.

2.2 Prioritizing information needs

Answering the research and monitoring questions as presented in Table 1 will require focus on specific information needs (e.g., geographic areas and scales, seasonality and temporal scales, species, parameters to measure, existing information gaps). Those information needs cover many diverse topics whose relative importance and urgency will need to be evaluated as programmatic priorities are established and implemented. In the Mapping and Monitoring phase, the specific information needs will result from information gaps in geographical coverage and use of different sampling gear types.

Recognizing that there are practical limits to how and when such information can be developed into useful products and advice to the COP, the SCG will identify and set priorities for an achievable set of targets in the JPSRM implementation plan. Examples of some of the topics to be considered and assigned priorities in the JPSRM implementation plans are outlined in Appendices 8 and 9.

2.3 Sources of research and monitoring information

Article 4.4 of the Agreement directs Parties to ensure that the JPSRM takes into account the work of relevant scientific and technical organizations, bodies and programs, as well as Indigenous Knowledge and local knowledge. The SCG recognizes that all of these sources of knowledge can provide valuable insights relevant to achieving the aim of the JPSRM.

There are many sources of currently available scientific research and monitoring information relevant to the JPSRM: 1) data collected jointly for the SCG through dedicated efforts by Parties' national research programs, 2) data and reports from external groups active in the Arctic, and 3) published literature and results of recent research expeditions. Whenever possible, the SCG and its working groups will seek opportunities to utilize relevant information from published literature as well as reports and data products from external groups (e.g., national research programs, multi-lateral research initiatives, and international programs).

Table 1. Research and monitoring questions guiding the work of the Joint Program of Scientific Research and Monitoring (JPSRM) (Appendix 2).

Overarching question	Specific questions
1. What are the distributions of species with a potential for future commercial harvests in the Central Arctic Ocean?	a. What fish species are currently present in the high seas? b. Do fishable concentrations of commercial species exist in the high seas? c. What are their distributions and abundance patterns? d. What are their local life-history strategies, habitat associations, and demographic patterns? e. Do these strategies, associations, or patterns differ among regions of the Arctic?
2. What other information is needed to provide advice necessary for future sustainable harvests of commercial fish stocks and maintenance of dependent ecosystem components?	a. What are the trophic linkages among fishes and between fishes and other taxonomic groups (i.e. quantify food webs, including identifying keystone forage species)? b. How do fish species abundances and distributions vary in response to climate variability (e.g. time scale of change, extreme events, declining sea ice, and biogeochemical changes)? c. Can the species be harvested sustainably with respect to both target fish stocks and dependent parts of the ecosystem? If not, what are the prospects for the development of fisheries in the future?
3. What are the likely key ecological linkages between potentially harvestable fish stocks of the central Arctic Ocean and the adjacent shelf ecosystems which includes support for Indigenous communities and local communities?	a. What are the connections between fish in the High Seas and those in the adjacent regions? b. What are the mechanisms that establish and maintain these linkages? c. How might fisheries in the High Seas and that in the adjacent and congruent portions of the shelf ecosystems interact, including fish stocks, fishable invertebrates (crabs, shrimp, mollusks), marine mammals, birds, and fisheries-dependent communities (which include those communities that are dependent on subsistence harvests of fish, invertebrates, and mammals)?
4. 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?	a. Which marine species will likely increase and decrease in population size and/or productivity in the central Arctic Ocean in the next 10-30 years? b. What changes in production and key linkages are expected in the coming 10-30 years? c. What northward population expansions are expected in the next 10-30 years? d. What are the anticipated impacts of change in ocean acidification in the next 10-30 years? e. How will existing and increased human activity and pressures in the region likely affect fish populations and ecosystems, which includes support for Indigenous communities and local communities, in the next 10-30 years? f. How could increased fishing activity affect bycatch species, seabirds, migratory and wide-ranging marine mammals, and Indigenous communities and local communities that depend upon these species to sustain their ways of living?
5. What Indigenous knowledge and local knowledge is available, and how can it be taken into account, to inform ecological baselines?	

Dedicated JPSRM expeditions in the Arctic Ocean may be organized to fill existing data gaps in accordance with the Implementation Plan to be developed. Considering the time and financial cost of such expeditions, the SCG should establish spatial and topical priorities to promote efficient data collection. As needed, the SCG may also encourage and organize coordinated or synoptic surveys, monitoring, and new initiatives implemented with national and international collaborators (Table 2). For example, recent scientific expeditions and projects have collected valuable ecosystem and fish data in the Agreement Area (e.g., the international MOSAiC expedition,[7] 2019-2020; CHINARE Arctic expeditions, 2019-2021; several SAS expeditions, 2020-2022;[8] the INTAROS[9] project that established a Pan-Arctic collaboration between organizations, programs and projects involved in developing Arctic observing systems, 2017-2022; and other recent programs and projects relevant to the central Arctic Ocean[10,11,12,13,14]). Where feasible, information from complementary international science efforts should be leveraged to inform the JPSRM, such as the integration of circumpolar monitoring data on focal ecosystem components in the CAO and surrounding Arctic marine areas by the Circumpolar Biodiversity Monitoring Program (CBMP),[15] reports by the ICES/PICES/PAME Working Group on the Integrated

Ecosystem Assessment for the Central Arctic Ocean (WGICA),[16] monitoring in the Atlantic and Pacific gateways by groups such as the Joint Russian-Norwegian Working Group on Arctic Fisheries[17] in the Barents Sea, the Distributed Biological Observatory (DBO)[18] in the Pacific gateway since 2010, and the joint Iceland-Greenland capelin and ecosystem survey in Iceland sea and Greenland sea on the western side of the Atlantic gateway the Russian–American Long-term Census of the Arctic (RUSALCA) from the Bering Strait to the northwestern Chukchi Sea since 2004, the Joint PICES/ICES Working Group on the Integrated Ecosystem Assessment for the Northern Bering Sea - Chukchi Sea[19], U.S. fish and marine mammal surveys in the northern Bering, Chukchi, and Beaufort Seas, and the North Pacific Research Board's Arctic Program.[20]

In addition to scientific knowledge,[1] Indigenous Knowledge offers an opportunity to develop a holistic understanding of Arctic ecosystems to inform and support the design of the JPSRM. The Inuit Circumpolar Council has defined Indigenous Knowledge as:

> Indigenous Knowledge is a systematic way of thinking applied to phenomena across biological, physical, cultural, and spiritual systems. It includes insights based on evidence and acquired through direct and long-term experiences and extensive and multigenerational observation, lessons, and skills. It has developed over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation.[1,37]

For example, Indigenous Peoples who live along the U.S. Arctic coast of Alaska hold extensive knowledge of the Pacific Gateway and are involved in guiding the research together with science in the region, especially in the North Slope of Alaska. They possess extensive Indigenous Knowledge of the region, such as related to bowhead whales, other marine mammals, ship strikes, ocean currents, and the arrival of new species in the area. In the Inuvialuit settlement region of Canada, where Inuit and the government of Canada co-manage the resources, Indigenous Peoples living in these areas see first-hand the environmental changes that are occurring, especially when there are extreme events.]

3 Scientific Coordinating Group Responsibilities under the JPSRM

3.1 Mapping and monitoring

The CAOFA requires the Parties to establish a JPSRM with the aim of improving the understanding of the ecosystems of the Agreement Area and, in particular, of determining whether fish stocks might exist in the Agreement Area now or in the future that could be harvested on a sustainable basis and the possible impacts of such fisheries on the ecosystem of the Agreement Area. For achievement of goals claimed in Article 4.1 and 4.2, A principal goal of the JPSRM is to provide the key information needed to develop answers to the research and monitoring questions that will enable the SCG to develop useful advice to the COP. The mapping phase of the JPSRM will provide a current understanding of species distributions, relative abundances, and population structure in relation to biotic and abiotic factors. The monitoring phase of the JPSRM will focus on identifications of temporal variability or trends in species distribution or ecosystem productivity. As noted above, the JPSRM's mapping and monitoring phases will utilize several sources of information including data collected by the Parties' national research programs as

[1] Scientific knowledge is defined as means knowledge obtained and tested through use of the scientific method. Scientific knowledge may also include the observation and classification of facts with the goal of establishing verifiable knowledge derived through induction and hypothesis.

well as data and reports obtained through published literature and collaborators external to the SCG. In the monitoring phase, the SCG shall seek deep intervention/participation/collaboration in national and international programs.

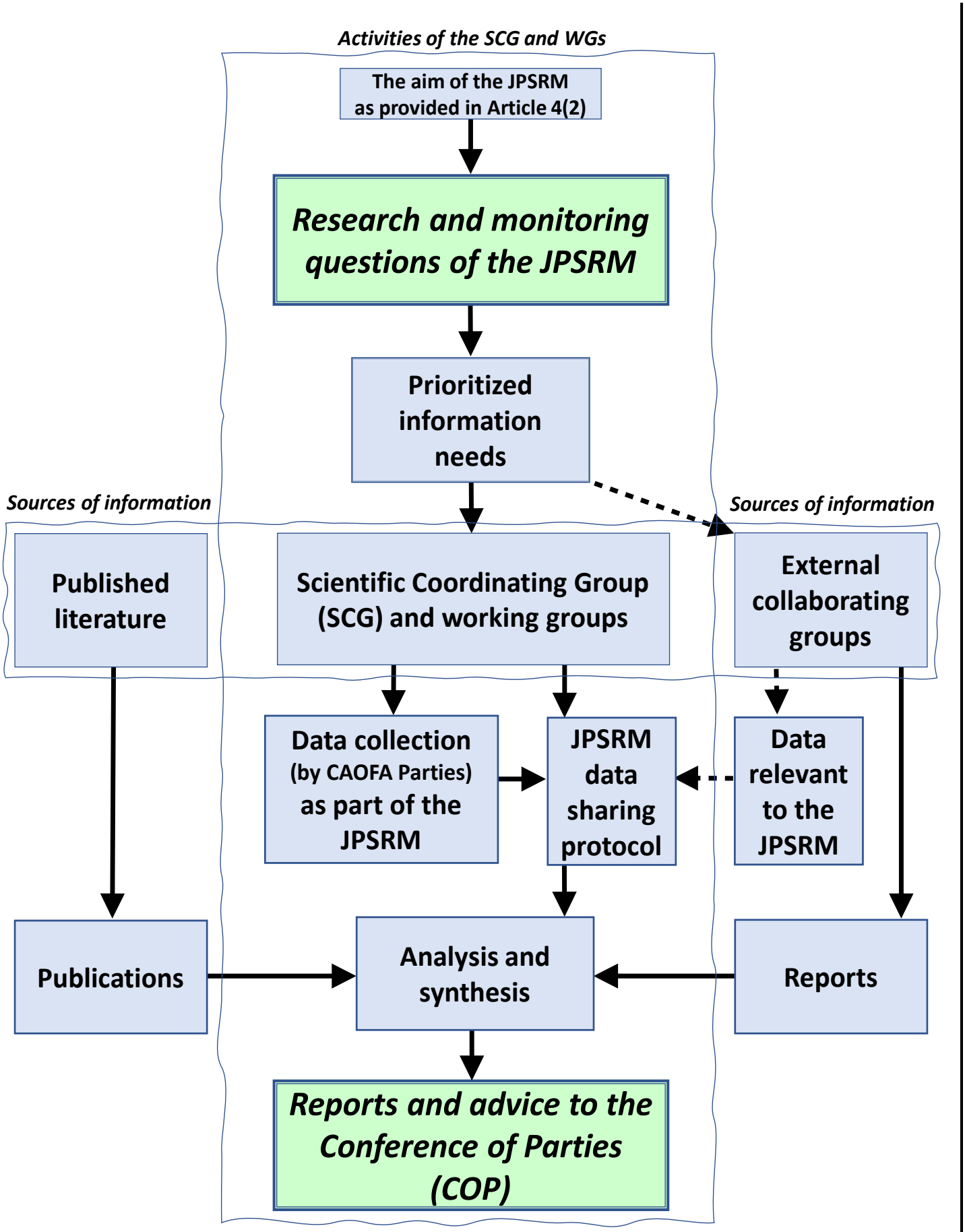
As detailed plans are developed for the implementation of the mapping and monitoring phases of the JPSRM, special attention should be given to identifying work relevant to the JPSRM that is already underway by external organizations and research initiatives, including efforts organized and led by Indigenous communities and organizations and local communities. It is clear that the Parties and the SCG cannot accomplish all of the JPSRM goals on their own. The high cost, logistical realities, and geographic breadth of the Arctic mapping and monitoring envisioned by the JPSRM require a collaborative approach. Several excellent research and monitoring programs currently exist that are collecting and analyzing data that are highly relevant to JPSRM goals (e.g., distribution and abundance, stock assessments, population status reviews, trophic interactions, and integrated ecosystem assessments). Therefore, the SCG will strive to encourage and promote the development of productive collaborations (and to avoid duplication) with some of the many external Arctic research groups (Table

Table 2. Examples of Arctic organizations and research initiatives that may be interested in sharing data and collaborating with the SCG through the JPSRM.

Group type	Group name	Acronym
Inter-governmental and international organizations	Arctic Council – Conservation of Arctic Flora and Fauna[21]	CAFF
	Arctic Council – Protection of the Arctic Marine Environment[22]	PAME
	Arctic Council – Arctic Monitoring and Assessment Program[23]	AMAP
	Arctic Council – Sustainable Development Working Group[24]	SDWG
	CAFF Circumpolar Biodiversity Monitoring Program-Marine[15,25]	CBMP-M
	CAFF Circumpolar Biodiversity Monitoring Program-Coastal[26]	CBMP-C
	ICES/PICES/PAME Working Group on Integrated Ecosystem Assessment for the Central Arctic Ocean[27]	WGICA
	International Arctic Science Committee[28]	IASC
	International Council for the Exploration of the Sea[29]	ICES
Inuit Circumpolar Council[30]ICC	Joint PICES/ICES Working Group on the Integrated Ecosystem Assessment for the Northern Bering Sea - Chukchi Sea[19]	PICES WG-44
	North Pacific Marine Science Organization[31]	PICES
	Pacific Arctic Group[32]	PAG
Multi-lateral research initiatives	Distributed Biological Observatory[5] (Pacific and Atlantic)[33]	DBO
	Drift Platform *Severny Polyus*[34]	DPSP
	European Fisheries Inventory in the Central Arctic Ocean[35]	EFICA
	Integrated Arctic Observations System[9]	INTAROS
	Multidisciplinary Drifting Observatory for the Study of Arctic Climate[7]	MOSAiC
	North Pacific Research Board[20]	NPRB
	Pacific Arctic Climate Ecosystem Observatory	PACEO
	Pan-Arctic Observing System of Systems[36]	Arctic PASSION
	Synoptic Arctic Survey[8]	SAS
	Tara Polar Station[37]	TPS

2) to share data, logistical platforms, and scientific expertise

Figure 5. From questions to advice – a framework of prioritized needs, information sources, processes, integration, and collaboration in support of the CAOFA Joint Program of Scientific Research and Monitoring (JPSRM) (solid lines indicate flow of information and products; dotted lines indicate pathways that may be agreed with external collaborators).



To answer key parts of the research and monitoring questions, the SCG will seek to organize dedicated field surveys to collect necessary information relevant to the priorities and topics as outlined in Appendices 8 and 9, which will be incorporated as part of the JPSRM implementation plan. Those efforts will be undertaken, as possible, through collaboration and joint support among the Parties' national research programs. The JPSRM implementation plan(s) will refine the specific information that will be needed (e.g., priority locations and seasons, parameters/indicators to map and monitor, types and frequency of data collection, analytical approaches).

A schematic framework describing the SCG's processes for using the JPSRM to move "From Aim to Questions to Advice" is presented in Figure 5. This framework identifies the JPSRM activities that the SCG and its working groups will conduct directly plus the contributions likely to be made by external groups and sources of relevant information.

3.2 Data management and sharing protocol

In accordance with Central Arctic Ocean Fisheries Agreement (CAOFA) and the *Recommendation of PSCG to Establish a PSCG Data Sharing Protocol Working Group (DSP-WG)* approved by the COP on May 31, 2022, the Data Management and Sharing Protocol shall be part of the Joint Program of Scientific Research and Monitoring (JPSRM), which builds upon the draft plan from the 5th FiSCAO meeting and was informed by the discussions during the PSCG meetings in 2022. This hybrid framework of Data Management and Sharing Protocol consists of a centralized data management system collected specifically for the JPSRM and a distributed data management system for relevant accessible data not directly associated with the JPSRM, also taking into account other international data management policies and sharing protocols and public data portals/repositories.

Objective

1. For the purpose of the CAOFA, this Data Management and Sharing Protocol shall serve as part of the JPSRM to promote data sharing efficiency towards the achievement of the JPSRM aim.

Data management

2. This Data Management and Sharing Protocol adopts a hybrid framework for data management to include the following:
    a. Data collected under the JPSRM are managed in a centralized data archive.
    b. Data collected by national scientific programs, and from sources external to the SCG and the Agreement that are relevant to the review and implementation of CAOFA are recorded and maintained through distributed data archives.

3. The SCG is responsible for the overall coordination of data management and data sharing. Specific responsibilities include:
    a. Identify roles and responsibilities of a Data Management Secretariat who will be responsible to store the JPSRM data managed in the centralized data archive and coordinate metadata of the original data in the distributed data archives.
    b. Identify the content and method of collection and sharing of Indigenous Knowledge and local knowledge.

c. Adopt and when necessary develop new standards and formats for data collection and management in accordance with international standards and following the internationally mandated principles of FAIR, CARE, TRUST, and EEE.[2]
d. Consider data submission time for different JPSRM datasets.
e. Consider potential embargo times for public accessibility of the different JPSRM datasets.

4. Establish a Data Management Secretariat to coordinate the collection, manage, and share the data managed through the centralized data archive.[3] Specific responsibilities of the Secretariat include:
   a. Inform all potential contributors of data to the JPSRM of the data management process under the Agreement and ensure that data will be made available swiftly and reliably, following the principles of the JPSRM data management plan.
   b. Develop and maintain the data management and sharing system.
   c. Ensure that JPSRM data and metadata are complete prior to acceptance.[4]
   d. Facilitate access by Parties of the JPSRM data for the purpose of implementation of the CAOFA.
   e. Facilitate inclusion and sharing of Record metadata for other scientific data relevant to the JPSRM from distributed data archive where appropriate.

5. The centralized data archive shall include the following:
   a. Data collected under the JPSRM.
   b. Indigenous Knowledge and local knowledge collected under the JPSRM.
   b. Metadata collected by national scientific programs.
   c. Metadata from relevant sources external to the SCG and the Agreement.
   d. Citation list of publications related to JPSRM data, Indigenous Knowledge, or local knowledge.

6. The distributed data archives may include the following information relevant to the implementation of CAOFA (harmonized text with 2b):
   a. Other scientific data collected by other national scientific programs and other sources external to the SCG.
   b. Historical data.
   c. Environmental or ecological data.
   d. Indigenous Knowledge and local knowledge as provided by its respective knowledge holders.

7. The data collected under the JPSRM (JPSRM data) and managed by the centralized data archive shall include:
   a. Raw data: the data recorded by observation equipment with minimal processing to remove extraneous values recorded between sampling events, and essential calibrations.
   b. Quality controlled data: the data after quality control that can be directly used for mapping and ecosystem evaluation.

[2] Added by EU.
[3] Comment from EU: We may consider writing instead: overseeing all data relevant to the JPSRM, including those from external sources.
[4] Comment from Canada: Are we referring to data validation / cleaning / remediation? If so, we would need to discuss how this "quality" will be checked? Further, what if the data transmitted are in such a state that cleaning it/ensuring quality places considerable workload on the individual handling it? Can the individual ask the Party to resend the dataset with corrections?

c. Data products: the data generated from mapping and evaluation of fish stocks and the ecosystem.

8. The JPSRM data should be submitted in the following time:
   a. The metadata will be submitted within one month after the completion of the data collection.
   b. The raw data will be submitted within 3 months after the completion of the data collection.
   c. The quality controlled data will be submitted within 1 year after the completion of the data collection with consideration for data quality control requirements consistent with section 3d.
   d. Metadata collected by national scientific programs data may be submitted to the centralized data archive within 1 year after the completion of the data collection.

9. The metadata for the centralized data archive will adopt the WMO Core Profile of the ISO 19115: Geographic Information Metadata standard.[5]

10. The JPSRM data shall be quality controlled by the original data observer or the owner of the observation instrument to ensure the quality of the data being processed.

11. Data submitted to the centralized data archive shall be quality checked by the Data Management Secretariat prior to acceptance into the archive.

Data sharing[6]

12. The JPSRM data shall be exchanged among all Parties in a free and unrestricted manner for the purpose of implementing the CAOFA.

13. Data collected from national programs, Indigenous Knowledge,[7] local knowledge, and international organizations shall respect national and international data policies.

14. The maximum duration prior to public sharing of JPSRM data would not exceed two years after the completion of the data collection (e.g., project or cruise). The implementation plan will address the level of data made publicly available.[8]

15. All Parties shall have equal rights and obligations regarding the management and sharing of data generated by the JPSRM.

16. The JPSRM data managed by the centralized data archive before public sharing will be password protected and accessible only by authorized Party individuals.

[5] Question from EU: Are there more metadata standards to consider?
[6] One example for a data sharing agreement is OBIS: https://manual.obis.org/policy
[7] Users are advised to consult the Circumpolar Inuit Protocols for the Equitable and Ethical Engagement: https://hh30e7.p3cdn1.secureserver.net/wp-content/uploads/EEE-Protocols-LR-WEB.pdf
[8] Suggestion of EU: Consider adding the reference to para 3(d)

17. For the purposes of implementing the CAOFA before public sharing, users shall directly apply to the Data Management Secretariat for access to JPSRM data, and the Secretariat shall directly provide the data upon confirmation.

18. For JPSRM scientific data intended for peer review publication, users shall apply directly to the data provider for review and final decision as to whether to use and publish the data.

19. For JPSRM Indigenous Knowledge intended for publication or public dissemination, acknowledging the unique nature of interpretation of Indigenous Knowledge, users shall apply directly to the knowledge provider for review and final decision as to whether to use and publish the knowledge.

20. For scientific data, Indigenous Knowledge or local knowledge collected under the JPSRM users shall apply directly to the data provider for possible use of the data in publication or any form of public dissemination not directly related to CAOFA, and the data provider has the final decision whether the data can be used and published. This practice is encouraged and should be followed after the two year data embargo (point 14) has ended.

21. The users shall apply directly to the data provider for access to data included in the distributed data archive. The data provider shall decide whether to share and provide data.

22. The JPSRM data will include data Digital Object Identifier (DOI) standards supported by international coordination groups such as the Research Data Alliance (RDA). The Data Management Secretariat shall entrust an existing organization to help data providers develop DOIs if their institutional or national data archive cannot provide the service.

23. When using the JPSRM data, the source of the data should be cited in the report or paper by means of DOI or in the acknowledgments department. If a published report or article uses data from different sources, specify the source of all the data.

24. A report or paper published using the JPSRM data, if the data provider or survey monitor contributed to the report or paper, the author of the paper or report should contact the data provider about whether to list the data provider or survey as a co-author.

25. The centralized data archive will develop a citation list of publications from the submitted citations. Whenever possible, the archive will use DOIs to link to a publication to its data source(s). The shared archive will make the citation list public via the archive website to provide a continuous record of applications and analyses of JPSRM data and JPSRM scientific achievements.

Terminology

26. *Centralized data management system* means that the data collected under the JPSRM are stored at a single physical location.

27. *Distributed data management system* means that the data collected by national program are stored by different programs or Parties.

28. *Metadata* are data that provides information about other data, but not the content of the data, such as the text of a message or the image of itself.

29. *Data provider* is the original entity that collected the information or provider of the information to the JPSRM archive.

30. *JPSRM data* are the scientific data, Indigenous Knowledge, or local knowledge collected under the JPSRM.

3.3 Reports and advice to the Conference of Parties (COP)

As products of the JPSRM, the SCG will submit bi-yearly summary reports to the COP based on JPSRM data collection, analyses, and syntheses. JPSRM participants will also be encouraged to publish their results in peer-reviewed journals to promote broad distribution and public awareness of the evolving ecosystem science occurring in the central Arctic Ocean.

The most important outcome of the JPSRM will be the scientific advice that the SCG will be able to generate and submit to the COP for its consideration. That advice will enable the COP to take science-informed decisions on important issues concerning management of possible central Arctic Ocean fisheries as well as their potential impacts on dependent and vulnerable species, Arctic marine ecosystems, and subsistence of Arctic Indigenous communities. To that end, it is important that the JPSRM collect data on all aspects of the CAO ecosystem to have the information that will be needed to provide advice based on sound science and Indigenous Knowledge.

4 External Sources of Data

4.1 Collaborations and protocols

Providing focused information and advice to the COP will require substantial efforts by many. Foremost will be the research and monitoring activities taken directly by the SCG through the implementation of the JPSRM, while collaborations with relevant Arctic groups external to the SCG will be helpful for the JPSRM to succeed. Wherever possible, the JPSRM will seek to solicit and develop collaborations with international and national expeditions, research projects, and monitoring programs. For example, existing Arctic programs could be encouraged to contribute to the aim of JPSRM. Similarly, it would be very helpful if existing and new research programs operating in Arctic shelf ecosystems and the Pacific and Atlantic gateways would consider incorporating JPSRM objectives into their sampling protocols and sharing of the data.

Collaborations in the Agreement Area and linked ecosystems involving joint expeditions, coordinated ships' cruise tracks, standardized sampling protocols, cooperative deployments of scientific moorings (e.g., acoustic, optical), and the sharing of samples, data, and analytical expertise will add tremendous strength to the JPSRM. Examples of groups and research initiatives external to the SCG that may be interested in collaborating with the SCG and Parties' national programs in support of the JPSRM are listed in Table 2. Details and plans for developing such collaborations will be developed as part of the JPSRM implementation plan.

There are many ways that the JPSRM can connect to established international and national expeditions planning research projects, and monitoring programs relevant to the objectives of the JPSRM (Table 3). In these cases, most of the costs for infrastructure and research are already financed and could be leveraged to collect additional data relevant for the JPSRM. The disadvantage to this approach is that the area, route, time and other parameters of the expedition will be decided by the expedition organizers and the JPSRM will have to work with the data collected. However, for projects that are still being planned or that will occur for several more years there may be opportunities for the SCG to become a project partner and therefore contribute to joint expedition planning and resourcing.

Table 3. Possible opportunities for external groups to measure JPSRM indicators.

Type of expedition	Possibilities for the JPSRM	Costs for the JPSRM
1. Dedicated icebreaker or drift platform for JPSRM research in the Agreement Area	Decide upon expedition area, route, time, etc. and collect the complete set of JPSRM indicators	Very high costs for ship/platform infrastructure and for JPSRM equipment and scientists
2. JPSRM owned buoys to be deployed by icebreakers opportunistically	Connect to scientific oceanographic expeditions for deployment	Development of buoys, e.g., ice-tethered buoy for fish and plankton research
3. Any icebreaker or drift platform equipped for scientific research in the Agreement Area	Include as many indicators of the JPSRM as possible in all scientific (geological, oceanographic, atmospheric, biological etc.) expeditions	Extra costs for adding fishery research (acoustics, long lines, ring nets, trawling, box coring, etc.) and JPSRM scientists to the expeditions
4. Any icebreaker or drift platform accessing the Agreement Area for other reasons than scientific research (tourism, etc.)	At least collection of hydroacoustic data for mapping fish distributions	Extra costs for equipping the vessels with acoustic equipment appropriate for JPSRM data collection. JPSRM scientists are only needed before and after the expedition
5. Vessels normally working in and near ice-covered waters in the Arctic and subarctic for scientific research or monitoring	Include as many indicators of the JPSRM as possible in all scientific (geological, oceanographic, atmospheric, biological, etc.) expeditions and extend the cruise track into the Agreement Area when the ice cover allows	Extra costs for adding fishery research (acoustics, long lines, ring nets, trawling, box coring, etc.) and for extending the expeditions into the Agreement Area when the ice cover allows
6. Fishery vessels normally working in the Arctic shelf seas for standard monitoring programs	Include as many indicators of the JPSRM as possible in the standard monitoring programs and extend the cruise track into the Agreement Area when the ice cover allows	Extra costs for extending the expeditions into the Agreement Area when the ice cover allows
7. Indigenous Knowledge	Include Indigenous Knowledge holders in the design and planning of scientific research expeditions as well as on expeditions themselves	Extra costs to support the engagement of Indigenous Knowledge holders
8. Local knowledge	Include expertise of individuals or organizations (e.g., commercial fishing captains, etc.,) who have detailed knowledge of the CAOFA area in design and planning or execution of scientific research expeditions.	Extra costs to support the engagement of local knowledge holders.
9. Exploratory fishing	Collection of data concurrent to exploratory fishing	Costs to outfit exploratory fishing vessels and add observers

Existing national and international monitoring programs in the Arctic shelf seas could be prepared to go further north if ice conditions allow (see Appendix 5 for a recent compilation). Examples include the Joint Russian-Norwegian monitoring program in the Barents Sea,[11] the Chinese National Arctic Research Expedition in the Chukchi Sea, the Distributed Biological Observatory (DBO) in adjacent regions to the Agreement Area in the Pacific Arctic and complementary efforts developing for the Fram Strait, and the Pacific Arctic Climate Ecosystem Observatory (PACEO), which includes operations in both the Pacific gateway and the Agreement Area.

Examples of other possibilities for the JPSRM are to connect to upcoming scientific icebreaker expeditions and new initiatives. Examples of the latter are a Pan-Arctic Observing System of Systems, Arctic PASSION;[12] a research project organizing a pan-Arctic Observation and Monitoring action including plans for an Arctic-Atlantic DBO (started 2021); the new Russian drift platform *Severny Polyus*[13] designed for 2-years autonomous drifting in thick Arctic sea ice focusing on meteorology and oceanography (started 2022); and the *Tara Polar station*,[14] a research station that is planned to drift in the CAO continuously from 2025 to 2045 collecting on-site biological data.

4.2 Data sharing and reports

The SCG will explore the possibility that some external collaborators listed in Table 4 may be interested in establishing a formal relationship with the SCG to support the JPSRM in their competences. For example, it is anticipated that certain intergovernmental research and monitoring programs (e.g., the Arctic Council's CAFF Circumpolar Biodiversity Monitoring Program (both CBMP marine and coastal groups) and ICES/PICES/PAME Working Group on Integrated Ecosystem Assessment for the Central Arctic Ocean (WGICA) may be amenable to providing data or preparing reports to the SCG focused on specific topics that address JPSRM questions and prioritized information needs (Table 4 and as illustrated by dotted lines in Figure 5). Integrating such information into SCG analyses and syntheses would likely be a very effective way to strengthen the JPSRM and the SCG's advice to the COP.

5 Implementation

5.1 JPSRM implementation plan

Although this framework document has outlined a broad vision of how the JPSRM will be structured, a considerable number of details still need to be formulated. Fortunately, discussions by the Provisional Scientific Coordinating Group (PSCG) in recent years raised several important topics and suggestions that may help to guide the development of the implementation plan. During past discussions, there was general agreement on the priorities of the Implementation Plan of the CAOFA JPSRM and a series of topics that should be addressed to provide details and priorities for the JPSRM. Appendix 8 lists the priorities of the Implementation Plan, and Appendix 9 lists some of these topics (as identified in previous meetings of FiSCAO and the PSCG). Additional information that will assist in developing the JPSRM implementation plan will be identified by the SCG and its working groups.

This implementation plan will build on and revise as needed the recommendations in Appendix 8 and Appendix 9 from previous PSCG and FiSCAO meetings.

5.2 Provisional timeline

The SCG will establish milestones and reports aiming for completion of the implementation plan by June 2024. The operational phase of the JPSRM can start immediately after the COP has approved the JPSRM Framework, e.g., by initiatives of single Parties or preferably groups of Parties. This means that data in the context of the JPSRM can already be collected before the Implementation Plan is in place. The Implementation Plan will be revised regularly.

Table 4. Examples of external Arctic groups that may be interested in helping to answer the JPSRM research and monitoring questions through collaboration with the SCG (see Table 2 for additional groups).

Overarching questions	Specific questions	Inter-governmental and international organizations	Multi-lateral research initiatives
1. What are the distributions of species with a potential for future commercial harvests in the central Arctic Ocean?	a. What fish species are currently present in the High Seas? b. Do fishable concentrations of commercial species exist in the High Seas? c. What are their distributions and abundance patterns? d. What are their local life-history strategies, habitat associations, and demographic patterns? e. Do these strategies, associations, or patterns differ among regions of the Arctic?	Circumpolar Biodiversity Monitoring Program-Marine (**CBMP-Marine**) Working Group on Integrated Ecosystem Assessment in the CAO (**WGICA**) International Council for the Exploration of the Sea (**ICES**) N. Pacific Marine Science Org(**PICES**)	Drift Platform *Severny Polyus* (**DPSP**) European Fish. Inventory in CAO (**EFICA**) Multidisciplinary Drifting Observatory for Study of Arctic Climate (**MOSAiC)** Pacific Arctic Climate Ecosystem Observatory (**PACEO**) Synoptic Arctic Survey (**SAS**)
2. What other information is needed to provide advice necessary for future sustainable harvests of commercial fish stocks and maintenance of dependent ecosystem components?	a. What are the trophic linkages among fishes and between fishes and other taxonomic groups (e.g., quantify food webs identifying keystone forage species)? b. How do the abundances and distributions of species of potential commercial interest vary as a function of climate variability (e.g., time scale of change, extreme events, declining sea ice, and biogeochemical changes)? c. Can the species be harvested sustainably with respect to both target stocks and dependent parts of the ecosystem? If not, what are the prospects for the development of fisheries in the future?	Circumpolar Biodiversity Monitoring Program-Marine (**CBMP-Marine**) Working Group on Integrated Ecosystem Assessment in the CAO (**WGICA**) International Council for the Exploration of the Sea (**ICES**) North Pacific Marine Science Organization (**PICES**) Pacific Arctic Group (**PAG**)	European Fisheries Inventory in the CAO (**EFICA**) Pacific Arctic Climate Ecosystem Observatory (**PACEO**) Synoptic Arctic Survey (**SAS**)
3. What are the likely key ecological linkages between potentially harvestable fish stocks of the central Arctic Ocean and the adjacent shelf ecosystems that support Indigenous and local communities?	a. What are the connections between fish in the High Seas and those in the adjacent regions? b. What are the mechanisms that establish and maintain these linkages? c. How might fisheries in the High Seas affect adjacent and congruent portions of shelf ecosystems, including fish stocks, fishable invertebrates (crabs, shrimp, mollusks), marine mammals, birds, and fisheries-dependent communities (which include those communities that are dependent on subsistence harvests of fish, invertebrates, and mammals)?	Circumpolar Biodiversity Monitoring Program-Marine (**CBMP-Marine**) Working Group on Integrated Ecosystem Assessment in the CAO (**WGICA**) International Council for the Exploration of the Sea (**ICES**) North Pacific Marine Science Organization (**PICES**) Pacific Arctic Group (**PAG**)	Distributed Biological Observatory (**DBO**) European Fish. Inventory in CAO (**EFICA**) Integrated Arctic Observations System (**INTAROS**) Multidisciplinary Drifting Observatory for Study of Arctic Climate (**MOSAiC)** Pacific Arctic Climate Ecosystem Observatory (**PACEO**) Synoptic Arctic Survey (**SAS**)
4. 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?	a. What marine species will be productive in the Agreement Area in the next 10-30 years? b. What changes in production and key linkages are expected in the coming 10-30 years? c. What northward population expansions are expected in the next 10-30 years? d. What are the anticipated impacts of changes in ocean acidification in the next 10-30 years? e. How will increased human activity in the region (e.g., ship noise, ship traffic, industrial activity, and pollution affect fish populations, dependent species, ecosystem health, and Indigenous and local communities in the next 10-30 years? f. How will increased fishing activity affect other species bycatch, migratory and wide-ranging marine mammals and birds, and the Indigenous and local communities that depend upon these species to sustain their ways of living?	Circumpolar Biodiversity Monitoring Program-Marine (**CBMP-Marine**) Working Group on Integrated Ecosystem Assessment in the CAO (**WGICA**) International Council for the Exploration of the Sea (**ICES**) North Pacific Marine Science Organization (**PICES**) Pacific Arctic Group (**PAG**)	Distributed Biological Observatory (**DBO**) European Fisheries Inventory in the CAO (**EFICA**) Integrated Arctic Observations System (**INTAROS**) Multidisciplinary Drifting Observatory for Study of Arctic Climate (**MOSAiC)** Pacific Arctic Climate Ecosystem Observatory (**PACEO**) Synoptic Arctic Survey (**SAS**)
5. What Indigenous Knowledge is available to inform ecological baselines?		Inuit Circumpolar Council (**ICC**)	

6 Citations

Citation 1	Inuit Circumpolar Council. 2022. Circumpolar Inuit protocols for equitable and ethical engagement. [https://hh30e7.p3cdn1.secureserver.net/wp-content/uploads/EEE-Protocols-LR-WEB.pdf]
Citation 2	Jakobsson M, et al. 2020. The International Bathymetric Chart of the Arctic Ocean, Version 4.0. Scientific Data 7:176 [https://doi.org/10.1038/s41597-020-0520-9]
Citation 3	PAME. 2013. Large Marine Ecosystems (LMEs) of the Arctic Area: Revision of the Arctic LME Map (Second Edition). PAME International Secretariat [https://www.pame.is/projects/ecosystem-approach/arctic-large-marine-ecosystems-lme-s] and [https://www.pame.is/images/03_Projects/EA/LMEs/Factsheets/13_Central_Arctic_Ocean_LME_.pdf]
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Citation 8	Synoptic Arctic Survey (SAS): [https://synopticarcticsurvey.w.uib.no]
Citation 9	Integrated Arctic Observation System (INTAROS): [http://intaros.eu]
Citation 10	Ecosystem mapping in the Central Arctic Ocean (CAO) during the MOSAiC expedition. Publications Office of the European Union (2021) [https://data.europa.eu/doi/10.2926/714618]
Citation 11	Ecosystem mapping in the Central Arctic Ocean (CAO) during the SAS-Oden expedition. Publications Office of the European Union (2022) [https://data.europa.eu/doi/10.2826/958629]
Citation 12	Expedition Report SWEDARCTIC Synoptic Arctic Survey with icebreaker Oden (2022) [https://www.diva-portal.org/smash/get/diva2:1712331/FULLTEXT01.pdf]
Citation 13	The Nansen Legacy Joint Cruise 2-2 2021 – Cruise Report. The Nansen Legacy Report Series 30/2022 [https://septentrio.uit.no/index.php/nansenlegacy/article/view/6413/6498]
Citation 14	Arctic Ocean 2022 Cruise Report IMR Cruise ID 2022710. Norwegian Polar Institute (2022) [https://brage.npolar.no/npolar-xmlui/handle/11250/3013026]
Citation 15	Arctic Council's CAFF Circumpolar Biodiversity Monitoring Program – Marine [https://www.caff.is/marine]
Citation 16	ICES/PICES/PAME Working Group on Integrated Ecosystem Assessment for the Central Arctic Ocean (WGICA) [https://www.ices.dk/community/groups/Pages/WGICA.aspx]
Citation 17	Joint Russian-Norwegian Working Group on Arctic Fisheries (JRN-AFWG) [https://www.hi.no/en/hi/nettrapporter?query=&serie=imr-pinro]
Citation 18	Distributed Biological Observatory (DBO): [https://www.pmel.noaa.gov/dbo]
Citation 19	Joint PICES/ICES Working Group on the Integrated Ecosystem Assessment for the Northern Bering Sea - Chukchi Sea [https://meetings.pices.int/members/working-groups/wg44]
Citation 20	North Pacific Research Board Arctic Program [https://nprb.org/arctic-program/#section-1]
Citation 21	Arctic Council's CAFF Working Group (Conservation of Arctic Flora and Fauna) [https://www.arctic-council.org/about/working-groups/caff]
Citation 22	Arctic Council's PAME Working Group (Protection of the Arctic Marine Environment) [https://www.arctic-council.org/about/working-groups/pame]
Citation 23	Arctic Council's AMAP Working Group (Arctic Monitoring and Assessment Program) [https://www.amap.no]
Citation 24	Arctic Council's SDWG Working Group (Sustainable Development) [https://www.arctic-council.org/about/working-groups/sdwg]

Citation 25	CAFF Marine Biodiversity Monitoring [https://www.arctic-council.org/projects/marine-biodiversity-monitoring]
Citation 26	Arctic Council CAFF Circumpolar Biodiversity Monitoring Program – Coastal (CBMP-Coastal) [https://www.caff.is/coastal]
Citation 27	ICES/PICES/PAME Working Group on Integrated Ecosystem Assessment for the Central Arctic Ocean (WGICA) [https://www.ices.dk/community/groups/Pages/WGICA.aspx]
Citation 28	International Arctic Science Committee (IASC) [https://iasc.info/]
Citation 29	International Council for the Exploration of the Sea (ICES) [https://www.ices.dk/Pages/default.aspx]
Citation 30	Inuit Circumpolar Council (ICC) [https://www.inuitcircumpolar.com/]
Citation 31	North Pacific Marine Science Organization (PICES) [https://meetings.pices.int/]
Citation 32	Pacific Arctic Group (PAG)[https://pag.arcticportal.org/]
Citation 33	Distributed Biological Observatory (DBO) [https://dbo.cbl.umces.edu/]
Citation 34	Severny polyus: [http://www.energyglobalnews.com/russian-drift-station-severny-polyus-has-started-north-pole-41-expedition]
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Citation 36	Pan-Arctic Observing System of Systems [Arctic PASSION): [https://arcticpassion.eu]
Citation 37	Tara Polar Station: [https://fondationtaraocean.org/en/schooner/tara-polar-station]

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Appendix 2	Report of the First Meeting of the Conference of the Parties to the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean, Incheon, Korea, November 23-25, 2022 (CAOFA-2022-COP1-10) [https://apps-afsc.fisheries.noaa.gov/documents/first-meeting-COP.pdf]
Appendix 3	Final Report of the Fourth Meeting of Scientific Experts on Fish Stocks in the Central Arctic Ocean (2017) [https://apps-afsc.fisheries.noaa.gov/documents/fourth-meeting-FiSCAO.pdf]
Appendix 4	Final Report of the Fifth Meeting of Scientific Experts on Fish Stocks in the Central Arctic Ocean (2018) [https://apps-afsc.fisheries.noaa.gov/documents/fifth-meeting-FiSCAO.pdf]
Appendix 5	Report of the First Meeting of the Provisional Scientific Coordinating Group (PSCG) of the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (2020) [https://apps-afsc.fisheries.noaa.gov/documents/first-meeting-PSCG.pdf]
Appendix 6	Report of the Second Meeting of the Provisional Scientific Coordinating Group under the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (2022) [https://apps-afsc.fisheries.noaa.gov/documents/second-meeting-PSCG.pdf]
Appendix 7	Report of the Third Meeting of the Provisional Scientific Coordinating Group under the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (2022) [https://apps-afsc.fisheries.noaa.gov/documents/third-meeting-PSCG.pdf]
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Appendix 9	Excerpts from FiSCAO and PSCG meetings providing examples of topics that should be addressed when establishing JPSRM priorities

10 List of Abbreviations

ABNJ	Areas Beyond National Boundaries
AMAP	Arctic Monitoring and Assessment Program (a working group of the Arctic Council)
AIERP	Arctic Integrated Ecosystem Research Program (a research initiative of the U.S. North Pacific Research Board)
AMAP	Arctic Mapping and Assessment Program (a working group of the Arctic Council)
PASSION	Pan-Arctic Observing System of Systems
CAFF	Conservation of Arctic Flora and Fauna (a working group of the Arctic Council)
CAO	Central Arctic Ocean
CAOFA	Central Arctic Ocean Fisheries Agreement
CBMP	Circumpolar Biodiversity Monitoring Program (a circumpolar program of the Arctic Council's CAFF WG)
CAOFA COP	Conference of the Parties of the Central Arctic Ocean Fisheries Agreement
CDOM	Chromophoric (or Colored) Dissolved Organic Matter
CTD	Oceanographic instrument for measuring conductivity (salinity), temperature and depth in the water column
DBO	Distributed Biological Observatory
DOI	Digital Object Identifier
DPSP	Drift Platform *Severny Polyus*
DSP-WG	Data Sharing Protocol Working Group of the SCG
EEZ	Exclusive Economic Zone
EFICA	European Fisheries Inventory in the Central Arctic Ocean Consortium
EU	European Union
FiSCAO	Scientific Experts On Fish Stocks In The Central Arctic Ocean

IASC	International Arctic Science Committee
ICC	Inuit Circumpolar Council
ICES	International Council for the Exploration of the Sea (intergovernmental)
IEA	Integrated Ecosystem Assessment
IK	Indigenous Knowledge
LK	Local knowledge
INTAROS	Integrated Arctic Observations System
JPSRM	Joint Program of Scientific Research and Monitoring
LME	Large Marine Ecosystem (developed by the USA NOAA to identify ocean areas for conservation purposes)
MM-WG	Mapping and Monitoring Working Group of the SCG
MOSAiC	Multidisciplinary drifting Observatory for the Study of Arctic Climate
NPRB	North Pacific Research Board
PACEO	Pacific Arctic Climate Ecosystem Observatory (a international research initiative of the Pacific Arctic Group)
PAG	Pacific Arctic Group
PAME	Protection of the Arctic Marine Environment (a working group of the Arctic Council)
PICES	North Pacific Marine Science Organization (intergovernmental)
PSCG	Provisional Scientific Coordinating Group
SAS	Synoptic Arctic Survey
SCG	Scientific Coordinating Group
SDWG	Sustainable Development Working Group (a working group of the Arctic Council)
TPS	Tara Polar Station
WGICA	ICES/PICE/PAME Working Group on the Integrated Ecosystem Assessment for the Central Arctic Ocean

Appendix 8: Data needed to fulfill the goals of the CAOFA JPSRM

1. Indicators, devices and methods

A broad set of JPSRM indicators, devices and methods will be tested during the three-year mapping phase. At the end of the mapping phase, the efficiencies of each of the indicators and the efforts to obtain reliable measurements will be evaluated. For the subsequent 13-year monitoring phase a smaller number of quantitative monitoring indicators will be selected for the JPSRM. During both the mapping and monitoring phases intercalibration of methods will take place regularly, and other forms of calibration and collaboration, e.g., the exchange of samples, will be facilitated within the JPSRM to maintain data consistency and allow data to be combined in analyses.

Table 3: JPSRM indicators in relation to the overarching research questions of the JPSRM (cf. Table 1). JPSRM question 5 is not included in the table as it asked about ILK data availability; it was not a question that would be addressed by the JPSRM. Ice camps including shorter or longer periods when an icebreaker is drifting with the ice with engines turned off)

Overarching question	JPSRM Indicator	Ecosystem parameter / knowledge gained
1. What are the distributions of species with a potential for future commercial harvests in the Agreement Area?	**Hydroacoustics with standardized settings** • Area scattering coefficient (NASC), 18, 38, 70 Khz, 0-800 m depth • Collected during open water or ice camps	Fish abundance and biomass
	Catch per unit effort with standardized long lines • Number of fish by species • Age distribution • Length distribution • Weight distribution • Collected during open water or ice camps	Fish species, age and size distributions [+Calibration of acoustic data (target strength)]
	Catch per effort with standardized trawling in larger leads and open-water areas • Number of fish by species • Age distribution • Length distribution • Weight distribution • Collected during open water or ice camps	Fish species, age and size distributions [+Calibration of acoustic data (target strength)]
	Population demographics • Sex • Maturity • Fecundity • Length frequency • Collected during open water or ice camps	Population trends
	Box-core sediment otoliths • Number of fish by species • ^{14}C age • Life-time age distribution	Fish species, age and size distributions during the Holocene (ca. 10,000 years) [provides fish data with climate variability for modelling studies]

	• Length distribution (modelled) • Weight distribution (modelled) • Collected during open water **Deep-sea video cameras** • Number of fish and squid • Species identification • Collected during ice camps **Environmental DNA (eDNA)** • Amplicon sequences cytochrome c oxidase subunit 1 (CO1), *Cyt* b • Amplicon sequences rRNA 12S • Metagenomic sequences • Collected during open water or ice camps	Fish and squid distributions Species distributions of fish, squid, their invertebrate prey, and their mammal and bird predators
2. What other information is needed to provide advice necessary for future sustainable harvests of commercial fish stocks and maintenance of dependent ecosystem components?	**Hydroacoustics with standardized settings** • Area scattering coefficient (NASC), 120, 200, 333 Khz, 0-800 m depth • Collected during open water or ice camps **Fish, zooplankton, marine mammal and seabird samples** • Stomach contents (genomic) • Stable isotopes (^{TM13}C, ^{TM15}N) • Fatty acids composition • Collected during open water or ice camps **Distribution/numbers /biomass of dependent ecosystem components** • Phytoplankton • Zooplankton • Benthos • Marine mammals • Sea birds • Collected during open water or ice camps **Ambient and fossil otoliths** • Stable isotope ^{TM13}C • Stable isotope ^{TM18}O • Collected during open water **Habitat data (water column, sea ice)** • Depth • Temperature • Salinity • Current direction and speed • Dissolved oxygen • Nutrient concentrations (e.g. nitrate, nitrite) • Carbonate system • Light levels	Fish prey distribution and biomass Trophic linkages among fishes and between fishes and other taxonomic groups Community composition Opportunities for interactions among trophic levels Reconstruction of ambient temperature and metabolic activity during life span Coupling between fish, squid and zooplankton abundances, distributions and trophic linkages and climate variability (food web modelling) Coupling between fish, squid and zooplankton abundances and distributions and ecosystem productivity (modelling)

	• CDOM fluorescence • Chlorophyll fluorescence • Chlorophyll *a* concentrations • Particle concentrations (e.g. particulate organic carbon, particulate nitrogen) • Flow cytometry • Particulate organic carbon and $\delta^{13}C$ • Benthos (abyssal community) • Marine litter (e.g. microplastics, PCBs, Hg, oil) • Bottom topography and type • Collected during open water or ice camps	
3. What are the likely key ecological linkages between potentially harvestable fish stocks of the Agreement Area and the adjacent shelf ecosystems that support Indigenous and Local Communities?	• Population genetics of fish, squid, invertebrates, marine mammals and seabirds caught both in the Agreement Area and adjacent regions in all seasons • Numbers of seabirds and mammals both in the Agreement Area and adjacent regions	Connectivity between fish in the Agreement Area and those in the adjacent regions Mechanisms that establish and maintain these linkages Abundance and connectivity of seabirds and marine mammals in the Agreement Area and adjacent regions
4. 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?	**Evaluation of the JPSRM indicators** • Literature studies in relation to the sampled JPSRM indicators and comparison of the JPSRM results with published data from other regions in the Arctic Ocean • Modelling studies of fish and squid abundances and distributions in relation to food web and ecosystem productivity • Evaluation if species can be harvested sustainably with respect to both target fish stocks and dependent parts of the ecosystem • Long-term trends in the nekton community • Long-term changes in the plankton community • Long-term changes in the benthic community	Which marine species are likely to be productive in the Agreement Area in the next 10-30 years Which changes in production and key linkages are expected in the Agreement Area in the coming 10-30 years What northward population expansions into the Agreement Area are expected in the next 10-30 years What are the anticipated impacts of changes in ocean acidification in the Agreement Area in the next 10-30 years How increased human activity in the Agreement Area (e.g. ship noise, ship traffic, industrial activity, and pollution) is expected to affect fish populations, ecosystem health, and communities in the next 10-30 years How increased fishing activity in the Agreement Area is expected to affect other species bycatch, migratory and wide-ranging marine mammals, and the Indigenous and local communities that depend upon these species to sustain their ways of living Evaluation of how fisheries in the Agreement Area might affect adjacent and congruent portions of shelf ecosystems, including fish stocks, fishable invertebrates (crabs, shrimp, mollusks), marine mammals, birds, and

		fisheries-dependent communities (which include those communities that are dependent on subsistence harvests of fish, invertebrates, and mammals)
5 What Indigenous Knowledge is available to inform ecological baselines?	• Historical and recent changes in harvests, number of animals (i.e. how did the catch of marine mammals and fish fluctuate over the years?) • Sea ice, ocean currents, tides, weather patterns, and other environmental conditions • observed by communities • Movement, distribution, and diet of marine mammals, fish and birds	• Direct, year-round observations of the ecosystems throughout generations • Abundance, distribution, and trophic linkages of invertebrates, fish, birds and marine mammals

2. Hydroacoustic data collection

Hydroacoustics with 38, 70 and 120 kHz transducers targeting 0-800 m of depth from all ships and drift platforms entering the Agreement Area. Hydroacoustics with a 38 kHz transducer is effective for observing fish with swim-bladders. Hydroacoustics with 70 or 120 kHz transducers have shorter effective observation ranges but can observe smaller organisms (e.g. zooplankton) or fish without a swim-bladder.

In the Eurasian Basin the central Arctic mesopelagic scattering layer occurs in the Atlantic water layer at 100-600 m of depth[9,10], but this may be lower on the Pacific side. No usable acoustic data can be collected while steaming in ice due to the sound of ice-breaking. Therefore, it is recommended to stop the engines for ten minutes and drift with the ice after a certain time window. For example: steaming 50 min, drifting 10 min. Drift platforms are ideal for collecting acoustic data. Disturbances from the ship can occur (electrical, mechanical, acoustic) and should be avoided while collecting acoustic water-column data. When possible, hydroacoustic measurements should be collected and combined with trawling, but this is only possible if open water is available. It may also be advantageous to use hydroacoustics on smaller platforms, such as submerged moorings, ROVs or autonomous gliders.

3. Sampling of fishes and benthos

Fish sampling methods adapted to the Agreement Area need to be developed further during the mapping phase. Methods need to be evaluated to ensure that vulnerable habitats are not damaged in the long term. Recent surveys have found very low abundance of mesopelagic fishes due to the low productivity of the ecosystem[14,15]; therefore, the sampling effort required to collect specimens is expected to be higher than in comparable surveys in subarctic or temperate waters. In the Eurasian Basin, long-line fishing seemed to be only successful for larger predatory fish species >30-40 cm, while small mesopelagic fish species could not

[9] *Snoeijs-Leijonmalm P, et al. (2021) A deep scattering layer under the North Pole pack ice. Progress in Oceanography 194:102560 [https://doi.org/10.1016/j.pocean.2021.102560]*

[10] *Snoeijs-Leijonmalm P, et al. (2022) Unexpected fish and squid in the central Arctic deep scattering layer. Science Advances 8:eabj7536 [https://www.science.org/doi/10.1126/sciadv.abj7536]*

be caught by line-fishing, gill nets, ring nets or traps. On the echosounder, the few fish that occur have been seen fleeing any sampling gear that is lowered in the water column (which proves that fish are present but difficult to sample). Trawling with ice-modified trawls has been successful[11]; the results have reaffirmed the low densities encountered by previous expeditions (*Annex 14-15*). Despite these challenges, the use of multiple fishing gears is encouraged in order to capture as diverse a range of fish samples as possible. In particular, sampling of sympagic fishes (ice-associated polar cod juveniles) in the Agreement Area is possible using a special-designed "Surface- and Under-Ice Trawl (SUIT)[12] that has proven successful at sampling sympagic fishes under ice cover. Benthic fishes observed in the central Arctic Ocean consist of non-commercial species, except for Greenland halibut *Reinhardtius hippoglossoides* of which single (juvenile) specimens have been encountered in the southern part of the Agreement Area during two sampling events (*Annex 04 and 14*). Although bottom trawling can be very disruptive to benthic habitats and should be avoided in sensitive benthic areas such as locations with concentrations of corals and sponges, trawls conducted for scientific purposes corresponding to the JPSRM will be allowed if precautionary measures are taken before trawl operation. Prior to using benthic trawls and other disruptive sampling methods the benthic habitat should be examined using non-disruptive methods such as drop cameras, near-bottom video sleds or ROVs to determine if the area represents a sensitive benthic area. For efficiency forward-looking trawl-mounted cameras could be used if they allow live-video that can be viewed by the captain that provides observation of the seafloor sufficiently far ahead of the sampling gear to allow the captain to abort deployment before the gear makes contact with the seafloor. In addition, benthos, particularly macrobenthos, play an important role in ecosystem functioning and processes. Benthic standing stocks may support key benthic-feeding apex predators, including Pacific walrus (*Odobenus rosmarus divergens*), gray whales (*Eschrichtius robustus*), and bearded seals (Erignathus barbatu), thus functioning as a crucial component in the Arctic food-web. Therefore, full considerations should be given to sampling of various benthic invertebrates using box corers or alternate methods.

4. Holocene otoliths

Fish species distributions in the Agreement Area over a longer time scale (Holocene, ca. 10,000 years) can be assessed from otoliths in deep-sea sediments (*Annex 12-13*). To collect enough otoliths a large box core sample is necessary (e.g., surface 50×50 cm, the Holocene layer in the CAO ca. 10-15 cm deep). The geological age of the otoliths is dated with the ^{14}C method, the age of the fish at death is determined from otolith increments. During the Holocene there have been warmer and colder periods, notably the Holocene thermal maximum from around 9000 to 5000 years before present[13]. Thus, the results can be used for modelling of fish abundance in relation to climate variability. The ambient temperature experienced by the fish is reconstructed with the stable isotope radio $\delta^{18}O$, and metabolic activity by the stable isotope ratio $\delta^{13}C$ 13C in the otoliths. The number of otoliths in each layer can be related to temperature and we can predict if fish stocks will increase with climate warming in the future. From the otoliths we can also extract the age of the fish when they died and assess the impacts of temperature on maximum age and age structure of fish stocks.

5. Environmental DNA

[11] *Ingvaldsen, R.B., Eriksen, E., Gjøsæter, H. et al. (2023). Under-ice observations by trawls and multi-frequency acoustics in the Central Arctic Ocean reveals abundance and composition of pelagic fauna. Scientific Reports 13, 1000. [https://doi.org/10.1038/s41598-023-27957-x]*

[12] *Van Franeker JA, et al. (2012). The Surface and Under Ice Trawl (SUIT). Technical Report [*https://www.researchgate.net/publication/297794282*]*

[13] *Park HS, et al. (2019) Mid-Holocene Northern Hemisphere warming driven by Arctic amplification. Science Advances 5:eaax8203 [*https://www.science.org/doi/10.1126/sciadv.aax8203*]*

Environmental DNA (eDNA) can be used to reconstruct species distributions. A genomic pipeline for Arctic samples focusing on fish and zooplankton is being tested by EFICA (the European Fisheries Inventory in the Central Arctic Ocean Consortium) and results will be evaluated by 20 February 2023 (*Figure 3*). Several methods using whole metagenome and amplicon sequencing are used to construct distribution maps of fish, squid, and key zooplankton, perhaps also birds and mammals. When taking eDNA samples all rules for clean sampling in molecular biology must be used. The method is very sensitive and special care should be taken to not contaminate samples from the water column and the ice with, e.g., fish bait (use obligate freshwater species as bait) or waste water discharge from the ship (forbid any ship discharge before sampling has been terminated at each sampling station).

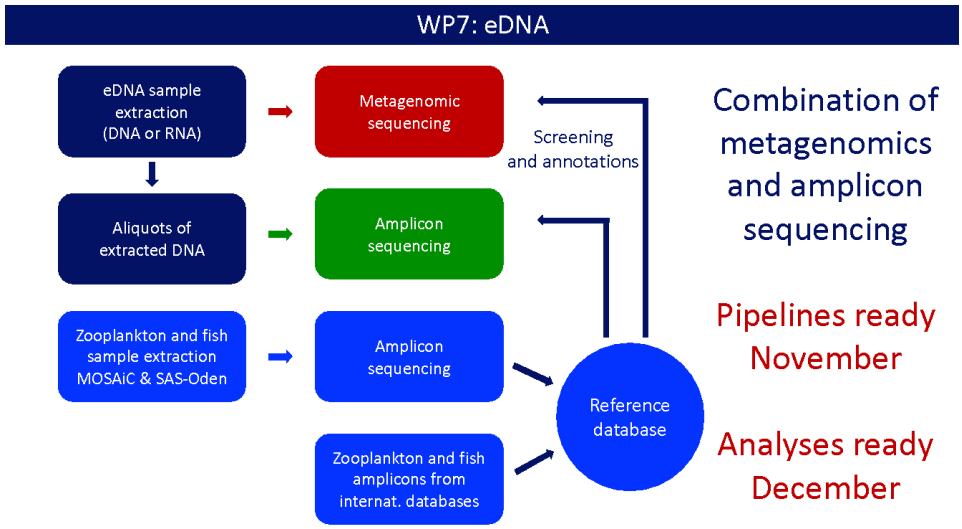

Figure 3: EFICA pipelines for eDNA analyses.

6. Deep-sea cameras

Underwater cameras, ROVs and AUVs currently exist that could be deployed to collect data on fish and invertebrate species both on the benthos and in the water column where sampling is extremely difficult. Combining image collection with automatic detection of moving objects (fish, squid, macrozooplankton) from drifting and moored platforms is a good complement to assess species distributions in the Agreement Area and could potentially be a non-destructive sampling method. Experience has indicated that attaching a camera to a CTD has limited success for fish and squid because a CTD moves fast except during water sampling for very short times at specific depths, and fish actively avoid the moving CTD. Due to the generally low abundance of fish and squid, recording many hours is necessary. Thus, targeted deployments of cameras is likely to result in higher success in capturing abundance and distribution patterns of fishes and squids. There has been considerable research in recent years into combining acoustic and optical surveys for fishes (e.g. deployments of cameras guided by acoustic observations of fish). ROV's and AUV's could both be deployed to target both midwater and benthic species. There is also potential to deploy towed camera systems, drift camera systems or stationary camera systems (e.g. floating in the water column, but anchored to the seafloor) that could cover larger areas and potentially require less cost and technological expertise. Size data for species can also be obtained from either using calibrated stereo cameras or laser systems. Finally, underwater cameras can be combined with other gear types for auxiliary data collection. For example mounting stereo-cameras in trawl nets can allow estimation of gear selectivity or even allow fishing with an open codend that becomes a non-destructive method of capturing abundance and size information.

7. Trophic linkages

Trophic linkages among fishes and between fishes and other taxonomic groups are studied by analyzing stomach contents with metabarcoding and by comparing stable isotope ratios $\delta^{13}C$ and $\delta^{15}N$ in zooplankton and fish muscle. An additional method used as a trophic tracer is fatty acid composition in fish (and squid) muscle and liver and in other components of the food web, but this method is more elaborate and expensive. Estimates of phyto- and zooplankton biomass and numbers will be based upon net catches, as well as from acoustic (AZFP and ADCP) data. Phyto- and zooplankton species will be determined from plankton net hauls. Sediment traps collect sinking particles associated with the phyto- and zooplankton distributions and carbon cycles. Mooring systems including sediment traps with physical, chemical, and biological sensors can monitor annual and interannual changes in phyto- and zooplankton communities.

8. Physical and biogeochemical data

As a standard, research vessels collect oceanographic data with a CTD to measure conductivity (salinity), temperature and depth. CTD rosettes usually carry other instruments as well, such as CDOM fluorescence, chlorophyll fluorescence, UVP particle concentrations. Water samples are taken to measure basic indicators of ecosystem productivity, such as dissolved oxygen, inorganic and organic nutrients, CO_2 (carbonates), chlorophyll *a* concentration, photosynthetic pigments, particulate organic carbon (POC), $d^{13}C$, flow cytometry (cell abundances of bacteria and primary producers), etc. Acoustic Doppler Current Profilers (ADCP) can be used to estimate changes in fluxes and water masses northward through the Atlantic and Pacific gateways, which may be linked to species range expansions either by affecting environmental conditions or entrainment of individuals. Moorings with ADCPs placed in various locations in the gateway would facilitate monitoring of changes in currents.

All these data are useful for modelling fish-stock abundance in relation to the environment and trophic status. For the JPSRM it would be useful to collect all CTD profiles available in international databases made in the Agreement Area during the last 30 years as well as all CTD profiles that will become available during the 14 years of the JPSRM.

9. Population genetics of fish and squid

Population genetic analyses of fish and squid caught both in the Agreement Area and adjacent regions establish connectivity pathways between coastal spawning areas and adults living in the Agreement Area. Principal candidates for such studies (based on the current knowledge) are polar cod *Boreogadus saida*, ice cod *Arctogadus glacialis*, Atlantic cod *Gadus morhua*, Greenland halibut *Reinhardtius hippoglossoides*, Walleye pollock *Gadus chalcogrammus*, Arctic skate *Amblyraja hyperborea*, and armhook squid *Gonatus fabricii* that all are known to occur in the Agreement Area. Other candidates include haddock *Melanogrammus aeglefinus, Bering flounder Hippoglossoides robustus, Alaska plaice Pleuronectes quadrituberculatus,* and beaked redfish *Sebastes mentella*. Many species of fish are also relied upon by Arctic Indigenous communities who live adjacent to the Agreement Area.

10. Distribution of birds and mammals

Distributions of marine birds and mammals both in the Agreement Area and adjacent regions are necessary to assess the abundance and connectivity of fish predators in the Agreement Area. Marine mammals, migratory birds and seabirds, their flyways and nesting colonies, are also significant and new to be

understood, especially with increasing changes in Arctic ecosystems. Many migratory birds, seabirds and marine mammals are relied upon by Arctic Indigenous who live adjacent to the Agreement Area; an important goal of the JPSRM is understanding potential impacts from fisheries on the ecosystem to ensure CAO ecosystems remain healthy and productive, including maintaining healthy marine mammal and bird populations that sustain ongoing harvests. Very few data exist from the Agreement Area and they are mainly anecdotal. It is anticipated that bird and marine mammal densities are currently low in the Agreement Area, with the exception of the Chukchi Sea. A possible task for the JPSRM could be to compile data from as many previous expeditions to the Agreement Area as possible, e.g., using photographic documentation by cruise participants.

11. Indigenous Knowledge and Local Knowledge

The ICC has defined Indigenous Knowledge as:

> "Indigenous Knowledge is a systematic way of thinking applied to phenomena across biological, physical, cultural, and spiritual systems. It includes insights based on evidence and acquired through direct and long-term experiences and extensive and multigenerational observation, lessons, and skills. It has developed over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation.
>
> Under this definition, Indigenous Knowledge goes beyond observations and ecological knowledge, offering a unique way of knowing to identify research needs and apply to research, monitoring, assessments, decision-making, policy and the overall understanding the Arctic – it is our Way of Life."

Inuit bring a holistic understanding of the Arctic ecosystem, our homeland, which looks at the dynamic relationship between its components that are interrelated and interdependent. Because of this unique understanding, Inuit have thrived and survived in the Arctic for thousands of years.

12. Local Knowledge

Local knowledge is the knowledge that people in a given community have developed over time, and continue to develop[14]. It is:

- Based on experience
- Often tested over centuries of use
- Adapted to the local culture and environment
- Embedded in community practices, institutions, relationships and rituals
- Held by individuals or communities
- Dynamic and changing

13. Modelling studies

Data regarding species distributions, particularly in relation to oceanographic conditions, water depth and benthic morphology and substrate (for benthic species), and results of diet studies and trophic analyses can be combined to develop models of CAO populations and communities. Given expected low abundances for most species and the relatively short duration of the mapping phase (3 years) local data on reproductive rates and other demographic parameters will be limited and likely will need to be borrowed from other populations for model development. The monitoring phase of the JPSRM will provide an opportunity to estimate demographic variables and patterns within the CAO to support model refinement prior to fishery development.

[14] FAO (2004). Training Manual "Building on Gender, Agrobiodiversity and Local Knowledge". [What is local knowledge? (fao.org)]

Appendix 9. *Excerpts from FiSCAO and PSCG meetings providing examples of topics that should be addressed when establishing priorities for the JPSRM implementation plan. These examples are not listed in priority order, and they comprise only a partial list of relevant topics to be considered in the implementation plan.*

Sampling information from subareas of the CAO High Seas and adjoining marine areas.
Criteria for prioritizing subareas in concerning the relative availability (or lack) of information, degree of sea ice loss, and water depth. Examples of potential demersal areas include the East Siberian Sea including the Chukchi Borderlands and waters northwest of Wrangel Island.
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.
Synoptic mapping surveys conducted over as much of the High Seas CAO as possible following standardized sampling protocols and the use of consistent data formats.
Historic and contemporary baseline data that may be available through indigenous and local knowledge holders regarding 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.
Data from previous data collection programs to be identified and prioritized for the Pacific and Atlantic gateways.
Pelagic surveys conducted in areas where there have been documented, observed, or expected northward range expansions by potentially harvestable species.
Surveys in areas where environmental changes have been documented or are expected to occur.
Identifying which indicators are most important for detecting change in the current and future status of commercial fish stocks and dependent (subsistence harvested and protected) species.
The extent to which the JPSRM should focus on marine species that are: 1) potential targets of commercial fisheries, 2) harvested for subsistence purposes, or 3) already protected by governmental or intergovernmental conservation measures.
Data collection priorities focusing on: 1) identifying fish species distributions and relative abundances, 2) understanding population structure and the factors affecting species distributions and productivity.
Assessing the availability and viability of data for species of commercial and subsistence interest, including: 1) distributions of potential commercial fishes and invertebrates, 2) fishing vessel activity in waters adjacent to the High Seas CAO, and 3) marine mammal and seabird abundance, distributions, diets, condition or foraging behaviors.
Cumulative impacts on ecosystems due to anthropogenic activities in addition to potential impacts of commercial fisheries (e.g., shipping, energy).
Understanding broad ecosystem components, including: zooplankton transport and potential establishment into the High Seas CAO, deep scattering layer, primary productivity and associated variables, sea ice, ocean currents, sea temperature, ocean acidification.
Current physical, chemical and biological oceanographic conditions and the distributions and abundances of marine invertebrates, fishes, mammals, and birds in the High Seas portion of the central Arctic Ocean and surrounding waters.