Final Report of

Study Group on the Arctic Ocean and the Pacific Gateways （SG-ARC）

October, 2023

Contents

1 Introduction

1.1 Background

The target Large Marine Ecosystems (LMEs) of WG39 and WG44 are the geographically and dynamically connected Central Arctic Ocean (CAO) and the Northern Bering Sea-Chukchi Sea (NBS-CS) (Figure 1). The CAO is in rapid transition, driven by North Pacific environmental changes in significant part, and has become accessible to a range of commercial activities. Rapid loss of sea ice cover has opened up the CAO for potential fishing opportunities. In this context, the agreement to Prevent Unregulated High Seas Fisheries in the CAO has been signed and entered into force, which will necessitate joint research and monitoring. The NBS-CS is also experiencing unprecedented warming and loss of sea ice as a result of climate change. Declines of seasonal sea ice and rising temperatures have been more prominent in the northern Bering and Chukchi seas as in most portions of the Arctic. Chronic and sudden changes in climate conditions in this Arctic gateway are clearly reshaping the system and its food-webs, and enlarging opportunities for commercial activities (shipping, oil and gas development and fishing), with uncertain and potentially wide-spread cumulative impacts. A coordinated integrated ecosystem assessment (IEA) of the CAO and NBS-CS thus is a useful and pertinent approach in this circumstance, especially given the substantial science and policy challenges emerging in the Arctic.

1.2 Past and current Status

1.2.1 WGICA

The Working Group for Integrated Ecosystem Assessment of the Central Arctic Ocean (WGICA) was established jointly by ICES and PAME in 2016. The goal of the working group is to conduct an Integrated Ecosystem Assessment (IEA) for the Central Arctic Ocean (CAO), a needed step to provide scientific advice on issues such as the prospect for future fisheries in the Arctic Ocean and sensitivity and vulnerability of marine ecosystems in relation to human activities (including shipping, fisheries, tourism). WGICA links Human activities, pressures and ecosystem vulnerability into a semi-quantitative risk analysis by assessing the spatial and temporal overlap using best available data. The first WGICA meeting was held in May 24-26, 2016, at the ICES headquarters in Copenhagen, Denmark. PICES joined WGICA in 2017 and WGICA became the Joint ICES/PICES/PAME working group for the CAO IEA. WGICA published comprehensive IEA Report No. 1 (Skjoldal, 2022) with IEA Report No. 2 underway.

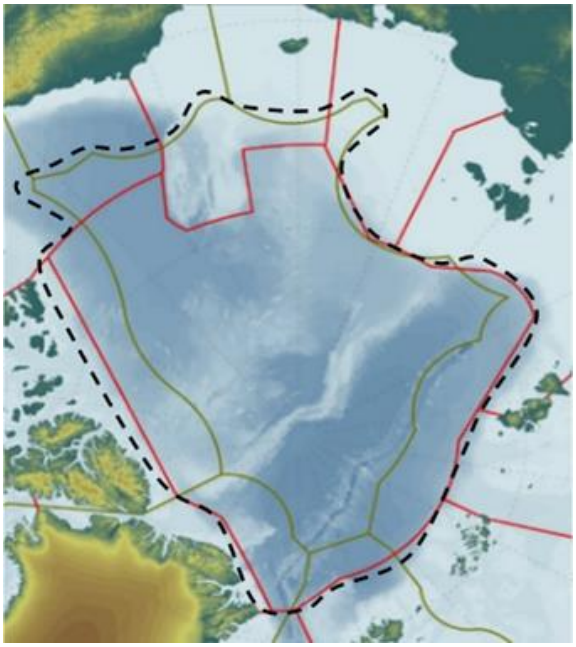

Figure 1. The Central Arctic Ocean study area (black broken line; CAO) with the Large Marine Ecosystems (red lines) as defined by PAME (Protection of the Arctic Marine Environment), one of the working groups in the Arctic Council, the borders of the five National Economic Zones (green), and the High Seas being the center area outside the 200 nautical miles of the five bordering nations.

1.2.2 PICES WG39

At PICES-2016, the ICES President requested that PICES join the existing Working Group for Integrated Ecosystem Assessment of the Central Arctic Ocean (WGICA), established jointly by ICES and PAME in 2016. This request was approved by Governing Council (Decision 2016/6/5). PICES joined as a co-sponsor of the group in 2017, making WGICA an ICES/PICES/PAME Working Group for Integrated Ecosystem Assessment of the Central Arctic Ocean.

WG39 will consider approaches and methodologies for the IEA in the Central Arctic Ocean. In PICES, WG39 was established for supporting WGICA in 2017.

Parent Committee: SB

Term: PICES-2016 – PICES-2022

Extended

at PICES-2018 until PICES-2021 (GC decisions S/4 (vii))

at PICES-2021 until PICES-2022 (GC decisions S/10 (x))

The following are Terms of Reference of WG39 approved in July 2020.

1. Review and consider approaches and methodologies for conducting an IEA of the CAO ecosystem;
2. 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;
3. Continue to examine the 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);
4. 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;
5. Review and report on new studies on fish as well as other biological components of the CAO ecosystem;
6. Continue to identify priority research needs and monitor how identified knowledge gaps (needed to improve IEA and management effectiveness) are being addressed and filled;
7. Prepare an Ecosystem Overview for the CAO ecosystem.

The first WG39 business meeting was held on September 24, 2017, at PICES-2017 in Vladivostok, Russia (http://meetings.pices.int/publications/Annual-Reports/2017/2017-WG-39.pdf).

The first workshop of WG39 "PICES contribution to Central Arctic Ocean (CAO) ecosystem assessment was held on March 22-23, 2018 at Hokkaido University, Sapporo, Japan. Since then, WG39 has been promoting workshops in subsequent PICES annual meetings:

- PICES-2018: W2, PICES contribution to Central Arctic Ocean (CAO) ecosystem assessment (Second)
- PICES-2019: W7, PICES contribution to Central Arctic Ocean (CAO) ecosystem assessment (Third)
- PICES-2020: VW4, How does the Pacific Arctic gateway affect the marine system

in the Central Arctic Ocean (WG39 and WG44 joint workshop)

- PICES-2022: W2, Integrated Ecosystem Assessment (IEA) to understand the present and future of the Central Arctic Ocean (CAO) and Northern Bering and Chukchi Seas (NBS-CS) (WG39 and WG44 joint workshop)

1.2.3 PICES WG44

Background and Purpose

The Northern Bering Sea-Chukchi Sea (NBS-CS) region is experiencing unprecedented ocean warming and loss of sea ice as a result of climate change. Seasonal sea ice declines and warming temperatures have been more prominent in the northern Bering and Chukchi seas as almost all other portions of the Arctic. Chronic and sudden changes in climate conditions in this Arctic gateway are increasingly impacting marine species and food-webs and expanding opportunities for commercial activities (shipping, oil and gas development and fishing), with uncertain and potentially wide-spread cumulative impacts. There are strong concerns about the impacts of climate change and industrial activities, and these impacts may be particularly pronounced in Arctic indigenous communities dependent on the health and stability of the ecosystem. The combination of unprecedented, rapid change and increased interest in the Arctic in general and the NBS-CS specifically make this an opportune time for a synthesis of issues and knowledge. An Integrated Ecosystem Assessment (IEA) can accomplish this synthesis.

Reporting to: FIS, HD
Term: Nov. 2019- Nov. 2023

Year 1 Deliverables:

- Inventory of metadata, knowledge, institutions and programs relevant to the Northern Bering Sea-Chukchi Sea LME. (accomplished)

Final Deliverables:

- Ecosystem description from both Indigenous world views and science (shared conceptual models), indicators and hypotheses. PICES Report and/or Journal article. Knowledge Gap and Next Steps Report. PICES Report and/or Journal article.

Current status (as of PICES 2022)

Approach and methodology. We developed three conceptual models with a team of interdisciplinary and multi-national scientists and Indigenous representatives from the Northern Bering and Arctic region. The models themselves were created using Mental Modeler software. Initial models were reviewed and refined over the course of several months. One important finding was the diverse ways of experiencing, thinking and talking about the marine ecosystem as informed by disciplinary training, worldview, and engagement over time. It was a challenge to include these multiple perspectives in a western science model that tends toward linearity and categorization. Indigenous worldviews may take more holistic and relational approaches to ecosystem elements, making kt a challenge to "box" entire concepts or domains as separate from others. In an attempt to bridge (and include) multiple perspectives, working group members offered qualitative descriptions to enhance the conceptual models and provide greater context.

The model results will be released in a PICES Report. Our next steps are to finish our IEA scoping document and finalize IEA goals by spring 2023. We are also planning on identifying indigenous partners this coming fall and winter.

Indigenous Knowledge provides valuable information that reflects deeply meaningful Indigenous worldviews to accommodate and respond to environmental changes. Resource policies, however, often develop outside of this realm of knowledge, instead, primarily relying on Western science. In an effort to better understand the complexities (cultural, linguistic, and institution) of Bering Sea coastal communities, the team developed an institutional model that identified linkages across spatial and governance levels. This model depicted the unweighted local, national, and global connections of individual communities in the area of study, indicating the complex connectivity of highly rural coastal communities. Indigenous knowledge sharing. "Multiple Ways of Knowing the Bering Sea-Chukchi Sea Ecosystem" workshop. Workshop organizers have transcribed the 2022 workshop notes and summarizing the ideas for bridging multiple knowledge systems into our IEA process. Including multiple knowledge systems in IEAs offers a longitudinal perspective across generations of ecological observations, and supports community resilience through information sharing, relationship building, and informed decision-making. The workshop included discussions about the vital importance of relationship building and co-production of knowledge methods in IEAs. Several points were emphasized including: the need to develop a shared language through co-production approaches. By first defining terms and confirming mutual understanding of concepts, it us then possible to build on those ideas that is inclusive of Indigenous worldviews in meaningful ways. A final report was distributed to the team.

Milestones: Shared report from first workshop. Distributed information in digital and hardcopy format. A manuscript is in development to submit for peer review.

We are in the process of organizing a larger workshop in 2023 in Seattle, WA at the PICES Annual meeting (October 20-21, 2023). Working in partnership with the Ocean Decade Collaborative Centre, we have invited 29 Indigenous Knowledge holders, issue experts, and practitioners to share information about bridging multiple knowledge systems in marine ecosystem assessments. The workshop is designed to provide an invited space for Indigenous knowledge holders to share information and experiences with the North Pacific marine environment. The second day will open to all PICES members for presentations to identify lessons learned across multiple regions. Deliverables include a final report and a North Pacific and Arctic marine ecosystem knowledge network.

1.2.4 WGIEANBS-CS

WGIEANBS-CS is ICES/PICES joint working group and the members and activities are fully same as WG44.

1.2.5 PICES SG-ARC

PICES took upon responsibilities concerning the CAO issues when it joined the WGICA (Joint PICES/ICES/PAME Working Group on an Integrated Ecosystem Assessment (IEA) for the Central Arctic Ocean (CAO)) by establishing WG39 in 2017. In 2019, PICES also established WG44 (Joint PICES/ICES Working Group on Integrated Ecosystem Assessment for the Northern Bering Sea - Chukchi Sea) in efforts to understand the Arctic system and its impacts to the sub-Arctic and mid-latitude North Pacific. An integrated ecosystem assessment (IEA) is a useful approach that is shared by these two Working Groups, particularly relevant with substantial science and policy needs emerging for the sustainable Arctic. This renders a coordinated IEA of the CAO and NBS-CS as a priority task. In addition, it is of particular significance to developing future approaches for The United Nations Decade of Ocean Science for Sustainable Development in the Arctic Ocean (UNDOS-Arctic), where science for resilience and sustainability is more important than anywhere else in the world oceans. Despite this continuing significance and unfinished commitment to WGICA and also WGIEANBS-CS, WG 39 ended the term with

the closure of PICES 2022 Annual Meeting and WG 44 will end the term with the closure of PICES 2023 Annual Meeting. In this context, PICES established Study Group on the Arctic Ocean and the Pacific Gateways (SG-ARC) to coordinate and integrate PICES scientific activities on the Arctic issues and to further advance the understanding of the Arctic system and linkages and impacts to the North Pacific.

1.3 Impacts of Arctic changes on its marine ecosystem and biodiversity and the linkage to mid-latitude oceans

Ecological monitoring of the Pacific Arctic conducted over the past ten years has shed light on the impacts of recent warming and reduced sea-ice conditions to Arctic marine ecosystems. In the period of 1974-2014, the date of sea ice retreat has occurred earlier in the year at a rate approximately -0.7 d/yr (Serreze et al., 2016). The years 2017-2019 were anomalously warm in the Northern Bering and Chukchi seas and further characterized by substantial winter sea ice loss (Huntington et al., 2020). Additional physical changes in the Pacific Arctic include increased transport of Pacific water through the Bering Strait increased storm activity in the High Arctic (prefaced by Moore and Stabeno 2015). These physical conditions underlie many ecological impacts that span the entire range of the Arctic ecosystem from phytoplankton and marine bacteria to marine mammals and ultimately impact Arctic native communities that rely on the marine ecosystem for sustenance and cultural value (Moore et al. 2018).

Warming ocean temperatures, reduced ice extent, and increased poleward advection of warmer Pacific water to the Chukchi Sea had modified the marine environment and food resources to resemble those of subarctic marine ecosystems. Goldstein et al. (2023) concluded that the combination of those aspects led to poleward shifts in the distributions of large-bodied (i.e., energy-rich) copepods in the Calanus genus and Arctic cod (*Boreogadus saida*) on the Chukchi Shelf with the dominance of subarctic water associated with reduced isotropic niche for forage fishes. The anomalously warm 2017-2019 period also affected the distribution of seabirds in the area (Kuletz et al., 2020), namely a decrease in piscivorous seabirds like murres (i.e., *Uria* spp.; Romano et al., 2020), an increase in planktivorous *Aethia* auklets, and a northern shift for short-tailed shearwaters (*Ardenna tenuirostris*). Benthic macroinvertebrates are a major component of the Chukchi marine ecosystem and while benthic thermal habitats are projected to increase for some benthic taxa (e.g., basketstars), the loss of cold thermal habitats affects the majority of the epibenthic biodiversity present in the Chukchi Sea (Logerwell et al., 2022). However, the expansion or contraction of the spatial

distributions of these benthic taxa will depend on how well they can acclimatize to continued long-term warming in the Arctic region.

These changes in the environmental conditions also favor the expansion of boreal marine taxa into a warmer Arctic Ocean. The more striking of these distributional expansions has been for gadids, e.g., walleye pollock, saffron cod, and Pacific cod (Wildes et al., 2022; Cooper et al., 2023; Maznikova et al., 2023). The expansion of large populations of adult pollock into the Western Chukchi Sea (Datsky et al., 2022; Emelin et al., 2022) led to recommendations to the development of a Chukchi Sea Russian pollock fishery in the early 2020s. The success of these subarctic fish populations expanding their ranges into the Arctic Ocean and posing potential competitive pressure to Arctic fish populations, i.e., Arctic cod, will depend on future thermal and advective conditions, successful adaptation, and continued poleward immigration.

Sea ice is an important physical component of many of the life histories of marine mammals. Pacific walrus (*Odobenus rosmarus divergens*) use ice floes to rest in between foraging trips as well as rear their young and molt. During a period of low ice cover in the Chukchi Sea (2008-2011), walruses were observed using more coastal and nearshore areas to forage for benthic invertebrates in lieu of more offshore areas occupied in past periods of higher ice cover (Jay et al., 2012). Polar bears (*Ursus maritimus*) which use both sea ice and land in their life history, utilized land for summering and denning for longer periods when substantial sea ice loss occurred (Rode, 2015). The end of the breeding season for bearded seals (*Erignathus barbatus*) is tied with the sea ice retreat, thus earlier sea ice retreat could alter breeding phenology (Crance et al., 2022). The increase in the number of open water days in the Chukchi and Beaufort seas may also potentially expand the usually Bering Sea-constrained wintering grounds and affect the distribution of summer foraging of bowhead whales (*Balaena mysticetus*). The concurrent expansion in the potential range of killer whales (*Orchinus orca*) into the Arctic Ocean introduces potential changes in the predation of fish and marine mammals (Clarke et al. 2013; Filatova et al. 2019).

1.4 Human activities and Pressures in the Arctic Ocean

Considerable progress has been made to document the levels of human activities and the human induced pressures on the central Arctic Ocean ecoregion. It is important to note at the outset that the focus is limited to the Central Arctic Ocean (CAO) and not the bordering Exclusive Economic Zones in the Arctic. This geographic distinction can create some difficulties accounting for activities and pressures that

overlap given that human activities within coastal communities in the region tend to stay within the EEZ. It is important to note however, that the effects of human activities within the CAO may extend well beyond. Work, so far, has generally taken a more inclusive approach rather than an exclusive approach in terms of characterizing activities and pressures. Still, it is useful to point out that historically, the Central Arctic Ocean has had less direct activity and thereby pressures than continental shelf areas which tend to become ice free and thus are more accessible to ship borne activity, have more fish and wildlife, coastal ports and other economic activity, etc.

The human activities on which there has been significant focus are nearly all vessel-based and surface oriented, i.e., transport, tourism, research, and military although research and military activities may have subsurface extensions. Indigenous communities across the region have observed increasing direct human activities offshore, as well as the resulting effects of those activities.

Fisheries are not a current activity. In 2021, Arctic nations agreed to a 16 year moratorium on fishing in the CAO until research demonstrates that sufficient resources to support a commercial fishery exist and can be sustained. That moratorium is set to end in 2037. Most human activities have increased in the CAO in recent years enabled by climate change and decreasing ice cover, but also motivated by a desire to study the rapidly changing Arctic and to take advantage of economic development. Most human activity in the CAO is seasonal with summer accessibility (limited to ice free summer months) Winter months with substantial sea ice cover have not been accessible historically; however technological advances in vessel design, shifts in political will, and warmer winters with less ice coverage continue to drive increases in marine traffic in the CAO. Since 1996, marine traffic in the Arctic has increased by 300% and continues to increase. Research vessels is the one activity on the rise during the winter season to better understand year-round ecosystem changes.

The scale and intensity of human activities is comparatively low given the large area of the CAO and the cost of operations in the high Arctic. Shipping mostly follows the Northern Sea Route with less following the Northwest Passage Route outside of the CAO. A modest amount of curiosity-driven tourism attracts tourists to the North Pole and ice camping. The extreme depths and other operational difficulties so far preclude mineral and oil and gas exploration and development. Such activities are carried out in a few areas on the Continental shelves.

Human generated pressures on the CAO result from both external, and to a limited extent, internal processes. Ship noise is recognized as a new element in the CAO

ecosystem, albeit minor at present. Marine debris and plastics, and the settling of air and water borne contaminants in ocean and atmospheric circulation is mostly from external sources. Of recent note is the CAO as an area where water borne plastics collect and there is growing concern about invasive species entering the CAO ecosystem. Further, because some of the seabird and marine mammal species migrate through the CAO, it is recognized that such species may be affected by human activities and pressures to an unknown degree. Indigenous communities in the Arctic are highly dependent on living marine resources in the CAO. As such, these communities will bear the brunt of any human activity driven effects, leading to concerns over inequitable distribution of impacts on vulnerable communities.

A major focus of work in the WGICA is gaining an understanding of the structure and functioning of the CAO an area that is little understood, with enormous gaps in observational data and with very difficult conditions for performing scientific research. Work of WGICA that is underway has sought preliminary ways to characterize the level of risk and our collective confidence in knowledge about by human activities and pressures as a way to better understand the vulnerability of the CAO to them. There is currently a joint author paper under construction for peer review that documents progress being made.

2. SG and the need for new EG

The Study Group on the Arctic Ocean and the Pacific Gateways (SG-ARC) was formed to help PICES better prepare for the new emerging issues in the Central Arctic Ocean and Pacific gateways. Until recently, two relevant working groups have been in operation and in cooperation within PICES, namely WG 39 and WG 44. These two groups share a range of research themes in areas closely connected geographically as well as in an ecosystem context. As mentioned above, joint WG 39/WG 44 workshops were held at the PICES Annual Meeting in 2020 and 2022. This SG-ARC is expected to continue until the WG 44 completes its mission, after which we have proposed to transition the SG into an Expert Group (EG) subject to the decision of PICES.

As mentioned in section 1.2.5, despite this continuing significance and unfinished commitment to WGICA and also WGIEANBS-CS, WG 39 ended the term with the closure of PICES 2022 Annual Meeting and WG 44 will end the term with the closure of PICES 2023 Annual Meeting. PICES need a new EG to serve as the liaison between WGICA and WGIEANBS-CS ICES/PICES joint activities after the conclusion of both WG 39 and WG 44. Time line of each WG/EG are summarized in Figure 2. PICES should understand the

impacts of Arctic changes on its marine ecosystem and biodiversity and the linkage to sub-Arctic and mid-latitude oceans (PICES target waters) and new EG could deliver more comprehensive scientific information on this subject including monitoring activities in the Arctic Ocean and Pacific gateways in communication with international initiatives, e.g., MOSAiC, SAS, UNDOS-Arctic, CAOFS, ESSAS etc. (Figure 3).

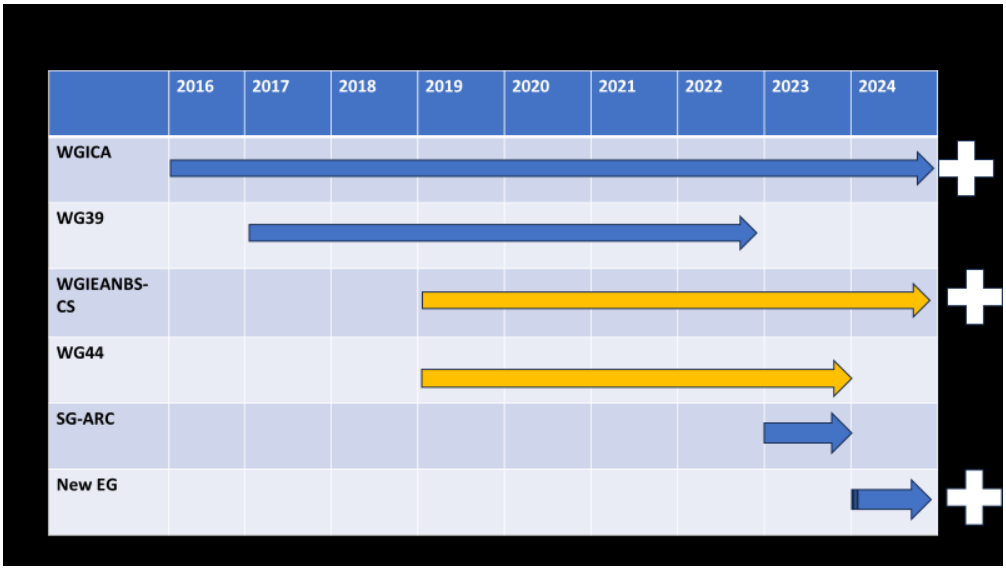

Figure 2. Time line of WG/EG

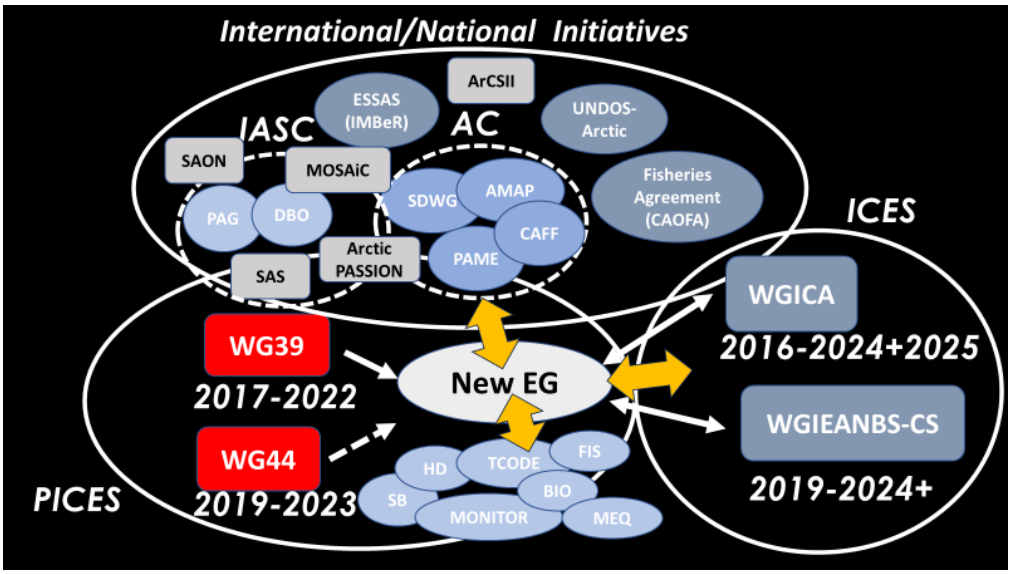

Figure 3. Relationship map between New EG and groups

3. Plan and contributions of new EG and the follow-up

The proposed EG when officially launched is expected to begin early 2024 The responsibilities of the group should include, although these have to be refined and clearly laid down in the Terms of Reference:

a) consolidate relevant PICES research output

b) identify future research agenda and possible areas of cooperation

c) generate advice how to connect with PICES research community and possibly create advice for the policy makers as well as the communities in the high latitude North Pacific

In order to fulfill these responsibilities, the EG will need to review and digest the research findings, continue collaborations with colleagues from the other side of the Arctic and deliver the policy-ready or at least policy-friendly product to the wider PICES community. The EG will also exert efforts to understand the indigenous perspectives on the issues and have those reflected in the deliberations of the group.

The EG will initially develop an agreed-upon three-year timeline. The work of the EG will focus mostly on the available data from published literature, rather than being field survey oriented, or assisting the designing process. Identification of key areas such as biological hotspots both in the sub-Arctic and the Central Arctic and delineating the mutually interacting mechanisms and the pathways will remain at the heart of the task of the EG for the first three years, at least. To undertake its work, the EG will hold online consultations once per year prior to the annual meeting in order to discuss the findings and distill tentative conclusions and to have them ready for report at the annual meeting. In the third year, at its end of the first term, the EG will organize a workshop to encapsulate the outcomes and determine future recommendations.

4. Conclusion

The variabilities of the Arctic Ocean strongly influence the global climate via atmosphere-ocean interactions and Arctic-subarctic freshwater and heat fluxes. The

changing ocean has had both local and far-reaching effects on atmospheric circulation, including intensified storms and more frequent extreme weather conditions. PICES should understand the impacts of Arctic changes on its marine ecosystem and biodiversity and the linkage to sub-Arctic and mid-latitude oceans and contribute the development of IEA in CAO and NBS-CS through the joint PICES/ICES cooperation.

Accessing and utilizing the best available information in understanding ecosystem processes requires the inclusion of multiple knowledge systems from an early stage. Drawing from successful methods used in other working groups, this group will work to bridge Indigenous Knowledges across the region with modern science to achieve more robust understanding. In conclusion, we propose new EG as Advisory Panel on the Arctic Ocean and the Pacific Gateways (AP-ARC) for this initiative.

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6. Appendix

A. Proposal of AP-ARC (separate file)