ICES/PICES/PAME WORKING GROUP ON INTEGRATED ECOSYSTEM ASSESSMENT (IEA) FOR THE CENTRAL ARCTIC OCEAN (WGICA; outcomes from 2021 meeting)

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ICES Scientific Reports

Volume 4 | Issue 6

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PICES

PAME Protection of the Arctic Marine Environment

ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

Contents

i Executive summary

The Working Group on the Integrated Assessment of the Central Arctic Ocean (WGICA) aims to provide a holistic analysis of the present and future status of the Central Arctic Ocean (CAO) ecosystem and human activities therein.

Climate change reduces sea ice, increases light penetration, causes regionally variable trends in stratification and mixing of the water column, increases inflow in both the Atlantic and Pacific sectors, and heating of waters at the surface and extending deeper. These changes in turn affect primary production and cascade through the foodweb to ice-associated fauna, zooplankton, fish, benthos, seabirds, and marine mammals.

These changes may be exacerbated by increasing human activities in and around the CAO, including increasing pollution from ship traffic and from the transport of contaminants to the ecoregion by rivers and ocean currents. The number of ships and distances travelled are increasing and it is anticipated that both commercial and tourist traffic by sea and air will continue to rise. The CAO is a sink for many pollutants such as microplastics, which have been found in sea ice and wildlife. Current and future threats to the ecoregion from human activities and pressures also include increased risk of oil spills and biodiversity loss if ocean mining expands into the Arctic.

While the Agreement to Prevent Unregulated Fishing in the High Seas Portion of the Central Arctic Ocean entered into force in June 2021 bans commercial fishing in the high seas of the CAO, fish populations continue to be impacted by the effects of a warming ocean, retreating ice cover, and acidification. These threats have important ecological and policy implications for the entire foodweb and the Arctic community.

During this past year, WGICA has further studied and described human activities and resulting pressures. In the next three years, WGICA will identify ecological, economic, social and institutional research questions, further stakeholder involvement, and identify integrated assessment methods that can help evaluate ecosystem conditions and changes.

ii Expert group information

Expert group name	ICES/PICES/PAME Working Group on Integrated Ecosystem Assessment (IEA) for the Central Arctic Ocean (WGICA)
Expert group cycle	Multiannual
Year cycle started	2019
Reporting year in cycle	3/3
Chair(s)	Martine van den Heuvel-Greve, Netherlands
	Lis Lindal Jørgensen, Norway
	Sei-Ichi Seito, Japan
Meeting venue(s) and dates	08–10 May 2019, Sapporo, Japan (26 participants)
	27–29 April 2020, Online (41 participants)
	12–12 April 2021, Online (31 participants)
	12–14 October, Online (60 participants)

1 The geography of the Central Arctic Ocean

The "Central Arctic Ocean" (CAO) Large Marine Ecosystem (LME) is about 3.3 million km² in surface area (red inner line in Figure 1) and consists of a High Seas area (2.8 million km² green inner line in Figure 1) as well as areas under the Russia, Canada, Denmark/Greenland and Norwegian jurisdiction.

WGICA considers the geographical area in the CAO LME including the High Sea of the Central Arctic Ocean as its geographical working area (black dashed line in Figure 1). The boundary of the WGICA geographical area follows the continental slopes along the 500 meter isobath on the Eurasian side and across the partly shallower Chukchi Borderland, crosses the deeper Canada Basin, and continues along the 500 meter isobath from the Canadian High Arctic to the shelf edge of North Greenland and the, crosses Fram Strait connects back to the slopes of the Barents Sea and the Russian Seas.

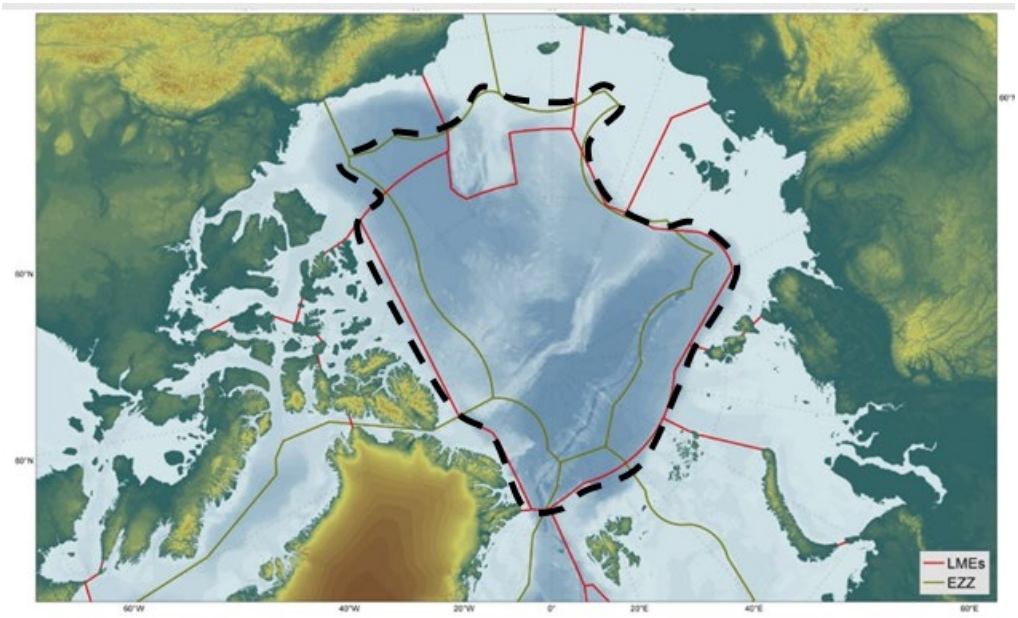


Figure 1. The Central Arctic Ocean LME (the inner red line) and the high sea above the Chukchi Borderland and Beaufort Sea make up the WGICA study area (black dashed line). The WGICA study area includes both areas under national jurisdiction (EEZ boundaries in green) as well as the High Seas beyond national jurisdiction (the red line); (source: ICES WGICA REPORT 2015 ACOM/SCICOM Steering Group on Integrated Ecosystem Assessments, ICES CM 2015/SSGIEA:11, REF. SCICOM & ACOM).

2 Main conclusions of the ToR (2019–2021)

The text for the ToR are taken from the Annual Report 2020 where the full text with all references and reference list can be found here: https://www.ices.dk/sites/pub/Publication%20Reports/Forms/DispForm.aspx?ID=36908

2.1 ToR a: Review and consider approaches and methodologies for conducting an Integrated Ecosystem Assessment (IEA) of the CAO ecosystem including Human Activities from the viewpoint of Climate and Vulnerability Assessments

The ToR a) was moved to WGICA ToRs 2022–2024.

2.2 ToR b: Review and report on ongoing and recent changes and events in the CAO associated with changes in sea ice, oceanographic circulation, and hydrographic properties

Summer sea ice extent in the past decade or so has remained fairly stable at -22 ± 8% relative to the mean climatic norm for the available range of satellite observations (1979–2019). Ice thickness declined massively across the central Arctic by 65%, from 3.59 to 1.25 meter, between 1975 and 2012. The Atlantic gateways to the Arctic Ocean are currently experiencing greater inflows, manifested in a warmer ocean and atmosphere, northward and eastward spread of Atlantic Water in the Barents Sea and the Nansen Basin, and reduced stratification and increased mixing in the upper ocean in the Eurasian Basin.

The Bering Sea (outside CAO) recorded unprecedented high sea surface temperatures in 2014 and the warm condition has persisted into 2019. The Canadian Basin showed strong freshening and a deepening of the nutricline and deep chlorophyll maximum. A more energetic state of the intermediate water layer in the CAO is projected in future years. This new state will be presumably supported by stronger currents and shear, leading to increased turbulent mixing and larger upward oceanic heat fluxes.

2.3 ToR 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

Microalgae, Sea Ice Biota and Zooplankton: Changes in the amount, type, timing and location of sea ice in the Arctic, along with related changes in light availability, temperature, salinity and nutrient concentrations in surface layers, are affecting the timing and abundance of primary production and the biomass and species composition of ice biota and the major zooplankton species, with likely important consequences for foodweb functioning.

Benthos: Diverse deep sea habitats, including undersea mountains, ridges, glacial deposits and other features provide benthic biodiversity, but little is known about changes to these and other deep sea communities. On the shelves, there is evidence of declining benthic biomass in the northern Bering Sea and the southern Chukchi Sea along with a northward shift in dominant macrofaunal biomass, which has also been observed in the European Arctic. The long lifetimes, slow growth-rates and low fecundity of deep sea organisms may make them vulnerable to human activities such as mining, oil exploitation, bottom fisheries, climate change as well as, noise, plastic and chemical pollution.

Fish: Diminishing sea ice, earlier melt, higher ocean temperatures and resulting changes in salinity, nutrient availability and prey availability are affecting the biomass, abundance and distribution of different fish populations, including that of polar cod (*Boreogadus saida),* a keystone Arctic species. Increased human presence in and near the CAO is exposing fish populations to plastic and other pollutants and increasing ocean noise, which has been shown to affect polar cod (*B. saida*) behaviour. Should commercial fishing, mining or oil development commence in the CAO, a variety of impacts on fish can be expected.

Marine mammals: Based on current knowledge, the CAO appears to be relatively scarcely populated by marine mammals; with continued ice retreat, however the importance of the CAO may increase over time, especially for ice dependent pelagic-feeding or generalist species like ringed, ribbon, harp and hooded seals, belugas (walrus, polar bear,) narwhals and bowhead whales, some of which are already experiencing population declines. Some polar bears currently also use sea ice in the CAO as a summer hunting habitat but increasing distance to denning habitats on land may compromise this strategy in the future. Many marine mammals rely on acoustics for key life functions; increasing human presence in the region will bring increasing noise from seismic airguns, ship engines, military operations, fisheries, research sonars and possible mining, which can interfere with vital behaviours.

Seabirds: Large numbers of breeding, non-breeding, and migratory seabird individuals use open water habitats in marginal shelf waters of the Central Artic region during summer and autumn, foraging on invertebrates and forage fish. However, few seabirds occupy the mostly ice-covered CAO region itself. Predicted ice-free summers in the CAO are likely to affect seabird populations, in part through impacts on prey species (e.g. *B. saida*). Other impacts of diminished sea ice range from smaller scales, e.g. reduction in ice-dependent species like ivory gulls and Ross's gulls, to possible large-scale changes in migration and distribution patterns of northern hemisphere marine birds. In addition, post-breeding and migrating marine birds in newly ice-free CAO waters

would overlap with increased vessel traffic (including more interactions during darker months), which will increase bird collisions with ships. Pollution or plastic debris, which can increase with vessel traffic, can also be detrimental to marine birds.

In addition, post-breeding and migrating marine birds in newly ice-free CAO waters would overlap with increased vessel traffic (including more interactions during darker months), which will increase bird collisions with ships. Pollution, including plastic debris, which can increase with climate change and further industrial development of the Arctic Ocean, can also be detrimental to marine birds.

2.4 ToR d: Assess the potential effects on the CAO ecosystem of recent, ongoing and future climatic and oceanographic changes on Human activities and recent ongoing pollution

The CAO and adjoining waters remain relatively unpolluted, but the Arctic Ocean is a sink for pollutants transported from lower latitudes, and pollution from local sources is also increasing. Emissions of chemical compounds (e.g. mercury, POPs) from outside the CAO are currently the main source of air pollution. Other pollutants, including flame retardants, pesticides, and phthalates, are an emerging concern. Macro-, micro- and nanoplastics, transported by rivers and ocean currents, have been found in sea ice and wildlife. Sea ice is an important sink for microplastics. The number of ships and the distances travelled are increasing in the Arctic; currently up to 45% of traffic is associated with fishing vessels, but larger vessel traffic is increasing. We also consider future activities that may impact the CAO as sea ice cover decreases. For example, oil spills from activities on the continental shelves may affect the CAO ecosystem. Ocean mining may expand into the Arctic, resulting in biodiversity loss even as most species in the CAO remain undiscovered or unidentified. An agreement has been made to ban commercial fishing in the high seas of the Central Arctic Ocean; still, the problem of Abandoned, Lost or otherwise Discarded Fishing Gear (ALDFG) is a factor to consider in the CAO area even if commercial fishing is not allowed. Tourism is generally associated with ships or, in smaller volumes, as flights to the North Pole.

2.5 ToR e: Review and report on new studies on fish of the CAO ecosystem

Research on marine fishes in the CAO and adjacent waters published during 2017–2020 is summarized, building on earlier summaries by other groups (e.g. related to the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean). Polar cod (*Boreogadus saida*), a keystone species in Arctic foodwebs, continues to be a research focus, with new publications detailing increasingly more about the species' ecology, distribution, genetics, links to other species and impacts from climate change. Other research has examined fish community structure and anticipated impacts of climate change (e.g. potential for species to expand northward into the CAO). Policy papers have also developed recommendations regarding commercial fishery development.

2.6 ToR f: Continue to identify priority research needs and monitor how identified knowledge gaps are being addressed and filled

Data collection of physical conditions, contaminants, primary and secondary producers and sea ice biota must be standardized and also obtained during winter. Mapping and baseline studies were identified as priorities for benthos, marine mammals and fishes including the development/use of new technology. Marine mammals need studies on life history, health and ecology.

Possible future fisheries development of new management tools can safeguard sustainable development of ecosystems and human stakeholders in the face of a rapidly changing environment. Studies of Arctic marine mammal sensitivity to low frequency anthropogenic noise were identified as a research priority.

2.7 ToR g: Prepare an Ecosystem Overview (EO) for the CAO ecosystem

Development of an Ecosystem Overview (EO) commenced in 2020 with the identification and prioritization of ecosystem pressures that would be considered. Links between the five main identified pressures (sea ice loss, non-indigenous species, contaminants, marine litter and noise), human activities and ecosystem components were initially discussed; these links were further examined by WGICA during 2020–2021. In November/December 2021 the EO was revised and reworked by the ICES Advisory Drafting Group (ADG).

3 Progress of deliverables during 2019–2021

3.1 The Ecosystem Overview of the CAO

- 2020–2021 several online workshops
- Draft delivered for ICES-light review April 2021
- Editing during April–August 2021
- Draft delivered for ICES full review August 2021
- ICES advisory board review September/October 2021
- Processing review comments 21–29 October 2021
  - Co-authors available for input and discussion?
- Final version beginning of December 2021

3.2 WGICA Report 2020

WGICA report 2020 is available at this link:

https://doi.org/10.17895/ices.pub.8007

3.2.1 Report 1: First Integrated Ecosystem Assessment report on the CAO

Ecosystem assessment of the Central Arctic Ocean: description of the ecosystem (reviewed, and now in edition)

This report will be published by ICES in the Cooperative Research Report (CRR) series which includes peer review and technical editing by ICES prior to publication.

The title of the report is: "Integrated Ecosystem Assessment of the Central Arctic Ocean: ecosystem description". The plan was to include also a section on vulnerability characterization. This part has now been moved to the second report where emphasis will be on human activities and their impacts on the CAO ecosystem. The chapters together provide a description of the ecosystem by ecosystem components following a traditional breakdown into oceanography, plankton, fishes, birds, etc.:

- Chapter 1 – **Introduction**
- Chapter 2 – **Topography, oceanography and sea ice**
- Chapter 3 – **Algae and primary production**
- Chapter 4 – **Zooplankton and invertebrate ice fauna**
- Chapter 5 – **Sympagic and pelagic bacterial communities**
- Chapter 6 – **Arctic benthos**
- Chapter 7 – **Fishes in the Central Arctic Ocean**
- Chapter 8 – **Marine birds: species occurrence and habitat use**
- Chapter 9 – **Marine mammals of and near the central Arctic Ocean**

The draft of the report was sent to ICES by the end of 2020 for per review. The Report is now in the editing phase before the publication.

3.2.2 Report 2 part 1: Human activities, pressures and management bodies (in preparation)

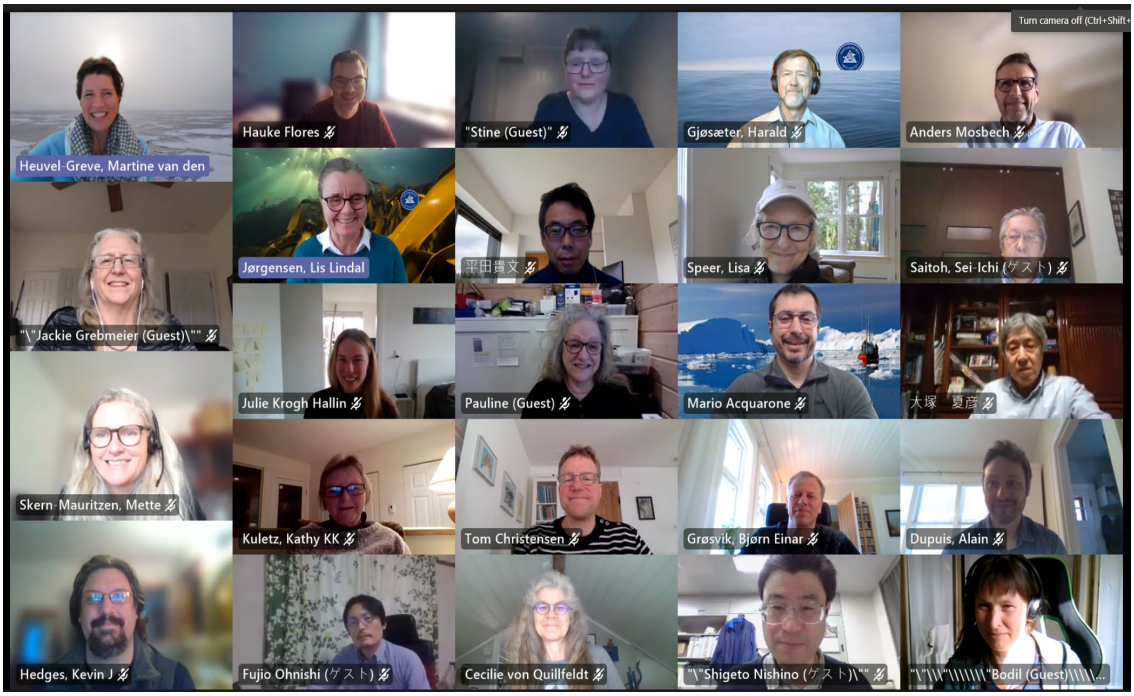
The outline of the report 2 part 1 has been circulated within the WGICA group and PAME and the chapters are currently being written by dedicated author groups from WGICA.

4 Meetings in 2021

4.1 Summary from the online WGICA spring meeting 12–13 April 2021

The WGICA group had a spring meeting to: 1) maintain the WGICA Vision of 2015 to provide the scientific background and annual status, trends and pressures reports for the CAO, 2) to kick-start Report 2 part 1 (Human activities, pressures and management bodies), 3) to finish the "possible future situation" of the EO, and 4) Prepare for the October annual meeting (Reports, new ToR, IA). The meeting was led by the co-leads: Lis

Lindal Jørgensen, Martine van den Heuvel-Greve and Sei-Ichi Saitoh. In total were 32 scientist and ICES secretariat members were participating on day one and 31 participating on day two. The agenda for the meeting is given in Annex 3.



Some of the WGICA participants from day 1

4.1.1 Report 2 part 1 – Human activities, pressures and ecosystem impact in the CAO LME

This report will cover the Central Arctic Ocean LME (Large Marine Ecosystem) as geographically defined by WGICA in the opening of this report (page 1). The focus is on present and future **human activities**, the **pressures from these human activities**, and the impact of these pressures on the living ecosystem. The report will also describe policy, management mechanisms, and existing measures. The report will include a final chapter on what type of analyses and models exist for compiling ecosystem, human activity, pressures and policy metadata. Report 2, part 1 draw from published per reviewed literature and information in Report 1 and the Ecosystem Overview Report. The six chapters are defined as follows:

REPORT 2, part 1

1. Existing human activities and environmental change originate outside the CAO and brought into the CAO by ocean currents, river water and airborne, and its pressures.
2. Existing human activities and environmental change originate inside the CAO (high sea area and in national continental shelfs) and its pressures.
3. Potential future human activities inside or originating in outside and transported inside the CAO (high sea area and in national continental shelfs) and its pressures.
4. How do the pressures impact the living Ecosystem: threshold limits for effects, uncertainty, and knowledge gaps for the CAO?
5. Existing management bodies and measures/best practices/tools/regulation in the CAO LME for ongoing Human activities (future activities?)
6. Risk analyses - the likelihood of human activities (happening inside and outside the CAO) to have an impact on the CAO ecosystem in the short (2021), medium (2030) and longer

To inspire the writing process, several presentations were given during the meeting, mainly based on recent publications relevant to the CAO LME and listed below each speaker.

- Dr Jessica Nilsson (Swedish Agency and head of PAME): Global transportation of pollution and particles into the CAO.

https://pame.is/projects/arctic-marine-pollution/desktop-study-on-marine-litter

https://pame.is/projects/arctic-marine-pollution/regional-action-plan-on-marine-litter

- Dr Haakon Hop (NPI): Why the Arctic sea ice is an important temporal sink and means of transport for **microplastic** and what is measured in the CAO vicinity.

Bergmann, M., Wirzberger, V., Krumpen, T., Lorenz, C., Primpke, S., Tekman, M.B. and Gerdts, G., 2017. High quantities of microplastic in Arctic deep-sea sediments from the HAUSGARTEN observatory. Environmental science & technology, 51(19), pp.11000-11010.

Obbard, R.W., Sadri, S., Wong, Y.Q., Khitun, A.A., Baker, I. and Thompson, R.C., 2014. Global warming releases microplastic legacy frozen in Arctic Sea ice. *Earth's Future*, *2*(6), pp.315-320.

Peeken, I., Primpke, S., Beyer, B., Gütermann, J., Katlein, C., Krumpen, T., Bergmann, M., Hehemann, L. and Gerdts, G., 2018. Arctic sea ice is an important temporal sink and means of transport for microplastic. *Nature communications*, *9*(1), pp.1-12.

- Dr Jacqueline Grebmeier (University of Maryland, USA): **Maritime ship traffic** in the Central Arctic Ocean High Seas as a case study with informed decision-making.

Berkman, P.A., 2020. Science Diplomacy and Its Engine of Informed Decisionmaking: Operating through Our Global Pandemic with Humanity. *The Hague Journal of Diplomacy*, *15*(3), pp.435-450.

Paul Arthur Berkman, Greg Fiske, Jacqueline M. Grebmeier and Alexander N. Vylegzhanin, 2021. In: Informed Decisionmaking for Sustainability. Volume 2. Building Common Interests in the Arctic Ocean with Global Inclusion. Eds. P Berkman, OR Young, AN Vylegzhanin, DA Balton, and O Øvretveit, Springer].

- Dr Henry P. Huntington (Ocean Conservancy, USA): **A future fishery**: Evidence suggests potential transformation of the Pacific Arctic ecosystem is underway.

H. P. Huntington, S. L. Danielson, F. K. Wiese, M. Baker, P. Boveng, J. J. Citta, A. De Robertis, D. M. S. Dickson, E. Farley, J. Craighead George, K. Iken, D. G. Kimmel, K. Kuletz, C. Ladd, R. Levine, L. Quakenbush, P. Stabeno, K.M. Stafford, D. Stockwell, C. Wilson 2020. Evidence suggests potential transformation of the Pacific Arctic ecosystem is underway. *Nature Climate Change*, *10*(4), pp.342-348.

- Dr Pauline Snoeijs-Leijonmalm (Stockholm University, Sweden): A deep scattering layer under the North Pole pack ice (**fish**).

Bluhm, B.A., Janout, M.A., Danielson, S.L., Ellingsen, I., Gavrilo, M., Grebmeier, J.M., Hopcroft, R.R., Iken, K.B., Ingvaldsen, R.B., Jørgensen, L.L. and Kosobokova, K.N., 2020. The Pan-Arctic continental slope: Sharp gradients of physical processes affect pelagic and benthic ecosystems. *Frontiers in Marine Science*, p.886.

Kosobokova, K.N., Hopcroft, R.R. and Hirche, H.J., 2011. Patterns of zooplankton diversity through the depths of the Arctic's central basins. *Marine Biodiversity*, *41*(1), pp.29-50.

Snoeijs-Leijonmalm, P., Gjøsæter, H., Ingvaldsen, R.B., Knutsen, T., Korneliussen, R., Ona, E., Skjoldal, H.R., Stranne, C., Mayer, L., Jakobsson, M. and Gårdfeldt, K., 2021. A deep scattering layer under the North Pole pack ice. *Progress in Oceanography*, p.102560.

- Dr Anders Mosbech (BIOS, Denmark) **Seabirds** and environmental impact of industrial activity in the CAO (or close by areas such as north of Greenland).

Albert, C., Helgason, H.H., Brault-Favrou, M., Robertson, G.J., Descamps, S., Amélineau, F., Danielsen, J., Dietz, R., Elliott, K., Erikstad, K.E. and Eulaers, I., 2021. Seasonal variation of mercury contamination in Arctic seabirds: a pan-arctic assessment. *Science of the Total Environment*, *750*, p.142201.

Circumpolar Oil Spill Response Viability Analysis – COSRVA https://dce2.au.dk/pub/SR375.pdf.

Gulas S., M.Downton, K.D'Souza, K. Hayden, T.R. Walker Declining Arctic Ocean oil and gas developments: opportunities to improve governance and environmental pollution control. Mar. Pol., 75 (2017), pp. 53-61.

Renedo, M., Amouroux, D., Albert, C., Bérail, S., Bråthen, V.S., Gavrilo, M., Grémillet, D., Helgason, H.H., Jakubas, D., Mosbech, A. and Strøm, H., 2020. Contrasting spatial and seasonal trends of methylmercury exposure pathways of Arctic seabirds: combination of large-scale tracking and stable isotopic approaches. *Environmental Science & Technology*, *54*(21), pp.13619-13629.

- Drs. Stine Frie & Mario Acquarone (IMR & AMAP) **Marine mammals** and noise.

Boertmann, D., Blockey, D., & Mosbech, A. 2020. Greenland Sea – an updated strategic environmental impact assessment of petroleum activities. Scientific Report from DCE – Danish Centre for Environment and Energy No.375, 380 pp. http://dce2.au.dk/pub/SR375.pdf

Duarte, Carlos M., *et al.* "The soundscape of the Anthropocene ocean. "*Science* 371.6529 (2021).

Hauser, Donna DW, Kristin L. Laidre, and Harry L. Stern. "Vulnerability of Arctic marine mammals to vessel traffic in the increasingly ice-free Northwest Passage and Northern Sea Route. "*Proceedings of the National Academy of Sciences* 115.29 (2018): 7617-7622.

New, Leslie & Clark, James & Condit, Richard & Costa, Daniel & Fleishman, Erica & Frid, A & Hindell, Mark & Klanjscek, Tin & Lloyd-Smith, J & Lusseau, David & Kraus, Scott & McMahon, Clive & Robinson, Patrick & Schick, Robert & Schwarz, Lisa & Simmons, Samantha & Thomas, Len & Tyack, Peter & Harwood, John. (2014). Using short-term measures of behaviour to estimate long-term fitness of southern elephant seals. Marine Ecology Progress Series. 496. 99-108. 10.3354/meps10547.

https://www.arctictoday.com/u-s-navy-submarines-surface-near-the-north-pole-as-icex-2020-gets-underway.

https://thebarentsobserver.com/en/security/2021/03/three-russian-nuclear-ballistic-missile-subs-broke-through-ice-north-pole.

- Professor Alf Håkon Hoel: What **management mechanisms** exist for the human activities in the CAO now and in future and what does they ask for.

UNCLOS+ANNEXES+RES.+AGREEMENT

https://www.imo.org/

https://www.isa.org.jm/

https://www.neafc.org/

- Dr Mette Skern-Mauritzen: How to evaluate **Risk**.

Holsman, K., Samhouri, J., Cook, G., Hazen, E., Olsen, E., Dillard, M., Kasperski, S., Gaichas, S., Kelble, C.R., Fogarty, M. and Andrews, K., 2017. An ecosystem-based approach to marine risk assessment. *Ecosystem Health and Sustainability*, *3*(1), p.e 01256.

The chapter teams of Report 2 part 1:

Chapter 1: Existing activities and changes outside CAO

Lead: Martine van den Heuvel-Greve
Contributors: Natsuhiko Otsuka, Shigeto Nishino, Bjørn Einar Grøsvik, Jessica Nilsson, Haakon Hop

Chapter 2: Existing activities and changes inside CAO

Leads Lis Lindal Jørgensen and Jessica Nilsson
Contributors: Jacqueline Grebmeier, (Paul Berkman?), Kathy Kuletz

Chapter 3: Potential future activities inside and outside CAO

Lead: Hauke Flores
Contributors: Pauline Snoeijs Leijonmalm, Harald Gjøsæter, Kevin Hedges (fishery), Karen Edelvang (Seabed-mining)

Chapter 4: Pressure impacts on ecosystem

Lead: Lisa Speer
Contributors: Kevin Hedges, Cecilie von Quillfeldt, Sei-Ichi Saitoh, Taka Hirata, Anne Kristine Frie, Jacqueline Grebmeier, Bodil Bluhm, Hauke Flores, Harald Gjøsæter, Kathy Kuletz, Anders Mosbech, Mario Acquarone, Bjørn Einar Grøsvik, Martine van den Heuvel-Greve, Lis L. Jørgensen

Chapter 5: Existing management bodies and measures in CAO for activities

Lead: Alf Håkon Hoel.
Contributor: Anders Mosbech (limited time until Sept), Lisa Speer, Alain Dupuis, Anne Kristine Frie

4.1.2 The Ecosystem Overview (EO) of the Central Arctic Ocean: status and planning

An Ecosystem Overview is an ICES advisory report supporting Ecosystem Based Management. The report is short and concise (maximum of 14–16 pages) highlighting the main characteristics and challenges the region faces. The first draft of the Ecosystem Overview for the Central Arctic Ocean was completed in November 2020. ICES conducted a light review of this draft in February 2021. An additional pressure assessment for a future sea ice free summer situation (ballpark 2050) was conducted online in March/April 2021. Results are being processed at the moment. The Ecosystem Overview will be finalised this year including a full review by ICES over summer.

New ToRs for 2022-2024

ToR was discussed at the meeting, drafted and send for circulation within WGICA, PAME and PICES.

4.2 Summary of 6th online Annual WGICA meeting: October 12–14 2021

The 6th annual meeting of the WGICA was planned as a physical meeting at the ICES HQ in Copenhagen, Denmark, but was conducted as a Webex meeting 12–14 October 2021 due to the COVID-19 travel restrictions. The meeting agenda is found in Annex 3.

The meeting was built-up as two meetings per 24 hours, with several hours in between, allowing participants from around the world to participate, and to be updated by online records of previous meetings

The annual WGICA meeting had 30 persons from 9 nations all around the northern hemisphere that gathered online. Participants: Norway, Denmark, Finland, Netherlands, USA, Japan, Korea and China, Germany, Russia, Canada, and Sweden are WGICA members and 36 persons participated in the meeting in addition to four participants from the ICES secretariat and one observer.

4.2.1 Meeting summary on planned products

WGICA have five ongoing products that is planned finalized and delivered in 2021, but with possibilities to become delayed and hence parts of the next three-year cycle (2022–2024).

Report 1: First IEA report on the CAO 2 Ecosystem assessment of the Central Arctic Ocean: description of the ecosystem – Report finalized but still in revision (ICES) and edition (responsible: Hein Rune Skjoldal).

Annual report–final interim report 2019–2021 (this report): Will answer the ToR 2019–2021 by providing short summaries from the 2020 report (responsible: Lis L. Jørgensen, Sei-Ichi Seito)

Ecosystem Overview (responsible Martine van der Heuvel-Greve)**:**

- 2020–2021–Several online workshops
- Draft delivered for ICES light review April 2021

- Editing during April–August 2021
- Draft delivered for ICES full review August 2021
- ICES advisory board (ADB) review September–October 2021
- Processing review comments 21–29 October 2021
- Co-authors available for input and discussion?
- Final ADB version of an EO as an ICES advisory product beginning of December 2021

The Annual meeting approved following timeline for 2021:

- April-May: Process input from ICES plus assessment of the future situation
- May-June: Receive comments from ICES EGs under HAPISG (Human Activities, Pressures and Impacts Steering Group)
- June: Complete final draft of the EO
- July–September: Full review by ICES
- October: Process of last comments
- November: EO completed
- December-January: Layout and publication by ICES

Terms of Reference 2022-2024–has been circulated within WGICA, PAME, ICES and PICES and approved.

Report 2 part 1:

The chapters of the Report 2 part 1 was presented for the meeting by the chapter lead and discussed. Below are the suggestions for further scientific information and references:

Relevant references and discussion points during the Oct meeting on Chapter 1: Existing human activities and environmental change originating outside the CAO and brought into the CAO by ocean currents, river water and airborne, and its pressures

Presented by Martine van den Heuvel-Greve.

Hop, H., M. Vihtakari, B.A. Bluhm, M. Daase, R. Gradinger, and I.A Melnikov. 2021. Ice-associated amphipods in a pan-Arctic scenario of declining sea ice. *Frontiers in Marine Science.*

Hop, H., A. Wold, A. Meyer, A. Bailey, M. Hatlebakk, S. Kwasniewski, P. Leopold, P. Kuklinski, and J.E. Søreide. 2021. Winter-Spring development of the zooplankton community below sea ice in the Arctic Ocean. *Frontiers in Marine Science* 8:609480.

Bluhm, B.A., H. Hop, M. Vihtakari, R. Gradinger, K. Iken, I.A. Melnikov, and J.E. Søreide. 2018. Sea ice meiofauna distribution on local to pan-Arctic scales. *Ecology and Evolution* 8: 2350-2364.

http://nsidc.org/arcticseaicenews/2020/05/

Increased water though the Bering Strait Bodil (Guest): Woodgate, R. A. (2018). Increases in the Pacific inflow to the Arctic from 1990 to 2015, and insights into seasonal trends and driving mechanisms from year-round Bering Strait mooring data. *Progress in Oceanography*, *160*, 124-154.

Woodgate, R. A., Weingartner, T. J., & Lindsay, R. (2012). Observed increases in Bering Strait oceanic fluxes from the Pacific to the Arctic from 2001 to 2011 and their impacts on the Arctic Ocean water column. *Geophysical Research Letters*, *39*(24).

Woodgate, R. A. (2018). Increases in the Pacific inflow to the Arctic from 1990 to 2015, and insights into seasonal trends and driving mechanisms from year-round Bering Strait mooring data. Progress in Oceanography, 160, 124-154. https://doi.org/10.1016/j.pocean.2017.12.007.

https://arcticdata.io/catalog/portals/DBO

Hauser, D. D., Laidre, K. L., Suydam, R. S., & Richard, P. R. (2014). Population-specific home ranges and migration timing of Pacific Arctic beluga whales (*Delphinapterus leucas*). *Polar Biology*, *37*(8), 1171-1183.

Hauser, D. D., Laidre, K. L., Suydam, R. S., & Richard, P. R. (2014). Population-specific home ranges and migration timing of Pacific Arctic beluga whales (Delphinapterus leucas). *Polar Biology*, *37*(8), 1171-1183.

Belugas Fig 1 in https://link.springer.com/content/pdf/10.1007/s00300-014-1510-1.pdf

Front. Mar. Sci., 19 June 2020 https://doi.org/10.3389/fmars.2020.00350

Summertime Chlorophyll *a* and Particulate Organic Carbon Standing Stocks in Surface Waters of the Fram Strait and the Arctic Ocean (1991–2015)

Belugas Fig 1 in https://link.springer.com/content/pdf/10.1007/s00300-014-1510-1.pdf

Map of recent sea ice biological sampling https://www.caff.is/marine/marine-expert-networks/sea-ice-biota

Hop, H., M. Vihtakari, B.A. Bluhm, P. Assmy, M. Poulin, R. Gradinger, I. Peeken, C. von Quillfeldt, L. M. Olsen, L. Zhitina, and I.A. Melnikov. 2020. Changes in sea-ice protist diversity with declining sea ice in the Arctic Ocean from the 1980s to 2010s. *Frontiers in Marine Science* 7:243.

K.N.KosobokovacE.C.Carmackdhttps://doi.org/10.1016/j.pocean.2015.07.011

https://www.sciencedirect.com/science/article/abs/pii/S0079661115001639#!

Possible future scenarios in the gateways to the Arctic for Subarctic and Arctic marine systems: II. prey resources, food webs, fish, and fisheries 22, https://doi.org/10.1093/icesjms/fsab122

https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15562 Ershova, E. A., Kosobokova, K. N., Banas, N. S., Ellingsen, I., Niehoff, B., Hildebrandt, N., & Hirche, H. J. (2021). Sea ice decline drives biogeographical shifts of key Calanus species in the central Arctic Ocean. *Global Change Biology*, *27*(10), 2128-2143.

https://ec.europa.eu/environment/marine/good-environmental-status/descriptor-2/index_en.htm

Reid, P.C.; Johns, D.G.; Edwards, M.I.N.; Starr, M.; Poulin, M.; Snoeijs, P. A biological consequence of reducing Arctic ice cover: Arrival of the Pacific diatom Neodenticula seminae in the North Atlantic for the first time in 800,000 years. Glob. Change Biol. 2007, 13, 1910–1921.

Review: Matul A, Kazarina GK (2020) The North Pacific Diatom Species Neodenticula seminae in the Modern and Holocene Sediments of the North Atlantic and Arctic. MDPI geosciences.

Hoffmann, Sarah Lena Eggers, Erika Allhusen, Christian Katlein, Ilka Peeken. Interactions between the ice algae Fragillariopsis cylindrus and microplastics in sea ice, Environment International, Volume 139, 2020, 105697, ISSN 0160-4120, https://doi.org/10.1016/j.envint.2020.105697.

https://www.pame.is/projects-new/marine-protected-areas/current-mpa-projects/403-modelling-arctic-oceanographic-connectivity-to-further-develop-pame-s-marine-protected-areas-toolbox

Baak, J. E., Linnebjerg, J. F., Barry, T., Gavrilo, M. V., Mallory, M. L., Price, C., & Provencher, J. F. 2020. Plastic ingestion by seabirds in the circumpolar Arctic: A review. Environmental Review DOI: 10.1139/er-2020-0029.

Kühn, S., Schaafsma, F.L., van Werven, B. *et al.* Plastic ingestion by juvenile polar cod (*Boreogadus saida*) in the Arctic Ocean. *Polar Biol* **41,** 1269–1278 (2018). https://doi.org/10.1007/s00300-018-2283-8

Peeken, I., Primpke, S., Beyer, B., Gütermann, J., Katlein, C., Krumpen, T., Bergmann, M., Hehemann, L. and Gerdts, G., 2018. Arctic sea ice is an important temporal sink and means of transport for microplastic. *Nature communications*, *9*(1), pp.1-12.

Notes:

- Need to separate clearly borealization and invasion by non-indigenous species.
- Plastic pollution of the ocean: report on state of knowledge of plastic pollution (both macro- and micro) in the Barents Sea region is under preparation and to be published soon under the Russian-Norwegian environmental commission

- Arctic sea ice is an important temporal sink and means of transport for microplastic. Nature Communications - Microplastic (MP) pollution in polar regions is a growing environmental concern, yet little is known regarding the role of sea ice as a sink and transport vector of MPs.
- Report on state of knowledge of plastic pollution (both macro- and micro) in the Barents Sea region is under preparation and to be published soon under the Russian-Norwegian environmental commission

Relevant references and discussion points during the Oct meeting on Chapter 2: Existing human activities and environmental change originate inside the CAO (high sea area and in national continental shelfs) and its pressures.

Presented by Paul Berkman, Lis L. Jørgensen, Anne Kristine Frie, Kathy Kuletz and Fujio Ohnisi.

Diversity of Shipping:

- Based on oldest AIS data having information on types and names of ships that are of high value to the analysis.
- Focus on connection between vessel and sea ice decrease on the Siberian shelf?
- Bering Sea data as being relevant to relation sea ice decrease and fishing activity.

Pollution from ships:

- Record high of fuel consumption by research vessels in 2020 (e.g. MOSAiC and accessory cruises but Oden expedition was on biofuel) and need to understand the record high in cruise ships in the pandemic year?
- https://en.wikipedia.org/wiki/COVID-19_pandemic_on_cruise_ships
- https://www.cdc.gov/quarantine/cruise/covid19-cruiseships.html
- Note that the input of ships on the Pacific side into the CAO is greater, although the shelf systems have more ship activity over the shelf in the Barents Sea. Also, the higher probability of CAO fisheries is currently projected for the Pacific sector and over the Chukchi Borderland. We are currently having fishing vessels in the northern Bering Sea in Oct and on the Russian side of the Chukchi Sea, fall fishing.
- Can the exercise on emissions also being done for NIS coming from ballast water? However, note that: NIS will have a hard time to survive in CAO water, may not be discharged at the CAO (but close to a harbour), may have been treated (ballast water treatment). So far only 1 NIS described for the CAO: A diatom... Hull fouling species often need hard substrate to settle on or attach to, that may not be available in the CAO.
- Regulations will reduce issues such as ballast water discharge (NIS), heavy fuels
- What are the risks of spreading viruses and diseases?
- The litter in the Pacific Arctic from ships was very large last year, but reduced this year. Plastic litter washing onto shores of St Lawrence Island and shores of the US arctic high last year. Litter was from projected from foreign vessel in the region due to language on litter.

Light:

- This might be a distinction without a difference, but were documented responses by fishes to changes in light determined to be direct responses to light or indirect responses through changes in zooplankton distributions?
- Only some information on light impact, not on light production other than number of vessels. Is there information on that? Differences in light production from different vessel types?
- This might be a distinction without a difference, but were documented responses by fishes to changes in light determined to be direct responses to light or indirect responses through changes in zooplankton distributions?

Noise:

- Sea ice is a source, shield and diffuser of underwater sound
- Cold water facilitates long distance sound propagation
- Salinity gradients affect sound propagation properties and contribute to seasonal and geographic variability
- Big knowledgegaps
- Oceanographic and atmospheric change and so do the sound production

Military:

- We don't have good information of potential impacts from military (noise, light). ICES will check with NATO if we can get some data on this. They are willing to share but we need to specify what data we need. No data received yet.
- Noise also comes from above (aircraft and missile practice)
- Home | NATO PA (nato-pa.int)
- 16_Radioactive_contamination_issues_in_the_Arctic_Nadezhda_Kasatkina.pdf (pame.is)

- A very relevant report is in the making by the NATO parliamentary assembly: 016 DSCTC 21 E - SECURITY HIGH NORTH - REPORT - LARSONNEUR | NATO PA (nato-pa.int)
- SECURITY CHALLENGES IN THE HIGH NORTH: This report reviews the growing strategic relevance of the 21st century Arctic, and the subsequent impact increased attention to the region may have on the international security environment in general, and the Alliance's High Northern flank in particular.

Relevant references and discussion points during the Oct meeting on Chapter 3: Potential future human activities inside or originating in outside and transported inside the CAO (high sea area and in national continental shelfs) and its pressures

Presented by Hauke Flores:

- This chapter is focused on future predicted human activities, pressures and potential impacts. It is suggested to move this chapter to after the next chapter on impacts.
- Seasonality needs to be considered in all chapters. This is very important for the CAO. For instance, in the CAO sea ice may disappear, but in winter it freezes back up so there will be no fishing and shipping activities possible in the ice covered winter / early spring.
- Input from expert on military is needed for chapter 3 (Fujio).
- Learn from other processes: AMAF/CAFF project on Climate Change effects on ecosystems and activities + Antarctic experiences with fishing, light and bird strikes

Possible future scenarios in the gateways to the Arctic for Subarctic and Arctic marine systems: II. Prey resources, foodwebs, fish, and fisheries 22, https://doi.org/10.1093/icesjms/fsab122

Relevant references and discussion points during the Oct meeting on Chapter 4: How do the pressures impact the living Ecosystem: threshold limits for effects, uncertainty, and knowledge gaps for the CAO (as defined by WGICA)

Presented by Lisa Speer

Assignments:

Pauline:	Microbial processes
Cecilie:	Primary producers
Hauke:	Ice fauna/zooplankton
Jackie and Bodil:	Benthos
Kevin and Harald:	Fish
Anders, Kathy Maria:	Seabirds
Stine, Mario:	Marine mammals

For each ecosystem component, authors should identify (in 5-7 pages max):

- Climate change-related effects (sea ice loss, advection, changes in temperature, salinity, acidification, stratification, etc).
- Effects of relevant pressures identified in Chapters 1 and 2 plus others as appropriate.
- Include relevant pressures resulting from current activities inside the CAO (shipping, military activities, tourism), including habitat alteration, light, noise, ship strikes, pollution (chemical and plastic).
- Relevant pressures resulting from current activities outside the CAO (invasive, plastic and chemical pollution transport, etc.).
  [Note: future fishing and seabed mining will likely exert significant pressures that will be addressed in the next report so you don't need to cover those and other future pressures]
- Trends and thresholds (where applicable/identifiable).
- Potential interacting/cumulative effects.

- Foodweb effects.
- Uncertainties and knowledge gaps.

Baak, J. E., Linnebjerg, J. F., Barry, T., Gavrilo, M. V., Mallory, M. L., Price, C., & Provencher, J. F. 2020. Plastic ingestion by seabirds in the circumpolar Arctic: A review. Environmental Review DOI: 10.1139/er-2020-0029.

Hoffmann, Sarah Lena Eggers, Erika Allhusen, Christian Katlein, Ilka Peeken (2020). Interactions between the ice algae Fragillariopsis cylindrus and microplastics in sea ice, Environment International, Volume 139, 105697, ISSN 0160-4120, https://doi.org/10.1016/j.envint.2020.105697.

Ershova, E. A., Kosobokova, K. N., Banas, N. S., Ellingsen, I., Niehoff, B., Hildebrandt, N., & Hirche, H. J. (2021). Sea ice decline drives biogeographical shifts of key Calanus species in the central Arctic Ocean. *Global Change Biology*, *27*(10), 2128-2143. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15562

Kühn, S., Schaafsma, F.L., van Werven, B. *et al.* Plastic ingestion by juvenile polar cod (*Boreogadus saida*) in the Arctic Ocean. *Polar Biol* **41,** 1269–1278 (2018). https://doi.org/10.1007/s00300-018-2283-8

Relevant references and discussion points during the Oct meeting on Chapter 5: Existing management bodies and measures/best practices/tools/regulation in the CAO (as defined by WGICA) for ongoing Human activities.

Presented by Alf Håkon Hoel

Aim for a descriptive, not too detailed account of the governance framework. 10 pages. (The 2011 Arctic Ocean Review phase I report has a comprehensive account).

Need to scale back ambitions signalled in draft outline–focus on global and regional levels of governance because the regionalism part of the global framework determine how governance is organized at regional and national levels.

- The Law of the Sea Convention (UNCLOS) and associated agreements and processes
- Deep seabed mining (1994) Fisheries (1995) Biodiversity ABNJ (202?)
- Biodiversity conservation and use: Convention on Biodiversity (CBD)
- Shipping: The International Maritime Organization (IMO)
- Fisheries: The UN Food and Agriculture Organization (FAO) many agreements, UN General Assembly
- Science: The Intergovernmental Oceanographic Commission (IOC)
- Pollution: A number of agreements, e.g. dumping at sea, ozone layer, POPs
- Climate: Framework Convention
- Arctic-specific circumpolar (e.g. polar bear conservation)
- Arctic-specific, in parts of the Arctic (e.g. Canada - Greenland cooperation)
- Partly Arctic (e.g. ICES)
- 1973 Agreement on Conservation of Polar Bears
- 2011 Search and Rescue Agreement
- 2013 Agreement on Cooperation on Oil Pollution Preparedness and Response
- 2016 Agreement on Enhancing International Arctic Scientific Cooperation
- 2017 International Code for Ships Operating in Polar Waters
- 2018 Agreement to Prevent Unregulated Fishing in the Central Arctic Ocean

4.2.2 Presentations given at the meeting relevant to the ToR 2022–2024

In 2022–2024 the WGICA working group on the CAO LME will work on three terms concerning: "stakeholders", "social, economic, and ecological (SEE) questions" and "methods for doing relevant IEA".

The work on the two first terms will begin in year 2022 and the following members of the WGICA volunteered to:

Identify relevant audience/stakeholders to the CAO-integrated ecosystem assessment (IEA): Mette Skern-Mauritzen, Fujio Ohnishi, Stanislovas Jonusas, Anders Mosbech, Allan Dupuis, Lis L. Jørgensen

Identify and prioritize the relevant Social, Economic, Ecological and Institutional (SEEI) objectives/questions: Pauline Snoeijs Leijonmalm, Mette Skern-Mauritzen, Kevin J Hedges, Sei-Ichi Seito, Fujio Ohnishi, Stanislovas Jonusas, Shigeto Nishino, Lis L. Jørgensen ((Paul Berkman, Alf Håkon Hoel)

To initiate the work on ToR to Identify relevant audience/stakeholders to the CAO-integrated ecosystem assessment (IEA), WGICA invited the "Workshop on Stakeholder Engagement Strategy (WGSHOES)" to inform on their work and Vera Köpsel, IMF, University of Hamburg provided a presentation.

WKSHOES (chairs: Alan Haynie & Vera Köpsel) examines stakeholder interactions across ICES expert groups, assesses needs and opportunities, and develops elements for a strategy to formalize stakeholder involvement in our groups. Specifically, WKSHOES will characterize potential stakeholder interaction goals as well as the key elements of a stakeholder engagement strategy to achieve these goals. It will also further describe key elements of any potential strategy, e.g. objectives, roles, principles, boundaries, monitoring, evaluation, etc. The group will also provide further information on stakeholder activities taking place within ICES, to make recommendations on monitoring and evaluating the impact of stakeholder engagement. In addition, the group will propose alternative approaches to improve and secure further inclusion and engagement by ICES with stakeholders, such as future hybrid meetings.

Read more:

https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/IEASG/2021/WKSHOES%20report%202021.pdf

Ballesteros, M. & M. Dickey-Collas (2020): Position Paper on ICES Stakeholder Engagement Strategy, ICES Draft: 14 August 2020.

Haynie, A. & V. Köpsel (eds.): Workshop on Stakeholder Engagement Strategy (WKSHOES). ICES Scientific Reports, Vol. 3, issue 75. https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/IEASG/2021/WKSHOES%20report%202021.pdf

UNEP (2005): From Words to Action – The Stakeholder Engagement Manual. Vol. 2: The Practitioner's Handbook on Stakeholder Engagement. Available at www.uneptie.org

To initiate the work on Identify and prioritize the relevant Social, Economic, Ecological and Institutional (SEEI) objectives/questions WGICA invited the workgroup on "Working Group on Balancing Economic, Social and Ecological Objectives (WGBESEO)" and Paulina Ramirez-Monsalve presented:

WGBESEO (Chair: David Langlet, David Goldsborough, Paulina Ramirez-Monsalve) develops a generic methodology for identifying, characterizing, and classifying social, economic, and ecological objectives - enabling the awareness of such objectives in ICES advisory process. WGBESEO synthesize existing information on social, economic, and ecological (SEE) management objectives derived from legal and policy documents within a multi-level governance setting in dialogue with relevant stakeholders. Based on this, the group identifies relevant charac-

teristics of SEE objectives and, finally, develops and tests a methodology for identifying and classifying these objectives in national, international or supra-national governance settings that can be applied repeatedly by ICES groups in different geographic settings. A variety of SEE objectives relevant to managing marine resources have been set out in legal and policy documents. Having a systematic comprehension of such objectives and information on potential trade-offs among them enables decisions to be made with better comprehension of the societal implications of alternative courses of action. The developed framework will enable the identification of management objectives for specific ecoregions in line with ICES Ecosystem Overviews.

Read more:

https://www.ices.dk/community/groups/Pages/WGBESEO.aspx

https://www.ices.dk/about-ICES/Documents/Resolutions/Science%20EG%20ToRs/IE-ASG/2021/WGBESEO%20Resolution%202020-2022.pdf

FAO_A diagnostic tool.pdf

Stephenson, R.L., Hobday, A.J., Cvitanovic, C., Alexander, K.A., Begg, G.A., Bustamante, R.H., Dunstan, P.K., Frusher, S., Fudge, M., Fulton, E.A. and Haward, M., 2019. A practical framework for implementing and evaluating integrated management of marine activities. *Ocean & Coastal.*

Stephenson, R.L., Wiber, M., Paul, S., Angel, E., Benson, A., Charles, A., Chouinard, O., Edwards, D., Foley, P., Lane, D. and McIsaac, J., 2019. Integrating diverse objectives for sustainable fisheries in Canada. *Canadian Journal of Fisheries and Aquatic Sciences*, *76*(3), pp.480-496. *Management*, *177*, pp.127-138.

To motivate the work in year 2023 on "Identify priority semi-quantitative and quantitative methods for doing relevant IEA for the CAO based on existing information already compiled in the WG's reports, EOs and CRR" WGICA invited the workgroup member Mette Skern-Mauritzen to start the process of identifying the Integrated Assessment Method to be used in order to answer the relevant research questions that identified Stakeholders has.

ICES has a "Workshop on Common Conceptual Mapping Methodologies" WKCCMM (Chair: Debbi Pedreschi, Marcos Llope, Maria Cristina Mangano) that will advance approaches to support inter- and transdisciplinary science via qualitative conceptual models to inform Integrated Ecosystem Assessment (IEA) throughout European seas and beyond. The aim is to create good practice guidelines for coherent conceptual mapping for IEA, through scoping participant needs, skill sharing, and knowledge transfer. The goal is to advance understanding of socio-ecological systems and facilitate practical implementation of ecosystem-based marine management.

The workshop will focus on developing a common understanding on conceptual mapping methodologies, their key uses and limitations, and processes for effective conceptual modelling with stakeholders for a variety of applications (e.g. developing foodwebs, socio-ecological modelling, scoping exercises, rapid/initial management action and/or impact evaluations). Discussion will include the use and development of 'strawman' models, exploration of case studies, and proposal of 'best practice' modelling guidelines.

The Skern-Mauritzen presentation showed the stepwise process from Stakeholders to social, economic, ecological and institutional (SEEI) objectives, and finally to Identify and implement semiquantitative and quantitative methods for linking the SEEI objectives to human activities, pressures and impacts.

A stakeholder "perspectives open, initial process method" was compared with a "focused feedback method" where the first was demanding in time and work, while the other was less challenging. A "middle way" was suggested.

A Semiquantitative risk assessment with key current and future risks could be merged with Stakeholder opinions on issues of concern; link to key ecosystem services, and Role of policy objectives in regulating key current and future risks; trade-offs.

Read more:

https://www.ices.dk/community/groups/Pages/WKCCMM.aspx

Cavanaugh *et al.* 2021. Future Risk for Southern Ocean Ecosystem Services Under Climate Change (MEASO program).

Christen M, Schmidt S (2012) A formal framework for conceptions of sustainability – a theoretical contribution to the discourse in sustainable development. *Sustainable Development* 20:400–410.

Mikkelsen N., Planque B., Arneberg P., Skern-Mauritzen M., Hansen C., Fauchald P., Holsman KK., Haynie A., Ottersen G. (in prep) Multiple stakeholders' perspectives on marine ecological systems, a case study on the Barents Sea. Planned for: Ocean & Coastal Management.

Harvey, C.J., Reum, J.C., Poe, M.R., Williams, G.D. and Kim, S.J., 2016. Using conceptual models and qualitative network models to advance integrative assessments of marine ecosystems. *Coastal Management*, *44*(5), pp.486-503.

Holsman, K., Samhouri, J., Cook, G., Hazen, E., Olsen, E., Dillard, M., Kasperski, S., Gaichas, S., Kelble, C.R., Fogarty, M. and Andrews, K., 2017. An ecosystem-based approach to marine risk assessment. *Ecosystem Health and Sustainability*, *3*(1), p.e01256.

Levin, P.S., Fogarty, M.J., Matlock, G.C. and Ernst, M., 2008. Integrated ecosystem assessment. *NOAA* Technical Memorandum, NMFS-NWFSC 92pg. 20 pp.

Levin, P.S., Fogarty, M.J., Murawski, S.A. and Fluharty, D., 2009. Integrated ecosystem assessments: developing the scientific basis for ecosystem-based management of the ocean. *PLoS biology*, *7*(1), p.e1000014. https://doi.org/10.1371/journal.pbio.1000014.

Pintér, L., Hardi, P., Martinuzzi, A. and Hall, J., 2012. Bellagio STAMP: Principles for sustainability assessment and measurement. *Ecological Indicators*, *17*, pp.20-28. doi:10.1016/J.ECOLIND.2011.07.001.

Skern-Mauritzen, M., Olsen, E. and Huse, G., 2018. Opportunities for advancing ecosystem-based management in a rapidly changing, high latitude ecosystem. *ICES Journal of Marine Science*, *75*(7), pp.2425-2433.

Waas, T., Hugé, J., Block, T., Wright, T., Benitez-Capistros, F. and Verbruggen, A., 2014. Sustainability assessment and indicators: Tools in a decision-making strategy for sustainable development. *Sustainability*, *6*(9), pp.5512-5534. doi:10.3390/su6095512.

Waas, T., Hugé, J., Verbruggen, A. and Wright, T., 2011. Sustainable development: A bird's eye view. *Sustainability*, *3*(10), pp.1637-1661. doi:10.3390/SU3101637.

4.2.3 WGICA Timeline 2021

When	What	Who
30 November 2021	draft chapters circulated to WGICA members (including provisional figures and tables)	Chapter leads send to Lis/Sei-Ichi
10 December 2021	Final date for comments on draft chapters to be send to chapter leads	All WGICA members
20 December 2021	Comments processed, new draft chapters circulated to WGICA members (including final figures and tables)	Chapter leads send to Lis/Sei-Ichi
Early 2022	Potential for further alignment	Chapter leads and co-authors

Suggested meetings during 2022

- Online meeting 13–14 April 2022 (Wednesday–Thursday) "Easter"
- Annual in person meeting 11–13 October 2022 (Tuesday–Thursday)

Annex 1: List of participants

WGICA 2019 Participants

Name	Institute	Country	Email
John L. Bengtson	NOAA Fisheries	USA	john.bengtson@noaa.gov
Yasushi Fukamachi	Hokkaido University	Japan	yasuf@arc.hokudai.ac.jp
Jacqueline Mary Grebmeier	University of Maryland	USA	jgrebmei@umces.edu
Naomi Harada	Japan Marine-Earth Science and Technology	Japan	haradan@jamstec.go.jp
Kevin James Hedges	Fisheries and Oceans Canada	Canada	Kevin.Hedges@dfo-mpo.gc.ca
Taka Hirata	Hokkaido University	Japan	tahi@arc.hokudai.ac.jp
Toru Hirawake	Hokkaido University	Japan	hirawake@fish.hokudai.ac.jp
Henry P. Huntington	Ocean Conservancy	USA	hhuntington@oceanconservancy.org
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Sei-ichi Saitoh	Hokkaido University	Japan	ssaitoh@arc.hokudai.ac.jp
Hyoung Chul Shin	Hokkaido University	Republic of Korea	hcshin@kopri.re.kr
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Annex 2: WGICA Resolution (2019–2021)

WGICA - ICES/PICES/PAME Working Group on Integrated Ecosystem Assessment (IEA) for the Central Arctic Ocean

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, Lindal Jørgensen, Norway, and Martine van den Heuvel-Greve*, Netherlands, 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	ICES Scientific Report by 1 September 2019	
Year 2020	27-29 April	Online meeting	ICES Scientific Report by 1 September 2020	Hein Rune Skjoldal, Norway and John Bengtson, USA as outgoing Chairs. Lis Lindal Jørgensen, Norway as incoming Chair
Year 2021	12-13 April 12-14 October	Online	Final ICES Scientific Report by 31 December 2021	Martine van den Heuvel-Greve, Netherlands, as incoming Chair

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 including Human Activities from the viewpoint of Climate and Vulnerability Assessments.	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 associated with changes 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 potential effects on the CAO ecosystem of recent, ongoing and future climatic and oceanographic changes on Human activities (shipping, tourism, possible future fisheries, seabed exploitation of minerals and security) and recent on-going pollution (contaminant, garbage, and micro plastics)	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 wil be included in the new IEA report for the CAO in 2021.
e	Review and report on new studies on fish of the CAO ecosystem (the High Seas).	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 ecchosounders 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

Year 1	**Review IEA methodologies for IEA of the CAO. Review and report new information and changes in the CAO ecosystem.**
Year 2	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.
Year 3	Prepare a second version IEA eport 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

Priority	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. 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).
Scientific justification	ICES IEA EGs provide science based assessments of ecosystem status, trends and vulnerabilities to support implementation of the ecosystem approach to management. 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. ToR b – The CAO is on a trajectory of reduction of sea ice with considerable interannual variablity. Trends and events will be reported to draw attention to the ongoing changes in the CAO. 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.

	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 expertice available in the WG. ToR e – It is expected that new information will be forthcoming on occurrence of fish and other biota in the CAO from planned research activies. 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. 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. ToR e – This will add to the suit of Ecosystem Overviews prepared and published by ICES.
Resource requirements	No major resourcing.
Participants	Experts from ICES, PICES, and PAME
Secretariat facilities	Support for meetings at ICES HQ, when appropriate.
Financial	No financial implications for ICES.
Linkages to ACOM and groups under ACOM	Link to ACOM through the development of Ecosystem Overviews and advice.
Linkages to other committees or groups	Within ICES links across all ICES IEA working groups and to HAPISG EGs on human pressures on marine ecosystems, such as pollution.
Linkages to other organizations	This is a joint ICES, PICES, and PAME WG.

Annex 3: Agenda 1

Monday 12 April

14:00: Short Presentation round (max 5 min, everybody to give a short presentation in the chat box = name, affiliation, no conflict of interest =nci)

14:05: The outline of Report 2 part 1 (Lis)

Presentations (max 10 min per presentation):

14:15: **1 Existing human activities and environmental change originate outside the CAO and brought into the CAO by ocean currents, river water and airborne, and its pressures.**

- Dr Jessica Nilsson (Swedish Agency and head of PAME): Global transportation of pollution and particles into the CAO.
- Dr Haakon Hop (NPI): Why the Arctic sea ice is an important temporal sink and means of transport for microplastic and what is measured in the CAO vicinity.

14:40: **2 Existing human activities and environmental change originate inside the CAO (high sea area and in national continental shelfs) and its pressures.**

- Dr Jacqueline Grebmeier (University of Maryland, USA): Maritime ship traffic in the central arctic ocean high seas as a case study with informed decision-making.

14:50: **3 Potential future Human activities inside or originating in outside and transported inside the CAO (high sea area and in national continental shelfs) and its pressures.**

- Dr Henry P. Huntington (Ocean Conservancy, USA): A future fishery: Evidence suggests potential transformation of the Pacific Arctic ecosystem is underway.
- Dr Pauline Snoeijs-Leijonmalm (Stockholm University, Sweden): A deep scattering layer under the North Pole pack ice

15:15: **4 How do the pressures impact the living Ecosystem (see also EO): threshold limits for effects, uncertainty, and knowledge gaps for the CAO?**

- Dr Anders Mosbech (BIOS, Denmark) Seabirds and environmental impact of industrial activity in the CAO (or close by areas such as north of Greenland
- Drs. Stine Frie & Mario Acquarone (IMR & AMAP) Marine mammals and noise

15:40: Discussion

16:00: End of day 1, but with the possibility to stay and continue the discussion

Tuesday 13 April

14:00: **6 Existing management bodies and measures/best practices/tools/regulation in the CAO LME for ongoing Human activities (future activities?)**

- Professor Alf Håkon Hoel: What management mechanisms exist for the human activities in the CAO now and in future and what does they ask for.

5 Risk analyses: The likelihood of human activities (happening inside and outside the CAO) to have an impact on the CAO ecosystem in the short (2021), medium (2030) and longer term (2050)

- Dr Mette Skern-Mauritzen: How to evaluate Risk

14:30: Discussion, timeline and responsible for writing of the Report 2 part 1 (Lis)

15:00: Ecological Overview "EO" (Martine)

- Short presentation of the current situations and ICES feedback on the December 2020 draft
- Results of the future assessment (March/April 2021)
- Timeline and responsibilities for preparation of the final draft

16:00: End of day 2 but with the possibility to stay on and continue the discussion

Annex 4: Agenda 2

6th WGICA annual meeting 12–14 October 2021
Goal of the meeting: discussion of Report 2 part 1
Meeting times are in CEST

Tuesday 12 October 2021

Session 1

08:00: Welcome and quick round around the table with documentation of interest of conflicts
08:15: Goal of this autumn meeting: discussion of Report 2–part 1:
08:20: Brief status updates and planning of our products:

- 08:20: Report 1 (Julie/Lis)
- 08:30: Annual report–final interim report 2019-2021 (Lis)
- 08:40: Ecosystem Overview (Martine)
- 08:50: Terms of Reference 2022–2024 (Lis)

09:00: Report 2–part 1:

- 09:00: Presentation Chapter 1: Existing human activities and environmental change originating outside the CAO and brought into the CAO by ocean currents, river water and airborne, and its pressures (Martine and others)
- 09:30: Discussion: chapter 1

10:00: Closure session 1

Homework: additional input for Chapter 1

Session 2

16:00: Recap of session 1

16:10: Report 2–part 1:

- 16:10: Discussion: additional input for chapter 1
- 16:30: Presentation Chapter 2: Existing human activities and environmental change originate inside the CAO (high sea area and in national continental shelfs) and its pressures (Lis and others)
- 17:00 Discussion: chapter 2
- 17:20: Presentation Chapter 3: Potential future human activities inside or originating from outside and transported inside the CAO (high sea area and in national continental shelfs) and its pressures (Hauke and others)
- 17:50: Discussion: chapter 3

18:00: Closure session 2

Homework: additional input for Chapters 2 and 3

Wednesday 13 October 2021

Session 3

08:00: Recap of session 2
08:10: Report 2–part 1:

- 08:10: Discussion: additional input for chapter 2
- 08:35: Discussion: additional input for chapter 3
- 09:00: Presentation Chapter 4: How do the pressures impact the living Ecosystem: threshold limits for effects, uncertainty, and knowledge gaps? (Lisa and others)
- 09:30: Discussion: chapter 4

10:00: Closure session 3

Homework: additional input for Chapter 4

Session 4

16:00: Recap of session 3
16:10: Report 2–part 1:

- 16:10: Discussion: additional input for chapter 4
- 16:40: Presentation Chapter 5: Existing management bodies and measures in the CAO LME for ongoing human activities (Alf Håkon and others)
- 17:10: Discussion: chapter 5
- 17:40: PM Timeline and actions report 2–part 1

18:00: Closure session 4

Homework: additional input for Chapter 5

Thursday 14 October 2021

Session 5

08:00: Recap of session 4
08:10: Report 2–part 1:

- 08:10: Discussion: additional input for chapter 5
- 08:40: Timeline and actions report 2–part 1

09:00: Report 2–part 2:

- 09:00: Timeline and ToR 2022–2024
- 09:10: Discussion or presentation: How to identify the relevant CAO stakeholders for whom we make an IA (Dr Vera Köpsel, WKSHOES)
- 09:25: Discussion or presentation: How to define Social, Economic, Ecological and Institutional scientific questions (Dr Paulina Ramirez, WGBESEO – pre-recorded)
- 09:40: Discussion: contents and experts

10:00: Closure session 5

Homework: additional input for report 2–part 2

Session 6

16:00: Recap of session 5
16:15: Report 2–part 2:
16:15: Presentation on Integrated Assessments (Dr Mette Skern-Mauritzen)
16:45: Discussion: content and experts
17:15: Scientific expeditions to the Central Arctic Ocean:

17:15: PM Presentation of 2021 cruises (SAS-Oden expedition (Professor Pauline Snoeijs, Stockholm University, Sweden), SAS-Norwegian expedition (Professor Bodil Bluhm, UiT, Norway), AK. Treshnikov expedition (Igor Melnikov, Russian Academy of Sciences), R/V Mirai Arctic cruise (Dr Nishino, JAMSTEC))

17:30: Presentation of future expeditions (≥2022: R/V Mirai Arctic cruise (Dr Nishino, JAMSTEC), AK. Treshnikov expedition (Igor Melnikov, Russian Academy of Sciences), AWI expeditions (Dr Hauke Flores, AWI, Germany)) and potential for collaboration addressing key knowledge gaps for the CAO

17:45: Overview actions and planning for 2021

17:55: Meeting dates in 2022

18:00: Closure of the meeting