

# ICES/PICES/PAME WORKING GROUP ON INTEGRATED ECOSYSTEM ASSESSMENT (IEA) FOR THE CENTRAL ARCTIC OCEAN (WGICA; output from 2019 meeting)

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# ICES Scientific Reports

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ICES/PICES/PAME WORKING GROUP ON INTEGRATED ECOSYSTEM ASSESSMENT (IEA) FOR THE CENTRAL ARCTIC OCEAN (WGICA; outputs from 2019 meeting)

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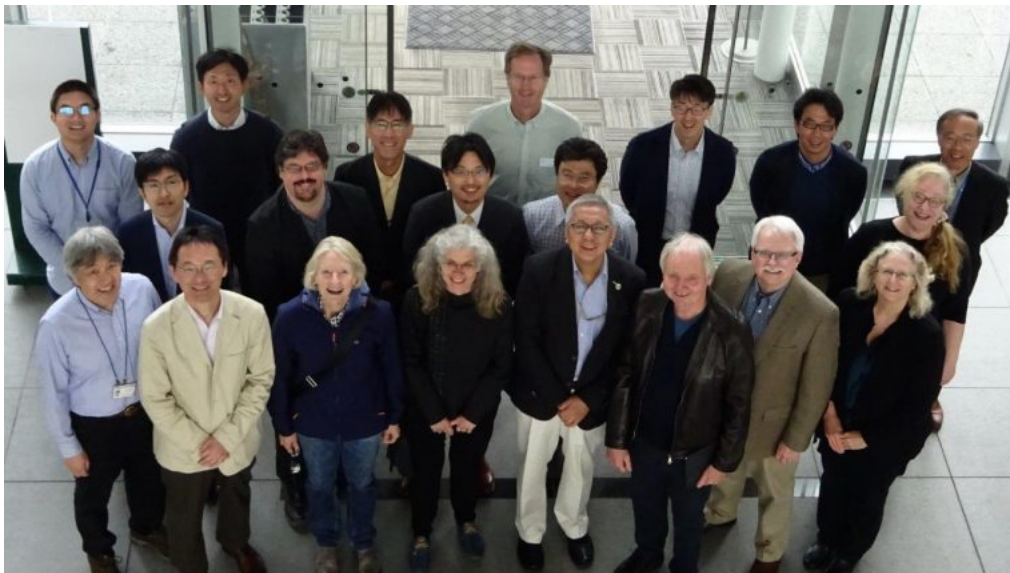
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## i Executive summary

The joint ICES-PICES-PAME Working Group on Integrated Ecosystem Assessment for the Central Arctic Ocean (WGICA) provides integrated ecosystem assessments (IEAs), including ecosystem overviews, for the Central Arctic Ocean (CAO). Over the last few decades, about half the area and  $\frac{3}{4}$  of the volume of the minimum sea ice in summer have been lost with a pronounced change from thick and old multiyear ice to now mostly thin and young ice (the 'Great melt'). The working group aims to improve the understanding of how much Great melt affects to climate and ecosystem variability of the core ICES area in the North Atlantic as well as in the Bering Sea and Gulf of Alaska in the North Pacific.

In late 2020, the group will publish the "Integrated Ecosystem Assessment of the Central Arctic Ocean: Ecosystem description and vulnerability characterization". The availability of biological and oceanographic time-series in the CAO to describe status and changes of the ecosystem is limited. WGICA will therefore seek to increase the use of satellite remote sensing data and numerical model output data for deriving information on changing of environment and lower trophic level ecosystem. WGICA will compile data from ongoing and recent changes and events in the CAO ecosystem and new studies on fish, such as the MOSAiC expedition (2019-2020) and the international Synoptic Arctic Survey (SAS).

WGICA is also compiling a second IEA report for the CAO ecosystem focusing on an overview of the ecosystem and vulnerability. A vulnerability characterization will include an assessment of human activities (climate and climate change, contaminants and pollution, shipping (including tourism), and potential future fisheries) and their pressures and impacts on the ecosystem.



## ii Expert group information

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|                                   |   |
|-----------------------------------|---|
| <b>Expert group name</b>          | ICES/PICES/PAME Working Group for Integrated Ecosystem Assessment of the Central Arctic Ocean (WGICA) |
| <b>Expert group cycle</b>         | Multiannual   |
| <b>Year cycle started</b>         | 2019  |
| <b>Reporting year in cycle</b>    | 1/3   |
| <b>Chair(s)</b>                   | John Bengtson, ICES, USA  |
|                                   | Sei-Ichi Saitoh, PICES, Japan   |
|                                   | Hein Rune Skjoldal, PAME, Norway  |
| <b>Meeting venue(s) and dates</b> | 8-10 May, Sapporo, Hokkaido, Japan (24 participants)  |

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# 1 Terms of Reference a – e

| ToR | Description   | Background  | Science Plan topics addressed | Duration         | Expected Deliverables   |
|-----|---|---|-------------------------------|------------------|---|
| a   | Consider approach and methodology (-ies) for doing an IEA for the CAO (based on the outcome of WKICA).  | Basis for carrying out IEA for the CAO; draw upon experiences in other IEA groups (WGNARS, WGINOSE, WGEAWESS, WGINOR, WGIBAR and WGIAB)   | SP Goal 1                     | Year 1           | Summary on approach and methodology in interim report   |
| b   | Assemble data and information and carry out appropriate statistical and other types of analyses including mathematical modelling  | Initial steps in an IEA   | SP Goal 1                     | Years 1 and 2    | Summary on data sources in interim report<br><br>Draft (incomplete) IEA of the CAO  |
| c   | Prepare an IEA outline for the current status of the CAO ecosystem (CAO LME and adjacent slope waters including Atlantic and Pacific inflows and relevant shelf-basin exchanges) and effects, potential effects and vulnerability in relation to climate variability and change and human activities such as Arctic shipping and potential future fisheries | IEA is an essential component of the EBM approach to human activities. Will provide a basis for advice in an ecosystem context on future Arctic marine shipping and fisheries taking into account ongoing and future climate change                               | SP Goal 1 and 2               | Years 2 and 3    | Draft (incomplete) outline of an IEA in interim report 2 <sup>nd</sup> year<br><br>First complete outline for an IEA for the CAO at the end of the 3 <sup>rd</sup> year |
| d   | Consider requirements and design of monitoring of the CAO to meet the need for repeated IEA in the near future as well as other types of assessments (which can be modular components of IEAs)  | The first approach towards an IEA of the CAO builds on existing data and information, mostly from research and modelling activities. There is a need to consider improved and additional monitoring to better meet the need for refinements and update of the IEA | SP Goals 1 and 2              | Years 1, 2 and 3 | Summaries in interim reports 1 <sup>st</sup> and 2 <sup>nd</sup> years<br><br>Summaries in final report after 3 <sup>rd</sup> year                                      |
| e   | Identify priority research issues which, when addressed, can improve the knowledge base for the future iterations of the IEA  | Carrying out an IEA will reveal gaps in knowledge that forms the basis for identifying priority research issues   | SP Goals 1, 2 and 3           | Year 3           | Summary in final report   |

## 2 Summary of work plan

|               |   |
|---------------|---|
| <b>Year 1</b> | Consider approach and methodology for IEA, start assembling of data and information, and consider monitoring requirements |
| <b>Year 2</b> | Continue assembling of data and information and carry out analyses. Prepare an initial and incomplete draft of IEA        |
| <b>Year 3</b> | Finalize IEA report and consider monitoring requirements and priority research issues                                     |



### 3 Conduct of the meeting

The meeting was held at CRIS building 4th floor Room B&C, Hokkaido University, in Sapporo, with Emi Yoshida from Arctic Research Center as local host. She provided nice weather, and Sapporo proudly displayed its natural and historical setting near the central Hokkaido. The meeting started at 10 am on Wednesday 8 May and closed at 3 pm on Friday 10 May.

The meeting was attended by 26 participants from 6 countries (Canada, Japan, Korea, Norway, Sweden and United States of America). The list of participants is included as Annex 2.

The agenda for the meeting is given in Annex 3. In presentations and discussion, information on the various parts of the ecosystem of the central Arctic Ocean (CAO), from physics through lower trophic levels to birds and mammals, was considered with emphasis on spatial aspects and trophic linkages. The issues of vulnerability and linkages between ecosystem components (species and groups of organisms) and human sectors, activities and pressures in the context of Integrated Ecosystem Assessment (IEA) were also on the agenda.

The presentations given at the meeting will be uploaded on the ICES SharePoint site for WGICA.

## 4 Outcome of the meeting

### 4.1 Approaches and methodologies for conducting an IEA of the CAO ecosystem (ToR a)

The approach taken for the first IEA report has largely been compilation of information through review of scientific literature. Members of WGICA have also brought with them new information from recent cruises and studies conducted in the CAO and the Atlantic and Pacific gateways leading into it. The CAO differs from other LMEs in having few biological and oceanographic time-series available to describe status and changes of the ecosystem. Exceptions to this are satellite-based monitoring of sea ice and some oceanographic parameters, which provides a very important source of information on the CAO. Most of the information on recent changes in oceanography and biology come from the many investigations carried out for many different scientific purposes by research icebreakers from many nations. Taken together, this provides a mosaic of information, which can be used to describe the ecosystem and recent and ongoing changes taking place.

The 'scientific review' method will continue to be a main avenue for compiling information and assessing the changing state of the CAO ecosystem. In addition, WGICA seek to increase the use of satellite-based remote sensing of ocean colour and derived information on phytoplankton biomass, composition and production. We also foresee more use of mathematical modelling, particularly 3-D physical models to explore and describe water circulation and oceanographic features. We will also attempt to use 1-D models to assess in more detail the vertical processes and nutrient fluxes, which determine rates of primary production in the strongly stratified CAO ecosystem.

### 4.2 Ongoing and recent changes and events in the CAO ecosystem (ToR b) and New studies on fish (ToR e)

Presentations given under these agenda items are summarized in the following.

#### **Shigeto Nishino: R/V Mirai cruises and their contributions to IEA CAO**

##### **Summary**

The R/V Mirai has conducted Arctic research cruises under two Japanese projects, GRENE and ArCS. During the periods of GRENE and ArCS projects, we have mainly focused on the northern Bering and Chukchi seas, because there are several biological hotspots that are associated with not only environmental but also potentially economic and social issues. The research findings obtained by the R/V Mirai cruises could contribute to the integrated ecosystem assessment (IEA) in the Pacific gateway of the central Arctic Ocean. To further help develop the IEA of the central Arctic Ocean (IEA CAO), we will extend the research area to the deep Canada Basin including the marginal ice zone where the ocean environment and ecosystem are not well studied. We are now planning the R/V Mirai Arctic cruises in collaboration with the Synoptic Arctic Survey (SAS), which is a coordinated multi-ship, multi-nation pan-Arctic ship-based sampling campaign to be conducted in 2020 and 2021 (see Figure 1).

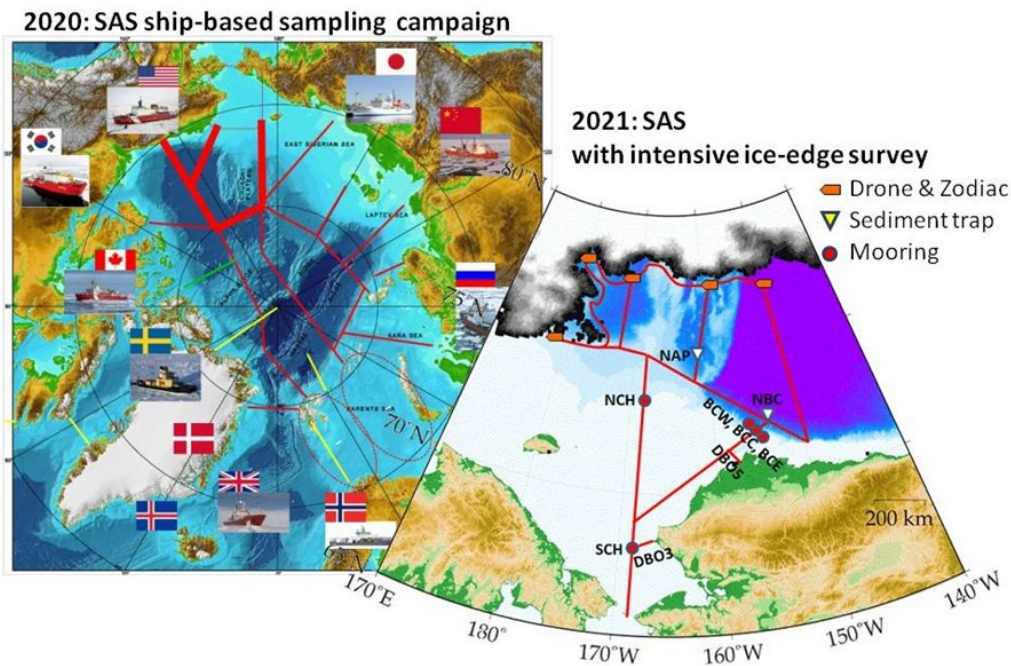


Figure 1. Planned R/V Mirai Arctic Ocean cruises in 2020 and 2021.

**Kevin Hedges: Canadian Research and Monitoring Relevant to the Central Arctic Ocean**

**Summary**

Kevin provided updated information on scientific activities in the Canadian Arctic including in the CAO. Canada is actively involved in the FiSCAO (Fish Stocks in the Central Arctic Ocean) process where a mapping survey and monitoring program are now being considered. The 'Last ice area' is the sea area north of Ellesmere Island which is considered of 'Outstanding Universal Value' due to the remaining multiyear sea ice and the specific conditions in this area. Scientific studies and conservation efforts aim to elucidate the biodiversity of habitats, species and genetics of this special area and include the use of autonomous moorings and surface instruments, as well as marine mammal surveys. The Canadian Beaufort Sea Marine Ecosystem Assessment (CBS MEA) is a continuation of the Beaufort Regional Ecosystem Assessment Marine Fishes Project (BREA MFP). The program addresses the variability and climate-driven change of forage species and ecosystem linkages, aiming to support co-management priorities, e.g. related to the food-base for marine mammals and subsistence fishes. Other activities include a multispecies survey (focused on Greenland halibut) and several exploratory inshore surveys in Baffin Bay and Davis Strait, as well as an ecosystem study around Southampton Island in northern Hudson Bay. These studies address habitat use, movement patterns, stock structure and trophic interactions of fish species and other compartments of the marine ecosystems in the eastern Canadian Arctic.

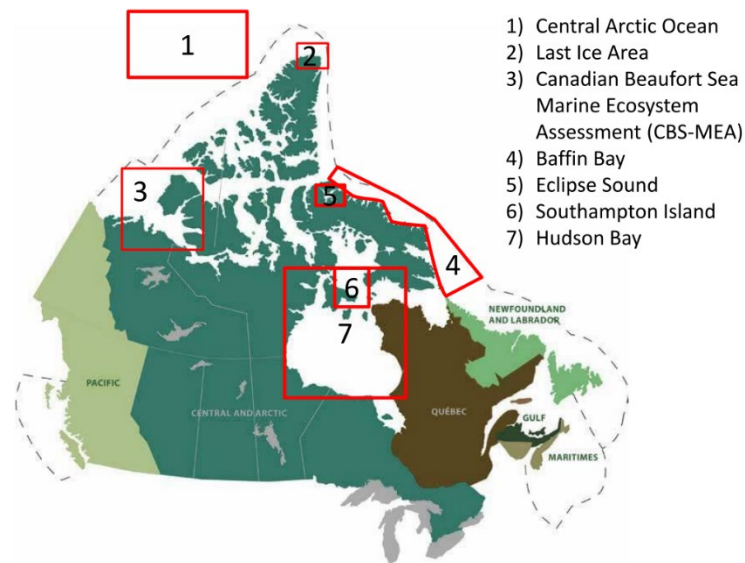
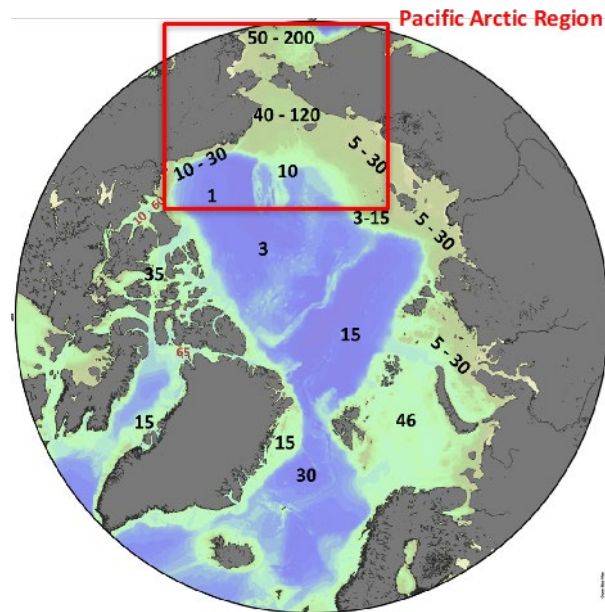


Figure 2. Map showing areas of dedicated research activities in the Canadian Arctic.

## Jacqueline Grebmeier: The Pacific Arctic: A Key Gateway Influencing the Central Arctic Ocean

### Summary

The goals of the Pacific Arctic Gateway activity in the WGICA are to describe the status and trends of ecosystem components in the region and the connection of these parameters to the Central Arctic Ocean. The Pacific Arctic Gateway has experienced rapid environmental change in recent years due to reduced sea ice extent (Frey et al. 2018) and seawater warming (Timmermans et al. 2017) that can impact shelf-basin exchange of water mass components and biological taxa into the offshore Arctic basin. The Chukchi Sea shelf system supports the highest annual net community production (40-120 g C/y) compared to the other Arctic shelf systems, with the lowest NCP in the CAO (Figure 1; Tremblay et al. 2015). *Calanus glacialis* is the common Pacific Arctic zooplankton over the shelf, but it has not been detected in any significant levels in the Canada Basin (Nelson et al. 2014). Similarly, the highest macrofaunal biomass occurs on the Pacific Arctic shelf regions (10-200 gC/m<sup>2</sup>), dominated by amphipods, bivalves, and polychaetes, with the lowest biomass of small organisms in the Canada Basin (Bluhm and Grebmeier 2011). Most observations of seabirds, marine mammals and fish utilize the high prey items over the Pacific Arctic shelf region (CAFF 2017). However, the limited sampling in the offshore Arctic Basin and CAO limit our understanding of the status and trends of these organisms in an ecosystem evaluation. In order to evaluate the connection of the shelf regions to the CAO the international Synoptic Arctic Survey (SAS) is under development for multiple cruises in the Pacific sector in 2020 and 2021 coincident with other pan-Arctic cruises. The goal of the SAS is to investigate physical forcing, carbon cycling, and ecosystem response in the water and sediments that can provide valuable data towards an ecosystem assessment of the shelf-to-basin ecosystem connectivity. Further details available in the international SAS science plan (<http://www.synopticarcticssurvey.info/splan.html>) and recent 2019 SAS workshop report (<https://web.whoi.edu/sas2019/>).



**Figure 3. Coarse spatial distribution of annual NCP (g C/ yr) across different sectors of the Arctic Ocean (composite from Tremblay et al. 2015).**

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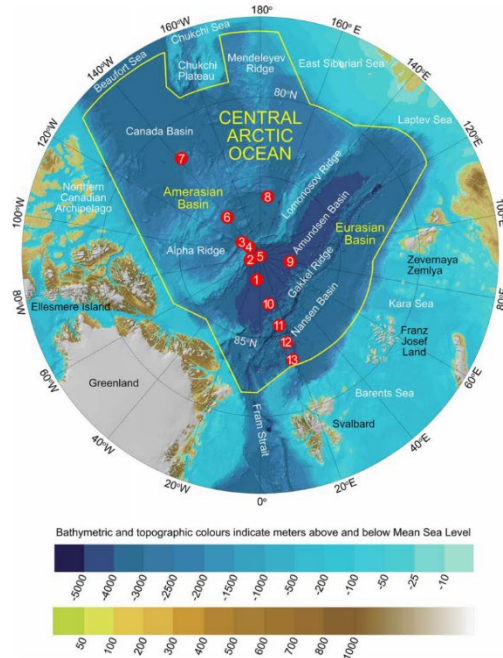
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### **Snoeijs Leijonmalm: A deep scattering layer under the North Pole sea ice**

#### **Summary**

She held a lecture presenting the 2016 Oden data, the manuscript of which will be submitted for publication before 15 May 2019. The lecture also briefly summarized the future plans for using the MOSAiC (2019-2020) and the Oden (2020) expeditions as ships-of-opportunity for the EFICA Consortium to collect new fish data. Like in the Archangelsk (Russia) meeting in April, the new

acoustic data from Oden were received with great enthusiasm and were referred to often during the rest of the workshop.



Good data were available from 13 stations

Figure 4. Map of acoustic observation stations by RV Oden.

### H.C. Shin: CAO fisheries agreement, at last and then, what?

#### Summary

He provided status on CAO fisheries agreement and some information from the meeting on Central Arctic Ocean Monitoring Program held in Arkhangelsk, Russia April 12-13, 2019.

Practically a moratorium for commercial fishing in CAO is for 16 years. Regulation of fisheries that have not even started. No permit issued for commercial fishing until proper management regime in place until good science and adequate information. Parties meeting at least every 2 years. Scientists must meet 3 months before and advise. Joint science program will have to be developed in 3 years time. No scientist meetings commissioned or requested to directly serve Governments.

FiSCAO; more of individual expert meeting, although supposedly government commissioned  
WGICA (ICES, PAME and PICES); more of international body initiation

### H.C. Shin: Korean Arctic Ocean studies with emphasis on ecosystem dynamics

#### Summary

He provided updated information on Korean Arctic Ocean studies during 2010-2017 using IBRV Araon (Figure 5). He introduced the result of study on phytoplankton community distribution in the Chukchi and East Siberian Seas. Future studies are summarized as follows:

1. Investigating the phytoplankton community structure & the primary production
2. Assessing the responses of phytoplankton community to a range of light conditions and Nutrients enrichment

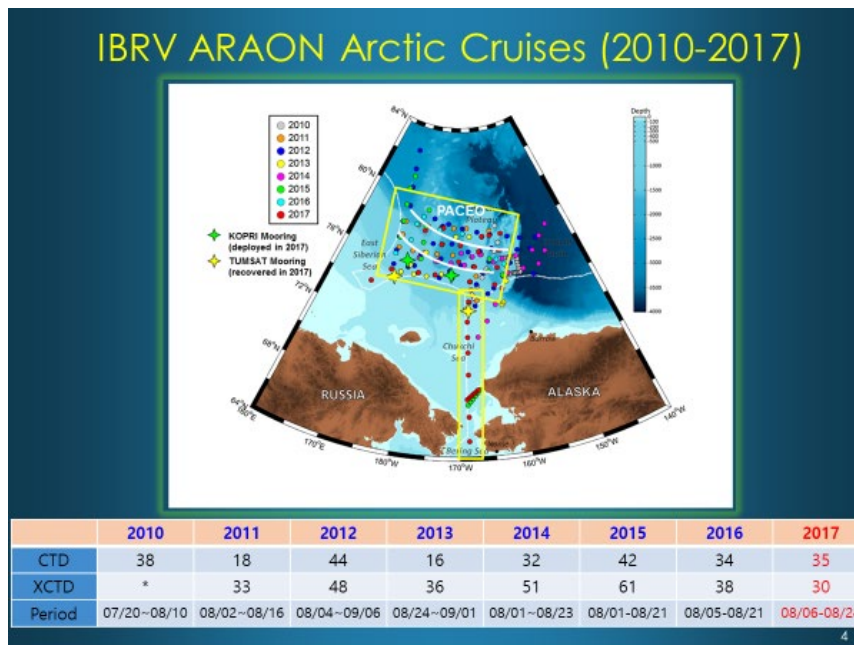


Figure 5. Map of Arctic cruises by IBRV Araon in 2010-2017.

### 4.3 Effects of climate change on the CAO ecosystem (ToR c)

The CAO ecosystem is undergoing substantial change associated with the massive and dramatic loss of sea ice, most pronounced in summer but also reflected in winter ice conditions. As a trend over the last few decades, about half the area and ¾ of the volume of the minimum sea ice in summer have been lost with a pronounced change from thick and old multi-annual ice to now mostly thin and young ice. This change which already has happened has been described as the ‘Great melt’.

We plan to summarize the documented or inferred biological and ecological changes associated with the Great melt. This will be through a scientific literature review of what have been found in the many recent studies in the CAO, including relevant information provided by working group members from ongoing studies.

### 4.4 Transport pathways and potential effects of contaminants (ToR d)

Pollution is a new item to be addressed in more detail by WGICA in the next IEA report planned for 2021. Pollution is a complex issue as evidenced by the extensive work on this topic by AMAP. For the CAO there are two aspects which we aim to examine: transport pathways and potential biological or ecological effects. AMAP produced a report on pathways in 2003 (Macdonald, R.W., T. Harner, J. Fyfe, H. Loeng and T. Weingartner, 2003. AMAP Assessment 2002: The Influence of Global Change on Contaminant Pathways to, within, and from the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xii+65 pp.). This report highlighted the combined effects of climate change on both physical and biological pathways of contaminants in the environment and foodwebs. We will build on this to address the changes in main pathways of contaminants using updated information on physical changes and trophic linkages in foodwebs. To the extent possible, we will also examine potential effects on biological compartments of the CAO ecosystem.

The work on this item requires a strengthening of the expertise on contaminants and pollution in the working group. We seek collaboration with AMAP to help us provide the necessary expertise. ICES has a Working Group on Biological Effects on Contaminants (WGBEC). We are also seeking collaboration with this group to help us with this new ToR on contaminants and pollution.

## 4.5 Ecosystem overview for the CAO (ToR g)

ICES are producing ecosystem overviews of various ecoregions (which correspond broadly to LMEs, e.g. the Barents Sea) in the ICES area following a template with sections on ecoregion description, key signals, pressures, and state of the ecosystem.

Inigo Martinez from the ICES secretariat provided a presentation with background information on the ICES ecosystem overviews. At this meeting the information was noted. WGICA plans to produce a draft Ecosystem overview for the CAO next year, to be revised and finalized for delivery to ICES in 2021. The information on the state of the ecosystem and pressures from human activities will be taken from the first (2018) and second (2021) IEA reports for the CAO (see below).

## 4.6 Completion of the first IEA report (2016-2018)

The main product from the first three years of work (2016-2018) of WGICA is an IEA report for the CAO:

*Integrated Ecosystem Assessment of the Central Arctic Ocean: Ecosystem description and vulnerability characterization.*

An outline of the report was agreed at the 3rd meeting of WGICA in St. John's last year. This comprised chapters on various compartments of the CAO ecosystem including physics, lower trophic levels, fish, birds, and marine mammals. The intersessional work on the report has followed the structure agreed in St. John's. The aim was to finish the report in early 2019 in time for the Arctic Council ministerial meeting in May of this year. We did not meet this deadline and work to complete the report has continued after spring.

The first report of WGICA is descriptive and contains a vulnerability analysis (as far as possible with the limited data), which is the first step of an IEA. There is now a first version of the manuscript (about 200 pages). In the Sapporo meeting this manuscript was carefully discussed, restructured at the chapter level, and a time schedule was agreed upon. According to this schedule, the CAO IEA Part 1 Report will be delivered in November 2019. The chapters of the report will be: Introduction (Purpose of this IEA for the CAO, Definition of the CAO, Map of the area and LMEs), Overview of the CAO (CAO key features, Pacific gateway, Atlantic gateway), Description of the CAO ecosystem (Climate, oceanography, sea ice, Pelagic and sympagic algae, Pelagic and sympagic bacteria, Zooplankton and ice fauna, fish and fish stocks, seabirds, marine mammals), and Vulnerability analysis.

The report will be published in the series of ICES Cooperative Research Reports. ICES will provide technical editing including peer review as part of the editorial process. At the time of finishing this meeting report (October 2019) we note further delay in finalizing the report. The co-chairs will meet in mid-October to discuss progress with the aim to provide a final draft report to ICES in December 2019.



## **4.7 A second IEA report for the CAO ecosystem in 2021**

The work on the various ToRs of the 2019-2021 work plan (see Annex 1) will be drawn together and used as components of a next IEA report for the CAO ecosystem. This will build on the first report, which contains a description of the ecosystem and a first vulnerability characterization, to go in more detail into an assessment of human activities and their pressures and impacts on the ecosystem. This will include climate and climate change (ToR c), contaminants and pollution (ToR d), shipping (including tourism), and potential future fisheries.

A more detailed plan of the second IEA report will be prepared in 2020.

## **4.8 Next meeting**

Venue and time for a next meeting in 2020 will be on WebEx 27-29 April. Contact the Chairs for more information.

## Annex 1: List of participants

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|                        |                           |        |                              |
|------------------------|---------------------------|--------|------------------------------|
| Masato Tanaka          | Hokkaido University       | Japan  | mtanaka@arc.hokudai.ac.jp    |
| Cecilie von Quillfeldt | Norwegian Polar Institute | Norway | Cecilie.quillfeldt@npolar.no |
| Senjie Yang            | Hokkaido University       | China  | 76008563@qu.com              |
| Toya Yukawa            | Hokkaido University       | Japan  | outdoor1026@gmail.com        |

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## Annex 2: Agenda for 2019 meeting

### **Wednesday, 8 May – Day 1**

#### **10:00 Welcome, introductions, and practical information**

- Welcome by host
- Introductions by Co-chairs
- Introductions of participants
- Practical information on meeting, facilities etc.

#### **10:20 Adoption of agenda and arrangements for the report of the meeting**

- Review of terms of reference
- Goal of the meeting
- Adoption of agenda
- Assignment of rapporteurs

12:00 Lunch break

#### **13:00 Ongoing and recent changes and events in the CAO ecosystem (ToR b)**

##### **Climate, oceanography and sea ice**

(Nishino) R/V Mirai cruises and their contributions to IEA CAO

(Kevin Hedges) Canadian Research and Monitoring Relevant to the Central Arctic Ocean

##### **Pacific gateway**

(Jacqueline Grebmeier) The Pacific Arctic: A Key Gateway Influencing the Central Arctic Ocean

##### **Primary production**

(Hein Rune Skjoldal) TBD

15:00 Break

#### **15:30 Ongoing and recent changes and events in the CAO ecosystem (ToR b)(continued)**

##### **Zooplankton and ice biota**

##### **Fish**

(Snoeijs Leijonmalm Sweden) A deep scattering layer under the North Pole sea ice

##### **Birds**

##### **Marine mammals**

(John Bengston) TBD

17:30 Close of meeting day 1

18:00-19:30 **Welcome Reception** (Restaurant Elm, Faculty House, N12W6 in Campus)

**Thursday 9 May – day 2**

09:30 Summary day 1

10:00 **Climate change and effects on the CAO ecosystem (ToR c)**

10:30 Break

11:00 **A Climate change and effects on the CAO ecosystem (ToR c) (continued)**

12:00 Lunch

13:00 **Approaches and methodologies for IEA (ToR a)**

(H.C. Shin) Central Arctic Ocean Fisheries Agreement and Incubating the Science Leadership: Acting Early for Later Pay-off

15:00 Break

15:30 **Initial consideration of how to address contaminants and pollution in the CAO (ToR d)**

17:30 Close of meeting day 2

19:00-21:00 **Group Dinner** (Sapporo Beer Garden)

**Friday 10 May – day 3**

09:30 Summary day 2

10:00 **New studies on fish and other components of the CAO ecosystem (ToR e)**

10:30 Break

11:00 **Ecosystem overview for the CAO - initial planning (ToR f)**

12:00 Lunch

13:00 **Next steps - intersessional work, next meeting**

14:00 **Summary, conclusions, and follow-up**

16:00 Close of workshop

## Annex 3: Resolutions

### ICES/PICES/PAME Working Group on Integrated Ecosystem Assessment of the Central Arctic Ocean (WGICA)

**2018/MA2/IEASG06** A Joint ICES/PICES/PAME Working Group on Integrated Ecosystem Assessment of the Central Arctic Ocean (WGICA), chaired by John Bengtson, USA, Sei-ichi Saitoh, Japan, and Lindal Jørgensen, Norway, will work on ToRs and generate deliverables as listed in the Table below.

|           | MEETING DATES | VENUE             | REPORTING DETAILS                           | COMMENTS (CHANGE IN CHAIR, ETC.)   |
|-----------|---------------|-------------------|---|--|
| Year 2019 | 8-10 May 2019 | Sapporo, Japan    | Interim report by 1 September 2019 to IEASG |  |
| Year 2020 | 27-29 April   | by correspondence | Interim report by 10 June 2020 to IEASG     | Hein Rune Skjoldal, Norway as outgoing Chair. Lis Lindal Jørgensen, Norway as incoming Chair |
| Year 2021 | To be decided | To be decided     | Final report by 31 December 2021 to IEASG   | Change of chairs   |

### ToR descriptors

| ToR | DESCRIPTION   | BACKGROUND  | SCIENCE PLAN CODES | DURATION  | EXPECTED DELIVERABLES   |
|-----|---|---|--------------------|-----------|---|
| a   | Review and consider approaches and methodologies for conducting an IEA of the CAO ecosystem.  | WGICA has produced a first version IEA report for the CAO. Before producing an updated and extended version, the basic approach and methodologies should again be considered. | 2.2, 6.1, 6.5      | Year 1    | Report outcome in the 2019 interim report.  |
| b   | Review and report on ongoing and recent changes and events in the CAO ecosystem associated with changes such as in sea ice, oceanographic circulation, and hydrographic properties. | There is a need to follow developments in the CAO resulting from the predicted further loss of sea ice and other physical changes associated with global climate change.      | 1.1, 2.2, 6.5      | Years 1-3 | New information will be reported in interim reports in 2019 and 2020. A more full account will be given as part of a second version IEA report for the CAO in 2021. |

|   |   |  |                    |            |  |
|---|---|--|--------------------|------------|--|
| c | Continue to examine effects of climate change on the CAO ecosystem by compiling and reviewing information on changes in response to the ongoing 'Great melt', and assess likely consequences to the CAO ecosystem of projected future changes associated with further loss of sea ice and other climate-related changes (i.e. a climate impact assessment). | This activity was started in the first 3-year period, and some information is included in the 2018 IEA report. There is a need to continue and carry out a more detailed assessment of the documented and/or inferred biological and ecological changes associated with the large physical changes that have already taken place (e.g. loss of half the area and ¾ of volume of summer sea ice). | 1.1, 1.3, 6.1, 6.5 | Years 1-3  | Progress will be reported in interim reports in 2019 and 2020. A more full account will be given as part of the new version of the IEA report for the CAO in 2021. |
| d | Assess the consequences of recent and ongoing climatic and oceanographic changes on transport pathways (physical and biological) and potential effects of contaminants in the CAO ecosystem.  | This is a new activity which relates to assessment of pollution in the CAO. Pollution can be expected to be one of the more serious threat to the CAO ecosystem and should be included in an IEA.  | 2.1, 2.5, 6.1      | Years 2, 3 | Progress will be reported in interim report in 2020. Aspects of pollution will be included in the new IEA report for the CAO in 2021.                              |
| e | Review and report on new studies on fish as well as other biological components of the CAO ecosystem.   | The information on many parts of the CAO ecosystem is still limited. New information is expected to come over the next few years as research ice-breakers pay more attention and use scientific echosounders and other observation techniques to record fish and other organisms in the water column and at the seafloor.  | 5.2, 6.1, 6.5, 6.6 | Years 1-3  | Progress will be reported in interim reports in 2019 and 2020. A more full account will be given as part of the new version of the IEA report for the CAO in 2021. |

|   |   |  |                         |            |  |
|---|---|--|-------------------------|------------|--|
| e | Continue to identify priority research needs and monitor how identified knowledge gaps (needed to improve IEA and management effectiveness) are being addressed and filled. | A by-product of doing the first version IEA of the CAO is a priority list of research needs. It is necessary to monitor how knowledge gaps are filled that will improve new versions of IEA. | 1.3, 2.2, 3.1, 6.1, 6.5 | Years 2, 3 | Progress will be reported in the interim report in 2020 and outcome reported in 2021.            |
| f | Prepare an Ecosystem Overview for the CAO ecosystem   | This will be an addition to the series of Ecosystem Overviews prepared by ICES.  | 6.5, 6.6                | Years 2, 3 | Draft version will be reported in the interim report in 2020 and final version reported in 2021. |

### Summary of the Work Plan

|               |  |
|---------------|--|
| <b>Year 1</b> | Review IEA methodologies for IEA of the CAO. Review and report new information and changes in the CAO ecosystem.   |
| <b>Year 2</b> | Review and report new information and changes in the CAO ecosystem. Address pathways and effects of contaminants, make an initial list of research needs, and prepare draft Ecosystem Overview.  |
| <b>Year 3</b> | Prepare a second version IEA report for the CAO with information on status and trends, including impacts of climate change, pollution, and other relevant human pressures. Report on research needs and prepare final draft of Ecosystem Overview. |

### Supporting information

|                                 |   |
|---------------------------------|---|
| <b>Priority</b>                 | <p>WGICA is one of several groups in ICES that do integrated ecosystem assessments, which is one of the priority action areas for ICES. Being a WG for the central Arctic Ocean, WGICA also contributes to the Arctic research action area. Jointly sponsored by PICES and the PAME working group of the Arctic Council, WGICA represents a collaborative effort that links ICES work in the wider Arctic Mediterranean Sea (the Nordic Seas and the central Arctic Ocean) with expertise on the Pacific Arctic through PICES.</p> <p>The work planned in WGICA will directly address ICES science priority area 6 Developing tools, knowledge and evidence of effective conservation and management and some elements of priority area 2 (Understanding ecosystems) and 3 (Impacts of human activities).</p> |
| <b>Scientific justification</b> | <p>ICES IEA EGs provide science based assessments of ecosystem status, trends and vulnerabilities to support implementation of the ecosystem approach to management.</p> <p>ToR a – The CAO is a data-deficient system where much of the data and knowledge comes from research activities, while monitoring is a more limited source of information. Based on the first version IEA report for the CAO, as well as experiences from the other IEA WGs in ICES, the approach and methods for IEA for the CAO will be considered prior to producing a second version IEA report in 2021.</p> <p>ToR b – The CAO is on a trajectory of reduction of sea ice with considerable interannual variability. Trends and events will be reported to draw attention to the ongoing changes in the CAO.</p>              |



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|   | <p>ToR c – The purpose and aim of this item is to provide a careful evaluation and summary of what we can say about the biological and ecological effects of climate change over the recent decades up to present. This can in turn be used for projections of likely effects of continued warming and loss of sea ice over next decades.</p> <p>ToR d – This item addresses pollution with focus on contaminant pathways (physical and biological) and potential effects in foodwebs of the CAO. The scale of activity will depend on the expertise available in the WG.</p> <p>ToR e – It is expected that new information will be forthcoming on occurrence of fish and other biota in the CAO from planned research activities. There is for instance increased awareness that scientific echosounders on research ice-breakers can provide valuable information. We will report on developments and include new information in the next IEA report.</p> <p>ToR d – This is an item meant to provide guidance to the research community at large on priority research issues to improve the knowledge base for continued IEA work.</p> <p>ToR e – This will add to the suit of Ecosystem Overviews prepared and published by ICES.</p> |
| <b>Resource requirements</b>                  | No major resourcing.   |
| <b>Participants</b>                           | Experts from ICES, PICES, and PAME   |
| <b>Secretariat facilities</b>                 | Support for meetings at ICES HQ, when appropriate.   |
| <b>Financial</b>                              | No financial implications for ICES.  |
| <b>Linkages to ACOM and groups under ACOM</b> | Link to ACOM through the development of Ecosystem Overviews and advice.  |
| <b>Linkages to other committees or groups</b> | Within ICES links across all ICES IEA working groups and to HAPISG EGs on human pressures on marine ecosystems, such as pollution.   |
| <b>Linkages to other organizations</b>        | This is a joint ICES, PICES, and PAME WG.  |

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