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Report of the Joint PICES/ICES Working Group (WG 44/ WGIEANBS-CS) on Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea

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Report of the Joint PICES/ICES Working Group (WG 44/ WGIEANBS-CS) on Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea

edited by
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Front cover:
Shore-fast ice of the Bering Sea, Nome, Alaska. (Photo credit: Sarah Wise, NOAA)

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Table of Contents

Abbreviations and Acronyms

ABL	Auk Bay Laboratory as part of NOAA NMFS AFSC (USA)
ADFG	Alaska Department of Fish and Game
AFSC	Alaska Fisheries Science Center as part of NOAA NMFS (USA)
AMAP	Arctic Monitoring and Assessment Programme
AMBON	Arctic Marine Biodiversity Observing Network
AOOS	Alaska Ocean Observing System
ASGARD	Arctic Shelf Growth, Advection, Respiration and Deposition
ASAMM	Aerial Surveys of Arctic Marine Mammals
BASIS	Bering Arctic Subarctic Integrated Survey
BEST	Bering Sea Ecosystem Study (combined with BSIERP)
BOEM	Bureau of Ocean Energy Management
BSIERP	Bering Sea Integrated Ecosystem Research Program
CAEP	Cetacean Assessment and Ecology Program
CAFF	Conservation of Arctic Flora and Fauna
CASCADE	Circum-Arctic Sediment CArbon DatabasE
CPK	Co-production of knowledge
CSESP	Chukchi Sea Environmental Studies Program
CTD	Conductivity, Temperature, Depth recorder
DBO	Distributed Biological Observatory
DFO	Department of Fisheries and Oceans (Fisheries and Oceans Canada)
Difar	Directional Frequency Analysis and Recording device
DVNIGMI	Far Eastern Scientific Hydrometeorological Institute (Russia)
EcoFOCI	Ecological & Fisheries Oceanographic Coordinated Investigations
EFH	Essential Fish Habitat
EMA	NOAA Ecosystem Monitoring and Assessment Program
GAP	Groundfish Assessment Program (as part of AFSC)
HABs	Harmful Algal Blooms
HMA	Hydro Meteorological Agency (Russia)
ICM	Indigenous Conceptual Model
IEA	Integrated Ecosystem Assessment
IERP	Integrated Ecosystem Research Program
IWC POWER	International Whaling Commission Pacific Ocean Whale and Ecosystem Research Programme
KOPRI	Korea Polar Research Institute
KPDC	Korea Polar Data Center
LME	Large Marine Ecosystem
MACE	Midwater Assessment and Conservation Engineering
MML-CAEP	Marine Mammal Laboratory-Cetacean Assessment and Ecology Program, AFSC
MODIS	Moderate Resolution Imaging Spectroradiometer

NBS	Northern Bering Sea
NBS-CS	Northern Bering Sea-Chukchi Sea
NGO	Non-Governmental Organization
NMFS	National Marine Fisheries Service (USA)
NMML	National Marine Mammal Laboratory (now known as MML; NOAA)
NOAA	National Oceanic and Atmospheric Administration (USA)
NSF	National Science Foundation
NPRB	North Pacific Research Board
NSB DWM	North Slope Borough Department of Wildlife Management (USA)
NSIDC	National Snow and Ice Data Center
OCSEAP	Outer Continental Shelf Environmental Assessment Program
PacMARS	Pacific Marine Arctic Regional Synthesis
PAM	Passive acoustic monitoring
PAME	Protection of the Arctic Marine Environment
PAROMS	Pan-Arctic Regional Ocean Model System
POI FEB RAS	Pacific Oceanological Institute, Far Eastern Branch Russian Academy of Science
RACE	Resource Assessment and Conservation Engineering
ROMS	Regional Ocean Modeling System
RUSALCA	Russian American Long-term Census of the Arctic
SBI	Shelf-Basin Interactions
SeaWIFS	Sea-viewing Wide Field-of-view Sensor
SHEBA	Surface Heat Budget of the Arctic Ocean project
SST	Sea Surface Temperature
TINRO	Russian Federal Research Institute of Fisheries and Oceanography
ToR	Terms of Reference
UAF	University of Alaska Fairbanks (USA)
USFWS	US Fish and Wildlife Service
USGS	United States Geological Survey
UW-APL	University of Washington-Applied Physics Laboratory
YOY	Young of the year (fishes)

Executive Summary

The Joint PICES/ICES Working Group on *Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea* (NBS-CS; WG 44) was established in 2019 at PICES-2019 in Victoria, Canada, and extended to 2023 due to COVID-19 restrictions that slowed the work of the group. Drs. Elizabeth (Libby) Logerwell (US) and Yury Zuenko (Russia) were the co-chairs. WG 44 (WGIEANBS-CS) was co-sponsored by ICES.

During its term, WG 44 produced an inventory of metadata, knowledge, institutions and programs relevant to the development of an Integrated Ecosystem Assessment (IEA) for the NBS-CS Large Marine Ecosystem (LME). In addition to an inventory of data, WG 44 developed ecosystem descriptions from both Indigenous world views and science – Multiple Ways of Knowing (see subsection 2.2) and Shared Conceptual Models (see subsection 2.3). The ecosystem descriptions were further developed into two conceptual models that focused on key components and interactions: Subsistence–Food Security and Climate–Fisheries. Finally, knowledge gaps and future actions to develop an IEA for the Northern Bering Sea–Chukchi Sea LME were described.

A next step for this work on conceptual models of the NBS-CS would be to run scenarios to determine how the system might react under a range of possible changes. Another next step would be to use the conceptual models to develop a data-driven Integrated Ecosystem Assessment. The inventory of metadata of information sources developed to fulfill WG 44's deliverables provides a guide to current data availability for such an effort.

1 Introduction

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 than in almost all other portions of the Arctic. Chronic and sudden changes in climate conditions in this Arctic gateway are having an increasing effect on 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 that are dependent on the health and stability of the ecosystem. The combination of unprecedented, rapid change and increased interest in the Arctic, specifically the NBS-CS, make this an opportune time for a synthesis of issues and knowledge. The development of an Integrated Ecosystem Assessment (IEA) can accomplish this synthesis.

To develop the foundation for an IEA, the following Terms of Reference and deliverables were adopted by the Joint PICES/ICES Working Group on *Integrated Ecosystem Assessment for the Northern Bering Sea – Chukchi Sea* (WG 44/WGIEANBS-CS) (Appendix 1).

General Terms of Reference:

1. Convene an interdisciplinary and international working group membership
2. Include Arctic peoples and Indigenous Knowledge systems
3. Identify and consult with partners and institutions

Year 1 Deliverables:

- Inventory of metadata, knowledge, institutions and programs relevant to the Northern Bering Sea–Chukchi Sea Large Marine Ecosystem.

Years 2 and 3 Deliverables:

- Ecosystem description from both Indigenous world views and science (shared conceptual models), indicators and hypotheses, including knowledge gaps and next steps.

2 WG 44 Achievements with Respect to Terms of Reference

2.1 Inventory of metadata

An inventory of metadata that includes knowledge, institutions and programs relevant to the Northern Bering Sea–Chukchi Sea Large Marine Ecosystem (LME) was compiled by WG 44 members (Appendix 2) and is provided in Appendix 3. The metadata set describes data for several biological categories: Adult fish, Benthic epifauna, Benthic infauna, Ecosystem modeling, Environmental drivers, Forage fish, Pelagic/Ice algal production, Process links, Zooplankton, Benthic foraging marine mammals, Pelagic seabirds, and General Arctic data. The metadata presented here are not exhaustive but focus on current data availability online and/or contacts available for data accessibility.

2.2 Ecosystem description from Indigenous world views and science – Multiple ways of knowing

A team within the WG membership was formed to address bringing together Multiple Ways of Knowing in IEAs. Led by Sarah Wise, the team consisted of Indigenous Knowledge holders and subject matter experts with experience developing and implementing the co-production of knowledge (CPK) framework. Core members were: Raychelle Daniel, Henry Huntington, Rebecca Ingram[1], Mellissa Maktuayaq Johnson, Nadja Steiner, Sarah Wise, and Eduard Zdor[2].

The CPK model developed by the Pew Charitable Trusts, Kawerak Inc., and Inuit Circumpolar Council Alaska (Fig. 1) provided a framework for our initial discussions of multiple knowledge systems and the potential for weaving together Indigenous Knowledge and academic science. Through the course of this work, the team used the framework to guide the operationalization of theoretical concepts around information sharing, Indigenous Knowledge, and practical pathways for ecosystem assessments centered around equitable knowledge sharing and meaningful collaboration.

[1,2] Rebecca Ingram (Integrated Ecosystem Assessment specialist) and Eduard Zdor (subsistence and Traditional Knowledge scholar) made significant contributions to the work of the group but were not formally appointed members of WG 44.

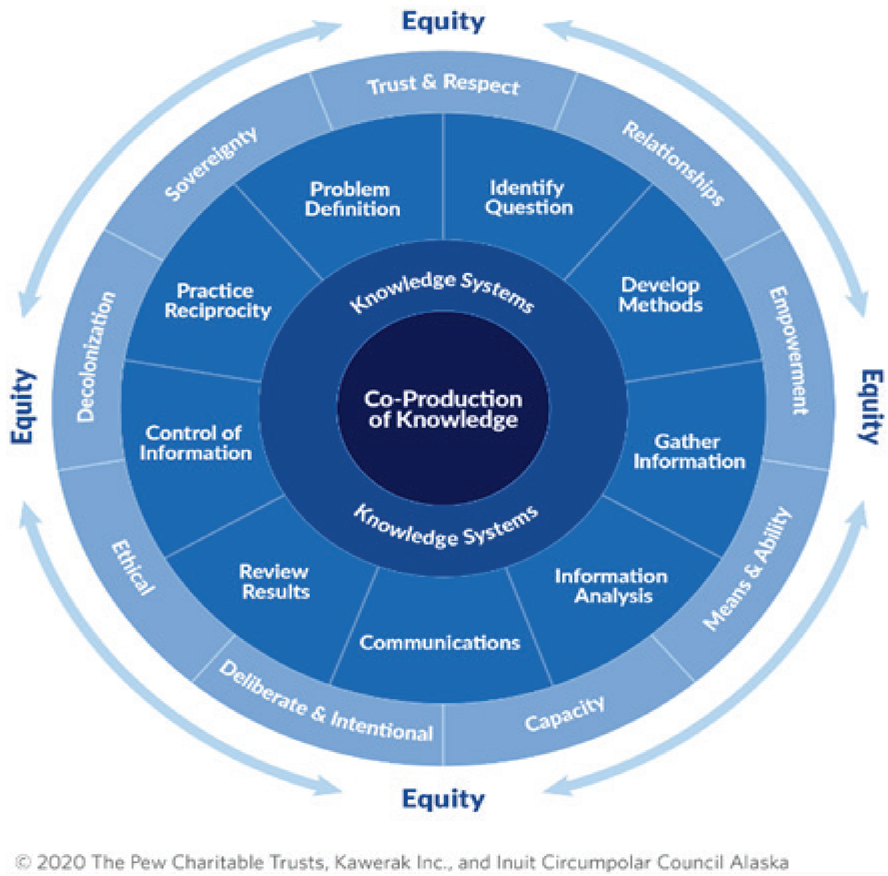

Fig. 1 The Co-Production of Knowledge wheel (© The Pew Charitable Trusts, Kawerak Inc., Inuit Circumpolar Council Alaska). Source: Daniel and Behe, 2017; Yua *et al*., 2022.

The objective of this Term of Reference (ToR) was to include Indigenous perspectives, Indigenous knowledge, and Indigenous voices from the beginning and throughout the IEA, in the process and products—not incorporated into the "academic science" sections, but in parallel, reflecting the importance and value of Indigenous Knowledge as informing IEAs with best available science. This was reflected by including multiple perspectives and knowledge systems at the beginning of the assessment process, which was important.

This work hinges on the understanding that humans are part of the ecosystem; as such, IEAs must incorporate social processes adequately to more fully reflect spatial and temporal linkages and ecosystem drivers. Indigenous Peoples have lived along the coasts of the Bering and Chukchi seas for thousands of years and continue to collect, test, and refine environmental observations. Drawing from and including multiple knowledge systems improves the depth and breadth of information within the ecosystem assessment for a more robust IEA.

Towards this goal we embarked on an institutional map, or "Lay of the Land." This model identified existing institutional bodies in the Bering Sea/Chukchi Sea region, coded for typology (such as educational, political, Indigenous-led, NGO), and mapped connections across spatial scale (*i.e.*, community, regional, state, national, international). Within this map, it is possible to better understand flows of information, social capital, and funds, and gain insight into social networks more broadly.

Given the complexity of these networks, a comprehensive model was developed for the Norton Sound region and then expanded across the Bering Sea and Chukchi Sea. "Lay of the Land" was discussed during a one-day closed door session at the Workshop on "*Indigenous and community-led approaches to support climate adaptation and resilience, and inform management in North Pacific and Arctic*" (W9) during PICES-2023 (Appendix 4). All data were then transferred to interactive modeling software (Kumu) for extensive modeling capabilities. Kumu software was selected because it is free to use, highly customizable, and offers broad accessibility. A parallel database of regional institutions, typologies, and organizational missions was created to feed the Kumu models. This is a living database in that it can be expanded both spatially, and over time.

In order to define the ecosystem holistically through multiple knowledge systems and perspectives, efforts were made to develop Indigenous Conceptual Models (ICMs) using an interdisciplinary methodology, framework, and team (Traditional Knowledge holders, scientists, managers). Our objectives were to define the ecosystem, promote enduring transdisciplinary partnerships, bridge knowledge systems to inform ecosystem-based-management, and identify key observations for Bering Sea and Chukchi Sea communities. To support the development of ICM, we held a series of workshops (Workshop I: August 2022 in Anchorage, Alaska; Workshop II: March 2023 in Nome, Alaska; and Workshop III: October 2023 in Seattle, WA).

Workshop I (*Multiple ways of knowing the Bering Sea-Chukchi Sea ecosystem*) was conducted on August 24–25, 2022, in Anchorage, Alaska, with the core team and other invited knowledge holders (see Appendix 4). A total of 18 people were invited. Additional funding was secured to provide full travel support and individual stipends for Indigenous Knowledge holders to compensate for their time and knowledge. Unfortunately, complications due to COVID-19 reduced the number of people able to attend in person. Despite the smaller number, or perhaps because of the same number, the workshop was able to meet its objectives and was seen as an overall success. The group suggested an additional workshop at the 2022 PICES Annual Meeting in Busan, Korea, that fall. Again, COVID-19 hindered this effort due to travel restrictions and illness so the workshop was rescheduled for the following year (for the 2023 Annual Meeting in Seattle, USA). See Appendices 4 and 5 for workshop summaries.

Workshop II (*Ecosystem changes and Norton Sound communities*) took place on September 14, 2022, in Nome, Alaska, at the University of Alaska Fairbanks Northwest Center. The purpose of this workshop was to allow for greater participation beyond select Indigenous Knowledge holders and team members. The meeting was open to the public and grounded in regional ecological concerns around fisheries and intersections with fisheries management.

Workshop III (*Indigenous and community-led approaches to support climate adaptation and resilience, and inform management in North Pacific and Arctic*) was developed in response to community interest in expanding visibility for bridging multiple knowledge systems in ecosystem science to inform management. There was considerable interest bringing Indigenous-led research and perspectives to the PICES scientific community for knowledge exchange to improve ecological understanding and build knowledge networks across practitioners. The team partnered with the Ocean Decade Collaborative Center of the Northeast Pacific to invite Indigenous Knowledge holders across the coastal Northeast Pacific from Alaska to California, including British Columbia. The workshop was well attended and provided a platform to communicate the importance and feasibility of Indigenous-led ecosystem research. See the W9 report from PICES-2023 in Appendix 4.

Sarah Wise's team, along with Indigenous, management, and science partners have continued to build out the institutional mapping of the NBS-CS ecosystem to illustrate the relationship between humans, institutions, and the ecosystem. Key ideas emerging from the team's work are:

- There is a need for recognition and support for more Indigenous-led work;
- There is a need for focus on relationships and relationship-building at the start of any ecosystem assessment;
- Data sovereignty is an important and delicate issue that must be addressed;
- There is a need for building capacity across institutions;
- Social science methods and approaches allow for greater attention to and understanding of knowledge production, social networks across scale, and the vital role of equity across scientific processes.

Future work should include leveraging examples of existing strong partnerships and engagement.

2.3 Ecosystem description from Indigenous world views and science – Shared conceptual models

2.3.1 Methods

Working Group 44 developed the initial conceptual models during a virtual workshop April 2022. Three breakout groups of eight to nine WG members were formed to build conceptual models. Each group had a pre-defined topic: Climate change and commercial fisheries (a.k.a. "Climate–Fisheries"); Climate-driven ecosystem change (a.k.a. "Ecological"); and Subsistence–Food Security. Breakout groups were not composed solely of experts in the particular topic. Instead the breakout groups were formed to have a diversity of expertise among climate, fisheries, ecology, subsistence and food security. After the workshop the Climate–Fisheries and Ecological models were combined into one model called "Climate–Fisheries" because of the substantial overlap between the two models. The models, Subsistence–Food Security and Climate–Fisheries, were then further refined to focus on the key components and interactions as determined by the WG members' expertise. WG members also provided literature references to support each interaction. The list of references for each linkage is not comprehensive but was designed as a starting point to further build linkages and identity data gaps.

Mental Modeler was used to build the conceptual models. Mental Modeler is modeling software that helps individuals and communities capture their knowledge in a standardized format that can be used for scenario analysis (https://www.mentalmodeler.com/). Based in Fuzzy-logic Cognitive Mapping, users can easily develop semi-quantitative models of environmental issues, social concerns or social-ecological systems by defining the important components of a system, and defining the relationships between these components.

2.3.2 Subsistence–Food Security conceptual model

The Subsistence–Food Security modeling group faced unique challenges, perhaps the largest of which was that the two topics are conceptually ill equipped to fit into linear, forward-flow models. This conceptual model was difficult to build because the final output/intent of the model would impact what elements should be included and focused on. The group's discussions highlighted that all elements within this conceptual model are connected in intricate ways, and changes in temporal and spatial access (*e.g.*, seasonality, species distributions) could strongly impact all relationships in the model. The exercise also felt contradictory to the Indigenous perspectives that shape and rely on the concepts in the model. Lastly, the group did not have time to discuss food sovereignty.

The Subsistence–Food Security conceptual model indicates positive relationships between food availability and security to several community parameters: subsistence, health, food sovereignty, and quality of life (Fig. 2 and Table 1). Food security reflects the ecosystem and the society that is attaining food security as part of that ecosystem. In other words, it is more than the production and availability of a certain number of fish, birds, mammals, or invertebrates in good condition. It includes cultural well-being, cultural continuity, and the reciprocal relationships that are essential to being part of a system that sustains a community of humans. The relationship between change in environmental conditions and industrial fishing depends on the rate of climate change. A high climate change scenario was predicted to result in an increase in fisheries potential, whereas a low climate change scenario was predicted to result in no change to fisheries potential (Tai *et al*., 2019).

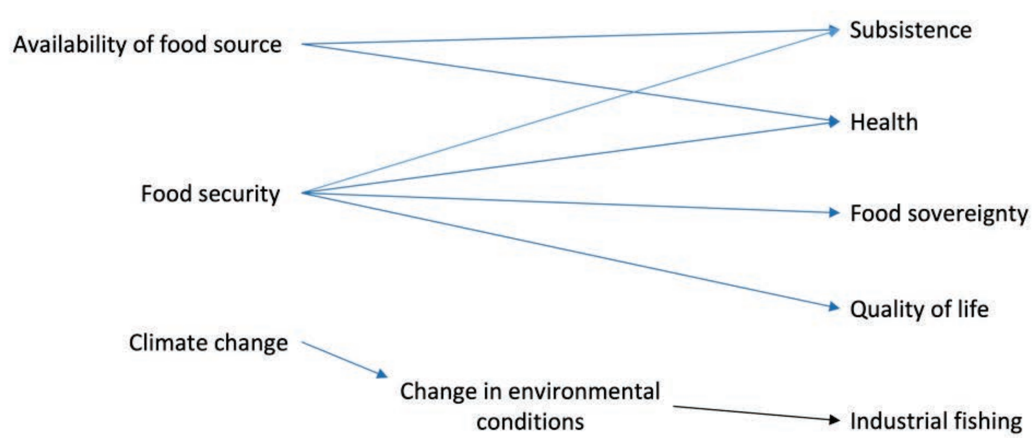

Fig. 2 Subsistence–Food Security model. Blue arrows indicate a positive relationship, black arrow indicates a variable relationship, depending on the rate of change in environmental conditions. See Table 1 for references.

Table 1 Interactions for the Subsistence–Food Security model with references indicated by numbers (see Table 2 for full citations).

	Subsistence	Health	Food sovereignty	Quality of life	Change in environmental conditions	Industrial fishing
Availability of food source	2, 3, 4					
Food security	5,6, 7, 8, 9, 10					
Climate change					15, 16, 17, 18, 19, 20, 21, 22, 23	
Change in environmental conditions						14

Note: The drivers/independent variables are listed in the first column of Table 1. The response/dependent variables are listed in the top row. Merged cells mean that the references describe the effects of drivers on multiple response variables. Blue indicates a positive relationship, gray indicates a variable relationship, depending on the rate of change in environmental conditions.

Table 2 Full citations for references for the Subsistence–Food Security model (shown in Fig. 1 and Table 1).

Number	Reference
2	Steiner NS *et al*. 2019. Impacts of the changing ocean-sea ice system on the key forage fish Arctic cod (*Boreogadus Saida*) and subsistence fisheries in the Western Canadian Arctic - Evaluating linked climate, ecosystem and economic (CEE) models. Front. Mar. Sci. 6: doi: 10.3389/fmars.2019.00179
3	Steiner NS *et al*. 2021. Climate change impacts on sea-ice ecosystems and associated ecosystem services. Elem. Sci. Anth. 9(1): 00007, https://doi.org/10.1525/elementa.2021.00007
4	Geoffroy M *et al*. 2023; The circumpolar impacts of climate change and anthropogenic stressors on Arctic cod (*Boreogadus saida*) and its ecosystem. Elementa: Sci. Anthr. 11 (1): 00097, doi: https://doi.org/10.1525/elementa.2022.00097
5	IPCC-IPBES report (Arctic example in chapter 6); https://www.ipcc.ch/report/ar6/wg2/chapter/chapter-6/
6	Pörtner HO *et al*. 2021. IPBES-IPCC co-sponsored workshop report on biodiversity and climate change; IPBES and IPCC. DOI:10.5281/zenodo.4782538
7	Suydam R and George JC. 2021. Current indigenous whaling. In: J.C. George and J.G.M. Thewissen, eds. The bowhead whale: *Balaena mysticetus*: biology and human interactions. London: Academic Press, pp. 519–535, doi:10.22621/cfn.v134i4.2737
8	Fall JA. 2018. Subsistence in Alaska: a Year 2017 update. Alaska Department of Fish and Game. https://www.adfg.alaska.gov/static/home/subsistence/pdfs/subsistence_update_2017.pdf
9	ICC-Alaska. 2015. Alaskan Inuit food security conceptual framework: How to assess the Arctic from an Inuit perspective. Technical Report. Anchorage: Inuit Circumpolar Council-Alaska.
10	Gadamus L and Raymond-Yakoubian J. 2015. A Bering Strait Indigenous framework for resource management: respectful seal and walrus hunting. Arctic Anthr. 52: 87–101.
14	Tai TC *et al*. 2019. Evaluating present and future potential of Arctic fisheries in Canada. Mar. Policy, 108: 103637, https://doi.org/10.1016/j.marpol.2019.103637

Table 2 Continued.

Number	Reference
15	SROCC report, AMAP climate change update, IPCC AR6, IPCC-IPBES working group report climate change and biodiversity. https://www.un.org/en/climatechange/reports
16	The IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC), 2019. https://www.ipcc.ch/srocc/
17	AMAP, 2021. Arctic Climate Change Update 2021: Key Trends and Impacts. Summary for Policy-makers. Arctic Monitoring and Assessment Programme (AMAP), Tromsø, Norway. 16 pp.
18	Pörtner HO *et al*. 2021. IPBES-IPCC co-sponsored workshop report on biodiversity and climate change; IPBES and IPCC. doi:10.5281/zenodo.4782538
19	Lannuzel D *et al*. 2020. The future of Arctic sea-ice biogeochemistry and ice-associated ecosystems. Nat. Clim. Change 10: 983–992. https://doi.org/10.1038/s41558-020-00940-4
20	The Working Group I contribution to the Sixth Assessment Report, Climate Change 2021: The Physical Science Basis was released on 9 August 2021. https://www.ipcc.ch/report/ar6/wg1/
21	The Working Group II contribution, Climate Change 2022: Impacts, Adaptation and Vulnerability. Released on 28 February 2022. https://www.ipcc.ch/report/ar6/wg2/
22	The Working Group III Contribution , Climate Change 2022: Mitigation of Climate Change was released on 4 April 2022. https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/
23	The Synthesis Report, Climate Change 2023: Synthesis Report was released on 20 March 2023 to inform the 2023 Global Stocktake under the United Nations Framework Convention on Climate Change. https://www.ipcc.ch/report/sixth-assessment-report-cycle/

2.3.3 Climate–Fisheries conceptual model

For the Climate–Fisheries conceptual model, the breakout group started with the fisheries that could be impacted by climate change and worked backwards to determine the climate forcing, oceanographic processes and lower trophic links that would have an effect on specific fisheries as well as working forwards to define potential ramifications on people (*e.g.*, communities, food safety, commercial fisheries).

The Climate–Fisheries model illustrates pathways from physical drivers, such as ocean temperature, sea ice and transport to nutrients, phytoplankton, lower trophic levels, benthic and pelagic organisms, marine birds and mammals, and community parameters (Fig. 3 and Table 3). In addition, the impacts of climate on the system overall and on species distribution are illustrated (inset) because of the number of published papers describing those relationships.

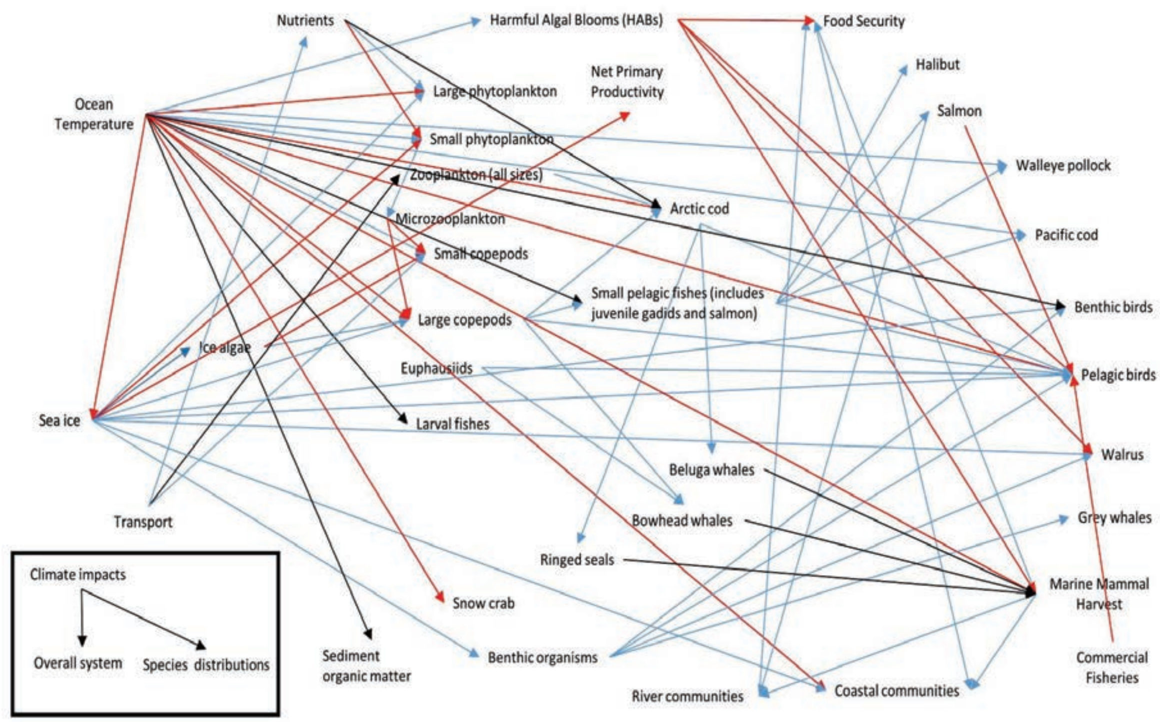

Fig. 3 Climate–Fisheries model. Blue arrows indicate a positive relationship and red arrows indicate a negative relationship. Black arrows indicate: a positive or negative relationship, depending on taxa, an effect on community structure or distribution, and/or an effect on phenology. See Table 3 for references.

The Climate–Fisheries conceptual model also included several components relevant to the human dimension, such as food security, marine mammal harvest, and coastal and river communities (Fig. 4). Food security is important to both river and coastal communities. There are positive relationships between marine mammal harvest and food security, in general, and coastal communities, specifically (river communities are related to salmon). Marine mammal harvest, in turn, is negatively impacted by warming ocean temperature and increasing harmful algal blooms (HABs), and positively affected by increases in beluga whales, bowhead whales and ringed seals. Loss of sea ice and other phenomena related to ocean warming have, overall, negative effects on coastal communities due to the disruption of familiar patterns and increased variability (Huntington *et al*., 2021).

Ocean temperature has direct effects on components across the range of trophic levels and habitats (Fig. 5). Many of the relationships are negative, as expected, but a few are positive. Specifically, warming ocean temperatures are expected to have a positive effect on small phytoplankton and small copepods, HABs and boreal gadids, such as walleye pollock and Pacific cod. Ocean temperature can also affect the phenology of phytoplankton (Nielsen *et al*., 2024).

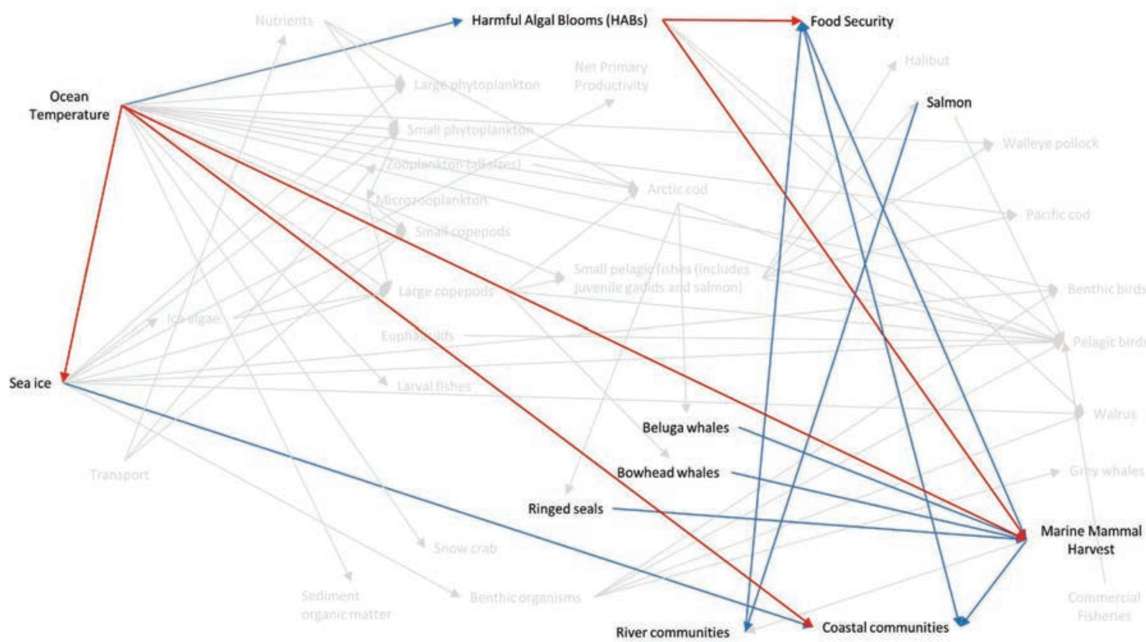

Fig. 4 Climate–Fisheries model. Relationships relevant to coastal communities. See Figure 3 for arrow color descriptions and Table 3 for references.

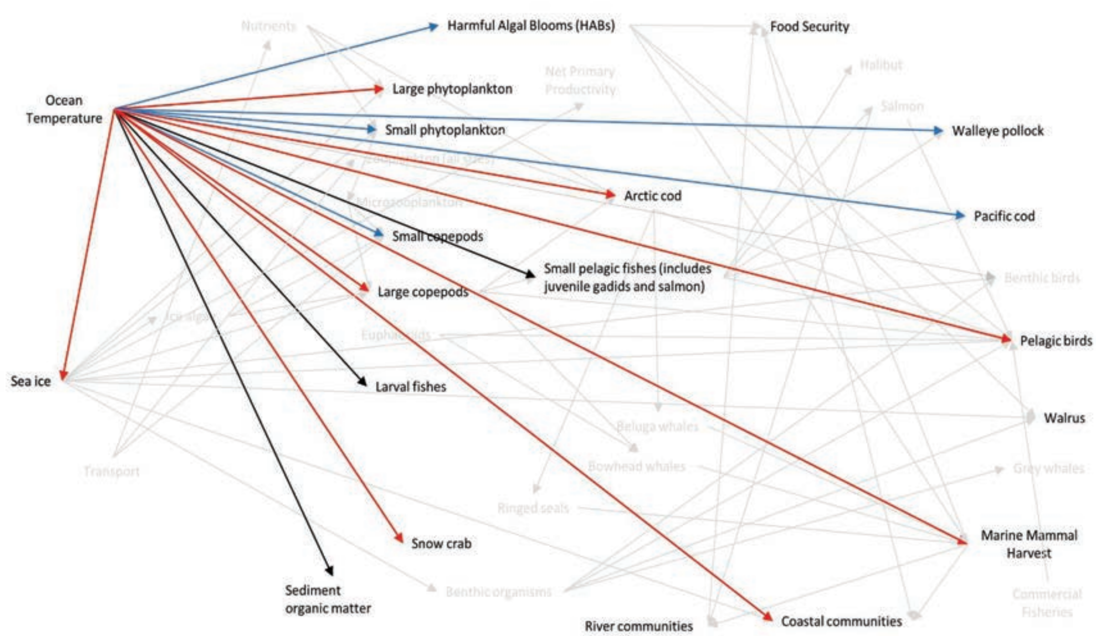

Fig. 5 Climate–Fisheries model. Direct effects of ocean temperature. See Figure 3 for arrow color descriptions and Table 3 for references.

The relationship between ocean temperature and sediment organic matter is neither positive nor negative because field samples and laboratory experiments have indicated that the source of carbon may change with warming to more terrestrial and bacterial carbon (Zinkann, *et al.*, 2022). The relationship between ocean temperature and small pelagic fishes is neither positive nor negative because some species show a positive relationship and some negative with increasing temperature. In addition, some studies indicate changes in distribution of fish with increasing temperature (see Table 3 for specific references).

Not surprisingly, sea ice also has direct impacts throughout the ecosystem (Fig. 6). Decreasing sea ice is expected to negatively impact ice algae, large phytoplankton and large copepods, benthic organisms, marine birds (benthic and pelagic foraging), and walrus. Decreasing sea ice is also expected to directly negatively impact coastal communities. On the other hand, decreasing sea ice is expected to positively impact small phytoplankton and net primary productivity.

HABs are an increasingly critical concern for NBS-CS coastal communities (Anderson *et al.*, 2022). The conceptual model shows that warming ocean temperatures are expected to increase HABs, with negative impacts on pelagic birds, walrus, marine mammal harvest, and food security (Fig 7).

Copepods are central to the food web in the Climate–Fisheries conceptual model (Fig. 8). The model shows that large copepods are prey for Arctic cod, small pelagic fishes, pelagic birds, and bowhead whales. Small copepods are relatively less important prey items. The size composition of the copepod community shifts to smaller taxa with ocean warming and loss of sea ice. In addition, increased transport increases the abundance of small copepods, some of which may be Pacific taxa. The structure of the food chain is also impacted by ocean warming. Small phytoplankton become relatively more abundant and microzooplankton become a more important player in the food web, decreasing the efficiency of energy transfer to copepods of all sizes in summer. In spring large phytoplankton and small and large copepods are directly linked (Gonzalez *et al.*, in review).

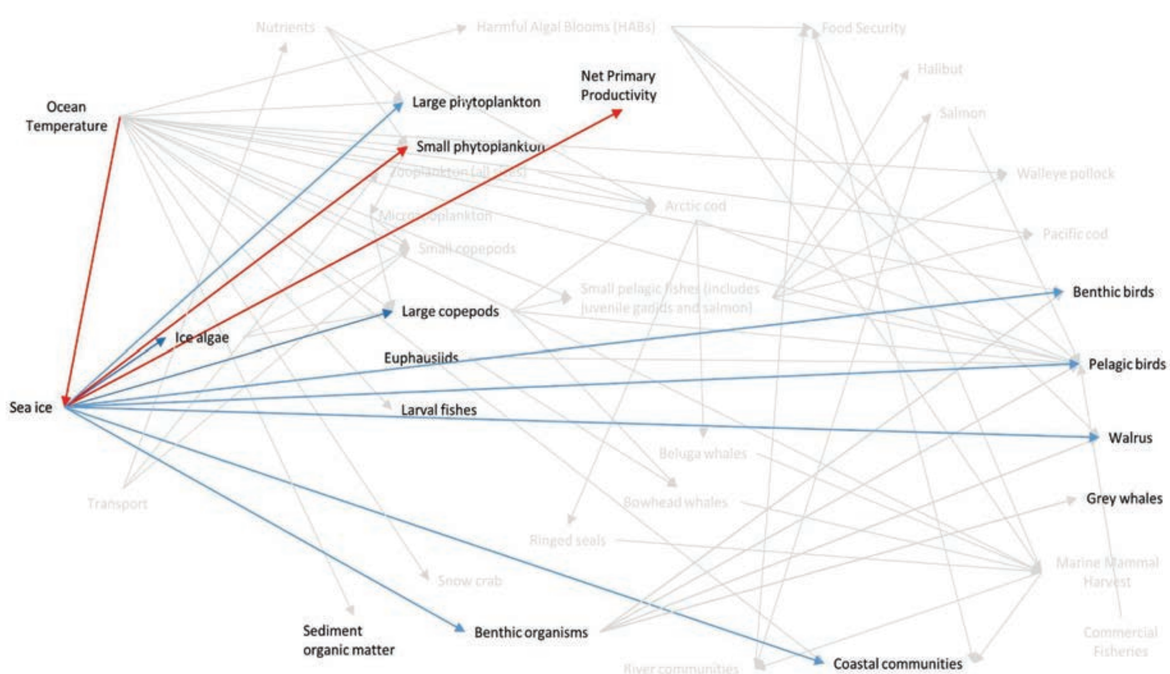

Fig. 6 Climate–Fisheries model. Direct effects of sea ice. See Figure 3 for arrow color descriptions and Table 3 for references.

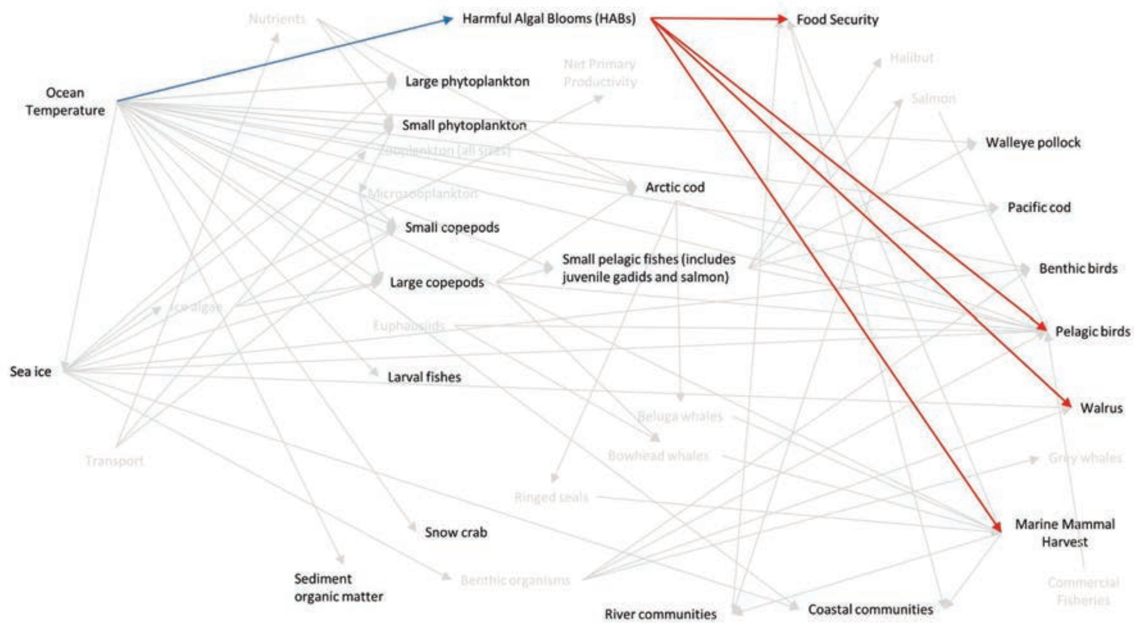

Fig. 7 Climate–Fisheries model. Relationships relevant to harmful algal blooms (HABs). See Figure 3 for arrow color descriptions and Table 3 for references.

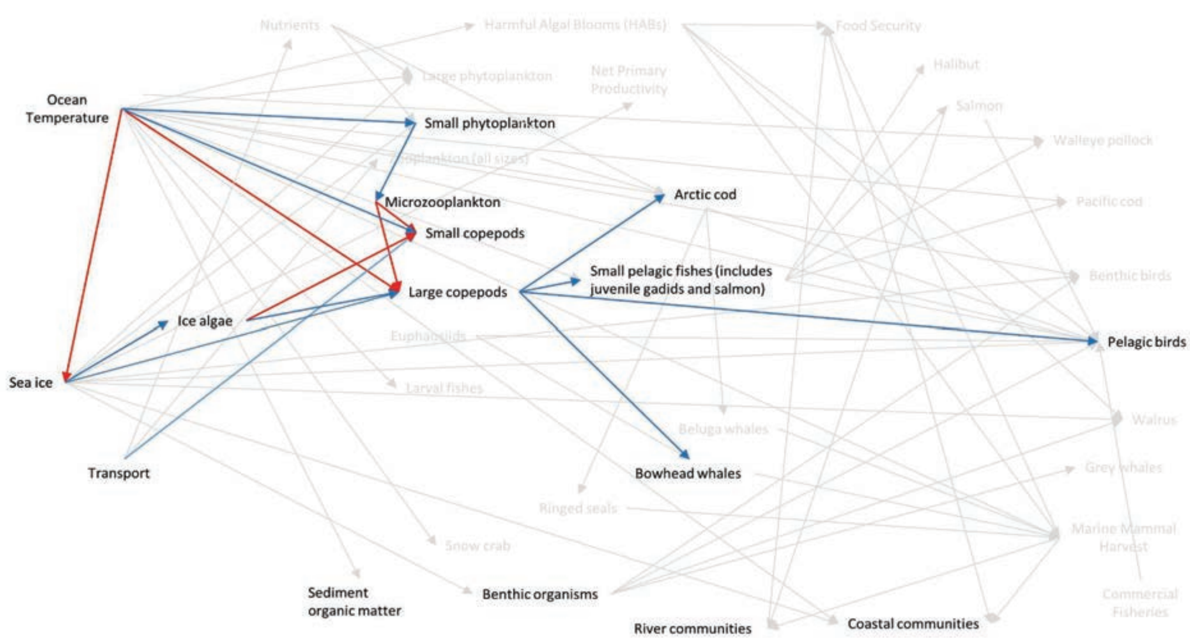

Fig. 8 Climate–Fisheries model. Relationships relevant to small and large copepods. See Figure 3 for arrow color descriptions and Table 3 for references.

The NBS-CS is regarded as a benthic-dominated ecosystem due to strong coupling between pelagic and benthic production (Grebmeier *et al*., 1989). The conceptual model shows that benthic organisms are important for benthic and pelagic birds, walrus, and gray whales (Fig. 9). Ocean warming and loss of sea ice are expected to have negative impacts on benthic organisms.

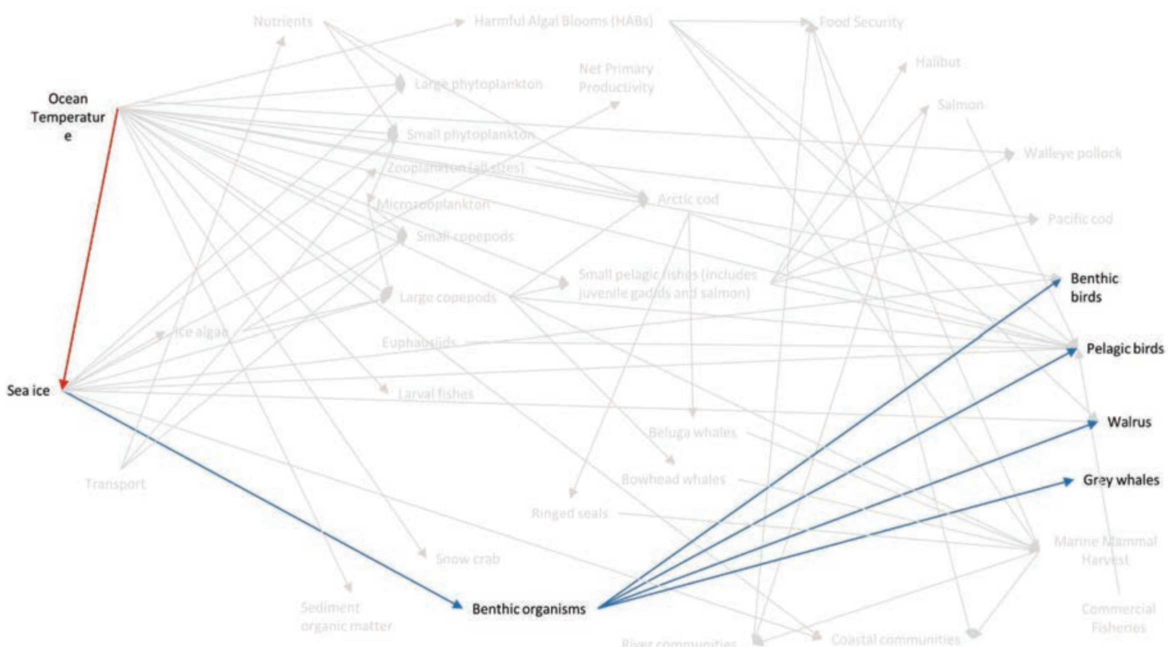

Fig. 9 Climate–Fisheries model. Relationships relevant to benthic organisms. See Figure 3 for arrow color descriptions and Table 3 for references.

Arctic cod play a central role in the NBS-CS food web. In the conceptual model, they are prey for pelagic birds, beluga whales, and ringed seals (Fig. 10). Arctic cod prey on large copepods, so the direct and indirect effects of ocean temperature, sea ice and transport on copepod abundance, size distribution, and food web structure described above affect them as well. The relationship between nutrients and Arctic cod is neither positive nor negative – nutrients have been shown to affect the distribution and community structure of pelagic fish (Cui *et al*., 2009).

Small pelagic fish other than Arctic cod (including gadids and salmon) are also a key component of the conceptual model (Fig. 11). They are prey for halibut, salmon, walleye pollock, Pacific cod, and pelagic birds. They prey on large copepods so the direct and indirect effects of physical drivers on copepod community size structure and food web structure described above impact them as well. The relationship between ocean temperature and small pelagic fish is neither positive nor negative because some species show a positive relationship with temperature and others show a negative relationship. In addition, some studies (see Table 3) have documented a change in distribution of small pelagic fish.

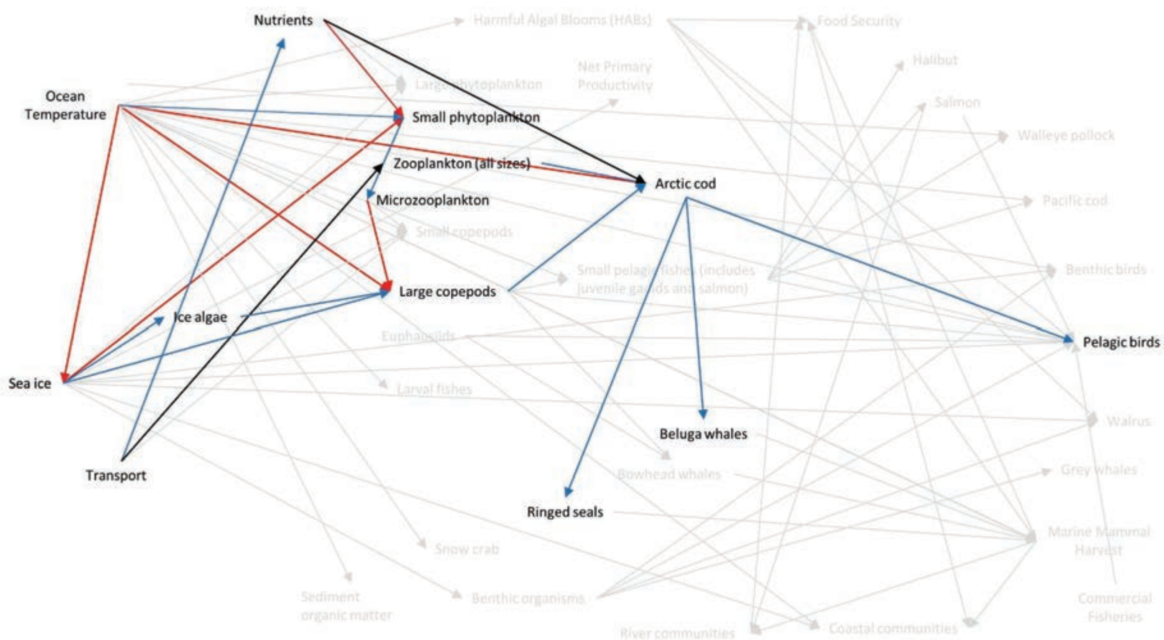

Fig. 10 Climate–Fisheries model. Relationships relevant to Arctic cod. See Figure 3 for arrow color descriptions and Table 3 for references.

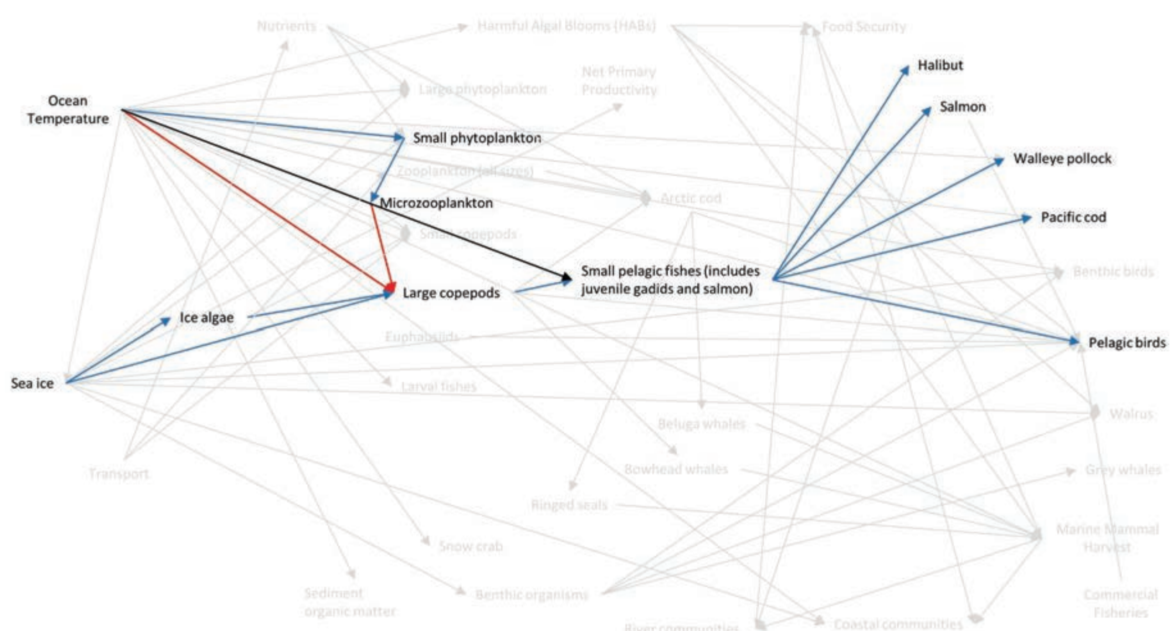

Fig. 11 Climate–Fisheries model. Relationships relevant to small pelagic fishes (including juvenile gadids and salmon). See Figure 3 for arrow color descriptions and Table 3 for references.

Pelagic birds appear to be an indicator for several physical and biological ecosystem components (Fig. 12). They are positively related to sea ice, benthic organisms, large copepods and euphausiids, and Arctic cod and other small pelagic fishes. They are negatively related to ocean temperature, HABs, and commercial fisheries. They are also negatively related to pink salmon, which are thought to be competitors with seabirds for shared prey (Springer *et al.*, 2014).

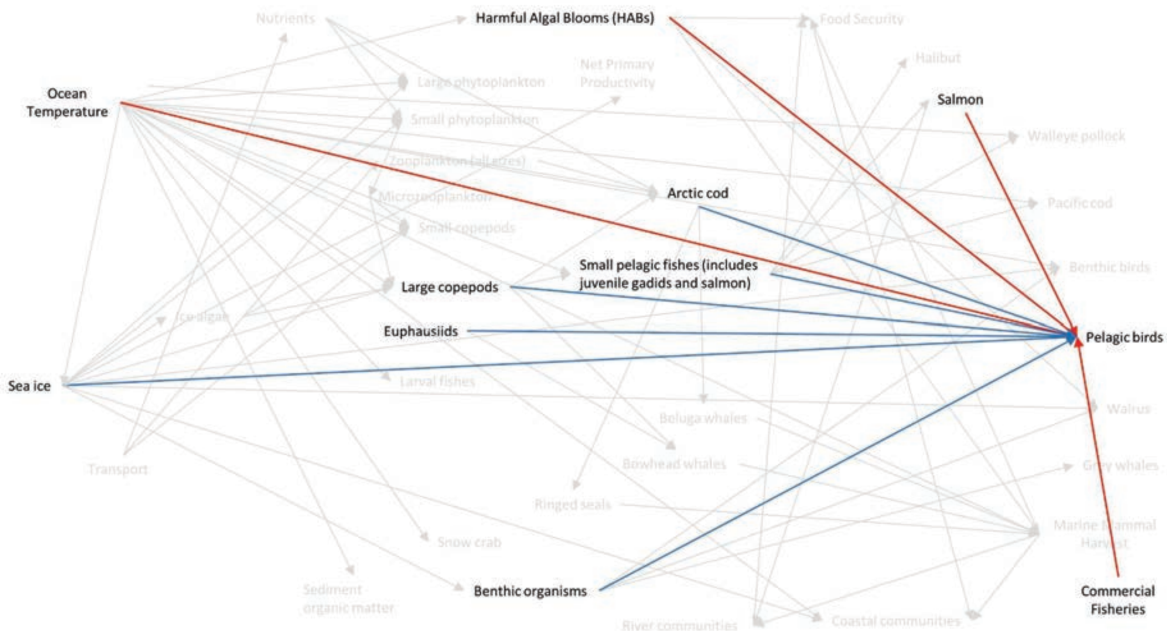

Fig. 12 Climate–Fisheries model. Relationships relevant to pelagic birds. See Figure 3 for arrow color descriptions and Table 3 for references.

Table 3 Interactions for the Climate–Fisheries model with references indicated by numbers (see footnotes for explanations and Table 4 for full citations).

	Overall System	Sea Ice	Ice Algae	Coastal Communities	River Communities	Species Distributions
Overall system	5, 6					
Ocean Temperature	115, 117, 118	156, 157		44		
Sea Ice	3		142, 143, 144	44		
Nutrients						
Ice Algae						
Small Phytoplankton						
Microzooplankton						
Zooplankton (general, all)						
Large Copepods						
Transport						
Commercial Fisheries						
Marine Mammal (Harvest)				43	7, 8, 9, 10	
Bowhead whales						
Beluga whales						
Ringed seals						
Salmon					8	
Food Security				11, 43, 130, 134, 139, 140	9	
Coastal Communities	141					
Harmful Algal Blooms (HAB)						
Climate Impacts	19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 115, 117, 118					17, 74, 75, 76, 77
Small Pelagic Fishes (juvenile gadids, salmon)						
Arctic Cod	4					
Euphausiids						
Benthic Organisms						

Table 3 Continued.

	Food Security	Marine Mammal (Harvest)	Walrus	Grey Whales	Bowhead whales	Beluga whales	Ringed seals
Overall system							
Ocean Temperature		14					
Sea Ice			129				
Nutrients							
Ice Algae							
Small Phytoplankton							
Microzooplankton							
Zooplankton (general, all)							
Large Copepods					152, 153, 154, 155		
Transport							
Commercial Fisheries							
Marine Mammal (Harvest)			10				10
Bowhead whales	7	150					
Beluga whales		151					
Ringed seals		150					
Salmon							
Food Security	9						
Coastal Communities	139,140	139, 140					
Harmful Algal Blooms (HAB)	15, 16, 108	16	16				
Climate Impacts							
Small Pelagic Fishes (juvenile gadids, salmon)							
Arctic Cod						148, 149	146,148
Euphausiids					152, 153, 154, 155		
Benthic Organisms			128	127			

Table 3 Continued.

	HABs	Sea Ice	Nutrients	Sediment organic matter	Small Phytoplankton	Large Phytoplankton	Net Primary Productivity
Overall system							
Ocean Temperature	108, 14, 107	29, 30, 31, 32, 33, 34, 35		120	40, 116	40, 116	
Sea Ice					109, 119	39, 109, 119	41, 109
Nutrients					40	40	
Ice Algae							
Small Phytoplankton							
Microzooplankton							
Zooplankton (general, all)							
Large Copepods							
Transport			37, 38, 132				
Commercial Fisheries							
Marine Mammal (Harvest)							
Bowhead whales							
Beluga whales							
Ringed seals							
Salmon							
Food Security							
Coastal Communities							
Harmful Algal Blooms (HAB)							
Climate Impacts							
Small Pelagic Fishes (juvenile gadids, salmon)							
Arctic Cod							
Euphausiids							
Benthic Organisms							

Table 3 Continued.

	Micro-zooplankton	Zooplankton (general, all)	Large Copepods	Small Copepods	Coastal Communities	Benthic Birds	Pelagic Birds
Overall system							
Ocean Temperature			113	19, 20, 113	44	114	17, 45, 78, 79, 84, 85, 86, 90, 91, 103, 105, 106, 114
Sea Ice					43	87, 88, 136	83, 84, 92, 104
Nutrients							
Ice Algae			17	17			
Small Phytoplankton	142						
Microzooplankton			142	142			
Zooplankton (general, all)							
Large Copepods							84, 93, 94, 95, 97, 98, 99, 103, 126
Transport		110		143			
Commercial Fisheries							89, 90
Marine Mammal (Harvest)							
Bowhead whales							
Beluga whales							
Ringed seals							
Salmon							100, 101
Food Security							
Coastal Communities							
Harmful Algal Blooms (HAB)							80, 82
Climate Impacts							
Small Pelagic Fishes (juvenile gadids, salmon)							45, 81, 84, 93, 95, 96, 97
Arctic Cod							93, 95, 104
Euphausiids							84, 93, 94, 95, 97, 98, 99, 102, 103
Benthic Organisms						87, 88, 133, 135, 136	93, 95

Table 3 Continued.

	Benthic Organisms	Small Pelagic Fishes	Larval fishes	Walleye pollock	Pacific cod	Arctic Cod	Halibut	Salmon	Snow crab (opilio)
Overall system						4			
Ocean Temperature		17, 47, 48, 49, 50, 51, 52, 53, 54, 55, 138	111	52, 57, 63, 65, 65, 124, 125	57, 60, 63, 66	52, 56, 57, 58, 59, 60, 61, 62, 123			112
Sea Ice	127								
Nutrients						138			
Ice Algae						2			
Small Phytoplankton									
Microzooplankton									
Zooplankton (general, all)						137			
Large Copepods		67, 68, 69, 137				137,122			
Transport									
Commercial Fisheries									
Marine Mammal (Harvest)									
Bowhead whales									
Beluga whales									
Ringed seals									
Salmon									
Food Security									
Coastal Communities									
Harmful Algal Blooms (HAB)									
Climate Impacts									
Small Pelagic Fishes (juvenile gadids, salmon)				70, 71	70, 71		70	45, 72, 73	
Arctic Cod									
Euphausiids									
Benthic Organisms									

The drivers/independent variables are listed in the first column. The response/dependent variables are listed in the top row. Blue indicates a positive relationship, red indicates a negative relationship. Gray indicates a positive or negative relationship, depending on taxa, an effect on community structure or distribution, and/or an effect on phenology.

Table 4 Full citations for references to the Climate–Fisheries model (shown in Figure 2 and Table 3).

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2.4 Knowledge gaps and next steps

The Food Sovereignty–Subsistence breakout group did not have time to fully explore the role of food sovereignty in their model. Other questions to explore include: How should we evaluate potential new food sources in the context of a traditional framework? Are new resources (*e.g.*, salmon or subarctic groundfish) a potential additional source of subsistence or an unwelcome or at least unfamiliar change? How should we consider these changes in evaluating challenges to maintaining cultural practices and norms? How should we think of these shifts in terms of community resilience? Finally, ensuring that a diversity of perspectives is included in developing a conceptual model is key in creating a model that most accurately reflects the system components and their interrelatedness. WG 44's modeling exercise included numerous international scientists with differing expertise. However, the group only contained two or three Indigenous perspectives, and could have been improved with more Native Alaskan voices.

The Climate–Fisheries model focused on trophic interactions (predation or competition) but other interactions with the environment, such as conditions for reproduction, should also be included. In addition, seasonality and phenology were not well-represented in the model.

A next step for this work on conceptual models of the NBS-CS would be to run scenarios to determine how the system might react under a range of possible changes. Mental Modeler software can be used for this task. Another step would be to use the conceptual models to develop a data-driven Integrated Ecosystem Assessment. The inventory of metadata of information sources developed to fulfill WG 44's deliverables provides a guide to current data availability for such an effort.

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Appendix 1

WG 44 Terms of Reference

1. Convene an interdisciplinary and international working group membership.
2. Include Arctic peoples and Indigenous Knowledge systems.
3. Identify and consult with partners and institutions.

Original Terms of Reference Deliverables

Year 1 Deliverables:

- Inventory of metadata, knowledge, institutions and programs relevant to the Northern Bering Sea–Chukchi Sea LME. PICES or ICES Report. Web-based repository.

Year 2 Deliverables:

- Ecosystem description from both Indigenous world views and science (shared conceptual models), indicators and hypotheses. PICES or ICES Report. Contribution to Arctic Report Card and or ecosystem status report.
- Report on Ecological Objectives (co-produced with PAME).
- Report on Ecological Values Workshop (co-produced with PAME).

Year 3 Deliverables:

- Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea LME. PICES or ICES Report. Contribution to NPESR. PAME-AMAP-CAFF Report. Contribution to Arctic Report Card.
- Journal articles
- Outreach activities
- Knowledge Gap and Next Steps Report. PICES or ICES Report.

Revised Terms of Reference Deliverables (May 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.

Appendix 2

WG 44 PICES Membership

WG 44 term: 2019–2022
Extended 1 year to 2023
Parent Committees: FIS, HD

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Appendix 3

WG 44 Arctic Metadata

The first column is a general Arctic research "Category" (*e.g.*, marine mammals, pelagic seabirds, *etc*.) followed by a generalized "Data type" description (*e.g.*, trawls, pelagic fishes, *etc*.). The field "Data source" refers to a general location of the data and/or the name of the research project. The column "Data links / Contact(s)" is a hyperlink to the data online as of the printing of this report and if the data are not online or are unknown, an agency and last known email contact is provided. Acronym definitions can be found on at the beginning of this report on page iv.

Category / Data type	**Data source**	**Data links / Contact(s)**
Adult fish / fish diet, consumption rates	AFSC Stomach Lab	https://www.fisheries.noaa.gov/inport/item/20485
Adult fish / lipid dataset, fish	AFSC ABL	https://www.fisheries.noaa.gov/inport/item/17285
Adult fish / acoustics, adult fish (beam trawls)	ArcticIERP	https://arctic-ierp.portal.axds.co/
Adult fish / bottom trawls / beam trawls	snow crab biomass, abundance, size frequency	https://arctic-ierp.portal.axds.co/
Adult fish / fish catch data	Pelagic trawl catch data	Pacific Fisheries Research Center (TINRO) / zuenko_yury@hotmail.com
Adult fish / fish catch data	Pelagic trawl catch data	Pacific Fisheries Research Center (TINRO) / zuenko_yury@hotmail.com
Adult fish / herring; possible other fish?	OCSEAP	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:OCSEAP
Adult fish / general portal for data	DataOne	https://search.dataone.org/data/query=arctic?
Adult fish / general portal for data	PacMARS	https://data.eol.ucar.edu/dataset/list?project=364&children=project&category=21
Adult fish / fish biomass, fish abundance	BSIERP, BEST (NPRB and NSF)	https://data.eol.ucar.edu/dataset/list?project=341&children=project
Adult fish / pelagic fishes	AFSC/RACE/MACE: Pollock Acoustic-Trawl Survey Biennial Bering Sea	https://www.fisheries.noaa.gov/inport/item/28186

Category / Data type	**Data source**	**Data links / Contact(s)**
Adult fish / pelagic fishes	AFSC/RACE/MACE: Pollock Acoustic-Trawl Survey Biennial Bering Sea	https://www.fisheries.noaa.gov/inport/item/28146
Adult fish / benthic fishes	AFSC/RACE/GAP: Eastern Bering Sea Annual Bottom Trawl Survey	https://www.fisheries.noaa.gov/inport/item/22008
Adult fish / benthic fishes	AFSC/RACE/GAP: Eastern Bering Sea Annual Bottom Trawl Survey	https://www.fisheries.noaa.gov/inport/item/22008
Adult fish / benthic fishes	ArcticIERP	https://nprb.org/arctic-program/
Benthic epifauna / species ID, biomass, abundance, functional traits, sediment	AMBON (MBON Data Portal)	https://www.uaf.edu/cfos/research/projects/arctic-marine-biodiversit/ / kbiken@alaska.edu
Benthic epifauna / macrobenthic invertebrates	PacMARS	https://data.eol.ucar.edu/dataset/255.009
Benthic epifauna / biomass, abundance	Various trawls	https://search.dataone.org/view/doi%3A10.5065%2FD67M05ZX
Benthic epifauna / invertebrate pathology, benthic organisms	OCSEAP	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:OCSEAP
Benthic epifauna / general portal for data	DataOne	https://search.dataone.org/data/query=arctic?
Benthic epifauna / general portal for data	PacMARS	https://data.eol.ucar.edu/dataset/list?project=364&children=project&category=21
Benthic epifauna / benthic epifauna, crab	BSIERP, BEST (NPRB and NSF)	https://data.eol.ucar.edu/dataset/list?project=341&children=project
Benthic epifauna	BOEM	http://arcticstudies.org/
Benthic epifauna / benthos	SBI Data Access	https://data.eol.ucar.edu/master_lists/generated/sbi/
Benthic epifauna / varies	RUSALCA	https://www.pmel.noaa.gov/rusalca/
Benthic epifauna / varies	ASGARD (Arctic Shelf Growth, Advection, Respiration and Deposition)	https://arctic-ierp.portal.axds.co/
Benthic epifauna / CTD casts	Norton Sound Crab Survey	https://www.adfg.alaska.gov/index.cfm?adfg=commercialbyareanortonsound.shellfish
Benthic epifauna / lipid dataset, invertebrates	AFSC ABL	https://www.fisheries.noaa.gov/inport/item/17285

Category / Data type	Data source	Data links / Contact(s)
Benthic epifauna / oceanographic	ArcticIERP	https://nprb.org/arctic-program/
Benthic infauna / Species ID, biomass, abundance, functional traits, sediment	Benthic samples; van Veen grabs	https://data.eol.ucar.edu/dataset/list?project=341&children=project
Benthic infauna / benthic infauna	Benthic samples; van Veen grabs	https://data.eol.ucar.edu/dataset/255.076
Benthic infauna / macroinfauna from CG Healy 2017	Benthic samples; van Veen grabs	https://search.dataone.org/view/doi%3A10.18739%2FA27M0414K
Benthic infauna / invertebrate pathology, benthic organisms	OCSEAP	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:OCSEAP
Benthic infauna / general portal for data	DataOne	https://search.dataone.org/data/query=arctic?
Benthic infauna	BSIERP, BEST (NPRB and NSF)	https://data.eol.ucar.edu/dataset/search?searchKey=BSIERP&searchType=ALL&max=100&offset=0&order=asc&sort=title
Benthic infauna	BOEM	http://arcticstudies.org/
Benthic infauna / benthos	SBI Data Access	https://data.eol.ucar.edu/master_lists/generated/sbi/
Benthic infauna / lipid dataset, invertebrates	AFSC ABL	https://www.fisheries.noaa.gov/inport/item/17285
Benthic infauna	ArcticIERP	https://nprb.org/arctic-program/
Benthic infauna	AFSC EFH	https://www.fisheries.noaa.gov/foss/f?p=215%3A28
Ecosystem modeling / updated model from Whitehead model	Ecopath, Ecosim	https://search.dataone.org/
Ecosystem modeling / general portal for data	DataOne	https://search.dataone.org/data/query=arctic?
Ecosystem modeling / general portal for data	PacMARS	https://data.eol.ucar.edu/dataset/list?project=364&children=project&category=21
Ecosystem modeling / models	BSIERP, BEST (NPRB and NSF)	https://data.eol.ucar.edu/dataset/list?project=341&children=project
Ecosystem modeling / oceanographic	ArcticIERP	https://nprb.org/arctic-program/
Environmental drivers / general portal for data	PacMARS	https://data.eol.ucar.edu/dataset/list?project=364&children=project&category=21
Environmental drivers / temperature, salinity, currents	Moorings: NBS: M5 (BS-5), M8 (BS-8); Chukchi: C1-9	https://www.pmel.noaa.gov/foci/foci_moorings/mooring_info/mooring_location_info.html
Environmental drivers / SST, ocean color (unreliable north), wind, salinity, sea level	Satellites (MODIS, SeaWIFS)	https://polarwatch.noaa.gov/catalog/

Category / Data type	Data source	Data links / Contact(s)
Environmental drivers / temperature, salinity, currents	Model (ex: ROMS, PAROMS)	https://www.ecofoci.noaa.gov/modeling
Environmental drivers / sea ice extent	NSIDC	https://nsidc.org/data/explore-data
Environmental drivers / atmosphere, ocean waves, wind	ERA5 winds (assimilated observational reanalysis)	https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5
Environmental drivers / sediment, carbon	PacMARS	https://arcticdata.io/catalog/portals/DBO
Environmental drivers / temperature, salinity, many other metrics	Chukchi Ecosystem Observatory (CEO) mooring array (northern CS)	http://research.cfos.uaf.edu/ceo/
Environmental drivers / monitoring sea ice	Canada (DFO) / Collaborative	Fisheries and Ocean Canada (DFO) / andrea.niemi@dfo-mpo.gc.ca
Environmental drivers / variability and change of the marine ecosystem	Canada (DFO) / DBO	Fisheries and Ocean Canada (DFO) / andrea.niemi@dfo-mpo.gc.ca
Environmental drivers / Pacific water inflow to the Arctic	Canada (DFO) /C3O Ships of Opp	Fisheries and Ocean Canada (DFO) / andrea.niemi@dfo-mpo.gc.ca
Environmental drivers / Pacific water in the Arctic Basin	University of Manitoba SHEBA Geochemical	Fisheries and Ocean Canada (DFO) / andrea.niemi@dfo-mpo.gc.ca
Environmental drivers / monitoring sea ice, Pacific water influence	Canada (DFO) / AIM	Fisheries and Ocean Canada (DFO) / andrea.niemi@dfo-mpo.gc.ca
Environmental drivers / contaminants, stable isotopes	University of Manitoba (SHEBA) Contaminants and Isotopes	Fisheries and Ocean Canada (DFO) / andrea.niemi@dfo-mpo.gc.ca
Environmental drivers / carbon fluxes, pCO_2	University of Manitoba ArcticNet	Fisheries and Ocean Canada (DFO) / andrea.niemi@dfo-mpo.gc.ca
Environmental drivers / model output particle tracking	NA (modeled dataset)	https://search.dataone.org/view/urn%3Auuid%3Adc3539de-e5b7-45f1-b5fa-62da23db3a16
Environmental drivers / alkalinity, attenuation/transmission, carbon dioxide, chlorophyll, conductivity, nitrate, nitrite, oxygen, phosphate, salinity, silicate, stable isotopes, water pressure, temperature	PacMARS / Chinare	https://data.eol.ucar.edu/dataset/255.081
Environmental drivers / general portal for data	DataOne	https://search.dataone.org/data/query=arctic?
Environmental drivers / sediment values	CASCADE	https://bolin.su.se/data/cascade

Category / Data type	Data source	Data links / Contact(s)
Environmental drivers / extensive bathymetry grid	AFSC/RACE/GAP/Prescott: Norton Sound Bathymetry	https://www.fisheries.noaa.gov/alaska/ecosystems/alaska-bathymetry-sediments-and-smooth-sheets
Environmental drivers / acoustic monitoring, baseline chemistry, benthic ecology, chemical oceanography, fisheries ecology, marine mammal ecology, physical oceanography, plankton ecology, nutrients, seabirds	CSESP	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:0124308
Environmental drivers / oceanographic	BSIERP, BEST (NPRB and NSF)	https://data.eol.ucar.edu/dataset/list?project=341&children=project
Environmental drivers / oceanographic	ArcticIERP	https://nprb.org/arctic-program/
Environmental drivers / hydrography, nutrients	NOAA AFSC EMA Program	https://www.ecofoci.noaa.gov/data-links
Environmental drivers / oceanography, marine chemistry, zooplankton	Russian Federal Research Institute of Fisheries and Oceanography	Pacific Fisheries Research Center (TINRO) / zuenko_yury@hotmail.com
Environmental drivers / temperature, salinity, dissolved oxygen, SiO_3, PO_4, pH profiles	DVNIGMI -Russian Hydrometeorological Agency	Pacific Fisheries Research Center (TINRO) / zuenko_yury@hotmail.com
Environmental drivers / physical oceanography, marine chemistry, marine biology (zooplankton)	Russian Fisheries Agency - Pacific (TINRO)	Pacific Fisheries Research Center (TINRO) / zuenko_yury@hotmail.com
Environmental drivers / meteorology, partial physical oceanography, chemical oceanography	Hydro Meteorological Agency (HMA)	Pacific Fisheries Research Center (TINRO) / zuenko_yury@hotmail.com
Environmental drivers / varies	Pacific Oceanological Institute (POI FEB RAS)	Pacific Fisheries Research Center (TINRO) / zuenko_yury@hotmail.com
Environmental drivers / sediment chemical characteristics	BOEM	http://arcticstudies.org/
Environmental drivers / nutrients	ASGARD	https://search.dataone.org/view/10.24431%2Frw1k6cn
Environmental drivers / various	Arctic Data Center General Link	https://arcticdata.io/catalog/data
Environmental drivers / various	UAF Data	https://www.uaf.edu/cfos/research/oarc/data-resources/
Environmental drivers / various	DBO Lines	https://arcticdata.io/catalog/portals/DBO/Data

Category / Data type	Data source	Data links / Contact(s)
Environmental drivers / various	KPDC	https://kpdc.kopri.re.kr/search/?q=Arctic&q=Chukchi
Environmental drivers / sediment, hydrography, oceanography, satellite, other	SBI Data Access	https://data.eol.ucar.edu/master_lists/generated/sbi/
Environmental drivers / AOOS data in support of the CSESP program	CSESP	https://www.chukchiscience.com/ ; https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:0124308
Environmental drivers / Chl-a depth stratified in situ, MODIS (surface optional depth only satellite)	AFSC	Alaska Fisheries Science Center Metadata Library / https://www.fisheries.noaa.gov/inport/item/7262
Environmental drivers / fluorescence, ice algae	AFSC	https://www.ecofoci.noaa.gov/data-links
Environmental drivers / total/size fraction Chl-a	BASIS	https://portal.aoos.org/#module-metadata/d4fe79aa-75b6-11e4-956f-00265529168c
Environmental drivers / water physics, current meter, wind, various	OCSEAP	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:OCSEAP
Forage fish / distribution, species composition, and abundance, size composition	Shipboard bongo nets	Alaska Fisheries Science Center Metadata Library / https://www.fisheries.noaa.gov/inport/item/7262
Forage fish / Age-0/Age-1 acoustic and midwater trawl	Shipboard nets, moorings, saildrone	Alaska Fisheries Science Center Metadata Library / https://www.fisheries.noaa.gov/inport/item/7262
Forage fish / acoustics age 0/1 gadids	Moored transducers	Alaska Fisheries Science Center Metadata Library / https://www.fisheries.noaa.gov/inport/item/7262
Forage fish / Age-1+	Beam Trawls	Alaska Fisheries Science Center Metadata Library / https://www.fisheries.noaa.gov/inport/item/7262
Forage fish / demersal fish community	Beam trawls	University of Alaska Fairbanks / College of Fisheries and Ocean Sciences / fmueter@alaska.edu
Forage fish / age and growth of saffron cod, Arctic cod, walleye pollock, Pacific cod (NBS only)	Demographics	Alaska Fisheries Science Center Metadata Library / https://www.fisheries.noaa.gov/inport/item/7262
Forage fish / demersal fish community	Beam trawls	University of Alaska Fairbanks / College of Fisheries and Ocean Sciences / fmueter@alaska.edu
Forage fish / gut contents	Fish diet and consumption rates	Alaska Fisheries Science Center Metadata Library / https://www.fisheries.noaa.gov/inport/item/7262
Forage fish / fish catch data	Pelagic trawl catch data	Pacific Fisheries Research Center (TINRO) / zuenko_yury@hotmail.com

Category / Data type	Data source	Data links / Contact(s)
Forage fish / fish catch data	Pelagic trawl catch data	Pacific Fisheries Research Center (TINRO) / zuenko_yury@hotmail.com
Forage fish / herring	varies	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:OCSEAP
Forage fish / general portal for data	DataOne	https://search.dataone.org/data/query=arctic?
Forage fish / forage fish abundance, acoustics, biomass	BSIERP, BEST (NPRB and NSF)	https://data.eol.ucar.edu/dataset/list?project=341&children=project
Forage fish / pelagic fishes, YOY, forage fish	AFSC/RACE/MACE: Pollock Acoustic-Trawl Survey Biennial Bering Sea	https://www.fisheries.noaa.gov/inport/item/28186
Forage fish / pelagic fishes, YOY, forage fish	AFSC/RACE/MACE: Pollock Acoustic-Trawl Survey Biennial Bering Sea	https://www.fisheries.noaa.gov/inport/item/28146
Forage fish / benthic fishes, YOY, forage fishes	AFSC/RACE/GAP: Eastern Bering Sea Annual Bottom Trawl Survey	https://www.fisheries.noaa.gov/inport/item/22008
Forage fish / benthic fishes, YOY, forage fishes	AFSC/RACE/GAP: Eastern Bering Sea Annual Bottom Trawl Survey	https://www.fisheries.noaa.gov/inport/item/22008
Forage fish / hydrography, nutrients, zooplankton, chlorophyll, ecosystem, Northern Bering Sea	NOAA AFSC EMA	Alaska Fisheries Science Center Metadata Library / https://www.fisheries.noaa.gov/inport/item/7262
Forage fish / fish diet, consumption rates	AFSC Stomach Lab	https://www.fisheries.noaa.gov/inport/item/20485
Forage fish / lipid dataset, fish	AFSC ABL	https://www.fisheries.noaa.gov/inport/item/17285
Forage fish / forage fish, Ecosystem, Northern Bering Sea	NOAA AFSC EMA Program	Alaska Fisheries Science Center Metadata Library / https://www.fisheries.noaa.gov/inport/item/7262
Forage fish / forage fish, pelagic	ArcticIERP	https://arctic-ierp.portal.axds.co/ ; https://nprb.org/arctic-program/
Forage fish / yellowfin sole juveniles diet, age, lipids, fatty acid	AFSC	Alaska Fisheries Science Center Metadata Library / https://www.fisheries.noaa.gov/inport/item/7262
Pelagic/ice algal production / satellite, Chl-a/fluorescence, primary production, estimates of size structure	MODIS, SeaWIFS, DBO sites	https://modis.gsfc.nasa.gov/data/ ; https://oceancolor.gsfc.nasa.gov/SeaWiFS/ ; https://arcticdata.io/catalog/portals/DBO
Pelagic/ice algal production / temperature, salinity, currents	Moorings: NBS: M5 (BS-5), M8 (BS-8); Chukchi: C1-9	https://www.pmel.noaa.gov/foci/foci_moorings/mooring_info/mooring_location_info.html
Pelagic/ice algal production / shipboard, chlorophyll	ArcticIERP, DBO, BASIS for NBS, etc.	https://arctic-ierp.portal.axds.co/ ; https://arcticdata.io/catalog/portals/DBO ; http://arcticstudies.org/

Category / Data type	Data source	Data links / Contact(s)
Pelagic/ice algal production / size fractionated chlorophyll	ArcticIERP, BASIS	https://arctic-ierp.portal.axds.co/ ; https://portal.aoos.org/#module-metadata/d4fe79aa-75b6-11e4-956f-00265529168c
Pelagic/ice algal production / shipboard; in situ primary production calculations/experiments	ArcticIERP	https://arctic-ierp.portal.axds.co/
Pelagic/ice algal production / shipboard; FlowCam in situ taxonomic ID of large phytoplankton and flow cytometry for abundance of small phytoplankton	ArcticIERP	https://arctic-ierp.portal.axds.co/
Pelagic/ice algal production / microplankton community composition and abundances based on microscopy analyses	Shipboard	Alaska Fisheries Science Center Metadata Library / https://www.fisheries.noaa.gov/inport/item/7262
Pelagic/ice algal production / primary productivity, phytoplankton	OCSEAP	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:OCSEAP
Pelagic/ice algal production / general portal for data	DataOne	https://search.dataone.org/data/query=arctic?
Pelagic/ice algal production / general portal for data	PacMARS	https://data.eol.ucar.edu/dataset/list?project=364&children=project&category=21
Pelagic/ice algal production / under ice CTD data; chlorophyll, many variables	NPRB and NSF	https://data.eol.ucar.edu/dataset/list?project=341&children=project
Pelagic/ice algal production / nutrient, sea ice, other	SBI Data Access	https://data.eol.ucar.edu/master_lists/generated/sbi/
Process Links / stable isotopes; Bulk C and N from copepods	ArcticIERP	https://arctic-ierp.portal.axds.co/
Process links / stables isotopes; bulk C and N and compound specific C and N stable isotopes of amino acids (CSIAA) from benthic animals	DBO sites	https://www.sciencedirect.com/science/article/pii/S0967064517304265
Process links / stable isotopes; organic carbon and nitrogen in organic fraction of sediments	DBO sites	https://arcticdata.io/catalog/portals/DBO; http://arcticstudies.org/
Process links / stable isotopes; bulk C and N from benthic invertebrates across the Chukchi Sea, also CSIAA	AMBON (RUSALCA and ASGARD)	https://www.uaf.edu/cfos/research/projects/arctic-marine-biodiversit/ / kbiken@alaska.edu

Category / Data type	Data source	Data links / Contact(s)
Process links / lipid/fatty acids; phytoplankon; zooplankton; young gadids	ArcticIERP	Alaska Fisheries Science Center Metadata Library / https://www.fisheries.noaa.gov/inport/item/7262
Process Links / drifting sediment traps / sediment traps at moorings	UAF	https://www.frontiersin.org/articles/10.3389/fmars.2020.548931/full
Process links / phytoplankton; zooplankton; microzooplankton; grazing rates	KOPRI cruise	See paper link under notes for several citations to grazing rates
Process links / microzooplankton (MZ) grazing rates	ASGARD 2017	https://search.dataone.org/data/query=asgard? / mlomas@bigelow.org
Process links / compound specific C and N stable isotopes of amino acids (CSIAA) from benthic animals	AMBON	https://www.uaf.edu/cfos/research/projects/arctic-marine-biodiversit/ / kbiken@alaska.edu
Process links / possible links	OCSEAP	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:OCSEAP
Process links / general portal for data	DataOne	https://search.dataone.org/data/query=arctic?
Process links / general portal for data	PacMARS	https://data.eol.ucar.edu/dataset/list?project=364&children=project&category=21
Process links / process links, many	BSIERP, BEST (NPRB and NSF)	https://data.eol.ucar.edu/dataset/list?project=341&children=project
Process links / water chemistry, stable isotopes, other	SBI Data Access	https://data.eol.ucar.edu/master_lists/generated/sbi/
Zooplankton / distribution, species composition, and abundance	Shipboard bongo nets (ArcticIERP, DBO, EcoFOCI, BASIS)	https://portal.aoos.org/#module-metadata/d4fe79aa-75b6-11e4-956f-00265529168c / david.kimmel@noaa.gov
Zooplankton / distribution, species composition, and abundance	Shipboard bongo nets (ASGARD)	https://search.dataone.org/data/query=asgard? / rrhopcroft@alaska.edu
Zooplankton / distribution, species composition, and abundance	Shipboard bongo nets (AMBON)	https://www.uaf.edu/cfos/research/projects/arctic-marine-biodiversit/ / rrhopcroft@alaska.edu
Zooplankton / distribution, species composition, and abundance	Continuous plankton recorder	https://gulfwatchalaska.org/monitoring/environmental-drivers/continuous-plankton-recorder/ ; https://www.fisheries.noaa.gov/inport/item/7262 / louise.copeman@noaa.gov
Zooplankton / gut contents	EcoFOCI and/or ABL	https://www.fisheries.noaa.gov/inport/item/12324 / johanna.vollenweider@noaa.gov
Zooplankton	OCSEAP	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:OCSEAP
Zooplankton / general portal for data	DataOne	https://search.dataone.org/data/query=arctic?
Zooplankton / general portal for data	PacMARS	https://data.eol.ucar.edu/dataset/list?project=364&children=project&category=21
Zooplankton / zooplankton, acoustics, biomass	BSIERP, BEST (NPRB and NSF)	https://data.eol.ucar.edu/dataset/list?project=341&children=project

Category / Data type	Data source	Data links / Contact(s)
Zooplankton / ecosystem, Northern Bering Sea	NOAA AFSC EMA Program	Alaska Fisheries Science Center Metadata Library / ed.farley@noaa.gov
Zooplankton / oceanographic	ArcticIERP	https://nprb.org/arctic-program/
Benthic foraging marine mammals / platform of opportunity sightings provide presence-only information; substrate type data available from ArcticIERP beam trawls	DBO, oil/gas industry (I think JASCO did all of the acoustic monitoring in the NE Chukchi for Shell)	Alaska Fisheries Science Center Metadata Library / jessica.crance@noaa.gov
Benthic foraging marine mammals / line-transect sightings provide data for deriving relative or absolute density	NOAA (N. Friday), IWC POWER (J. Crance)	Alaska Fisheries Science Center Metadata Library / jessica.crance@noaa.gov
Benthic foraging marine mammals / PAM - sonobuoys and towed arrays - provide presence-only information and information on noise	NOAA (C. Berchok), IWC POWER (J. Crance)	Alaska Fisheries Science Center Metadata Library / jessica.crance@noaa.gov
Benthic foraging marine mammals / photo ID may provide information on stock ID, residence time, life history parameters, and abundance	NOAA (MML-CAEP), IWC POWER (J. Crance)	Alaska Fisheries Science Center Metadata Library / jessica.crance@noaa.gov
Benthic foraging marine mammals / line-transect sightings provide data for deriving relative or absolute density or abundance	NOAA/BOEM (Ferguson), oil/gas industry (LGL)	Alaska Fisheries Science Center Metadata Library / jessica.crance@noaa.gov
Benthic foraging marine mammals / photo ID may provide information on stock ID, residence time, life history parameters, and abundance	ASAMM (Ferguson)	Alaska Fisheries Science Center Metadata Library / jessica.crance@noaa.gov
Benthic foraging marine mammals / imagery - strip transect surveys - may be used to derive estimates of absolute or relative density or abundance	NOAA (P. Boveng)	Alaska Fisheries Science Center Metadata Library / jessica.crance@noaa.gov
Benthic foraging marine mammals / imagery - body condition assessment	ASAMM (Ferguson)	Alaska Fisheries Science Center Metadata Library / jessica.crance@noaa.gov
Benthic foraging marine mammals / PAM provides presence-only data and information on noise	NOAA (Berchok), UW-APL (Stafford), oil/gas industry	Alaska Fisheries Science Center Metadata Library / jessica.crance@noaa.gov

Category / Data type	Data source	Data links / Contact(s)
Benthic foraging marine mammals / movement rates, distribution, activity states, dive behavior, in situ environmental variables	ADFG (Quakenbush & Citta), NSB DWM, NOAA (P. Boveng), USGS (Fischbach)	Alaska Fisheries Science Center Metadata Library / kate.savage@noaa.gov
Benthic foraging marine mammals / Carcasses may provide a source of energy to pelagic, benthic, and coastal ecosystems	NOAA (Ferguson, K. Savage)	Alaska Fisheries Science Center Metadata Library / kate.savage@noaa.gov
Benthic foraging marine mammals / marine mammals	OCSEAP	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:OCSEAP
Benthic foraging marine mammals / general portal for data	DataOne	https://search.dataone.org/data/query=arctic?
Benthic foraging marine mammals / general portal for data	PacMARS	https://data.eol.ucar.edu/dataset/list?project=364&children=project&category=21
Benthic foraging marine mammals / marine mammals	BSIERP, BEST (NPRB and NSF)	https://data.eol.ucar.edu/dataset/list?project=341&children=project
Benthic foraging marine mammals / marine mammal, cetacean stranding, cetacean entanglement, vessel strike, pinniped stranding, pinniped entanglement	Alaska Region Marine Mammal Stranding, Cetacean and Pinniped Entanglement, and Nonlethal Vessel Strike Reports, 1904–present	Alaska Fisheries Science Center Metadata Library / kate.savage@noaa.gov
Benthic foraging marine mammals /	Alaska Fisheries Science Center, 2020: AFSC/NMML	Alaska Fisheries Science Center Metadata Library / kate.savage@noaa.gov
Benthic foraging marine mammals / marine mammal; stranding; injury; mortality	Alaska Fisheries Science Center, 2020: AFSC/NMML: Known human-caused marine mammal injury and mortalities from 2007–present, https://www.fisheries.noaa.gov/inport/item/26375.	Alaska Fisheries Science Center Metadata Library / kate.savage@noaa.gov
Benthic foraging marine mammals / Aleutian Islands; Arctic Ocean; Atlantic Ocean; Bering Sea; Gulf of Alaska; Pacific Ocean	Alaska Fisheries Science Center, 2020: AFSC/NMML: Platforms of Opportunity Program (POP): 1950–present, https://www.fisheries.noaa.gov/inport/item/17407.	Alaska Fisheries Science Center Metadata Library / kate.savage@noaa.gov

Category / Data type	Data source	Data links / Contact(s)
Benthic foraging marine mammals / Difar; passive acoustics; seismic airguns; sonobuoy; marine mammal	Alaska Fisheries Science Center, 2020: AFSC/MML: Acoustics short-term passive monitoring using sonobuoys in the Gulf of Alaska, Bering, Chukchi, and Western Beaufort Seas, Summer 2007–2018, https://www.fisheries.noaa.gov/inport/item/17346.	http://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:0138863
Benthic foraging marine mammals / humpback whale (*Megaptera novaeangliae*); satellite telemetry	Alaska Fisheries Science Center, 2020: AFSC/NMML Location-only satellite telemetry data for North Pacific Humpback Whales in the Bering Sea, 2007–2011	http://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:0138946 https://www.fisheries.noaa.gov/inport/item/28149
Benthic foraging marine mammals / marine mammal	Whale broad-scale distribution southeastern Bering Sea 2008 (B66)	2008: doi:10.5065/D6MK69W1
Benthic foraging marine mammals / marine mammal	Whale broad-scale distribution southeastern Bering Sea 2010 (B66)	2010: doi:10.5065/D6KK98S3
Benthic foraging marine mammals / marine mammal, sea ice, ice cover, sea state, weather	Marine mammal watch, sea ice cover, sea state, weather, and visibility measurements from CCGS *Sir Wilfred Laurier*	2011: doi:10.18739/A26688J6H
Benthic foraging marine mammals / marine mammal, sea ice, ice cover, sea state, weather	Marine mammal watch, sea ice cover, sea state, weather, and visibility measurements from US CGC *Healy* (HLY1301)	2012: doi:10.18739/A2P843W2H
Benthic foraging marine mammals / marine mammal, sea ice, ice cover, sea state, weather	Marine mammal watch, sea ice cover, sea state, weather, and visibility measurements from US CGC *Healy* (HLY1201)	2013, *Healy*: doi:10.18739/A2JH3D285
Benthic foraging marine mammals / marine mammal, sea ice, ice cover, sea state, weather	Marine mammal watch, sea ice cover, sea state, weather, and visibility measurements from CCGS *Sir Wilfred Laurier* ; 2013	2013 *Laurier*: doi:10.18739/A22F7JR1W.

Category / Data type	**Data source**	**Data links / Contact(s)**
Benthic foraging marine mammals / marine mammal, sea ice, ice cover, sea state, weather	Marine mammal watch, sea ice cover, sea state, weather, and visibility measurements from CCGS *Sir Wilfred Laurier* ; 2014	2014:doi:10.18739/A2XP6V369
Benthic foraging marine mammals / marine mammal, sea ice, ice cover, sea state, weather	Marine mammal watch, sea ice cover, sea state, weather, and visibility measurements from CCGS *Sir Wilfred Laurier* ; 2015	2015: doi:10.18739/A2T14TP68
Benthic foraging marine mammals / marine mammal	Marine mammal watch from CCGS *Sir Wilfrid Laurier*; 2016	2016: doi:10.18739/A27P8TD2J
Benthic foraging marine mammals / marine mammal	Marine mammal watch from US CGC *Healy* (Hly17-02) ; 2017	2017: doi:10.18739/A25Q4RM2M
Benthic foraging marine mammals / acoustics, moorings	JASCO passive acoustics marine mammals	https://search.dataone.org/view/doi%3A10.5065%2FD64Q7S11
Benthic foraging marine mammals / lipid dataset, marine mammals	AFSC ABL	https://www.fisheries.noaa.gov/inport/item/17285
Benthic foraging marine mammals / marine mammal?	ArcticIERP	https://arctic-ierp.portal.axds.co/
Pelagic seabirds / marine seabird habitat, migratory seabird watch	OCSEAP	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:OCSEAP
Pelagic seabirds / general portal for data	DataOne	https://search.dataone.org/data/query=arctic?
Pelagic seabirds / general portal for data	PacMARS	https://data.eol.ucar.edu/dataset/list?project=364&children=project&category=21
Pelagic seabirds / seabirds	BSIERP, BEST (NPRB and NSF)	https://data.eol.ucar.edu/dataset/list?project=341&children=project
Pelagic seabirds / seabirds	AMBON	https://mbon.ioos.us/#search?type_group=all&tag|tag=ambon-projects&page=1
Pelagic seabirds / seabirds, marine birds	USFWS	U.S.A. Fish and Wildlife Service, kathy_kuletz@fws.gov / https://www.usgs.gov/centers/alaska-science-center/science/north-pacific-pelagic-seabird-database?qt-science_center_objects=0#qt-science_center_objects
Pelagic seabirds / seabirds, colonies, breeding birds	USFWS North Pacific Seabird Colony Register	http://axiom.seabirds.net/maps/js/seabirds.php?app=north_pacific#z=3&ll=55.00000,-170.00000
Pelagic seabirds / seabirds, breeding, populations, trends, colonies	USFWS Alaska Seabird Colony Monitoring	https://www.fws.gov/office/alaska-migratory-birds/seabirds-alaska
Pelagic seabirds / waterfowl, geese, ducks, seaducks, loons	USFWS Waterfowl Surveys	https://www.fws.gov/project/waterfowl-breeding-population-and-habitat-survey

Category / Data type	Data source	Data links / Contact(s)
Pelagic seabirds / seabirds	ArcticIERP	https://arctic-ierp.portal.axds.co/
Pelagic seabirds / seabirds, breeding, populations, trends, colonies	USFWS Alaska Seabird Colony Monitoring	https://www.fws.gov/office/alaska-migratory-birds/seabirds-alaska
Pelagic seabirds / seabirds, St. Lawrence Island, Bering Sea	USFWS Seabird Monitoring Data from St. Lawrence Island	https://www.fws.gov/project/seabird-science-alaska-sized-scale
Pelagic seabirds / shorebirds, breeding birds	USFWS Monitoring Shorebird Populations	https://www.fws.gov/project/estimating-alaska-shorebird-populations
General Data Arctic	General Data Arctic	https://arcticdc.org/products/partner-data-products
General Data Arctic	General Data Arctic	https://arcticdata.io/catalog/data

Appendix 4

Workshops and Meeting Reports from Past Annual and Inter-sessional Meetings Related to WG 44

PICES-2019
October 16–27, 2019, Victoria, Canada

Excerpted from:

Summary of Scientific Sessions and Workshops at PICES-2019

BIO Workshop (W17)
Scoping an IEA of the Northern Bering–Chukchi Seas LME

Convenors: *Libby Logerwell (USA, FIS), Kirstin Holsman (USA, NOAA IEA Program), Raychelle Daniel (USA, Pew Trusts), Yutaka Watanuki (Japan)*

Background

Preparing an Integrated Ecosystem Assessment for the Northern Bering–Chukchi Seas Large Marine Ecosystem (LME) is necessary to provide scientific advice on issues such as the prospect for future fisheries in the Arctic, vulnerability to increased shipping activities, impacts of oil and gas development, and consequences of climate change. The potential impacts of climate change on Arctic marine mammals and seabirds, many of which provide subsistence resources for local and indigenous communities is also a growing concern. A workshop focusing on scoping an IEA of the Northern Bering–Chukchi Seas LME was held to:
1. Review recent research, activities and priorities related to an IEA of Arctic Ecosystems;
2. Review the scientific interest, data availability and overall feasibility of conducting such an IEA for the Northern Bering–Chukchi Sea region;
3. Assess the opportunities to partner with other organizations to address the issues identified above;
4. If the above activities demonstrate the feasibility of conducting an IEA of the NBS–Chukchi Seas LME, then Terms of Reference for a Study Group or possibly a Working Group would be developed for PICES consideration.

Contributions were invited on ecosystem surveys and research activities in the Northern Bering-Chukchi Seas LME as well as on IEA in other ecosystems, lessons learned and best practices.

Summary of presentations

The purpose of the workshop was to assemble experts in the Northern Bering–Chukchi Sea LME and also in Integrated Ecosystem Assessment in other systems (such as ICES areas (*e.g.*, Barents Sea, Norwegian Sea), the SE Bering Sea and the California Current). The experts reviewed the interest, data availability and overall feasibility of conducting an IEA in the proposed ecosystems. We discussed ecosystem surveys and research activities in the Northern Bering–Chukchi Seas LME. We also discussed IEA in other ecosystems, lessons learned and best practices. We decided that conducting an IEA in the proposed area was timely, relevant and feasible. We proposed Terms of Reference and deliverables for a new PICES Working Group (possibly joint with ICES and the Joint EA-EG led by PAME), parented by FUTURE, to conduct the IEA.

List of papers

Poster presentations

Pacific Arctic seabird communities in a time of change
Kathy Kuletz, Daniel Cushing, Erik Osnas, Franz Mueter, Elizabeth Labunski and Adrian Gall

Applying NPRB Arctic IERP (2016-2019) research to inform an IEA in the Northern Bering Sea and Chukchi Sea
Matthew Baker, Danielle Dickson, Edward Farley, Seth Danielson, Carol Ladd, Kate Stafford and Henry Huntington

Sensitivity of Alaska marine food webs to mortality-based perturbations
George A. Whitehouse and Kerim Aydin

Synoptic meteorological controls on declining seasonal sea ice in the Bering and Chukchi Seas
Matthew G. Asplin, Todd Mudge, David Fissel, Dawn Sadowy and Keath Borg

FIS/BIO/POC Topic Session (S8)
Creating more effective Integrated Ecosystem Assessments (IEAs) in PICES countries

Co-sponsor: *ICES*

Convenors: *Alan Haynie (USA), Libby Logerwell (USA), Shigeto Nishino (Japan)*

Invited Speaker:
Phillip Levin (University of Washington, USA)

Background

Integrated Ecosystem Assessments (IEAs) are an adaptable approach to capture, understand, and communicate the diversity of interactions, ecosystem objectives, and resource trade-offs that occur within an ecosystem. While a core element of IEAs is the characterization of the natural ecosystem, humans are increasingly recognized as being central actors in most ecosystems, rather than an outside agent impacting the ecosystem. In this session, we are interested in elements of IEAs that capture how changes in the natural environment are being measured and the manner in which human activities are being incorporated into IEAs. IEAs have been implemented in a diversity of ecosystems in many PICES and ICES countries. In the United States, for example, IEAs are an important tool through which NOAA describes ecosystem trends and communicates the trade-offs of using marine resources for fisheries versus other uses. ICES, PICES and PAME have also recently worked to develop an IEA of the Central Arctic Ocean (WG 39). In addition, PICES scientists working in PAME have drafted practical guidelines for implementing the Ecosystem Approach across LMEs in the Arctic. Members and chairs of several ICES and PICES working groups are also active in IEA implementation. The goals of this session were to 1) describe developments in IEAs across PICES countries and beyond, 2) identify opportunities to better integrate social and natural science in IEAs and communicate this with PICES scientists, and 3) discuss future directions for developing and comparing IEAs across PICES countries and LMEs, with the aim of building a foundation for further discussions at the MSEAS-2020 meeting in Yokohama. The goal of the session was to provide a roadmap for how social and natural scientists can more effectively work together in IEAs and in interdisciplinary projects in general. We concluded the session with a discussion of next steps for IEA research in PICES countries.

Summary of presentations

On behalf of the co-conveners, Alan Haynie offered comments about the goals and scope of the topic session; and introduced the invited speaker, Dr. Phillip Levin. There were ten oral presentations, two of which were given by early career scientists; there was one poster. Presenters were from the US, China and Japan. Approximately 25 people attended and there was active participation and lively discussion involving all.

Dr. Phillip Levin presented a summary of Integrated Ecosystem Assessment (IEA) from idea to implementation. He presented the challenge of answering the question “Is the ocean healthy?”. He stressed that ocean ecosystems provide a large number of goods and services; that these services interact, often in ways we don’t understand; and that people place different values on different services. A quote from E.O. Wilson provided a good perspective on IEAs: “The world henceforth will be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely." Dr. Levin suggested that IEAs can answer four key questions: What is our vision of a healthy ocean? Is the ocean healthy? What can we do? Where should we start? The strengths of IEAs are that they: emphasize interactions among ecosystem components; consider humans as an integral part of the ecosystem; integrate ecological, social, economic, and institutional perspectives; and recognize their strong interdependences. A review of scientific literature on IEAs shows that IEAs have been conducted mostly in the US, Canada, Central American, Europe and Asia. He then presented the results of semi-structured interviews to answer the question "How are IEAs doing?". Some interviewees felt that IEAs were often too fisheries focused. Others pointed out the successes of IEAs, for example "The most recent reports are vital in having a starting point for management …it is probably the closest thing to facts we have out there. (State Fisheries Manager)". Operational objectives were regarded as an ongoing challenge: "IEAs are a powerful tool but without a clear statement of goals and objectives, and a clear vision, it is just cool science (Stakeholder)." In fact, a global review of Ecosystem Based Management plans showed that 65% lack operational objectives with specific targets. Dr. Levin presented an interesting example of a project merging science and indigenous knowledge, concerning herring and the Haida Gwaii people. Chief Gidansta told scientists that "once herring lost the elders, they lost their way to their spawning grounds". Scientific models comparing diffuse migration and learned migration arrived at the same conclusion. He concluded his excellent presentation by showing that where people, the planet and profit overlap is where sustainability resides.

Dr. Elliot Hazen presented a talk on behalf of Dr. Chris Harvey and Dr. Tobey Garfield on the California Current Integrated Ecosystem Assessment. He began his presentation with a thorough overview of the evolution of the NOAA IEA Program. He then described the recent Pacific Fisheries Management Council (PFMC) Climate and Communities Initiative which began in 2017. This initiative addresses an emerging ecosystem goal: fishing communities that are resilient to species distribution shifts, climate variability and climate change. Dr. Hazen presented a partial list of what they have learned regarding the IEA process. For example, IEA is more a *process* than a *product*; we don't have to study *everything* in the ecosystem to do IEA (scale an IEA to a specific need); relationship building in good times is helpful during bad times; implementation of IEA science into management is slow. He also presented ideas about building a sustainable IEA program: support of leadership is essential for long-term sustainability; funds will always be limiting, so we must create opportunities; we need greater permanent investment in social sciences; we must develop diverse tools and products that can reach diverse audiences.

Dr. Takafumi Hirata presented the results of a project to develop a vulnerability index for Arctic marine ecosystems, considering Planetary Boundary processes as an essential environmental forcing. Exposure to environmental forcing was derived from Principal Component Analysis among Planetary Boundary Processes (PBP). Sensitivity/susceptibility of marine ecosystem to forcing was based on the strength of correlation between ecosystem variable(s) and environmental forcing. Resilience of marine ecosystems to forcing was based on Principal Component Analysis among ecosystem indicators (biodiversity and primary production). Finally, the potential vulnerability of the system was calculated as an index aggregating all of the effects above. Dr. Hirata's results showed that from a global perspective, the Arctic Ocean is likely one of the oceans most influenced by ocean-relevant Planetary Boundary processes. From a regional perspective, the ice edge and the Canadian Archipelago ecosystems are potentially most vulnerable.

Dr. Kirstin Holsman presented on behalf of Dr. Kerim Aydin and Diana Evans on the Bering Sea Fishery Ecosystem Plan (FEP). The Bering Sea FEP was developed by the North Pacific Fishery

Management Council to: serve as a communication tool for ecosystem science and Council policy; create a transparent public process for the Council to identify ecosystem values and management responses; provide a framework for strategic planning that would guide and prioritize research, modeling, and survey needs; identify connected Bering Sea ecosystem components, and their importance for specific management questions; assess Council management with respect to ecosystem-based fishery management best practices, and identify areas of success and gaps indicating areas for improvement on a regular basis; provide a framework for considering policy options and associated opportunities, risks, and tradeoffs affecting FMP species and the broader Bering Sea ecosystem; and build resiliency of Council management strategies, and options for responding to changing circumstances. She stressed that the FEP facilitates co-production of knowledge. It aims to define Local Knowledge and Traditional Knowledge clearly in order to facilitate co-production of knowledge while protecting intellectual property as per the UN Declaration on the Rights of Indigenous Peoples (Articles 11.2, 31). The FEP has six ecosystem goals: maintain, rebuild, and restore fish stocks at levels sufficient to protect, maintain, and restore food web structure and function; protect, restore, and maintain the ecological processes, trophic levels, diversity, and overall productive capacity of the system; conserve habitats for fish and other wildlife; provide for subsistence, commercial, recreational, and non-consumptive uses of the marine environment; avoid irreversible or long-term adverse effects on fishery resources and the marine environment; provide a legacy of healthy ecosystems for future generations. Each of the ecosystem goals has a number of ecosystem objectives which serve as a bridge between ecosystem goals and ecosystem indicators for monitoring. She described two Action Module Work Plans: Evaluate effects of climate change and develop management considerations; and Develop protocols for Local Knowledge, Traditional Knowledge, and Subsistence. For outreach, NPFMC staff have developed story maps of FEP components, located on the BS FEP website at https://www.npfmc.org/bsfep/.

Dr. Changun Xu gave a talk on implementation of Ecosystem-Based Management for net cage farming in Sandu Bay, Fujian, China. This project took place in Sandu Bay, Ningde city, Fujian Province, China. Sandun Bay provides numerous ecosystem services, including: Large Yellow Croaker Habitat Reserve (MPA); algae farming; sailing/navigation channel; tourism and sightseeing; sewage discharge; and recently, net cage farming. Net cage farming has caused conflict between stakeholders because of disorderly expansion of cage farming and the lack of management. However, as a result of stakeholder meetings, policy makers, resource managers and scientists reached a consensus to incorporate ecosystem-based language into management plans. Dr. Xu and colleagues developed a Human Impact Matrix (HIM) where each cell represents the effect of a specific human activity on a specific ecosystem service. They then developed a qualitative scoring system to evaluate how strongly one human activity impacts ecosystem services.

Dr. Mariska Weijerman gave a talk on “Evaluating Management Strategies for Ecosystem Services in a Hawaiian Islands Coral Reef IEA”. Coral reefs are vulnerable to local population growth, wastewater management, fishing and coral bleaching. Ecosystem services provided by coral reefs include a resilient, productive reef, recreational uses (such as diving and snorkeling) and fishing (recreational and subsistence). She used the Ecopath with Ecosim (EwE) modeling framework to evaluate the performance of six management scenarios over the next 15 years. Based on the modeling results she created a decision support matrix for assessing the efficacy of each management scenario. Her results show that ecosystem models in IEAs make it possible to integrate natural and social science, take climate change impacts to the ecosystem into consideration, and evaluate socio-ecological tradeoffs of alternative management scenarios.

Dr. Robert Wildermuth presented his work on a Bayesian decision network model for ecosystem-based management of the Georges Bank social-ecological system. He explained how social-ecological models can assess multiple management objectives, account for multiple interactions and components, and integrate various sources of knowledge and information. He noted that they rely on data availability and an understanding of relationships. He developed a conceptual model of the Georges Bank social-ecological system which provided a framework. He then employed a Bayesian network to build on the framework. Bayesian networks are useful for this application because they reflect uncertainty in interaction strengths and functional form. They also allow prediction of the effects of management actions. Dr. Wildermuth presented the results of the Georges Bank *Wellamo* model (named after a Finnish legend). Take-home messages from initial model results are: there was additional correlation between Recreational Fishing and Profits; overall, ~70% of observed data predicted accurately; these may be driven by autocorrelation in the time series; and there were unexpected outcomes for Seafloor and Demersal Habitat in tested scenarios.

Dr. Marisol García-Reyes described a interesting new tool for cloud computing of key NASA oceanographic data: the PICES Regional Ecosystem Tool. This can be accessed from a web browser https://github.com/python4oceanography/PICES-tools (Click on the button to load the 'binder' with the PICES RET). Dr. García-Reyes gave a real-time demo of the tool, showing how the user can download satellite data (SST) for a PICES region over a specified period of time. The tool gives the user a time series graph of anomalies and a text file containing the data. The tool can be used to compare among regions, or compare among data (such as current, temperature and chlorophyll). All in attendance thought it was a really cool tool!

Dr. Gordon Kruse presented on behalf of lead author Dr. Judith Rosellon-Druker. Their presentation was on developing a placed-based participatory IEA framework for coastal communities in the Gulf of Alaska. Dr. Kruse reported on their place-based IEA case study in Sitka, Alaska, which is located in the eastern Gulf of Alaska. Conceptual models are an essential part of the IEA process, and so conceptual models were developed for the main species in the ecosystem. The conceptual models were developed with stakeholders in Sitka in focus group workshops. One workshop explored ecological connections, discussing environmental variables, prey, predators and competitors and knowledge gaps. A second workshop covered human dimensions, in particular residents' capacity to derive well-being from fisheries. The research team then developed Qualitative Network Models (QNM) to operationalize the conceptual models. The QNMs can be used to simulate the effect of press perturbations and show which linkages are most important for the species and life stage of concern, such as small adult herring. In summary, Dr. Kruse and colleagues found that Sitka stakeholders have a deep understanding of their local ecosystem, and their participation in the IEA process resulted in an informed and empowered community in relation to their local ecosystem and resources. Their long-term goal is to incorporate socio-ecological distinctive regions of the Gulf of Alaska into one unifying IEA framework.

Dr. Kelly Andrews spoke about "Human activity indicators - management levers that translate between ecological and human dimension components". He first described the conceptual model for the California Current IEA and asked how the various human activities affected all the components of the ecosystem. He described the different human activities and showed time trends, from the State of the California Ecosystem report. Despite the conceptual linkages, initial analyses showed no relationships or thresholds between human activities and ecosystem indicators. This is probably the result of the large, coast-wide scale at which the analyses were conducted. Smaller scale, spatially-matched analyses may be more informative. Dr. Andrews closed with an interesting example of potential positive effects of human activity on the ecosystem. For example, fishing club members do remove fish, but they also invite speakers to their club meetings who may inform them about ecological ideas such as the impact of fishing on long-lived rockfish. The result can be that those individuals promote the use of conservation measures to reduce mortality of fish, such as fish descending devices. Dr. Andrews' take home points were: indicators of human activities could provide "early warnings" of activities to monitor; most useful if human activity data are at comparable spatial and temporal scales to ecological and human dimension data; human activity and human dimension indicators should continue to be developed for missing links among nodes of the conceptual model; and "positive" indicators of human activities may provide information on the importance of these activities to conservation and management.

Session participants returned after coffee for open discussion. Dr. Libby Logerwell told the group about the new Working Group proposed to conduct an IEA of the Northern Bering–Chukchi Sea and welcomed input, feedback and participation. The group discussed the challenge of incorporating local, traditional and indigenous knowledge in a large area such as Alaska where communities are numerous and remotely located. The group then discussed whether there were web-based abilities for stakeholders to explore conceptual models, which would help develop objectives. It was mentioned that NOAA NEFSC is developing such tools for their Ecosystem Assessments.

A participant asked the question "Is the management system ready to deal with climate change?" The work of AFSC's ACLIM project was put forth as an example. One step is to define the management questions.

Another topic of discussion was the size and complexity of IEA reports. They can be overwhelming for stakeholders. One solution could be a shiny app, such as one that is being developed to explore data in AFSC Ecosystem Considerations reports. The Center in Hawaii is considering doing the same.

List of papers

Oral presentations

Connecting science and communities through Integrated Ecosystem Assessments (Invited)
Phillip S. Levin

A brief history of the California Current Integrated Ecosystem Assessment: How we got here, what we've learned, and where we're headed
Chris J. Harvey (presented by Elliott Hazen) and Toby Garfield

Potential vulnerability of the Arctic marine ecosystem due to environmental changes
Takafumi Hirata, Yoshio Masuda, Jorge García Molinos, Irene Alabia, Toru Hirawake, Sei-Ichi Saitoh

The Bering Sea Fishery Ecosystem Plan as a guidance tool for ecosystem-based fishery management in Alaska
Kerim Aydin (presented by Kirstin Holsman) and Diana Evans

Implementation of "ecosystem-based management" for net cage farming in Sandu bay Fujian China. an approach towards ecologically sustainable form of development
Changan Xu, Peng Wu, Shixin Huang and Xu Tang

Evaluating management strategies for ecosystem services in a Hawaiian Islands coral reef IEA
Mariska Weijerman, Jeffrey Polovina, Jamison Gove, Ivor Williams, William Walsh and Dwayne Minton

A Bayesian decision network model for ecosystem-based management of the Georges Bank social-ecological system
Robert P. Wildermuth, Gavin Fay, Sarah Gaichas and Geret DePiper

Cloud computing of key NASA oceanographic data: Implications for automating aspects of ecosystem status reports
Marisol García-Reyes, Chelle Gentemann and William Sydeman

Developing a placed-based participatory IEA framework for coastal communities in the Gulf of Alaska
Judith Rosellon-Druker, Kerim Y. Aydin, Curry J. Cunningham, Stephen Kasperski, Gordon H. Kruse, Jamal H. Moss, Melissa Rhodes-Reese, Ellen Spooner, Marysia Szymkowiak and Ellen M. Yasumiishi

Human activities - developing indicators that can translate costs and benefits across the human dimension and ecological domains of the socio-ecological system
Kelly S. Andrews, Karma C. Norman and Chris J. Harvey

Poster presentations

Sea ice reduction in the Arctic Ocean: its impact on biogeochemical cycles
Naomi Harada, Jonaotaro Onodera, Eiji Watanabe and Katsunori Kimoto

PICES-2020
Virtual Annual Meeting

Report of Working Group 44 on *Joint PICES/ICES Working Group on Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea*

The Joint PICES/ICES Working Group on the *Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea* (WG 44) met for the first time on September 1 and 2, 2020, virtually. All members were present except two from China and one from Korea who were out at sea; and one from Japan who had a conflict with another meeting (*WG 44 Endnote 1*). Nonetheless there was representation from all PICES member countries and ICES. The meeting was co-chaired by Drs. Elizabeth (Libby) Logerwell (USA) and Yury Zuenko (Russia). The meeting agenda was reviewed by members and adopted without revision (*WG 44 Endnote 2*).

AGENDA ITEMS 2, 4
Background, review of Terms of Reference

The goals of this meeting of WG 44 were:
- Review WG44 Terms of Reference
- Introduce the members to each other and discuss potential contributions of each to the IEA
- Discuss the approach and methodology for the IEA. Specifically:
  - The relationship of this WG to other programs/projects
  - Ideas from the NOAA IEA Program (Holsman) and ICES WGIBAR and WGICA
  - The scope of the IEA (What? Who? How?)
- Discuss ways to develop Indigenous knowledge sharing
- Review preliminary inventories of metadata and institutions/programs
- Draft the 2021 Work Plan

AGENDA ITEM 5
Work Plan 2020–2021

WG members developed and finalized the 2020–2021 Work Plan and identified WG members to lead work under each Term of Reference. Deliverables, deadlines, meetings and reports are detailed in *WG 44 Endnote 3*.

Scoping the IEA

The NOAA IEA approach provided a starting point for our discussions on scoping the IEA (Fig. 1). We discussed the first phase of the cycle: defining the system and goals. We developed a draft scoping document which will be finalized over the course of the next year (see the 2021 Work Plan, *WG 44 Endnote 3*).

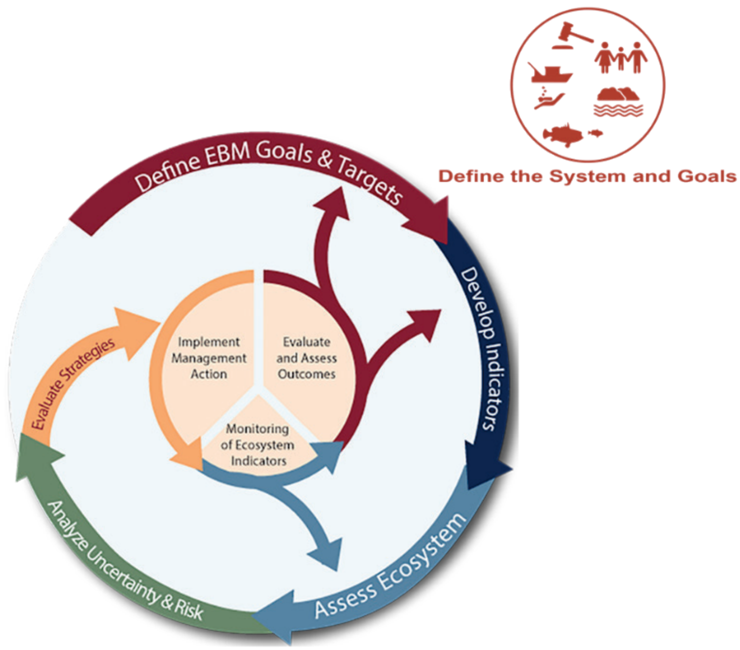


Figure 1. The NOAA IEA approach (www.integratedecosystemassessment.noaa.gov).

Indigenous knowledge sharing

The co-production of knowledge model developed by the Pew Charitable Trusts, Kawerak Inc., and the Inuit Circumpolar Council Alaska (Fig. 2), provided a framework for our initial discussions of Indigenous Knowledge sharing which will be expanded and finalized as part of our 2021 Work Plan.

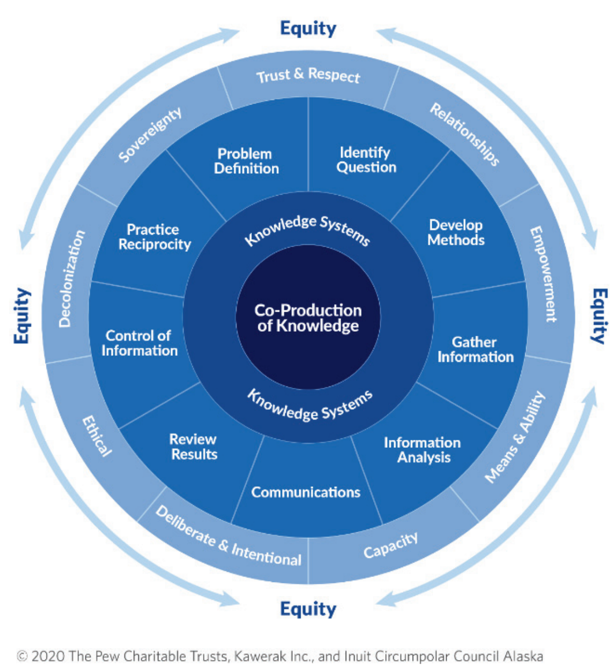


Figure 2. The Co-Production of Knowledge wheel (© The Pew Charitable Trusts, Kawerak Inc. and Inuit Circumpolar Council Alaska).

Inventory of metadata

Before the WG meeting, members were asked to submit metadata on scientific surveys in the NBS-CS using a Google form. Surveys have been conducted by all PICES member countries (Fig. 3). We anticipate that the final inventory (developed during the 2021 Work Plan) will contain many more surveys.

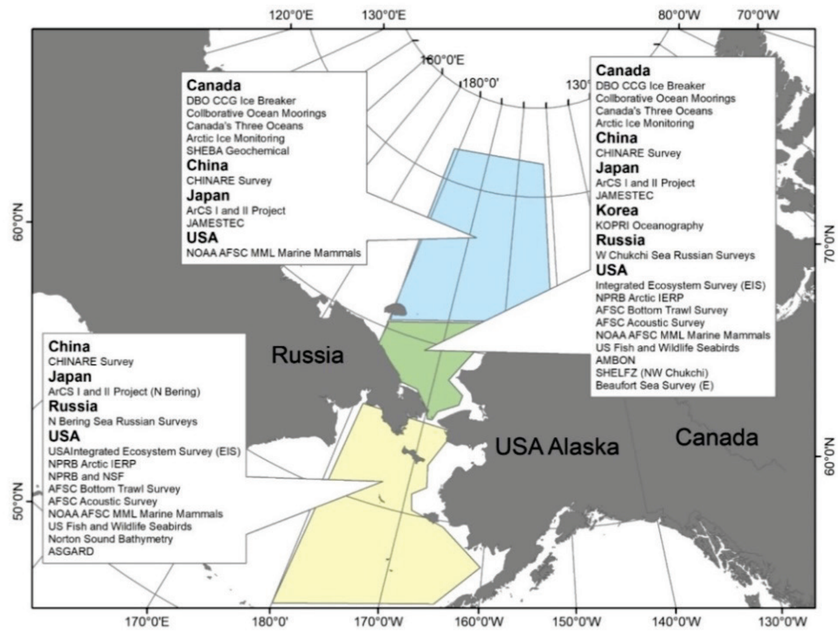


Figure 3. Preliminary inventory of metadata on scientific surveys in the Northern Bering Sea (yellow), Southern Chukchi Sea (green) and Northern Chukchi Sea and Central Arctic Ocean (blue).

AGENDA ITEM 6
Requests

- Addition of one Japanese member, Kohei Matsuno from Hokkaido University who has expertise in marine environments, and the biology and distribution of zooplankton in the Bering Sea and Chukchi Sea.
- Addition of two Canadian members, Nadja Steiner from DFO Science and Martin Nantel, DFO Pacific Region's Indigenous Science Liaison.
- A 1-day business meeting at PICES-2021.
- Proposal for a ½-day workshop on "*The northern Bering Sea–Chukchi Sea Integrated Ecosystem Assessment: Recent findings, progress, and the way forward*" convened by WG Co-Chairs, Logerwell and Zuenko (*WG 44 Endnote 4*). The goal of the workshop would be to share information among WG 44 members and with other researchers studying the NBS-CS ecosystem. Topics to be discussed are: 1) describe the work on the IEA to date, and 2) recent findings about the NBS-CS ecosystem, especially those that shed new light on the ecosystem's status, changes, and processes. It was recommended by Science Board to combine this workshop with a workshop proposed by WG 39 Joint PICES/ICES/PAME Working Group on an *Integrated Ecosystem Assessment for the Central Arctic Ocean*. WG 44 Co-Chairs have preliminarily agreed to this.

- To extend the term of the WG one year (until 2023). The reason is that the Co-Chairs and members were approved late in year 2020, such that little work could be accomplished during Year 1. The chair's (Logerwell) nomination was approved April 23, 2020. The final, Russian, membership nominations were approved on August 24, 2020, one week before the WG business meeting. The ToRs require 3 full years to complete. This extension has also been requested and granted by ICES.

WG 44 Endnote 1

WG 44 participation list

Members

Elizabeth A. Logerwell (USA, PICES Co-Chair)
Yury I. Zuenko (Russia, PICES Co-Chair)
Matthew Baker (USA)
Lee Cooper (USA)
Raychelle Daniel (USA)
Lisa B. Eisner (USA)
Elena Eriksen (Norway/ICES)
Megan Ferguson (USA)
Takafumi Hirata (Japan)
Kirstin Holsman (USA)
Henry Huntington (USA)
Katrin Iken (USA)
Mellisa Johnson (USA)
Kirill Kivva (Russia)
Kathy Kuletz (USA)
Andrea Niemi (Canada)
Shigeto Nishino (Japan)
Qi Shu (China)
Aleksei Somov (Russia)
Diana Lynn Stram (USA)
Sarah Wise (USA)

Members unable to attend

China: Zhongyong Gao, Changan Xu
Japan: Yutaka Watanuki
Korea: Hyoung Sul La

Observers

Kohei Matsuno (Japan)

WG 44 Endnote 2

WG 44 meeting agenda

September 1, 2020, 18:00-21:00 Pacific Daylight Time (GMT-7)

- Welcome and logistics
- Background of WG 44
- Member Introductions: research interests and possible contributions to the WG (5 minutes each)
- Review WG 44 Terms of Reference (ToR)

September 2, 2020, 18:00-21:00 Pacific Daylight Time (GMT-7)

- Develop Work Plan for Year 2020-21
  - Inventories of metadata and institutions/programs
  - Determine approach and methodology
  - Develop Indigenous knowledge sharing
- Present the preliminary inventories
- Develop a preliminary outline of approach and methodology
- Requests

WG 44 Endnote 3

Integrated Ecosystem Assessment of the Northern Bering Sea–Chukchi Sea (NBS-CS) (WG 44) 2020–2021 Work Plan

1. Determine approach and methodology for conducting an IEA in the Northern Bering–Chukchi Sea LME.
   a. Deliverable: Draft "Methods" for IEA publication
      i. Continue editing the scoping document from Day 1 of September business meeting
      ii. Identify goals, objectives, partners
      iii. Develop co-production of knowledge
   b. Deadline: Fall 2021 PICES Annual Meeting
   c. WG Member leads: Holsman, Daniel, Stram
   d. Meetings:
      i. Monthly virtual status report meetings
      ii. Intersessional virtual/in-person workshop (Date and location TBD) to invite partners to give feedback on draft scoping document
   e. Identify a centralized location for draft documents and resources.
2. Compile an inventory of scientific metadata and of institutions and programs
   a. Deliverable: Metadata, knowledge, institutions and programs relevant to the Northern Bering Sea–Chukchi Sea LME.
      i. PICES or ICES Report summarizing metadata with data gaps identified.
      ii. Google form-based inventory
   b. Deadline: Fall 2021 PICES Annual Meeting
   c. WG member leads: Logerwell, Zuenko
   d. Meetings: Monthly virtual status report meetings
3. Development of Indigenous knowledge sharing with knowledge holders, to facilitate co-production of knowledge while protecting intellectual property as per the UN Declaration on the Rights of Indigenous Peoples (Articles 11.2, 31).
   a. Deliverable: Draft "Methods" for IEA publication
   b. Deadlines: Fall 2021 PICES Annual Meeting
   c. WG Member lead: Wise
   d. Meetings:
      i. Local virtual conversations in Indigenous communities. Possibly in collaboration with PAME EA-EG October and January virtual conversations in Alaska.
      ii. Intersessional virtual/in-person workshop. Possibly in collaboration with PAME EA-EG Value Workshop (Date and location TBD)
4. Reports
   a. Oral reports to PICES parent committees: FIS and HD. September 2020
   b. PICES Annual Progress Report. Due: October 2020

WG 44 Endnote 4

Proposal for a Workshop on
“*The Northern Bering Sea–Chukchi Sea Integrated Ecosystem Assessment: Recent findings, progress, and the way forward*”
[later merged with WG 39 workshop]

Convenors: Elizabeth (Libby) Logerwell (USA), Yury Zuenko (Russia)

Duration: ½ day

PICES Working Group 44 (WG 44) is undertaking an integrated ecosystem assessment (IEA) of the northern Bering Sea and Chukchi Sea (NBS-CS), a three-year effort that began in 2020. In the first year, WG 44 determined its approaches and methods for conducting the IEA, compiled an inventory of scientific metadata and relevant institutions and programs, and developed a plan for co-production of knowledge with Indigenous partners. At the same time, the region’s ecosystem continues to change rapidly and more data and knowledge are being compiled from many active projects and programs. The purpose of this workshop is to share information among WG 44 members and with other researchers studying the NBS-CS ecosystem. Doing so will ensure that the IEA incorporates the most up-to-date information and facilitates networking among researchers who may be, or be interested in becoming, contributors to the IEA.

We welcome submissions that (1) describe the work on the IEA to date, and (2) present recent findings about the NBS-CS ecosystem, especially those that shed new light on the ecosystem’s status, changes, and processes.

PICES-2021

Virtual Annual Meeting

Report of Working Group 44 on *Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea*

The Joint PICES/ICES Working Group on the *Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea* (WG 44) held its second meeting on September 23, 2021, virtually. Twenty-one members were present, representing all member countries (*WG 44 Endnote 1*). The meeting was co-chaired by Drs. Elizabeth (Libby) Logerwell (USA) and Yury Zuenko (Russia). After self introductions, Dr. Kim Rand (NOAA) volunteered to act as rapporteur. The meeting agenda was reviewed by members and adopted (*WG 44 Endnote 2*).

AGENDA ITEM 3
Metadata status

The 2021 Work Plan specifies that WG 44 will "Compile an inventory of scientific metadata and of institutions and programs. Deliverable: Metadata, knowledge, institutions and programs relevant to the Northern Bering Sea–Chukchi Sea LME". Dr. Rand reported that a metadata workbook with multiple spreadsheets by data type (with DATA LINKS when available) called "Arctic_Metadata" is housed on the WG 44 Google drive. Metadata continues to be added on a continuous basis by many scientists as part of several working groups. The spreadsheets are:

- Environmental Variables
- Pelagic Ice Algal Prod
- Process links
- Zooplankton
- Forage Fish
- Adult fish
- Benthic Infauna
- Benthic Epifauna and Crab
- Marine Mammals
- Seabirds
- Data Not Public

AGENDA ITEM 4
Approach and methodology, status and upcoming milestones

Dr. Kirstin Holsman reported on the status of developing the IEA approach and methodology. In 2021 Drs. Holsman, Raychelle Daniel, and Diana Stram completed the draft outline of "Scoping the NBS and Chukchi Sea Integrated Ecosystem Assessment". The outline listed 6 activities to support scoping the IEA:

1) Identify participants in and beneficiaries of IEA activities and products,
2) Identify goals for the regional IEA,

3) Develop conceptual models,
4) Identify key indicators and metrics for each goal and objective for the IEA
5) Identify management advice and products, and
6) Identify the timeline and future steps of the IEA.

The upcoming milestones are:

- 2022–2023: Complete sections within the document
- 2023: Conceptual models
- 2023–2024: Finalize IEA outline and identify next steps

AGENDA ITEMS 5 AND 6

Including multiple ways of knowing the ecosystem and revised timeline

This activity was formally called "Indigenous knowledge sharing". R. Daniel, H. Huntington, R. Ingram, M. Johnson, S. Wise and E. Zdor reported on this activity.

A document describing the "Lay of the Land" has been drafted, containing the following information:

- Key entities
- Specific participants for goal setting and Indigenous Conceptual Models (ICM)
- Workshop protocols
- Opportunities for inclusion

During winter 2021 the group will identify best practices for collaborative goal setting and prepare a shareable draft report.

The upcoming milestones for Year 2 are:

- Coordinate with partners for workshops (January)
  - Bering Strait Festival (August)
  - RAC meetings
  - Arctic Council (October)
  - PAME (September)
  - LKTKS (April)
- Conduct Workshops
  - Conduct a minimum of 3 workshops, 1 virtual and 2 in person. (Spring and summer)
- Collaboratively set goals
- Develop ICM

The preliminary milestones for Year 3 are:

- Synthesize results (January)
- Communicate science
  - Submit journal article on methods (February)
  - Final Report for communities (December)
  - Presentation (s)

AGENDA ITEM 7
NOAA IEA proposal

Dr. Holsman reported that there is travel funding ($15,000) for the FY22-24 plan.

AGENDA ITEM 8
ICES ASC IEA topic session

Dr. Logerwell reported on a proposed topic session for the ICES ASC in September 2022. The proposed title is "Integrating Ecosystem Assessments"[1], and proposed conveners are Libby Logerwell, Paulina Ramirez-Monsalve and Benjamin Planque. The topics of the session would be:
1) how to set IEA objectives (ESEI),
2) how to perform IEAs (methods and tools),
3) how to translate IEAs into advice and
4) how to complete the full IEA cycle.
Talks would be invited on:
- practical aspects and method development
- stakeholder engagement
- inclusion of Indigenous knowledge
- communication of best practices
- progress on moving towards integrated socio-ecological assessments

AGENDA ITEM 9
WG 39/WG 44 joint workshop

A joint WG 39 (*Integrated Ecosystem Assessment for the Central Arctic Ocean*)/WG 44 workshop on "*Integrated Ecosystem Assessment (IEA) to understand the present and future of the Central Arctic Ocean (CAO) and Northern Bering and Chukchi Seas (NBS-CS)*" (postponed from PICES-2021 due to COVID-19), was resubmitted for PICES-2022 (*WG 44 Endnote 4*) and later approved by Governing Council. It will be 1.0 day (0.5 day + 0.5 day). There will be two sessions with focus on CAO and NBS-CS, and a session for joint deliberation will be prepared. The objectives are to discuss present ecosystem processes in the CAO and the NBS-CS based on achievements from existing and future research programs such as MOSAiC and SAS, numerous NBS-CS programs, and Indigenous Knowledge.

AGENDA ITEM 10
WG 44 workshop

A 1-day workshop for PICES-2022 has been proposed (and approved) on "*Bridging multiple way of knowing within an Integrated Ecosystem Assessment (IEA) to understand the social and ecological changes in the Northern Bering and Chukchi Seas (NBS-CS)*" (*WG 44 Endnote 5*). The main objectives for the workshop are to 1) describe linkages and knowledge pathways among regional organizations across scale (*e.g.*, Indigenous communities, government agencies, NGOs, research networks, academic institutions) in the NBS-CS, and 2) document meanings, relationships, processes, and values associated with the NBS-CS ecosystem using a framework rooted in Indigenous Knowledge and designed to

[1] This topic session was not approved by ICES to be included in the ASC

coordinate diverse perspectives. The results of the workshop will inform the regional NBS-CS IEA process while offering an innovative model for broader knowledge synthesis and co-production.

AGENDA ITEM 11
2022 Work Plan

The WG members reviewed the Terms of Reference and agreed on a Work Plan for 2022 (*WG 44 Endnote 3*).

AGENDA ITEM 12
Proposals for inter-sessional meetings/co-sponsored events

Not discussed.

WG 44 Endnote 1

WG 44 participation list

<u>Members</u>

Elizabeth A. Logerwell (USA, PICES, Co-Chair)
Yury I. Zuenko (Russia, PICES, Co-Chair)
Andrea Niemi (Canada)
Nadja Steiner (Canada)
Zhongyong Gao (China)
Changan Xu (China)
Takafumi Hirata (Japan)
Shigeto Nishino (Japan)
Hyoung Sul La (Korea)
Kirill Kivva (Russia)
Matthew Baker (USA)
Lee Cooper (USA)
Raychelle Aluaq Daniel (USA)
Lisa B. Eisner (USA)
Kirstin Holsman (USA)
Henry P. Huntington (USA)
Katrin Iken (USA)
Mellisa Johnson (USA)
Kathy Kuletz (USA)
Diana Lynn Stram (USA)
Sarah Wise (USA)

<u>Members unable to attend</u>

China: Qi Shu
Japan: Kohei Matsuno, Yutaka Watanuki
Russia: Aleksei Somov
USA: Megan Ferguson

<u>Observers</u>

Becky Ingram (USA)
Kim Rand (USA)

WG 44 Endnote 2

WG 44 meeting agenda

1. Welcome, adoption of agenda, appointment of rapporteur
2. Introduce ourselves and guests
3. Metadata, status and upcoming milestones (Kim Rand)
4. Approach and methodology, status and upcoming milestones (Kirstin Holsman)
5. Indigenous knowledge sharing, status and upcoming milestones (Sarah Wise)
6. Revised timeline due to COVID restrictions
7. NOAA IEA proposal (Kirstin Holsman)
8. ICES ASC IEA topic session
9. WG39/WG44 joint workshop
10. WG 44 workshop
11. 2022 Work Plan
12. Proposals for inter-sessional meetings / co-sponsored events

WG 44 Endnote 3

Integrated Ecosystem Assessment of the Northern Bering Sea–Chukchi Sea (NBS-CS) (WG 44) 2021–2022 Work Plan

1. Determine approach and methodology for conducting an IEA in the Northern Bering–Chukchi Sea LME.
   a. Activities
      i. Identify participants in and beneficiaries of IEA activities and products
      ii. Identify goals for the regional IEA
      iii. Intersessional Conceptual Model workshop (if funding can be secured from NOAA IEA Program). May need to delay to Year 3.
   b. Deliverable: Scoping document
   c. WG member leads: Wise, Daniel, Huntington, Heflin
   d. Target date: Fall 2022 PICES Annual Meeting
2. Including multiple ways of knowing the ecosystem
   a. Activities
      i. Coordinate with partners for workshops (January)
      ii. Conduct workshops (Spring, Summer and Fall)
      iii. Collaboratively set goals
   b. Deliverable: Indigenous Conceptual Model (October 2022)
   c. WG member leads: Wise, Daniel, Huntington, Heflin
   d. Target date: Fall 2022 PICES Annual Meeting
3. Describe the key physical, biological and human elements of the ecosystem
   a. Activities
      i. Develop shared conceptual models including both Indigenous Knowledge and science (see 1. and 2. above)
         1. Review of hypotheses for ecosystem dynamics
         2. Identify potential indicators of the above key elements
   b. Deliverables: Outline of Ecosystem description from both Indigenous world views and science, indicators and hypotheses
   c. WG member leads: Holsman, Daniel, Stram, Wise, Daniel, Huntington, Heflin o
   d. Deadline: Fall 2022 PICES Annual Meeting (finalize Report in Year 3, delay due to COVID restrictions)

WG 44 Endnote 4

Proposal for a WG39/WG44 joint Workshop on
"Integrated Ecosystem Assessment (IEA) to understand the present and future of the Central Arctic Ocean (CAO) and Northern Bering and Chukchi Seas (NBS-CS)"
resubmitted for PICES-2022

PICES sponsors: SB and FIS

Duration: 1.0 day (0.5 day + 0.5 day). There will be two sessions with focus on CAO and NBS-CS, and a session for joint deliberation will be prepared.

Convenors: Sei-Ichi Saitoh (Japan), Hyoung Chul Shin (Korea), Libby Logerwell (USA), Yury Zuenko (Russia)

Suggested invited speaker: Lis L. Jørgensen (Norway/PAME)

The target LMEs of WG 39 and WG 44 are the Central Arctic Ocean (CAO) and the Northern Bering Sea–Chukchi Sea (NBS-CS) respectively. These two regions are geographically and dynamically connected. The CAO is in rapid transition, driven by North Pacific environmental changes. The rapid loss of sea ice cover has opened up the CAO to a range of activities, including potential fishing opportunities. In this context, the agreement to Prevent Unregulated High Seas Fisheries in the CAO has been signed and will be soon 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 warming temperatures are prominent in the northern Bering and Chukchi seas as in most regions of the Arctic. Chronic and sudden changes in climate conditions in this Arctic gateway are clearly altering 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. An integrated ecosystem assessment (IEA) is a useful approach in this circumstance, particularly with substantial science and policy challenges emerging in the Arctic, and thus a coordinated IEA of the CAO and NBS-CS should be a priority. WG 39 has published IEA Report No.1, which provides a description of the ecosystem in the CAO and is beginning to prepare IEA Report No.2, which will deal with impacts from human activities as well as vulnerability characterization. WG 44 was formed in spring 2020 and is just beginning its work. The communication and interaction between WG 39 and WG 44 are warranted to promote overall understanding of the Arctic and neighboring oceans. The main objectives for the workshop are to describe and discuss present ecosystem processes (sources, signals, significance) in the CAO and the NBS-CS based on achievements from existing and future research programs such as MOSAiC and SAS, numerous NBS-CS programs, and Indigenous Knowledge. In addition, it will help to explore and develop future approaches for IEA and jointly organized monitoring in both regions.

WG 44 Endnote 5

Proposal for a Workshop on
"Bridging multiple ways of knowing within an Integrated Ecosystem Assessment to understand the social and ecological changes in the Northern Bering and Chukchi Seas
at PICES-2022

Duration: 1 day

Convenors: Sarah Wise (USA), Mellisa Johnson (USA), Nadia Steiner (Canada), Yutaka Watanuki (Japan)

Invited speakers: Elder Richard Slats (USA), Lauren Divine (USA)

The target LME of WG 44 is the Northern Bering Sea–Chukchi Sea (NBS-CS) which is undergoing rapid transition caused by climate change. Declines in seasonal sea ice, increased storm events, and warm temperatures are driving substantial changes in socio-ecological systems. New commercial opportunities such as shifting fisheries, oil and gas exploration, increased vessel traffic (shipping and access to land-based natural resources), and Arctic tourism will have uncertain cumulative impacts on coastal communities in the Northern Pacific and beyond. The NBS-CS Integrated Ecosystem Assessment will improve understanding of critical interconnected systems processes and inform decision-making and management. Including Indigenous Knowledge in the IEA provides best available expert knowledge to understand the past, present, and future socio-ecological conditions of the region. Indigenous Peoples across North Pacific communities have relied on marine resources for food security, social cohesion, economic livelihood, and cultural continuity for millennia. Including Indigenous Knowledge in the IEA process will enhance understand of changing social-ecological conditions while offering a longitudinal perspective across generations of ecological experience and observations. Employing a co-production approach, this workshop will generate a collaborative understanding of the multiple ways of knowing, experiencing, using, and valuing the North Pacific ecosystem. The main objectives for the workshop are to 1) describe linkages and knowledge pathways among regional organizations across scale (*e.g.*, Indigenous communities, government agencies, NGOs, research networks, academic institutions) in the NBS-CS, and 2) document meanings, relationships, processes, and values associated with the NBS-CS ecosystem using a framework rooted in Indigenous Knowledge and designed to coordinate diverse perspectives. The results of the workshop will inform the regional NBS-CS IEA process while offering an innovative model for broader knowledge synthesis and co-production.

Workshop Report on "*Multiple ways of knowing the Bering Sea–Chukchi Sea ecosystem*"

August 24–25, 2022, Anchorage, Alaska, USA

In attendance

Sarah Wise (Facilitator)
Becky Ingram (Facilitator)
Carolina Behe
Lauren Divine
Ann Fienup-Riordan
Cyrus Harris
Henry Huntington
Vivian Korthuis
Mellisa Maktuayaq Johnson
Richard Slats

Invited but unable to attend

Mabel Baldwin-Schaeffer Raychelle Daniel
Maija Lukin
DelbertPungowiyi
Brenden Raymond-Yakoubian
Julie Raymond-Yakoubian
Nadja Steiner
Eduard Zdor

Table of Contents

Summary

The Multiple Ways of Knowing the Bering Sea-Chukchi Sea Ecosystem workshop took place on August 24-25, 2022. Participants largely guided discussions on both days, which allowed for agenda topics to be discussed when most relevant and comfortable. Topics included Indigenous Knowledge and worldviews, values and perspectives, changing ecosystems, and current fisheries management processes.

A large portion of the workshop included discussing how current management processes differ from, and can conflict with, Indigenous worldviews. This included the consensus that it is inappropriate to expect these knowledge systems to "fit into" Federal management processes. Some individuals pointed out specific examples of differences, including:

- Resource management often appears to lack any focus on relationship building or the guiding values that a community has.
- Management processes emphasize economic value, but that does not account for cultural meaning or spiritual importance.
- Adapting to changing climates and social states requires flexibility, and often management structures get in the way of community flexibility.
- Large complex models are frequently used in science and management, but they do not accurately represent reality. The ecosystem, and intertwined communities, are not linear as these models suggest.
- A loss of meaning occurs when translation is required (such as translating an Indigenous language into English, or an Indigenous perspective into a Western framework).

In response, participants began discussing and expanding on existing examples to create and shape an equitable process that begins with Indigenous communities. Overall, building and maintaining relationships was emphasized as having a central role in effective and equitable management processes.

Direct actions suggested by this group for Federal fisheries management include involvement of Indigenous community members, supporting youth involvement, creating a professional position to increase capacity for this work, and adding more coordination, communication, and consultation directly with communities in their places. In general, it was agreed that the marine environment cannot be tied to one individual thing, such as food security or economic livelihood. As one person stated, *"We are water people,"* suggesting people's ties to the water are central to existing, and as such, *"the ocean must be protected"*—not only for this generation, but for future generations to come.

As a group, it was recognized that these key points will not be solved overnight. However, we can use the tools and platforms available, as well as create new platforms, to create necessary changes.

Workshop Goals

The aim of this workshop was to discuss multiple ways of knowing the Bering Sea and Chukchi Sea ecosystem and ways to include them in Federal management processes (such as the IEA). The intention of the workshop was to offer a space for Alaska Native cosmologies to lead our thinking through changing marine ecosystems, and shape future steps to inform management.

Workshop Objectives & Expected Outcomes

The workshop objectives and outcomes were reviewed at the beginning of the workshop to gather consensus. The third outcome was added by participants during that review.

Objectives

1. Share stories, lessons, and perspectives on changing conditions in the Bering and Chukchi Sea ecosystems.
2. Identify and explore ways to observe and communicate ecosystem change across groups.
3. Create ideas and guidance for including Traditional Knowledge and Indigenous perspectives in Federal management processes.

Anticipated Outcomes

1. Guidance and tangible steps to weave together multiple knowledge systems in Federal assessment processes (such as the IEA).
2. Gauge support and interest in a follow up meeting.
3. Summary of workshop in the form of 1-page summary and full report summary.

Approach

The Multiple Ways of Knowing the Bering Sea-Chukchi Sea Ecosystem workshop took place on August 24-25, 2022. The original agenda included designated sections on each day to focus on discussion questions that had been drafted ahead of time. However, rather than using the agenda as a schedule, it was used as a guide. Participants largely guided discussions on both days, which allowed for agenda topics to be discussed when most relevant and comfortable. Topics of discussion included Indigenous Knowledge, worldviews, values, and perspectives, changing ecosystems, and current fisheries management processes. A large portion of the workshop included discussing how current management processes differ from, and can conflict with, Indigenous worldviews. In response, participants began expanding on existing examples of Indigenous Conceptual Models (e.g., the Circumpolar Inuit Protocols for Equitable and Ethical Engagement) and discussed what would be needed to create a more equitable Federal fisheries management process that begins with Alaska Native communities and their knowledge and worldviews.

Discussion Summaries

The following is a summary of participant discussions that took place over the course of the two day workshop. These summaries are products of reviewing notes and transcriptions from both days. Summaries are not exhaustive and do not encompass everything discussed, but are an effort to present key topics. All quotes come from workshop participants.

In summarizing our findings from this workshop, we have organized ideas and concepts discussed into sections. However, it's important to note that the structure of this report does not necessarily reflect how discussions took place. Participant conversations were all-encompassing rather than focused on individual, discrete topics. We acknowledge that in writing this report, we are separating topics in a manner that may not have happened during the workshop. We do this to help organize and streamline the information for ease of interpretation. We recognize that it is important to remain reflexive in our positions and presentation of this information. Borrowing from one participant, it is critical that we find a way to, *"capture all of those ways of looking at things, rather than the typical fashion of dividing it into little pieces."*

Sharing stories, lessons, and perspectives from Indigenous worldviews

"Tribal voices are a constant."

Workshop participants shared detailed descriptions and examples of what it means to hold an Indigenous worldview. While reading this section it is important to keep in mind the words of a participant who explained that the Bering Sea and surrounding waters mean far more than the words that have been or will be used to describe it. Similarly, another participant stated that having an Indigenous worldview is, *"a prelude to describing the world."* The following paragraphs describe what was shared at the workshop, and also acknowledge that this can only be a limited summary due to the authors' own limitations in understanding. We welcome continued dialogue and input as we grow and share understandings.

> *"When we say health and wellness, this is not just people health and wellness, we always have to explain that, both those things, because we're always trying to translate everything to English."*

Participants emphasized that from an Indigenous worldview nothing is separate, everything is connected, and that all things are possible. This was reiterated many times through messages such as, *"[The ocean is] a part of us and we are a part of the ocean."* The condition of the environment is deeply felt from an Indigenous perspective because of this connection. As another participant described *"[The ocean is a] part of who we are."* Participants explained that this attunement to the ecosystem leads to an understanding that comes from being entwined with and paying attention to the ecosystem across generations and through millennia. The shared and cumulative knowledge that results is *"indirectly transmitted to us as an Indigenous person,"* as one participant explained. None of this can *"be found in a textbook."*

Participants reiterated that *"our air, our land, our sea is our food source,"* which invokes the need and purpose for this connectedness. The ecosystem is not perceived as a resource to be extracted and used, but as part of the self, the community, and the ancestors. One participant explained that a person needs, *"to become a part of the environment in order to safely go in and out to harvest and come back home again."* This also relates to a dominant value that participants expressed in the meeting: the importance of never taking more than you need while hunting, fishing, or gathering. To take more than one needs or can share is both disrespectful and harmful to the ecosystem and ecosystem health. This belief spawned conversation about the motivations underlying various fishing sectors. Participants used large-scale industrial fishing to highlight the differing value systems across fisheries. People fish for different reasons and are informed by different values. It was brought up that this value is in direct opposition to some commercial fishery operations, such as trawling, which is seen as taking excessive amounts of fish for economic gain, while harming the environment.

Participants also explained that stories are a critical part of communication among Alaska Natives. Stories are a method for sharing information and knowledge about place, family, ways of life, meanings, and the environment. Stories are used to communicate through space and time, such as while traveling to new or different places. As one participant explained:

> *I wanted to add how important stories are, because that's how we communicate when we travel to other places. We come back and we tell stories of all kinds of things, and when we go places, we tell stories of how it is back home. So stories are the methodology in which we provide information through.*

Observing and communicating ecosystem change

As mentioned above, Indigenous communities have been observing ecosystem changes for millennia and stories are a main way that these observations are shared or communicated. In participant opinions, this method is starkly different from Western science methods that underpin Federal management processes researching or addressing ecosystem change. This can lead to an impasse in communication. *"There's so much more meaning in an ecosystem or in the environment that are difficult to describe, they're difficult to communicate because of different perspectives and different languages that we all use."*

In an attempt to translate their messages, community members often *"code-switch,[1]"* a term workshop participants used to describe how Alaska Natives change the way they discuss a topic or share stories to translate information into a non-native language. Some participants explained this process results in a homogenization of the information because the content is filtered, simplified, and distilled, until it lacks much of the true meaning. The information can become uprooted and disconnected, effectively meaningless. The difference in language and meaning can be a wedge when trying to form relationships, build trust, and develop collaborations: a disconnect forms between the researcher/groups asking and the communities sharing.

Participants discussed how various research methods and approaches can increase the divide. For example, scientific models are used to predict and report ecosystem changes in management

[1] The practice of alternating between two or more languages or varieties of language in conversation. Encyclopedia Britannica defines code-switching as the "process of shifting from one linguistic code (a language or dialect) to another, depending on the social context or conversational setting".

processes. Predicting changes with models is viewed as incomplete and potentially harmful because they neglect to include many relationships, social bonds, Indigenous Knowledge, Indigenous representation, and diverse values. The models frequently portray 1:1 correlations which do not reflect lived reality.

> *I know there's all kinds of models, so I know it can have fifty things going in and fifty things coming out, but that's a real problem to me because it's still a one to one correlation, like over and over and over again, and it still is neglecting the relationships—whether it's between humans or humans and others—the thing is the relationships.*

These types of models are drastically different from how many Alaska Natives interact with the ecosystem. Knowledge that is derived from generations of lived experience and shared reflection is dynamic and multifaceted, emphasizing observation, interaction, and adaptation. The concept of change is deeply embedded in daily life and ways of knowing the environment. *"The concept of climate change is not new to Indigenous People… We continue to adapt to our environment and we're going to always adapt to our environment."* As one participant explained that while change is constant, there is critical importance to knowing their Indigenous history and identity, and the enduring strength of relationships:

> *If you're strong in your Inupiaq identity then climate change is something you can deal with because we deal with change all the time. If you're not strong in your Inupiaq identity, you have much bigger problems than climate change. And [we have talked] about language, education, community wellbeing, all those kinds of things. Essentially, if [all of that is] taken care of, the relationship with the environment takes care of itself. But if we just focus on the relationship with the environment, we miss everything.*

Participants discussed several examples of ecosystem changes that have resulted in cultural changes in their lifetimes. One participant shared the importance of subsistence foods to health and well-being. For example, elders from their community lost access to traditional foods when a senior living facility became a part of a Federal facility, thus disconnecting them from their culture and community. *"So, our elders moved [to the new facility]. But, unfortunately, their foods didn't. Now, there was something wrong there."* Another discussed how an elder in their community had felt about not being able to teach subsistence to their children. *"We can't go back to where we once held our summer camp, fish camp, to this day we still can't go back there. We have to send our children to fish camps to teach them subsistence."* These changes can be experienced as loss, not just in access to space or nutrition (which are critically important), but of self, identity, and linkages to their community that reverberates across generations.

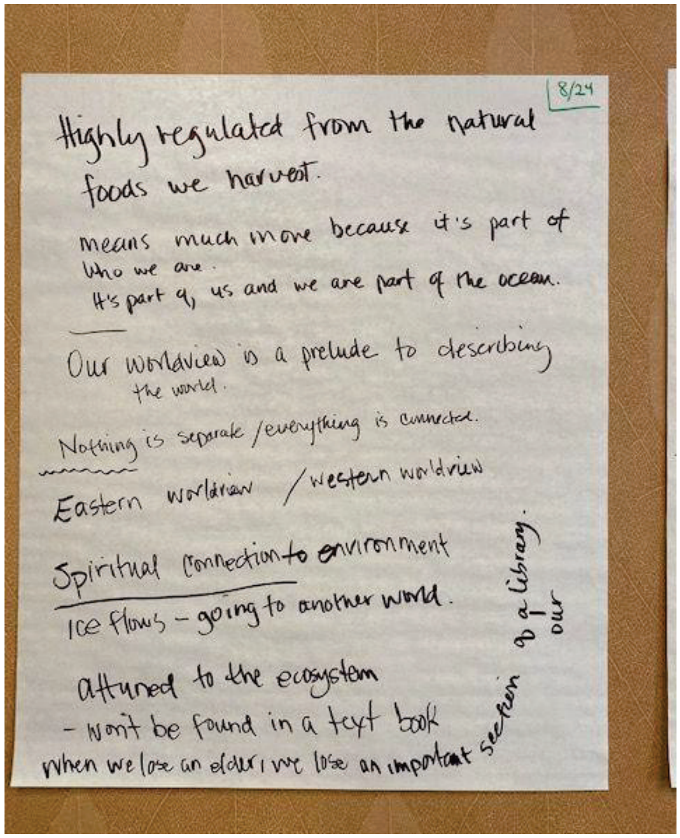


Figure 1: Discussions about traditional foods brought up the juxtaposition that hunting, fishing, and gathering traditional foods is "highly regulated," yet eating those foods is critical because it is part of the fabric of being.

Participant reflections and guidance for including Traditional and Indigenous Knowledge in Federal research and decision-making processes

"A strategy for framing Indigenous Knowledge to be embedded within policies across the Federal government. Right now that's missing."

Participants discussed how Indigenous worldviews differ from, and do not fit into Western perspectives at the center of Federal ecosystem research and decision-making. Of critical importance, one participant explained, *"We didn't come to the coastal areas by mistake. Our Indigenous ancestors chose to settle here. We are survivors."* This sentiment highlighted (among many things) the shared understanding that Indigenous communities survive because of their way of life and worldview (which is embodied in IK). Participants described their understanding of Western science as a way to examine the environment, and control it for a predetermined, "desirable" condition. This differs starkly from *"following the weather and animals"* to connect to the environment, gain sustenance, learn, teach, share, and thrive.

Participants explained it is impossible to isolate one element to decide on the desired condition of the environment without considering the context and linkages across the entire system. Subsistence practice relies on a suite of species which shift in availability and access according to a broad range of factors including, but not limited to: season, weather patterns, gear, skillset, abundance, preference, and regulatory frameworks. 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 relying primarily on Western science and governance systems. As one participant stated, *"They don't understand our way of life. Yet they have these systems that they impose on our way of life."* Another said to the group that it seems like there seems to be an *"Eastern versus Western"* dynamic, which causes trauma and hardship for Indigenous communities and unsustainable natural resources.

Discussions of how the current research and decision-making process takes place highlighted enduring disparities, inequities, and insufficient communication. The group discussed the need for ongoing relationships across scientists, agency staff, and community members to support frequent and meaningful communication, knowledge sharing, and increased understanding.

Research projects can often feel extractive to Indigenous communities if benefits are not clearly outlined well in advance. Linkages to decision-making processes seem arbitrary and biased at times, neglecting the crucial element of human relationships and collaboration which helps to develop and support trust. "*They come into our meetings with their own agenda, and we never get a chance to say anything."*

Participants collectively defined some terms that were central to their understanding of collaboration and the inclusion of multiple knowledge systems. The group saw the degrees of engagement and inclusion as a process, with the goal being Indigenous led science embedded in Indigenous research priorities. They identified terms covering a range of inclusion from no inclusion to full self-efficacy across the process:

> **Sovereignty**: Indigenous-led efforts stemming from Tribal priorities, concerns, and interests. Scientists may be invited into the process, but not lead.
> *"What can tribes do themselves, without having to ask permission?"*
>
> **Involvement**: Varying degrees of collaboration from invitations to participate to partnerships. Led by Western scientists with Tribal involvement.
> *"What can tribes be involved in, participate in, invited to…Being able to sit at other people's table."*
>
> **Colonialism**: No engagement with Tribes. Extractive research that seeks to examine Western science priorities. No benefits to the communities.
> *"What others are doing to Tribes."*

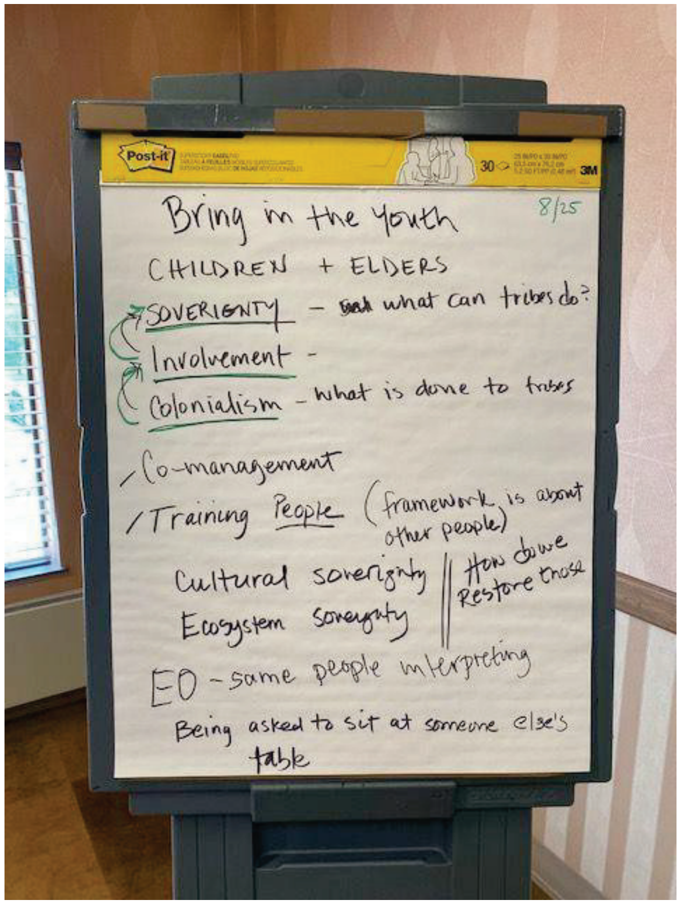


Figure 2: Notes documenting the discussion of the framework of current management processes according to participants.

The group felt the need to continue efforts to move toward greater engagement through relationship building, partnerships, and inclusion of multiple perspectives. It was stated that this process requires learning and knowledge sharing across groups including Western scientists. Participants saw a role for capacity building: training people to be able to conduct strong collaborative research that supports cultural and ecological sustainability. By first recognizing the value of Indigenous Knowledge and understanding the importance of cultural and ecological sovereignty, people can then develop relationships based on trust that allow for knowledge exchange.

Ways to move forward

The points below summarize the values discussed. They represent ideas that came out of workshop discussions, but participants also stressed that these represent only the beginning of this discussion. Each section below is meant to help organize what was discussed, but acknowledge that the sections are not mutually exclusive or exhaustive. There were several concerns about including Indigenous Knowledge in Western science that were discussed throughout the two days. Below are some of the considerations for moving forward as well as key areas of concern.

Alaska Native worldviews and values are the foundation

Participants discussed the need for a bridge or network between the Federal processes and Indigenous communities. Participants agreed this bridge should look like a network built upon several values, rooted in an Alaska Native worldview. Alaska Native cosmologies must lead, rather than follow, during all stages of the process. This will require stepping away from what feels like the standard, Western, homogenized approach to embrace different perspectives and alternative methods.

More than Economic Value

Economic valuation of resources and ecosystem services is an inherently limited and one-dimensional approach to understanding the depth of reliance on and rich meaning of ocean organisms. Monetary value can be used as one metric of a financial relationship. Within the Bering Sea and Chukchi ecosystem, however, there are a range of dynamic and profoundly social processes linking humans with the marine environment and each other far beyond the scope of economic value. To explore these requires looking beyond a simple metric to incorporate other ways of measuring value and meaning. The activity of fishing not only brings cash to a community, but reinforces ties within families and across communities. It provides a means to teach and to learn. The act of fishing and sharing the catch provides meaning, imbuing the time with connection to one's identity as Tribal member, as a provider, as part of something larger than yourself. Additionally, decisions that result in determining economically viable fish inevitably result in other fish and habitat being deemed "not viable," which is a preposterous idea. If more values were included beyond economics, this would be clear.

Relationships are Critical

Participants discussed the importance of relationship building as a cornerstone of this process. Participants also described how these critical relationships exist between humans *and* non-human species. Participants reiterated that conflict is bad for the ecosystem: if people are fighting or not working together, the ecosystem will suffer. Strong, quality relationships indicate strong, healthy ecosystems.

One participant used salmon management as an example of how conflict is actually supported by current management processes. And how, in response to this conflict, salmon species are *"going away." "That's a way our forefathers taught us not to fight."*

In order to build these relationships, face-to-face meetings that happen regularly are very important. Some key steps to building relationships were offered: involving more young people, bringing the work to communities, engaging on each communities' terms, and bolstering network capacity (via financial support, hiring interns, or other means of support).

Responsibility for Solutions

Participants agreed they felt as though the responsibility of sustainable decision-making and cultural survival fell to Indigenous communities without the tools or full authority to enact the changes needed. Despite the sheer scale of the effects of climate change and other disruptions, people discussed how the responsibility of upholding their worldview and way of life falls to small, often underserved, and under-resourced communities. While the drivers of climate change are well outside the scope of rural Arctic, the impacts are felt keenly in these communities. Additionally, Western scientists continue to turn to Indigenous knowledge holders for improved understanding and potential solutions. As one participant said, *"The onus is on us."* Others agreed that there needs to be a shift to incorporate others in the responsibility for solutions toward adaptation and resilience. Developing strategies that facilitate informing Federal research through Indigenous Knowledge is one step forward. Others suggested training programs and budget mechanisms to build capacity across knowledge holders. Specific examples included: create a job shadow program to engage Indigenous youth; build budgets *"from the ground up"* rather than top-down to ensure adequate funding for building enduring partnerships; develop and utilize grants to support community work; and include paid time off to support subsistence practice within paid positions.

Finally, a large part of responsibility also requires *"doing the homework,"* prior to engaging with Indigenous communities. Long before the design phase of research that occurs in proximity to Tribes, Tribal communities, or resources of interest, researchers should be familiar with existing guidance and protocols in the area. Examples of such protocols are the Circumpolar Inuit Protocols on Equitable and Ethical Engagement, the Native Village of Kotzebue Research Protocol[2], or the forthcoming Local Knowledge, Traditional Knowledge, Subsistence Protocol developed by the North Pacific Fisheries Management Council[3].

Equity in the Process

Participants discussed a need for increased attention, additional strategies, and greater commitment to enhancing equity when working with tribes and Indigenous knowledge holders. This would bring action to the Presidential Memorandums on Indigenous Knowledge and Federal decision making[4].

Participants highlighted the need for greater representation of Elders and youth within Federal agencies, getting more youth involved, and increasing representation in research and management across regions. To address equity issues, participants offered several ideas: support community driven processes financially and with expertise; plan meetings far in advance and send notice to everyone involved in written and electronic form; translate documents as necessary; invest in regionally appropriate communication strategies; and hold meetings in communities to facilitate participation and to share the financial and physical burden of travel.

Ongoing Communication

Participants identified a lack of communication between communities and governing bodies. A participant mentioned, "*We all say we were so glad when the consultation rule came out with the Federal agents and their agencies about consulting with a tribe before they do anything."* They went on to say that despite the consultation rule, communication is still lagging. This leads to frustration and break down in trust: *"But nobody's doing any consultation. They just come back after the fact and they*

[2] Principles for the Conduct of Research in the Arctic U NATIVE VILLAGE OF KOTZEBUE RESEARCH PROTOCOL (Adapted from the Principles for the Conduct of Research in the Arctic). 2018, https://policycommons.net/artifacts/1690859/principles-for-the-conduct-of-research-in-the-arctic-u/2422498/

[3] Circumpolar Inuit Protocols on Equitable and Ethical Engagement

[4] OSTP CEW ITEK Memo 2022. OSTP CEQ IK Guidance 2022. Executive Order 13175 (Consultation and Coordination With Indian Tribal Governments). Executive Order 13985 (Advancing Racial Equity and Support for Underserved Communities Through the Federal Government)

just say this is how it is." There are structural challenges in communication pathways which create obstacles among parties. Addressing these challenges can improve communication.

Participants stated the need for relationships and trust prior to knowledge sharing. Several people stated that if scientists want to learn how communities are identifying, observing, and responding to change in the ecosystem, they must first develop a relationship with the community. This relationship begins with communication. This requires increasing coordination and consultation with tribes, Tribal Council, and communities themselves. Attention must be given to facilitating communication. Some suggestions include: encouraging tribal members to speak freely in their preferred language or style, following communication protocols that first locate individuals within their family, community, location, and space. Participants agreed that it is inappropriate to transfer or translate knowledge into the language of Western science; rather, it is important to learn within the context of Indigenous worldviews to gain understanding. One participant said, *"How we talk to each other reflects how we're seeing things."* The act of translation into Western scientific narratives can dilute or obscure the meaning. Language is deeply connected to cultural meaning and central to staying connected and maintaining their way of life.

Another level of communication ensures that scientists explain the purpose of their research prior to beginning any work, clearly including how Indigenous Knowledge might be documented, used, included, cited, or shared. Indigenous Knowledge holders reflect cross-generation knowledge sharing, refined, interpreted, and embedded in the broader tribal community social processes. As such, it is essential to gain permission--with the above specifics--from Tribal authorities (e.g., Tribal Councils, Elders, and other relevant parties) prior to sharing IK. Communication also requires asking scientists and decision-makers what may hinder them from understanding information that communities share with them, so that this can be addressed. This highlights the need to discuss, early in the process, the purpose of knowledge sharing, and what may be the outcome, as well as continuing clear communication pathways to support transparency and maintain trust.

One example discussed regarding communication is the linkages between sharing information with researchers and how that information may (or may not) be used for management processes. There may be ambiguity and confusion about how Federal research is used to inform management and the expectation for action. For example, ecological information may be gathered about a specific event, fishery, or region. From the community's perspective, there may be an expectation that the sharing of information will influence future action. The delineation of Federal agencies (across scientific research, regulatory, and management branches) is not always clear. Additionally, multiple entities contact tribes and individuals frequently and with multiple projects, ideas, meetings, requests, and questions. The complexity of just how these agencies nest across the Federal system is not always clearly understood which can lead to unfulfilled expectations and degrading of trust.

Increased understanding in how each of the bodies interact and the distinct roles as they relate to marine resources could help to inform expectations of any knowledge sharing. This also intersects with the topic of how a community benefits from sharing.

Overall, more open and active communication is needed. Increasing communication can also look like using new and innovative approaches such as using social media as a tool and creating space/acceptance for Indigenous authors on papers, discussions, and in consultations.

Reciprocity

The group discussed what reciprocity means in the context of knowledge sharing, which revolves around the ideas of equity, relationships, and communication. One participant described reciprocity as holding a relationship with the environment, in which you give back because the environment is going to give back to you in dynamic and multifaceted ways. They went on to explain that this is in stark comparison to the motive of giving back to the environment for economic reasons, which is perceived as lacking dimension and depth.

Reciprocity suggests the motivation to act with the purpose of taking care or caring for. Acting for the purpose of economic benefits is not reciprocal but extractive, because it lacks the exchange of care component.

The group discussed how it would be beneficial to teach reciprocity, and what it means to be responsive to, versus in control of, the environment. The group emphasized the importance of the community learning to care for the environment. It was stated that one cannot learn these ways in a book or from scientific models. Learning to care is done through the senses, from the body: from watching the wind shift, smelling the ocean, hearing the seabirds, tasting the fish, and listening to knowledge holders imbue meaning into those experiences. In this way, knowledge is living and deeply embedded in the body of knowledge holders.

Reciprocity also means that researchers and managers who interact and collaborate with Indigenous Peoples and communities should—at the minimum—share any results.

Communities want information about the environment around them. Some participants suggested there should be established and agreed upon pathways for this. Participants agreed that one strategy moving forward could be to begin each research effort that involves communities with the following questions:

- How would the community prefer that researchers share results?
- What about this research could the community benefit from the most?
- What does it look like for the work to be effectively and properly communicated with your community?

These core questions offer a basic framework to assist in Federal research processes and assessments such as the IEA.

Creating a “pathfinder” role

Participants discussed the need for a person or position that can act as a bridge across knowledge systems: someone who understands Alaska Native cosmologies and values, but who is able to venture into new areas, gather information, and return to the community to build understanding and create a path forward. One participant described the position as, “a pathfinder.” The pathfinder’s purpose would be to communicate among communities and Federal agencies to better understand, “what’s out there and makes sense for us.” The group also said that the first steps would be to determine what skills, attributes, variables, and knowledge this person should hold to ensure bi-directional communication and cooperation among communities and government. The role of a pathfinder underscores the need for trust building and mutual understanding across entities. Such a person would be able to navigate multiple knowledge systems and worldviews to develop a path forward toward shared goals.

Create a guide on ways to consider Indigenous Knowledge alongside Western science

Participants discussed the need for consistent guidance in appropriate Indigenous engagement processes whether in research or resource management. Several people named similar protocols or guidelines used in specific circumstances (such as the Circumpolar Inuit Protocols for Equitable and Ethical Engagement); however, it was agreed there was a need for Federal level guidance with clear action steps. Ideally, this document would reflect multiple perspectives and value systems and provide practical guidance to appropriately and equitably engage with Indigenous Knowledge. The values listed above are examples of what that framework should include and look like, however it is important to note that this was not intended to be complete or comprehensive. Including guidance on co-production methods would increase understanding, not only of the benefits of co-production approaches, but support the foundational steps necessary for co-production.

Indigenous-led conceptual ecosystem models

Conceptual models are one tool to develop greater understanding of complex ecosystem processes. Conceptual models rooted in Indigenous Knowledge can illustrate important ecological linkages based in Alaska Native cosmologies. The group discussed the potential value of Indigenous conceptual models as a way to bring together multiple knowledge systems. There was support for this idea if the model included additional meaning and could depict relationships. One participant said, *"You could show connections, you can show the relationships, and all of the pieces that need to be paid attention to."* Participants were quick to state, however, that these models would not be sufficient as standalone images. Including the *"right context"* is necessary. It is important to show humans as reciprocal agents within the ecological flow, with both benefits and obligations. One person clarified that the model could show, *"relationships within the system, but I think the relationships between humans is really important, too. You hear this again and again and again from Indigenous communities, that if people are fighting, that doesn't go well for the ecosystem."* In addition, the role of the stories were seen as valuable in deciphering models. It isn't enough to show the linkages; it is important to explain the meaning within relationships. "*I think it's a really good approach because those relationships and values aren't just human, and so really talking about those stories, too. Your relationship with the walrus has all of those too, right?"*

Visual models along with stories can be effective ways to teach and learn about ecological processes in ways that keep meanings intact rather than abstracting select elements, taking them away from the larger context, and rendering them disjointed from Indigenous perspectives, and thus meaningless. One participant described:

> *A unique approach to management is following the weather and the animals, but those things have to be explained, so then if you have [a model as] an imagery for them, then you just explain to them: when we say health and wellness this is not just people health and wellness, we always have to explain that, both those things, because we're always trying to translate everything to English.*

Acknowledging and addressing concerns

Several concerns were raised during this workshop. Many have been highlighted above, but we want to ensure they have been explicitly stated since they were raised within discussions.

Indigenous Knowledge is deeply interwoven in Indigenous cultural, historical, and social worldviews. Separating threads of knowledge from this nest of understanding can diminish its meaning and significance. Participants emphasize the need to consider Indigenous Knowledge as valuable in its own right, by itself, independent of other forms of knowledge. One participant explains "[Indigenous Knowledge] *won't be found in a text book, when we lose an Elder, we lose an important section of our library.*"

According to participants, the importance of shared stories are not understood, valued, or prioritized by Western science methods and perspectives, or in management frameworks. *"The Federal management processes are not interested in hearing those stories, lessons, and perspectives and applying them in management processes in a meaningful way."*

It was agreed that Indigenous communities are often asked to answer questions from scientists and managers frequently, as a part of the Federal management process. It is often unclear where the information goes, how it is used, and the result of sharing. Despite sharing stories in response to questions, participants said, *"Our voices are not being heard."* Additionally, after sharing a lot of information, many negative impacts have resulted. As participants stated:

- *"We've been sharing a lot of info, and that info has been used against us. Let's protect us from that."*
- *"Nothing is done with the stories [we share]. They are not being applied in a meaningful way."*
- *"We've provided the negative impacts of bottom trawling to our life. Nothing changes."*

The group also discussed that it is often unclear how sharing knowledge or stories will benefit their communities directly. When knowledge or stories are shared, there is an unspoken promise or agreement that communities will receive something beneficial in return for sharing. Several participants explained that their actual experiences were often very different. Sharing knowledge takes energy, effort, and emotional work. To have knowledge "taken" without any community benefit returned feels extractive.

Finally, participants described frustration with instances when researchers asked narrow questions about a specific topic and did not want responses that diverged from that topic. These instances send a message that if stories do not fit within the Western science research container, they are not valuable and cannot be included. Participants emphasized the importance of bringing together and valuing multiple knowledge systems to increase understanding, particularly given the significant changes the area is undergoing.

Participant Feedback

At the end of the second day, workshop facilitators asked participants for feedback.

In response to what went well and what participants felt they got out of the workshop:

- Open learning environment
- Gathering Indigenous perspectives
- Male and female participants
- "Not being asked to be something that I'm not"
- In person, small group, informal (comfortable), free flowing agenda and flexibility
- "A mix of Indigenous Knowledge bearers and non-Indigenous allies is a strong mix (and male/female mix) for this kind of conversation and advancing this work."
- Excellent participants
- Flexible agenda
- Taking the time we needed
- Respectful listening
- From notes: open space to let participants say what they came to say

In response to what could/should be done differently:

- Shorter hours
- Extra day if needed (rather than long days)
- Clearer communication about any group activities outside of workshop days (e.g., group dinner)

In response to what should be done next:

- Regional community meeting
- Enthusiasm that this will continue
- Desire for a larger gathering at the next PICES meeting that allows for Indigenous led discussion and relationship building.

Next Steps

During the workshop, participants brought up examples of existing literature, studies, and guides that have been created for scientists and managers to be used as guidance for collaborating, co-production, and partnerships. Examples included the Circumpolar Inuit Protocols on Equitable and Ethical Engagement and co-production frameworks. We believe that these are key in guiding the next steps of the Bering Sea & Chukchi Sea IEA process.

We believe that the IEA process can be reimagined in a way that implements these suggestions for improvement and puts them into practice. The IEA process is traditionally focused on interactions between the social and ecological components of an ecosystem, and lacks the inclusion of multiple epistemologies and knowledge systems. We envision an expansion in which the guidance provided in this workshop shapes future steps focused on:

- Using the IEA process to include synthesis and collaboration.
- Building relationships between communities and organizations (local, regional, national, and multinational), and using these relationships as indicators for the IEA process.
- Reshaping the IEA process so that co-production is integrated throughout (through in-person meetings, increased communication, and supporting the involvement of Indigenous community members in whatever means is best for them/their community)

PICES-2022
September 23–October 2, 2022, Busan, Korea

Excerpted from:

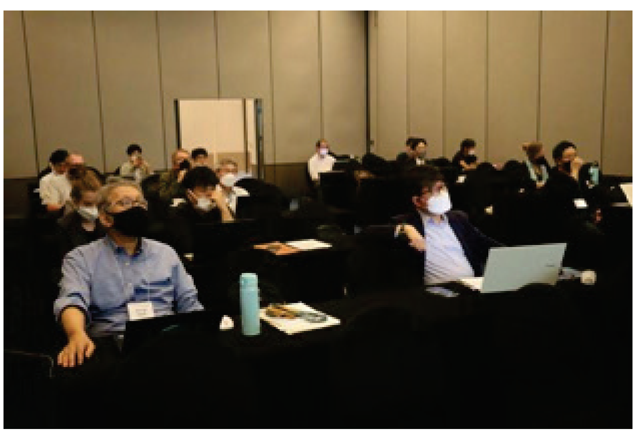
Summary of Scientific Sessions and Workshops at PICES-2022

FIS/HD/SB Workshop (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)

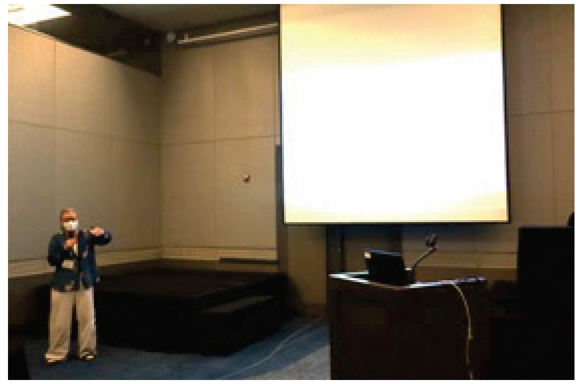
Convenors

Sei-Ichi Saitoh, Hyoung-Chul Shin, Libby Logerwell and Yury Zuenko

The target LMEs of WG 39 and WG 44 are the Central Arctic Ocean (CAO) and the Northern Bering Sea-Chukchi Sea (NBS-CS), that are geographically and dynamically connected. CAO is in rapid transition, driven by North Pacific environmental changes in significant part, has become accessible to a range of 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. 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. An integrated ecosystem assessment (IEA) is a useful and pertinent approach in this circumstance, particularly with substantial science and policy challenges emerging in the Arctic, and this renders a coordinated IEA of the CAO and NBS-CS a priority task.



The main objectives for the workshop were to describe and discuss present ecosystem processes (sources, signals, significance) in the CAO and the NBS-CS based on achievements from existing and future research programs such as MOSAiC and SAS, numerous NBS-CS programs, and Indigenous Knowledge. In addition, it is of particular significance to developing future approaches for The United Nations Decade of Ocean Science for Sustainable Development in these oceans, where science for resilience and sustainability is more important than anywhere else and the relevant, regional UN program is yet to be properly initiated. There were about 30 attendants at this one day in-person workshop on September 25 (Sun), 9:00-18:00 (Busan, Republic of Korea), 2022 (**photo left**). Two invited, 8 oral and one poster presentations were made at W2. PICES members from four countries and ICES member from Norway contributed the presentations. The workshop started with a brief introduction by Prof. Sei-Ichi Saitoh, outlining the background of CAO and NBS-CS issues and objective of this workshop.



In the morning session, Dr. Lis Lindal Jørgensen, one of the co-chairs of WGICA, gave the first invited talk titled "Activities of the ICES-PICES-PAME working group on Integrated Ecosystem Assessment for the Central Arctic Ocean (WGICA)" (**photo right**). She noted that the main results from the ongoing reporting of the main human activities (global sources, shipping, military and tourism), pressures (contaminants, garbage, noise, non-indigenous species (NIS), disturbance, ship traffics, *etc*.) and the work on describing the vulnerability of the ecosystem. Dr. Ferdenant Mkrtchyan gave a recorded talk titled "About remote monitoring of water surface and ice cover of the Arctic". He described the physical foundations of water and ice characteristics based on micro wave remote sensing data. Dr. Dong-Gyun Han gave a presentation titled "Passive acoustic monitoring in the Arctic Ocean for Integrated Ecosystem Assessment". He collected underwater acoustic data using an autonomous passive acoustic recorder in the East Siberian Sea from August 2017 to August 2018. The correlations between temporal variability of sound pressure levels and marine environmental data such as sea ice concentration, extent, drifting speed, wind speed, and ocean current were determined. Mr. Wuju Son gave a talk titled "Vertical behavior of key copepod species subsequent to the midnight sun period in the East Siberian continental margin, Arctic Ocean". He presented the vertical distribution of the key copepod species (*Calanus glacialis*, *Calanus hyperboreus*, and *Metridia longa*) subsequent to the midnight sun period in the Arctic Ocean. The findings could provide insight into monitoring and assessing the variation of the zooplankton distributions in the rapidly changing Arctic marine environment. Dr. Irene D. Alabia gave a talk titled "Arctic marine biodiversity and species co-occurrence patterns under recent climate". She pointed out that regional differences in the spatial patterns in species richness in the Arctic, despite the overall increasing trend in pan-Arctic during 2000-2019. Sea ice loss and rising temperatures have driven northward expansion of apex and mesopredators in major Arctic gateways. Dr. Jee-Hoon Kim gave a presentation titled "Inter-annual changes of the mesozooplankton community structure in the Central Arctic Ocean (CAO) and Northern Bering and Chukchi Seas (NBS-CS) during summers of 2016-2020". He described mesozooplankton distribution in the Arctic (CAO, NBS, CS) and composition of zooplankton and total abundance related to the water mass distribution from multi-year observations in the NBS & CS and suggested that these variable patterns of mesozooplankton communities fluctuate latitudinally from south to north as warming progresses on a regional and bathymetric scale. This could be used to infer the future status of mesozooplankton communities in the study area.

In the afternoon session, Dr. Lisa B Eisner gave the second invited talk titled "Recent ecosystem research in the Chukchi and north Bering seas". She provided an overview of recent ecosystem research in the north Bering and eastern Chukchi seas. Ecosystem level projects include Arctic Integrated Ecosystem Studies (IES) phase 1 (2012 and 2013) and 2 (2017, 2019) in August-September, and Arctic Shelf Growth Advection Respiration and Deposition (ASGARD, 2017 and 2018) in June. She also introduced a recently NPRB-funded synthesis proposal to evaluate pelagic–benthic coupling that will use data from these projects and other surveys (*e.g.*, DBO) to model and predict the impact of a warming climate on pelagic and benthic ecosystems including trophic interactions and energy flow between these systems. Dr. Kirill Kivva gave a talk titled "Spatio-temporal variability of ice retreat in the Pacific Arctic". He investigated the spatiotemporal variability of the date of ice retreat (DOR) in the Bering Sea, the Chukchi Sea and the adjacent Arctic regions. He noted that the differences in sea ice retreat between regions are mostly associated to the wind forcing in the Bering Sea and variability of heat transport through the Bering Strait in the Chukchi Sea. He continued to give another talk titled "Distribution of water masses in the Chukchi Sea in August 2019 and their chemical characteristics". He used observation data from hydrographic surveys in the East Siberian Sea and found high temperature in Siberian coastal water (SCW) and differences in nutrient content and chemistry of different water masses. Dr. Fujio Ohnishi, a social scientist, gave a talk titled "The development of Japan's Arctic Policy and the citizens' awareness". He analyzed the interest of Japan's general public in relation to Arctic policy and emphasized the need to better disseminate the results from Arctic research to the general public.

In general discussion, Dr. Hyoung Chul Shin summarized the overall presentations and discussion at the workshop and noted 1) The workshop has presented updates on present studies/research in the CAO. Furthermore, how best to use the UNDOS-Arctic initiatives will need to be included in future works. Existing/emerging gaps in knowledge will need to be continually identified to guide future research. 2) WG 44 (NBS & CS) will continue to work on the following activities another year: pooling of existing datasets and comparative studies between Arctic gateways using such datasets and inclusion of community-based research in northern Canada. Finally, he led the discussion on the proposal of a new EG advisory panel (AP-ARC), to advance the work of WGs 39 and 44 in the Arctic Ocean context, and to bring more experts to this one-stop EG for Arctic issues. This was agreeable to both working groups and supported by the workshop participants. GC later agreed to establish a new study group, SG-ARC for one year until next PICES 2023. SG-ARC will consist both WG 39 and WG 44 members. Group photos were taken at the closure of the workshop, although the featured picture does not have all the participants unfortunately. (**photo below**)

2022 Report of WG 44 on the *Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea*

The Joint PICES/ICES Working Group on the *Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea* (WG 44) held its third meeting on August 31, 2022, virtually. Eighteen members were present, representing all member countries (*WG 44 Endnote 1*). The meeting was chaired by Dr. Elizabeth (Libby) Logerwell (USA). After self introductions, the meeting agenda was reviewed by members and adopted (*WG 44 Endnote 2*)

AGENDA ITEM 3
Approach and methodology, status and upcoming milestones

We developed three conceptual models with a team of interdisciplinary and multi-national scientists and with input from a few indigenous representatives. The models were created using Mental Modeler software. 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 to identify indigenous partners this coming fall and winter.

AGENDA ITEM 4
Indigenous knowledge sharing, status and upcoming milestones

"Multiple Ways of Knowing the Bering Sea-Chukchi Sea Ecosystem" workshop was held August 24–25, 2022 in Anchorage, and convened by Sarah Wise *et al*. Workshop organizers are in the process of transcribing the workshop notes and summarizing the ideas for bringing in Indigenous knowledge into our IEA process. The workshop included discussions about the challenges of terminology and language (*e.g.,* understanding what the term "Indicators" means) and the concept of time. Milestones: Share report from first workshop. Distribute information that is not digital. Organize a larger, more inclusive meeting in 2023 in Seattle, WA.

AGENDA ITEM 5
2023 Work Plan

WG members discussed a draft Work Plan and agreed on milestones and deliverables (*WG Endnote 3*). An extension of WG44's term to fall 2024 was requested to FIS and HD parent committees.

AGENDA ITEM 6
Proposal for new Advisory Panel on Arctic issues

Dr. Logerwell presented a proposal for an Advisory Panel on the Arctic Ocean and the Pacific Gateways, and Terms of Reference (*WG 44 Endnote 4*). WG members discussed its merits. It was generally agreed that this AP may be a natural evolution following WG 44 and so would be timelier after completion of WG 44 activities in 2024. Dr. Alison Deary (NOAA AFSC) was nominated to be an East Pacific co-chair if the proposal is accepted.

AGENDA ITEM 7
Proposals for meetings / co-sponsored events

See *WG 44 Endnote 5*.

WG 44 Endnote 1

WG 44 meeting participation list

Members

Libby Logerwell (Co-chair, USA)
Yury Zuenko (Co-chair, Russia)
Andrea Niemi (Canada)
Zhongyong Gao (China)
Qi Shu (China)
Changan Xu (China)
Taka Hirata (Japan)
Kohei Matsuno (Japan)
Shigeto Nishino (Japan)
Yutaka Watanuki (Japan)
Hyoung Sul La (Korea)
Kirill Kivva (Russia)
Matt Baker (USA)
Megan Ferguson (USA)
Katrin Iken (USA)
Jamal Moss (USA)
Diana Stram (USA)
Sarah Wise (USA)

Members unable to attend

Canada: Nadja Steiner
Russia: Alexei Somov
USA: Lee Cooper, Raychelle Danielle, Lisa Eisner, Kirstin Holsman, Henry Huntington, Mellisa Johnson, Kathy Kuletz

Observers

Julie Kellner (ICES)
Ali Deary (USA)
Becky Ingram (USA)

PICES

Sonia Batten (Executive Secretary)

WG 44 Endnote 2

WG 44 meeting agenda

1. Welcome, adoption of agenda, appointment of rapporteur
2. Introduce ourselves and guests
3. Approach and methodology, status and upcoming milestones (Moss or Logerwell)
4. Indigenous knowledge sharing, status and upcoming milestones (Sarah Wise)
5. 2023 Work Plan; Request extension?
6. Proposal for new Advisory Panel on Arctic issues (AP-ARC)
7. Proposals for inter-sessional meetings / co-sponsored events

WG 44 Endnote 3

2022–2023
WORK PLAN

1. Determine approach and methodology for conducting an IEA in the Northern Bering–Chukchi Sea LME.
    a. Activities
        i. Identify participants in and beneficiaries of IEA activities and products
        ii. Identify goals for the regional IEA
        iii. Intersessional Conceptual Model in person workshop (if funding can be secured from NOAA IEA Program).
        iv. PICES 2023 workshop (title TBD)
    b. Deliverable(s):
        v. Scoping document
    c. WG member leads: Holsman, Daniel, Stram, Moss, Logerwell
    d. Target date: Spring 2023 WG44 virtual meeting
2. Including multiple ways of knowing the ecosystem
    a. Activities
        i. Indigenous Conceptual Model workshop (September 2022)
        ii. PICES 2023 workshop (title TBD)
    b. Deliverable(s) and target dates:
        i. Drafted Elements of Indigenous Conceptual Model (October 2022)
        ii. Final Elements of Indigenous Conceptual Model (Fall 2023)
        iii. PICES 2023 workshop plans (Spring 2023)
    c. WG member leads: Wise, Daniel, Huntington, Heflin
3. Describe the key physical, biological and human elements of the ecosystem
    a. Activities
        i. Develop shared, integrated conceptual models including both Indigenous Knowledge and science (see 1. and 2. above) (start integration discussions at PICES 2023 workshop; continue work through 2024)
            1. Review of hypotheses for ecosystem dynamics
            2. Identify potential indicators of the above key elements
    b. Deliverables: Ecosystem description from both Indigenous world views and science, indicators and hypotheses (Fall 2023)
    c. WG member leads: Holsman, Daniel, Stram, Wise, Daniel, Huntington, Heflin

Note: This work plan accomplishes Years 1 and 2 Activities and Deliverables as detailed in our ToR. A one-year extension will be requested to complete Year 3 Activities and Deliverables in our ToR.

WG 44 Endnote 4

Proposal for an Advisory Panel on the *Arctic Ocean and the Pacific Gateways*

Acronym: AP-ARC

Potential Parent Committee: Science Board (SB), FIS, MONITOR

Term: Nov. 2022-TBD

Background

The Central Arctic Ocean (CAO), that is in between the North Pacific and North Atlantic, is in rapid transition, in interaction with and impacting these waters. It has become more accessible to a range of activities. For example, 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 Pacific gateway to the CAO, *i.e*., the Northern Bering Sea–Chukchi Sea (NBS-CS) is also experiencing unprecedented warming and loss of sea ice as a result of climate change. Declines of seasonal sea ice and warming temperatures have been more prominent in the northern Bering and Chukchi seas than in the European 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 widespread cumulative impacts.

PICES took upon responsibilities in 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 WG 39 in 2017. In 2019, PICES also established WG 44 (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 and 44 will end the term with the closure of the PICES 2022 Annual Meeting. In this context, we propose PICES establish AP-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.

Proposed Terms of Reference (ToRs)

1. Coordinate and promote the joint scientific activities of PICES to further advance the understanding the Central Arctic Ocean and its interaction and linkage with its Pacific Gateways;
2. Convene workshops/sessions to engage those involved in IEA and monitoring of the Arctic Ocean and its Gateways;
3. Represent and coordinate responses of PICES concerning the Arctic Ocean and the connected waters in cooperation with partners and other international organizations, including WGICA (Joint PICES/ICES/PAME Working Group on an *Integrated Ecosystem Assessment (IEA) for the Central*

Arctic Ocean (CAO)), and WGIEANBS-CS (Joint PICES/ICES Working Group on *Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea*);

4. Develop recommendations for PICES to better collaborate within PICES and with larger international initiatives relevant to the Arctic Ocean including the UN Decade of Ocean Science.

Proposed Co-Chairs (Two west and two east)
Sei-Ichi Saitoh (WG 39) (Japan) - ssaitoh@arc.hokudai.ac.jp
Hyoung Chul Shin (WG 39) (Korea) - hcshin@kopri.re.kr
Alison Deary (USA) - Alison.Deary@noaa.gov
Sarah Wise (WG 44) (USA) - Sarah.Wise@noaa.gov

Proposed Membership*
Andrea Niemi (WG 44) (Canada)
Nadja Stefanie Steiner (WG 44) (Canada)
Zhongyong Gao (CC-S, WG 39, WG 44) (China)
Guangshui Na (FUTURE-SSC, MEQ, SB, WG 35, WG 39) (China)
Fang Zhang (WG 39) (China)
Hyoung Chul Shin (WG 39) (Korea)
Hyoung Sul La (WG 44) (Korea)
Sei-Ichi Saitoh (WG 39) (Japan)
Fujio Ohnishi (WG 39) (Japan)
Takafumi Hirata (WG 44) (Japan)
Yury I. Zuenko (CREAMS-AP, POC, S-CCME, SG-UNDOS, WG-35, WG-40, WG-44) (Russia)
Kirill Kivva (WG 44) (Russia)
Alison Deary (USA)
Sarah Wise (WG 44) (USA)
Elizabeth A. Logerwell (FIS, WG 44) (USA)
Lisa B. Eisner (MONITOR, WG 44) (USA)
David L. Fluharty (WG 39) (USA)
*This is a tentative membership, in future, almost WG 44 member will join to this AP.

Reference

Skjoldal, H. R. (Ed.). 2022. Ecosystem assessment of the Central Arctic Ocean: Description of the ecosystem. ICES Cooperative Research Reports Vol. 355. 341 pp. https://doi.org/10.17895/ices.pub.20191787

WG 44 Endnote 5

Proposal for a Workshop on
"Collaborative and knowledge sharing approaches to support climate change adaptation and social-ecological system resilience"
at PICES-2023 [later merged with
"Indigenous and community-led approaches to coastal ecosystem resilience in the Pacific"
and renamed as
***"Indigenous and community-led approaches to support climate change adaptation and ecosystem resilience in the North Pacific and Arctic"*]**

Convenors: Sarah Wise (USA), Kirstin Holsman (USA), Kathy Mills (USA), Steven Alexander (Canada)

Suggested Invited Speakers: Maktuayaq Johnson (USA), Cyrus Harris (USA), Raychelle Daniel (USA), Richard Slats (USA), Vivian Korthuis (USA)

Duration: 1 day

Fishing communities are on the frontline of climate change. Supporting resilience and climate adaptation requires strong relationship building, trust, and collaborative knowledge creation that centers on multiple knowledge systems including Indigenous perspectives and Traditional Knowledge. While climate empirical change information and observations are abundant, challenges and opportunities remain to match the scale of information to community local needs and regional impacts, and to account for dynamics around community adaptation and response. This interactive workshop builds on Joint ICES/PICES WG 44's work focusing on hearing from Indigenous communities to identify values and actionable guidance to create space for Indigenous Knowledge in marine management processes. Additionally, the workgroup complements a proposed S-CCME open meeting and both the S-CCME and Joint ICES/PICES WG 44 business meetings at the 2023 Annual Science meeting in Seattle. The workshop has two main objectives: 1) share and learn from multiple knowledge systems, processes, and perspectives around climate change and resilience within remote fishing communities; 2) provide examples of and lessons learned from transdisciplinary and collaborative science rooted in strong partnerships, through engagement from multiple stages in its development--from conceptualization, to implementation, toward products and outcomes. The one day workshop will include a panel of invited Indigenous speakers and transdisciplinary science practitioners, interactive discussion sessions, and time allocated for collaborative creation. We encourage participation from Indigenous Knowledge holders, community members, scientists, and resource managers involved in research projects based in collaborative frameworks. Outcomes of the workshop will include a collaborative report highlighting best practices and/or lessons learned, a peer-reviewed publication on diverse methodological approaches to transdisciplinary work. Other outcomes based on discussion among participants on ways to bring together multiple ways of knowing and multiple types of knowledge, expertise, and experience to inform decision-making to be decided by workshop participants.

PICES-2023
October 23–27, 2023, Seattle, USA

Indigenous and community-led approaches to support climate adaptation and resilience, and inform management in North Pacific and Arctic

"Lay of the Land"

W9 – Workshop Report

PICES-2023
October 20–21, 2023
Seattle, WA, USA

TCODE/HD Workshop (W9)
Indigenous and community-led approaches to support climate adaptation and resilience, and inform management in North Pacific and Arctic

Convenors:
Rebecca Martone (Canada), Kathryn Sheps (Canada), Sarah Wise (USA), Natalie Ban (Canada), Sanae Chiba (PICES Secretariat), Kirstin Holsman (USA, S-CCME, AFSC-NOAA), Kathy Mills (USA, SICCME, GMRI), Steve Alexander (Canada, DFO)

Invited Speakers:
Yutaka Watanuki (Japan), Patrick O'Hara (Canada, DFO), Mirian Kim (Korea), Andrew Ross (Canada)

Co-sponsors:
ICES, PSC

Background
The Ocean Decade Collaborative Center for the Northeast Pacific (DCC) and NOAA's Alaska Fisheries Science Center (NOAA) jointly convened a workshop, *Indigenous-led approaches to support climate change adaptation, resilience and informed management in the North Pacific and Arctic*, that was held October 20th and 21st as part of the PICES 2023 Annual Meeting in Seattle, WA. Our aim was to share ways to weave together multiple knowledge systems and identify pathways to expand collaborations and partnerships in ecosystem research, climate change adaptation, and informed management processes.

Objectives

The conveners set three main objectives for this workshop:

1. Bring together marine and coastal knowledge holders (including Indigenous and Traditional Knowledge holders, climate scientists, and ocean practitioners) to share stories, lessons, and perspectives of living with changing marine ecosystems.
2. Provide a safe space to build relationships, and share stories and lessons learned from Indigenous-led work.
3. Facilitate a cross regional knowledge network of Indigenous Knowledge holders, community leaders, and ocean practitioners to facilitate ongoing collaboration beyond the PICES annual meeting.

Workshop Summary

The workshop consisted of a one-day "closed door" invitational and participatory deliberative dialogue session, and a second half-day open-door knowledge sharing session open to participation from anyone registered for the PICES Annual Meeting. Participants joined the workshop from across the NE Pacific and beyond: participants included members of Indigenous communities from Washington, British Columbia and Alaska, as well marine scientists and "boundary spanners[1]" from the US, Canada, EU, and Australia.

[1] A "boundary spanner" is an individual who can connect people across social, societal or cultural silos (Hatch *et al.*, *2022*).

Day 1

Day 1 started with a blessing, and a shared commitment to productive and collaborative work. The group participated in a comprehensive round of introductions so that participants could learn about the backgrounds and expertise of everyone in the room. During this period, some members reminded the group of the urgency of this work, particularly given the rapid pace and far-reaching effects of climate change on Indigenous communities. There was shared discussion on climate driven impacts on coastal communities in the North Pacific and Arctic including dramatic declines in key subsistence and commercial marine species, increased marine traffic and associated impacts, reduced sea ice, increased storm events (both in frequency and severity), and changing ecological systems. Indigenous communities are coping with these changes with limited resources and capacity, further exacerbating the harmful effects. The group was reminded that Indigenous coastal communities have been experiencing, engaging with, and learning from ecological changes for millennia: “We are still here and we will continue to adapt.” It was agreed that climate research must embrace a commitment to benefit frontline Indigenous communities.

Discussion continued, focusing around collectively addressing two questions:

1) *What are some ways that communities and scientists are weaving Indigenous Knowledge and Western science together to inform climate adaptation and coastal and ocean stewardship?*
2) *What are some of the elements that you think are critical for enabling successful collaboration?*

These questions were considered in open dialogue, as a large group.

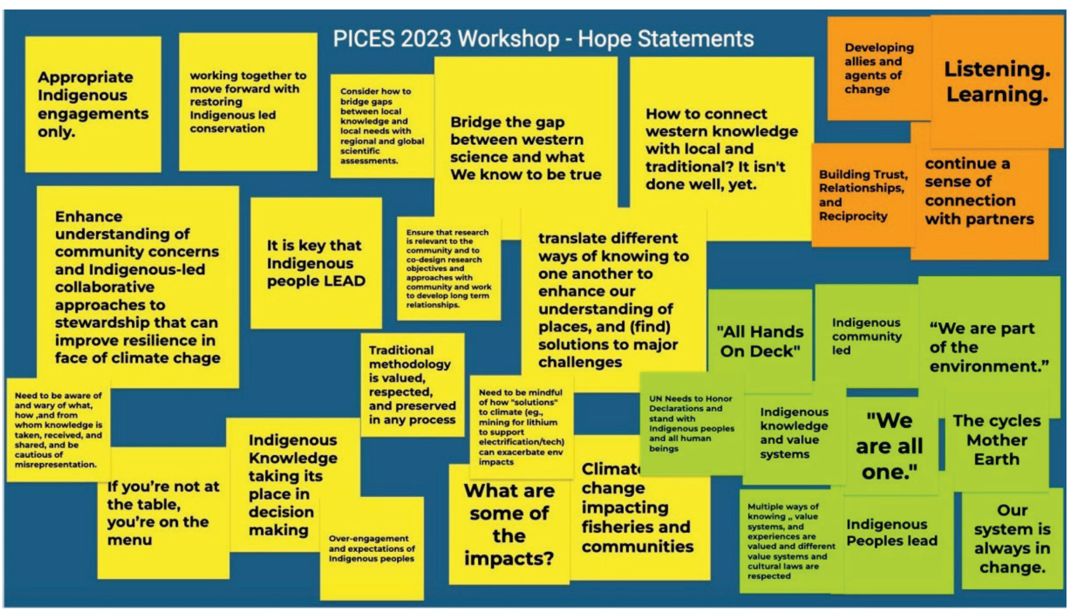


Figure Caption: A jamboard used to capture ideas and messages from participant introductions and intention statements shared on Day 1 of the workshop, we chose to use a jamboard for this portion of the conversation to enable remote/online participants to share their reactions.

Indigenous Knowledge and Knowledge Systems

Participants described their relationships with Indigenous Knowledge and Indigenous Knowledge Systems. People shared a general agreement that Indigenous Knowledge is not a monolithic entity that can just be ‘engaged with’ or ‘blended’ with Western science, as one participant described it, “as ingredients in a recipe.” Everyone has different knowledge, and people come to know things in different ways based on their own experiences, values, and relationships. Indigenous Knowledge Systems derive from millennia of observation, and place-based relationships in which many Indigenous peoples continue to coexist with plants, animals, elements, environments, and ecosystems, rather than from observations of systems that are viewed or valued as separate from the observer. Participants reported that Indigenous perspectives often view these relationships as intimate, in which human and non-human members are engaged in caring and caretaking relationships with each other.

In this formulation, Indigenous Knowledge Systems are values-based systems, complete within themselves and deeply embedded in cultural understanding and experience, and cannot easily be compared to Western ways of knowing. Often Western knowledge considers values and responsibilities as distinct from observation. When considered from Indigenous perspectives, Western scientific approaches appear to divorce observations from outcomes; its values can be seen as uncaring, or even violent, because of the lack of reciprocities and care relationships.

Discussing the Differences Between Indigenous Knowledges and Mainstream Science

Having established some shared understanding about Indigenous Knowledge Systems and their complexity, the group moved to the question about how to work alongside--or in tandem with--Western scientific knowledge and approaches (see Question 1). Participants talked about their experiences, either their own, or those with which they were familiar, working with multiple knowledge systems. Many people shared that they felt like Western scientists did not fully appreciate or understand the ways in which their requests, or attempts at collaboration were mis-matched with the kinds of knowledge being sought. This included treating Indigenous Knowledge and Indigenous Knowledge Systems as less valid than Western scientific approaches, both due to prejudice, racism, and the continuing impacts of colonialism, as well as the lack of existing best practices, frameworks, or accessible tools to help integrate various worldviews in a scientific rubric. Several participants spoke of a lack of care in the treatment of Indigenous Knowledge, and by extension, Indigenous People are given in some Western scientific approaches. This engaged the curiosity of some participants: what would it mean for oceanographers to not consider themselves apart or separate from the waters and ecosystems they observe and study? How could we bring this kind of relationality into ocean sciences?

Participants discussed the differences in values between Western science and Indigenous approaches. Western science emphasizes broad knowledge sharing and values communication and sharing ideas and results far and wide. This cultural value differs from many cultures, which may link responsibility and obligation with knowledge holding: only those with the permission and teachings to understand how to responsibly care for the knowledge are able to hold and share knowledge. In these contexts, open and liberal communication may not be seen as a positive attribute.

Participants often returned to the idea of Western scientists as needing to listen--in more than one way--to other cultures, perspectives, and ways of seeing the world. This requires not just listening to what community members say, but also understanding broader interrelationships and impacts with ecosystems and people. Participants wanted to be clear that speaking to one community member about a particular piece of work was likely not sufficient for meaningful community engagement. As Indigenous Knowledge Systems are often relational, knowledge in those systems can also be personal and intimate, and community members may disagree about various observations, approaches and protocols. Further, it is important to remember that community members may hold different forms of knowledge relevant to a particular question. In order to meaningfully engage with Indigenous communities when doing research, it is important to engage with the community, and seek perspective and guidance from multiple knowledge holders, rather than rely on one voice, unless directed by the community to do so.

Reciprocity

In order to act as allies for Indigenous communities, Western scientists should be mindful that reciprocity is a core value and necessary for any type of collaborative work. Researchers should consider how they are reciprocating and offering value to the Indigenous communities in which they work. There were many examples mentioned--whether organizing science work so that it is primarily responsive to community needs, ensuring the research tackles questions of importance to communities, supporting community systems in place, and appropriately compensating and crediting community members for their time and contributions. Participants shared experiences where Western scientists asked questions that were seen as not relevant or useful for the community they were engaging. Experiences of extractive work, where scientists 'take' or 'use' Indigenous Knowledge without permission and without appropriate context were also shared. These experiences lead to poor outcomes for the research, the relationships, and the possibility of future collaborations.

Elements of Successful Collaboration

When asked what elements were necessary for successful collaboration (see Question #2), participants overwhelmingly pointed to the need to address the resourcing of these collaborations, particularly the way science funding can be shared with participating community members and the length of time that scientists are willing to commit to engaging and working within communities. Capacity limitations (whether limitations on funding or labor resources) was a central topic. The need for long-term funding and funding available to support Indigenous participation in initial, early, and ongoing planning stages of work were emphasized. Several participants agreed that longer-term funding and support for Indigenous communities engaged in scientific research helps to create better scientific outcomes, as it allows for the development of checks and balances, as well as gives time and space for Indigenous communities to participate fully. Often community members, especially those working with Guardians or in stewardship positions, are active in multiple projects and fielding requests for further or new collaborations, above and beyond the work they may be doing for their own communities and organizations. This also calls back to the need for collaboration to be reciprocated by Western scientists, as discussed earlier. One way that collaboration and exchange can be reciprocated by Western-based institutions is by providing funding that can be used to build or increase capacity for engagement, participation and collaboration within Indigenous communities.

Building Trust and Equitable Partnerships in Urgent Times

After the lunch break, participants moved into three smaller groups for continuing discussion. Participants engaged in conversation about the kinds of supports needed for different actors to show up for equitable scientific collaborations. Participants also tackled a thorny question: it is often said that relationships are built at the speed of trust, but climate change can present urgent challenges to coastal communities - how can we ensure even urgent needs are met? The conversations across the three breakout groups were substantially different, but touched on some common themes and ideas.

All the groups discussed the need to acknowledge, and address power dynamics in collaborative projects and processes. One group talked about the necessity of Western scientists to acknowledge that bridging the gap between Western and Indigenous perspectives requires respecting the social and cultural values on which those differences in perspectives are based. One participant described this as the difference between managing “a resource” as opposed to managing “a revenue”. Another person described the difference between a “natural resource” and an “ancestor or family member”. Multiple examples of this difference were mentioned by participants. One example is salmon on the Pacific coast, where fisheries management is based on maximizing sustainable yields (as informed by the Western value of profit maximization). In contrast, many Indigenous perspectives focus on human-ecological-salmon relationships, maximizing the livelihoods of the salmon, as well as the many people and other species who depend on them. The group provided additional examples of how differences in values inform both regulatory structures and decision- making, which can lead to real harm for Indigenous communities, further deteriorating trust between communities and researchers

This points to a fundamental difference across multiple perspectives and approaches. It is important to note that many Indigenous People rely heavily on coastal and marine resources: they live with the risk of ecological deterioration in their communities, which directly affects their--and those of their children’s and grandchildren’s--health, social wellbeing, cultural cohesion, and ecosystem processes. Participants agreed that Indigenous-led research is necessary for more robust and balanced research that can inform improved decision-making across regions. Given the rapid and profound effects of climate change, the urgency for more inclusive and equitable research was recognized. There was acknowledgment of slow changes (such as this workshop at the PICES Annual Meeting); however, it was noted that the speed of change is not equivalent to the speed at which key populations and essential habitats are declining.

Context matters

While there may be some lessons that can be learned in one location and applied to the benefit of people and place in other jurisdictions, participants shared examples about how this tendency to categorize and generalize across locations, ecosystems, and species can lead to inaccurate findings and mistaken understandings. Several participants compared this kind of piecemeal approach to examples of preferred holistic approaches--rooted in Indigenous perspectives--to collaboration. One example was shared about Western scientists trying to communicate about a species of fish, using one of its Indigenous names. The scientists in question did not understand that the name of that fish was only used in certain contexts and locations and not others. This led to confusion among community members and the scientists were unsuccessful at gaining the knowledge they were seeking. Employing more holistic approaches to collaborating with Indigenous Knowledge holders early in research planning and designing critical questions might have avoided this kind of confusion.

Principles of data equity and sovereignty were also discussed. As one participant stressed, “data are key to empowering Indigenous communities.” Many talked about the imbalance in how knowledge is viewed and leveraged within Western science. If Western science can ‘confirm’ what Indigenous Peoples have known and passed down in teaching for generations, this confirmation is sometimes necessary for Indigenous participants to be treated equitably in collaboration with Western scientists. Participants mentioned the OCAP principles (Ownership, Control, Access and Possession) as a critical correction to past data practices — permission needs to be sought and granted in order to collect data and work in Indigenous lands and waters, and at every stage in the scientific process, from very early stages of articulating a hypothesis all the way through and including authorship to Indigenous collaborators.

Day 2

The final half-day of the workshop provided an opportunity for participants to share the work that they have been involved with in their communities, showcasing examples of Indigenous-led research in ecosystem management, climate change adaptation and resilience. A wide range of project types and approaches were shared from across the NE Pacific and the Arctic in a variety of formats. This agenda was decided upon collaboratively by workshop participants at the end of the first day of discussions, and all workshop participants had the opportunity to share their work with interested members of the PICES community.

After an opening to start us off in a good way, participants from northwestern Alaska shared stories and experiences as climate change has driven substantial social, economic, and ecological changes in their communities. One participant shared his experience of mourning the loss of “the mother ice” every year (the first solid winter sea-ice) and the many resources the ice brings to his marine resource dependent community: walrus, seal, polar bear, among others. The effects of climate change are leading to the uncertain arrival of mother ice, a reduction in the thickness of this ice, and diminished access to these critical species and practices. He also shared teachings that his grandfather directed him to pass along relating to climate change, and the need to protect ecosystems and his way of life so that they are not lost permanently. Another participant shared a short film about Indigenous-led research (Ikaaġvik Sikukun or “Ice Bridges”)[2] that occurred in his community. The project focused on the thickness of sea-ice, examining how decreasing sea ice leads to increased risk, and reduced access to subsistence foods in his community. Not only is the sea-ice less safe to travel on, but decreased mobility leads to decreases in hunting which has real impacts on the food security of his community. Another participant from the Yukon River Drainage Fisheries Association[3] (YRDFA) presented information on several of their collaborative projects with Alaska Native communities in the Yukon region. In partnership with communities along the Yukon River watershed area, YRDFA has conducted research on a range of topics of interest to communities including, invasive species, salmon health, Traditional Knowledge, water quality, and community resilience.

From Haida Gwaii, participants shared work involved in creating a marine planning program based on Haida Knowledge about the oceans: the Haida Gwaii Marine Plan[4], a collaboration between the Council of the Haida Nation and the Province of British Columbia. Another participant shared a recent collaboration between Parks Canada and the Haida Nation, X̱ aayda Gwaay.yaay K̲uugaay Gwii Sdiihltl’lx̱ a: The Sea Otters Return to Haida Gwaii[5]. This project explored how the recent return of Sea Otters (ku*k̲uu in Haida language) might be understood and related to by the community on Haida Gwaii.

Two presentations from participants focused on the ways in which they were learning from other Indigenous communities in order to find solutions to problems in their own home communities. A member and staff of the Swinomish Indian Tribal Community shared about how learning the ancient Indigenous practice of clam gardens from relatives in British Columbia was leading to a revitalization of knowledge and culture in his Washington State community, which was an emotional and meaningful experience for this participant[6]. An Indigenous participant from Australia currently living in Washington State discussed how he was learning from communities along the NE Pacific coast, and noted similarities and differences between Indigenous-led approaches to ecosystem and fisheries

[2] Ice Edge, the Ikaaġvik Sikukun Story: https://www.youtube.com/watch?v=P9RzfGtLWHo
[3] https://yukonsalmon.org/
[4] https://haidamarineplanning.com/initiatives/haida-gwaii-marine-plan/
[5] https://parks.canada.ca/pn-np/bc/gwaiihaanas/nature/conservation/restauration-restoration/kuu
[6] https://wsg.washington.edu/research/clam-gardens/

management across continents: he planned on sharing this experience with Indigenous communities in Australia.

Next, we had a screening of a short film, Tsunami 11th Relative, that documents an example of a culturally sensitive coastal resilience project around Tsunami safety on Vancouver Island, BC with the Ka:'yu:'k't'h'/Che:k:tles7et'h', Nuchatlaht, Ehattesaht, Mowachaht / Muchalaht, and Quatsino First Nations. Indigenous elders spoke about their experiences with tsunamis and storms that have affected their coastal community and described how Indigenous Knowledge about tsunamis has helped Western scientists better understand impacts of sea-level rise and coastal hazards on this region, as well as helped develop culturally sensitive disaster response and management plans.

We closed our workshop with words from an Elder from St. Lawrence Island, Alaska, stressing the importance of working together to face the climate crisis, and the consequences of our failures. These words were a call to action and a reminder of the urgency of the work we are doing together, and the need to continue to move forward, despite the complexity and challenges.

Conclusions

We hope PICES continues to equitably engage with Indigenous leaders in the US and Canada, as well as across the North Pacific when designing and implementing research. There are many examples of excellent, rigorous Indigenous-led work happening across the northeast Pacific coast; this workshop was a crucial first step to more equitably include multiple voices and perspectives in marine science. We encourage PICES to engage with Indigenous leaders and boundary spanners in these meetings–as well as on the PICES planning bodies--to support equitable collaborative research.
If PICES, as an organization, is interested in engaging more Indigenous leaders and including more Indigenous approaches:

- It is not appropriate for Indigenous People and perspectives to be siloed in only a few workshops, instead, integrated throughout the committees and working groups;
- PICES already deals with cultural differences, so perhaps it would not be difficult to include additional cultural perspectives;
- Indigenous participants must be supported financially and with other resources - i.e. honoraria for speakers and Indigenous Knowledge holders in addition to travel and accommodation support and stipends - most other participants are part of national delegations, and have other forms of support for their work;
- Engagement and outreach is a big task, but would be an important one - do not leave this to national governments that are often already in conflict with Indigenous communities and First Nations over resource and ecosystem management;
- PICES needs to provide more time for edits and review by participants prior to publication of PICES reports; and,
- It is important to acknowledge, address, and work to rectify inequities in participation, funding and recognition, and recognize that this work needs to be part of PICES's mission, if it wishes to increase Indigenous participation in PICES working groups and events.

References

Hatch, M. B. A., J. K. Parrish, S. S. Heppell, S. Augustine, L. Campbell, L. M. Divine, J. Donatuto, A. S. Groesbeck, and N. F. Smith. 2023. Boundary spanners: a critical role for enduring collaborations between Indigenous communities and mainstream scientists. Ecology and Society 28(1):41. https://doi.org/10.5751/ES-13887-280141

2023 Report of Working Group in *Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea*

The joint PICES/ICES Working Group on the Integrated Ecosystem Assessment for the Northern Bering Sea–Chukchi Sea (WG 44) held two meetings in 2023—one virtual meeting on August 31 and one hybrid meeting on October 25 during PICES 2023 in Seattle. Thirteen members were present at the August virtual meeting and twelve members were present at the October hybrid meeting. There was one visitor during the October meeting (*Endnote 1*). Both meetings were chaired by Dr. Elizabeth (Libby) Logerwell (USA). After self-introductions, the meeting agendas were reviewed by members and adopted (*Endnote 2*).

AGENDA ITEM 3 (virtual meeting)
Progress on 2023 revised Work Plan

The chair reminded WG members that the Work Plan and Terms of Reference were revised (and approved) in Spring 2023 (*Endnotes 3 and 4*). The PICES Secretariat reminded the Chair and WG members that the WG tenure would end in Fall 2023 with one year hence to submit the Final Report. The Chair requested that members send references for linkages in the conceptual models in support of the Final Deliverable in the revised Terms of Reference (*Endnote 4*). Sarah Wise presented an update on the work of her team on "Including multiple ways of knowing" including the PICES 2023 workshop.

AGENDA ITEM 4 (virtual meeting)
Requests for Science Board recommendation

There were no proposals for new Expert Groups nor requests for travel support or events.

AGENDA ITEM 5 (virtual meeting)
Plan for PICES 2023 WG meeting

The Chair requested that by the PICES 2023 meeting, the key linkages (annotated with references) for each conceptual will have been identified. WG members decided that the meeting would be used for writing and making the results more concrete. It was noted that several WG members will not be able to attend PICES2023 due to travel restrictions.

AGENDA ITEM 3 (hybrid meeting)
Progress on Multiple Ways of Knowing

Sarah Wise gave an update on the activities of her team (Raychelle Daniel, Henry Huntington, Rebecca Ingram, Mellissa Maktuayaq Johnson, Nadja Steiner, and Eduard Zdor) working on issues around multiple ways of knowing the NBS-CS ecosystem. The group's overarching goal is to examine EBM goals and targets in a way that bridges multiple knowledge systems. This allows for broader representative goals and understanding and greater inclusion of meanings. Through a series of workshops, including one held at PICES-2023, Wise's team along with indigenous, management and science partners, have conducted institutional mapping of the NBS-CS ecosystem that illustrates the relationship between humans, institutions, and the ecosystem. Key ideas emerging from the team's work are a need for more Indigenous-led work, a call for more focus on relationships and relationship-building, addressing the issue of data sovereignty, a need for building capacity, and the requirement that future work should include leveraging examples of existing strong partnerships and engagement.

AGENDA ITEM 4 (hybrid meeting)
Update on AP-ARC

The chair gave an update on the proposed new Advisory Panel on Arctic Issues. WG members expressed interest in recruiting a co-chair with expertise in social sciences. WG members asked how this AP would overlap with other Arctic organizations such as the Arctic Council AMAP Working Group and the Pacific Arctic Group.

AGENDA ITEM 5 (hybrid meeting)
Update on timeline, Final Report deadline

The chair reminded members that the WG's tenure will end at this meeting and that the Final Report will be due in one year (at PICES 2024).

AGENDA ITEM 7 (hybrid meeting)
Finalize conceptual models, key linkages and references

WG members discussed the current status of the conceptual models and plans for finalizing them and preparing the Final Report. It was noted that the Ecological model is contained within the Climate-Fisheries model, so a separate effort to finalize the former model and provide key linkages and references is not needed. Members discussed the idea of integrating all the models into one comprehensive model and then examining specific interactions from the two perspectives (climate-fisheries and subsistence-food security).

WG members expressed interest in publishing a paper on the network mapping. Kirstin Holsman will organize bi-weekly meetings with interested members to get the paper off the ground. There is a need to identify a group ready to start working on the analyses for the paper. This core group will lead/work on the manuscript and evaluate confidence in the interactions that have been identified.

Kirstin Holsman gave an overview of Calibrated Confidence Language. The process provides guidance on agreement and confidence when working on multiple knowledge sources (including lived experience and Indigenous knowledge). The process combines confidence and documented relationships. For example, you may know there is a link between two things, but don't have much confidence or you may know of a strong documented relationship between two things.

AGENDA ITEM 8 (hybrid meeting)
Open journaling or breakout groups to start drafting Final Report/Journal paper

The WG agreed that the chair (Logerwell) will create a rough draft/outline of the Final Report, establish a timeline of milestones towards completing the report, and identify WG members for specific action items (e.g., drafting text, preparing figures, assembling references). WG members were reminded of the key deliverables from the revised ToR (*Endnote 4*): metadata on data sources and institutions (completed); ecosystem descriptions (conceptual models); knowledge gaps; and next steps.

WG 44 Endnote 1

August 2023 WG44 participation list

Members
Libby Logerwell (USA, Co-Chair)
Yury Zuenko (Russia, Co-Chair)
Andrea Niemi (Canada)
Nadja Steiner (Canada)
Changan Xu (China)
Lee Cooper (USA)
Takafumi Hirata (Japan)
Shigeto Nishino (Japan)
Hyoung Sul La (Korea)
Matthew Baker (USA)
Lisa Eisner (USA)
Henry Huntington (USA)
Jamal Moss (USA)
Sarah Wise (USA)

Members unable to attend
China: Zhongyong Gao, Qi Shu
Japan: Kohei Matsuno, Yutaka Watanuki
Russia: Kirill Kivva, Aleksei Somov
USA: Raychelle Daniel, Megan Ferguson, Kirstin Holsman, Katrin Iken, Mellisa Maktuayaq Johnson, Kathy Kuletz, Diana Stram

Observers
Kim Rand

October 2023 WG44 Meeting Participation list

Members
In person:
Libby Logerwell (USA, Co-Chair)
Changan Xu (China)
Matthew Baker (USA)
Lee Cooper (USA)
Kirstin Holsman (USA)
Sarah Wise (USA)

Virtual:
Nadja Steiner (Canada)
Hyoung Sul La (Korea)
Kathy Kuletz (USA)
Jamal Moss (USA)

Members unable to attend
Canada: Andrea Niemi
China: Zhongyong Gao, Qi Shu
Japan: Takafumi Hirata, Kohei Matsuno, Shigeto
Nishino, Yutaka Watanuki
Russia: Yury Zuenko, Kirill Kivva, Aleksei Somov
USA: Raychelle Daniel, Lisa Eisner, Megan Ferguson, Henry Huntington, Katrin Iken, Mellisa Maktuayaq Johnson, Diana Stram

Observers
In person: Jackie Grebmeier
Virtual: Kim Rand

WG 44 Endnote 2

WG 44 meeting agendas

INTEGRATED ECOSYSTEM ASSESSMENT OF THE NORTHERN BERING SEA – CHUKCHI SEA (NBS-CS) (WG 44) WORKING GROUP MEETING
AUGUST 31, 2023 15:00-16:00 PACIFIC DAYLIGHT TIME (UTC-7) ZOOM MEETING
HTTPS://US 02WEB . ZOOM . US / J /5 13 0 09 5 10 5

Chair: Libby Logerwell
Rapporteur: Kim Rand

Topic	Start time	minutes
Welcome, adoption of agenda, appointment of rapporteur	1500	5
Introduce ourselves and guests	1505	10
Progress on 2 02 3 R EVISED Work Plan	1515	15
Requests for Science Board recommendation (new EG, travel support, events, etc.)	1530	10
Plan for PICES2023 WG meeting (25 October 9:00-17:30)	1540	20

INTEGRATED ECOSYSTEM ASSESSMENT OF THE NORTHERN BERING SEA – CHUKCHI SEA (NBS-CS) (WG 44) WORKING GROUP MEETING
WEDNESDAY OCTOBER 25, 2023 09:00-17:30 PACIFIC DAYLIGHT TIME (UTC-7) HYBRID MEETING
IN PERSON: WESTIN SEATTLE ROOM VASHON II
ZOOM: HTTPS://US02WEB.ZOOM.US/J/5437544800

Chair: Libby Logerwell
Rapporteur: Matt Baker and Jamal Moss

	Duration	Time finish
Welcome, adoption of agenda, appointment of rapporteur	:05	9:05
Introduce ourselves and guests	:25	9:30
Progress on Multiple Ways of Knowing (Wise)	:20	9:50
Update on AP-ARC (Logerwell)	:10	10:00
Update on timeline, Final Report deadline (Logerwell)	:15	10:15
Conceptual Models, key linkages and references (Logerwell and/or Rand) Google Link HERE	:30	10:45
Plan for today	:15	11:00
Break (start at 10:30)	:15	11:15
Finalize conceptual models, key linkages, and references	1:00	12:15
Lunch (12:30-14:00)	1:45	14:00
Open journaling or breakout groups to start drafting Final Report/Journal paper • Identify key linkages for the Ecological model (all) • Calibrated confidence language (Kirstin) • Visualizations for simplified models • Identify gaps (all) • Examples of strong partnerships (Sarah)	3:00	17:00
Wrap up	:30	17:30

WG 44 Endnote 3

Integrated Ecosystem Assessment of the Northern Bering Sea – Chukchi Sea (NBS-CS) (WG 44)

2022-2023
WORK PLAN
2023-02-10 REVISION

1. Determine approach and methodology for conducting an IEA in the Northern Bering – Chukchi Sea LME. Develop conceptual model(s).
   a. Activities
      i. Identify participants in and beneficiaries of IEA activities and products ii. Identify goals for the regional IEA
      iii. April 2023 Intersessional workshop (virtual). Open journaling to outline PICES Press Article
      iv. Individual WG members draft section(s) of Article
      v. October PICES 2023 meeting: Report on draft of PICES Press Article on conceptual model process and products. Brainstorming contributions to NPRB NBS IERP call for proposals.

   b. Deliverable(s):
      i. PICES Press Article (and journal article?). Fall 2024
      ii. Contribution to NPRB NBS call. TBD (depending on NPRB deadlines)

   c. WG member leads: Moss, Logerwell, Wise

2. Including multiple ways of knowing the ecosystem
   a. Activities
      i. Indigenous Conceptual Model workshop (September 2022)
      ii. PICES 2023 workshop **-** Indigenous and community-led approaches to support climate change adaptation and ecosystem resilience in the North Pacific and Arctic (W9)

   b. Deliverable(s) and target dates:
      i. Drafted Elements of Indigenous Conceptual Model (October 2022)
      ii. Final Elements of Indigenous Conceptual Model (Fall 2023)
      iii. PICES 2023 workshop plans (Spring Fall 2023)

   c. WG member leads: Wise, Daniel, Huntington, Johnson

3. Provide guidance document(s) for future WGs (PICES, ICES, PAME, etc.) to create an IEA product for the NBS-CS. Fall 2024

WG 44 Endnote 4

WG 44 REVISED Terms of Reference

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.

Appendix 5

PICES Press Article Related to WG 44

NORTH PACIFIC MARINE SCIENCE ORGANIZATION PICES PRESS Vol. 31, No. 1 | Winter 2023

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)

Sei-Ichi Saitoh, Hyoung-Chul Shin, Libby Logerwell and Yury Zuenko

Group photo from Central Arctic Ocean, Northern Bering and Chukchi Seas Integrated Ecosystem Assessment Workshop (W2)

The target Large Marine Ecosystems (LMEs)of WG39 and WG44 are the Central Arctic Ocean (CAO) and the Northern Bering Sea-Chukchi Sea (NBS-CS), that are geographically and dynamically connected. The CAO is in rapid transition, driven by North Pacific environmental changes in significant part, and has become accessible to a range of 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. An integrated ecosystem assessment (IEA) is a useful and pertinent approach in this circumstance, particularly with substantial science and policy challenges emerging in the Arctic, and this renders a coordinated IEA of the CAO and NBS-CS a priority task.

The main objectives for the workshop were to describe and discuss present ecosystem processes (sources, signals, significance) in the CAO and the NBS-CS based on achievements from existing and future research programs such as MOSAiC and SAS, numerous NBS-CS programs, and Indigenous Knowledge. In addition, it is pertinent and timely to develop future approaches for *The United Nations Decade of Ocean Science for Sustainable Development (UNDOS)* in these oceans, where science for resilience and sustainability is more important than anywhere else and

Vol. 31, No. 1 | Winter 2023 PICES PRESS NORTH PACIFIC MARINE SCIENCE ORGANIZATION

Central Arctic Ocean, Northern Bering and Chukchi Seas Integrated Ecosystem Assessment Workshop (W2) Participants

the relevant, regional UN program is yet to be properly initiated. There were about 30 attendees at this one-day in-person workshop held Sunday, September 25, 2022, from 09:00–18:00 in Busan, Korea. Two invited, 8 oral and one poster presentation were made at W2. PICES members from four countries and one ICES member from Norway contributed presentations. The workshop started with a brief introduction by **Prof. Sei-Ichi Saitoh**, outlining the background of CAO and NBS-CS issues and the workshop objectives.

In the morning session, **Dr. Lis Lindal Jørgensen**, (above) one of the Co-Chairs of WGICA, gave the first invited talk entitled *"Activities of the ICES-PICES-PAME working group on Integrated Ecosystem Assessment for the Central Arctic Ocean (WGICA)"*. She noted that the main results from the ongoing reporting of the main human activities (global sources, shipping, military and tourism), pressures (contaminants, garbage, noise, non-indigenous species (NIS), disturbance, ship traffic, etc.) and the work completed to describe the vulnerability of the ecosystem. **Dr. Ferdenant Mkrtchyan** gave a recorded talk entitled *"About remote monitoring of water surface and ice cover of the Arctic"*. He described the physical foundations of water and ice characteristics based on micro wave remote sensing data. **Dr. Dong-Gyun Han** then gave a presentation entitled *"Passive acoustic monitoring in the Arctic Ocean for Integrated Ecosystem Assessment"*. He collected underwater acoustic data using an autonomous passive acoustic recorder in the East Siberian Sea from August 2017 to August 2018. The correlations between temporal variability of sound pressure levels and marine environmental data such as sea ice concentration, extent, drifting speed, wind speed, and ocean current were determined. **Mr. Wuju Son** gave a talk entitled *"Vertical behavior of key copepod species subsequent to the midnight sun period in the East Siberian continental margin, Arctic Ocean"*. He presented the vertical distribution of the key copepod species (*Calanus glacialis, Calanus hyperboreus,* and *Metridia longa*) subsequent to the midnight sun period in the Arctic Ocean. The findings could provide insight into monitoring and assessing the variation of the zooplankton distributions in the rapidly- changing Arctic marine environment. **Dr. Irene D. Alabia** gave a talk entitled *"Arctic marine biodiversity and species co-occurrence patterns under recent climate"*. She pointed out that regional differences in the spatial patterns in species richness in the Arctic, despite the overall increasing trend in pan-Arctic during 2000-2019. Sea ice loss and rising temperatures have driven northward expansion of apex and mesopredators in major Arctic gateways. **Dr. Jee-Hoon Kim** gave a presentation entitled "Inter-annual changes of the mesozooplankton community structure in the Central Arctic Ocean (CAO) and Northern Bering and Chukchi Seas (NBS-CS) during summers of 2016-2020". He described mesozooplankton distribution in the Arctic (CAO, NBS, CS) and composition of zooplankton and total abundance related to the water mass distribution from multi-year observations in the NBS & CS and suggested that these variable patterns of mesozooplankton communities fluctuate latitudinally from south to north as warming progresses on a regional and bathymetric scale. This could be used to infer the future status of mesozooplankton communities in the study area.

NORTH PACIFIC MARINE SCIENCE ORGANIZATION PICES PRESS Vol. 31, No. 1 | Winter 2023

In the afternoon session, **Dr. Lisa B. Eisner** gave the second invited talk entitled *"Recent ecosystem research in the Chukchi and north Bering seas"*. She provided an overview of recent ecosystem research in the north Bering and eastern Chukchi seas. Ecosystem level projects include Arctic Integrated Ecosystem Studies (IES) phase 1 (2012 and 2013) and 2 (2017, 2019) in August-September, and Arctic Shelf Growth Advection Respiration and Deposition (ASGARD, 2017 and 2018) in June. She also introduced a recent NPRB-funded synthesis proposal to evaluate pelagic–benthic coupling that will use data from these projects and other surveys (e.g., Distributed Biological Observatory (DBO)) to model and predict the impact of a warming climate on pelagic and benthic ecosystems including trophic interactions and energy flow between these systems. **Dr. Kirill Kivva** gave a talk entitled *"Spatio-temporal variability of ice retreat in the Pacific Arctic"*. He investigated the spatiotemporal variability of the date of ice retreat (DOR) in the Bering Sea, the Chukchi Sea and the adjacent Arctic regions. He noted that the differences in sea ice retreat between regions are mostly associated with the wind forcing in the Bering Sea and variability of heat transport through the Bering Strait in the Chukchi Sea. **Dr. Kivva** then gave another talk entitled *"Distribution of water masses in the Chukchi Sea in August 2019 and their chemical characteristics"*. He used observation data from hydrographic surveys in the East Siberian Sea and found high temperature in Siberian coastal water (SCW) and differences in nutrient content and chemistry of different water masses. **Dr. Fujio Ohnishi**, a social scientist, gave a talk entitled *"The development of Japan's Arctic Policy and the citizens' awareness"*. He analyzed the interest of Japan's general public in relation to Arctic policy and emphasized the need to better disseminate the results from Arctic research to the general public.

In general discussion, **Dr. Hyoung Chul Shin** summarized the overall presentations and discussion at the workshop and noted:

1. The workshop has presented updates on present studies/research in the CAO. Furthermore, how best to use the UNDOS-Arctic initiatives will need to be included in future works. Existing/emerging gaps in knowledge will need to be continually identified to guide future research.

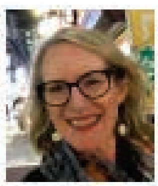
2. WG44 (NBS & CS) will continue to work on the following activities another year: pooling of existing datasets and comparative studies between Arctic gateways using such datasets and inclusion of community-based research in northern Canada.

Finally, he led the discussion on the proposal of a new EG advisory panel (AP-ARC), to advance the work of WGs 39 and 44 in the Arctic Ocean context, and to bring more experts to this one-stop EG for Arctic issues. This was agreeable to both working groups and supported by the workshop participants. GC later agreed to establish a new study group, SG-ARC for one year until PICES-2023. SG-ARC will consist both WG39 and WG44 members. Group photos were taken at the closure of the workshop, although the feature picture at the beginning of this report unfortunately does not include all of the workshop participants. The full list of participants is available on PICES website for each relevant Expert Group, listed under products, for workshops held during PICES-2022.

Vol. 31, No. 1 | Winter 2023 PICES PRESS NORTH PACIFIC MARINE SCIENCE ORGANIZATION

Dr. Sei-Ichi Saitoh (ssaitoh@arc.hokudai.ac.jp) is Research Professor of Arctic Research Center, Hokkaido University. He has over 30 years of experience working as a satellite and fisheries oceanographer, GIS specialist, and consultant on fisheries issues in the North Pacific Ocean and its adjacent seas. He also studied the impact of climate change and global warming on marine ecosystems in sub-Arctic and Arctic seas. Within PICES he has been a member of MONITOR T/C and Co-Chair of WG39. He was also one of sub project directors of the national flagship project, the Arctic Challenge for Sustainability (ArCS) supported by MEXT, Japan 2015-2019.

Dr. Hyoung Chul Shin (hcshin@kopri.re.kr), a biological oceanographer by training, participated in and coordinated numerous expeditions to the Antarctic and the Arctic. On top of Antarctic krill biology, his activities and interests include the management of marine living resources in polar waters. He has been serving on the Korean delegation to the negotiation and implementation of the Central Arctic Ocean Fisheries Agreement. He is also part of the Central Ocean Ecosystem assessment efforts by WGICA and PICES WG 39, while serving as the vice President and chief scientist of the Korea Polar Research Institute.



Dr. Libby Logerwell (libby.logerwell@noaa.gov) is a Research Fishery Biologist at the Alaska Fisheries Science Center of NOAA-Fisheries in Seattle, Washington. Her research focuses on oceanographic processes that influence the distribution and abundance of seabirds, ichthyoplankton, juvenile and adult fish and epibenthic megafauna. She is a PI on the North Pacific Research Board Arctic Integrated Ecosystem Research Project. She is a member of the PICES Fishery Science Committee and Co-Chair of the PICES/ICES WG44 on Integrated Ecosystem Assessment of the Northern Bering-Chukchi Sea.

Dr. Yury Zuenko (zuenko_yury@hotmail.com) is a physical oceanographer, currently the head of Fisheries Oceanography Lab. in the Russian Research Institute of Fisheries and Oceanography, its Pacific branch (TINRO) located in Vladivostok, Russia. His activities and interests include a wide spectrum of physical and biogeochemical processes in the Far-Eastern Seas and North-West Pacific, from downscaling of the global climate change to bioproductivity of estuaries and environmental impact on physiology and reproduction of particular commercial species. He is a permanent member of the PICES Physical Oceanography and Climate Committee and its CREAMS Advisory Panel, previously worked in the MODEL Task Team of CCCC and several working groups, and now is a Co-Chair of the PICES/ICES WG44 on Integrated Ecosystem Assessment of the Northern Bering-Chukchi Sea.