Statement for the 2018 Arctic Observing Summit

The need for collaborative, stakeholder-based Arctic observing networks

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Despite scientist claims and billions of dollars spent on environmental change research, there is little evidence of improved decision-making (Cash et al. 2003; Dilling and Lemos 2011; Lemos et al. 2012, cited in Ford et al. 2013; Wall et al. 2017). Coproduction, a collaborative method where stakeholders are involved in all phases of research, increases the likelihood of practitioner uptake by enhancing perceptions of saliency, credibility, and legitimacy (Cash et al. 2003). Stakeholder interaction to enhance usability is emerging in Arctic observing network (AON) programs with efforts to advance the AON dual role of scientific understanding and decision support (e.g. Eicken et al. 2011, 2016a, b; Lovecraft 2013, 2016; Brigham n.d.). Currently, science priorities dominate AON design (cf. SEARCH 2005; ADI 2012; Lee et al. 2015), but collaborative research to address stakeholder needs is emerging as a best practice to transform AON science and monitoring activities into usable information products (Pearce et al. 2009; Lovecraft et al. 2013; NRC 2014; Eicken et al. 2016a). However, effective stakeholder engagement is costly, and coproduction is potentially not a practical systematic approach (Sutherland et al. 2017). Given the importance and challenge of effective stakeholder engagement to achieve usability, the Arctic Observing Summit should identify best practices and evaluate the costs and benefits of collaborative approaches to support strategies to realize societal benefits (cf. IDA 2017).

Arctic system services, or ecosystem services (cf. MA 2005) relevant to the Arctic, is a useful construct put forward by AON researchers to identify observation parameters that are important to stakeholders at local and regional scales (Eicken et al. 2009, 2016a; ADI 2012). The necessity of the ecosystem services AON design approach to include stakeholders in the design process positions it as a methodological pathway to AON coproduction and usability. The ecosystem services approach opens opportunities for the AON research community to engage the myriad of existing and emerging stakeholder collaborations in the Arctic that identify observing priorities ranging from initiatives at the federal level such as the U.S. Committee on the Marine Transportation System Arctic Integrated Action Team to local communities, which are known to be particularly challenging to engage effectively (cf. Lee et al. 2015; Eicken et al. 2016a; Johnson et al. 2013, 2015). Stakeholder-based AON design also opens opportunities for collaborations with research communities that are advancing methods for effective stakeholder interaction for environmental information usability (e.g. Wall et al. 2017; Lathrop et al. 2017).

The AON decision support goals challenge current observation design approaches that emphasize science priorities. While the need for stakeholder-based AON design has been voiced by the AON research community (Eicken et al. 2009, 2016a; ADI 2012), knowledge about cost effectiveness of implementation is lacking. What we know from the usability literature is that stakeholders must be included in the research process for environmental information to influence decision outcomes, even if overall scientific credibility is diminished from the perspective of other stakeholders and researchers (Cash et al. 2003; Mitchell et al. 2006). In light of AON decision support goals including advancing relevant societal benefit areas (IDA 2017), the AON research community would benefit by identifying collaborative research best practices and evaluating associated costs and benefits with scaling them for integration into AON programs. Stakeholder-based AON cost-effectiveness themes to explore include:

a. *Enhancing stakeholder access to AON data and resources*. Often environmental observation data are used for a single purpose such as addressing a science question. Collaborating with stakeholders in the process of addressing science questions to also address decision support information needs would benefit society by promoting multiple uses of data created from AONs. Lee et al. (2015) explains how pooling of AON resources can occur at the tactical level in AON implementation where communities of practice emerge from mutual interest in observing Arctic system variables. Adapting existing AONs to also address stakeholder needs is one way that stakeholder access to AON resources can occur without changing core scientific questions that currently dominate AON design. Other determinants of access including data storage and management, metadata, software usability, and user capacity also need to be addressed in the context of designing AONs to realize societal benefit areas.

b. *Enhancing usability of AON information products*. While stakeholder engagement is costly, it is necessary to achieve decision support outcomes using AONs. What are the cost and benefits associated with engaging with existing "boundary organizations" such as Alaska's Landscape Conservation Cooperative? What are the costs and benefits associated with engaging existing stakeholder collaborations for proof-of-concept or sustained interaction? What are the best practices for engaging Arctic stakeholders while balancing saliency, credibility, and legitimacy of AON information products?

c. *Enhancing AON program effectiveness.* Evaluating the costs associated with enhancing stakeholder access to AON data and resources and information usability should be compared against the possibilities for demonstrated societal benefit outcomes that would justify sustaining AON programs.

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Vision and Mission of "IEEE in the North and South Poles"

Antarctica is the "continent of every continent," where representatives from each region on Earth perform continuous scientific and technical activities that benefit the future of the planet and its inhabitants.

The Arctic is a place where all continents that were once kept apart by a sea of ice are now connected through waters that global warming is rendering navigable. The persisting ice cover decline will allow increasing amounts maritime navigation.

Both Antarctica and the Arctic epitomize the concept of a truly global effort, the ideal meeting point of people, solutions, vision for the future of humanity. IEEE is the world's largest technical profession organization with more than 423,000 members in over 160 countries. Since IEEE is a truly global organization, seeking to unite technical communities, advanced concepts and disciplines across the globe for the benefit of humanity, IEEE is working to identify ways in which it can most productively contribute to the activities in a location that so closely mirrors its own mission.

The IEEE in the North and South Poles (INSP) ad hoc committee started its activities in 2017, and during its first year of existence it has already triggered and supported a number of activities that will continue/expand in 2018:

- InuCube: a Cubesat project led by the University of Manitoba to educate, raise awareness of the challenges of the Artic, and to perform some basic Earth Observations.
- The Young Professionals in Space (YPinSpace) bootcamp to train students and recent graduates in space techniques and technologies, with a focus on Earth Observation and in particular in cryospheric applications. After a successful first edition in Bangalore, India, in November 2017, the next edition will take place at the Universitat Politècnica de Catalunya in Barcelona, Spain in July 2018: https://www.ypinspace.com/young-professionals-in-space-in-barcelona/
- The IEEE GRSS Student Grand Challenge: a competition of 5 international teams of students to create an end-to-end drone-based Earth Observing system and mobile phone app with focus in cryospheric applications.
- The IEEE Dataport: an on-line, perpetually free-of charge repository of data sets up to 2TB to be used for research and other scientific studies: https://ieee-dataport.org/topic-tags/north-and-south-poles-0
- The IEEE Access Special Section: a dedicated special section entitled "Addressing Economic, Environmental and Humanitarian Challenges in the Polar Regions" in the new full open access IEEE journal, featuring a high impact factor (3.244 in 2016), is accepting submissions. This Special Section in IEEE Access welcomes contributions from a wide range of topics dealing with the emerging challenges in polar regions:

http://ieeeaccess.ieee.org/special-sections/addressing-economic-environmental-humanitarian-challenges-polar-regions/

The topics of interest include, but are not limited to: environmental changes experienced by the polar regions (cryosphere, land, oceans, and atmosphere); remote and in situ sensors, and their associated technologies; sensor networks for weather and climate modelling; development of working environments for feature extraction from imagery; convolutional neural networks in image feature extraction and analytics; telecommunication technologies; transportation techniques and technologies, including drones and other autonomous vehicles; ecological, security and health issues associated with an increased human presence in an isolated environment; economic exploitation of the polar regions, including fisheries and oil exploration; educational and outreach activities concerning the changes that polar regions are undergoing.

- The organization of the Antarctic and Southern Ocean Forum (ASOF) 2017. In 2018, ASOF 2018 is being organized as well as its North Hemisphere counterpart, the Artic and Northern Ocean Forum (ANOF) 2018 workshop, to gather scientists, engineers and decision makers with the following interests:

Autonomous Observing

- ROV/AUV/ASV technology
- Communications gateways e.g. surface vehicles
- Control system development
- Deep autonomy / under-ice navigation – gliders, Argo floats
- Atmospheric sampling from land and sea (autonomous balloons, Lidar, Cloud radar and atmospheric profilers), weather stations, moorings
- Intelligent sensing / sampling
- Autonomy in a polar environment.

Observation Technologies

- Atmospheric lidar, cloud radar and atmospheric profilers
- Miniaturization, automation and ruggedization of instrumentation, (multiple deployment of low cost samplers)
- Long-term instrument stability, self-calibration
- Problems of high latitude and long range operation
- Ice profiling instruments, englacial & sub-glacial instrument deployment, new drilling technology/methods
- Acoustics at high latitudes – navigation, data and tomography
- Advanced drifter technology,
- Airborne deployment of oceanographic instruments
- Mission risk assessment

Sustained measurements

- Oceanographic mooring technologies
- Remote sensing and satellite calibration
- Animal borne sensors – developments, data streams and methods

Biology and biomass

- Fisheries and mid-water acoustics
- Genomics sampling and sensing

Data Science

- Data Storage – long-term monitoring, swappable data
- Data Transfer – real time monitoring; event triggering
- Data processing for new under-ice data sets
- Instrument communications and tracking

Last, but not least, IEEE seeks its participation in other international fora such as the Artic Council, where it can contribute with its technical expertise, or in the Artic University. To graphically illustrate how each IEEE Society can contribute to address the “Artic Challenges” within the scope of each Society/Council, a series of short videos (3-5 min) will be created in English and Spanish.

Arctic Observing Summit (AOS)

Statement: Circumpolar Biodiversity Monitoring Programme (CBMP)

Relevant to all themes: but especially for themes 2 and 3

Facilitating more rapid detection, communication, and response to the significant biodiversity-related trends and pressures affecting the circumpolar world.

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The overall objective of this statement is to inform the Arctic Observing Summit, Davos 2018, about the Circumpolar Biodiversity Monitoring Programme, as part of the discussion related to pan-Arctic observing and reporting systems.

The The Conservation of Arctic Flora and Fauna (CAFF) is the biodiversity working group of the Arctic Council and has a mandate is to address the conservation of Arctic biodiversity, and to communicate its findings to the governments and residents of the Arctic, helping to promote practices which ensure the sustainability of the Arctic's living resources. It does so through various monitoring, assessment and expert group activities. CAFF's projects provide data for informed decision making to resolve challenges arising from strategies to conserve the natural environment while permitting regional growth. This work is based on cooperation among all Arctic countries, indigenous organizations, international conventions and organizations.

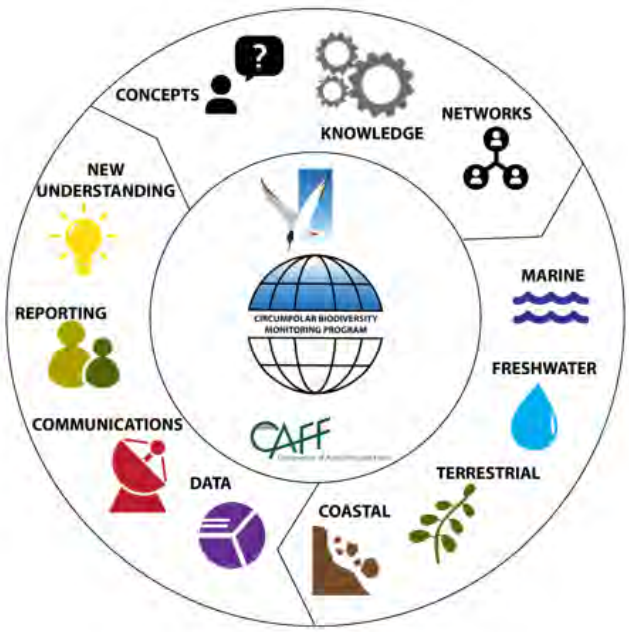
As the Arctic continues to experience intense and accelerating change, with climate change at the forefront, it has become increasingly important to effectively and sustainably manage Arctic ecosystems. CAFF operates at the interface between science and policy and as such is positioned to develop common responses on issues of importance. In order to deliver informed policy advice to decision-makers, it is important that accurate, credible and timely information on current and predicted changes in the Arctic's ecosystems are made available. To efficiently address this information CAFF created the Circumpolar Biodiversity Monitoring Program (CBMP – www.cbmp.is [1]), an international network of scientists, government agencies, indigenous organizations and local

[1] The CBMP is a response to Arctic Council recommendations that have called for improved and better coordinated, long-term Arctic biodiversity monitoring e.g. from the Arctic Climate Impact Assessment (ACIA) and reinforced by the recommendations of the Arctic Biodiversity Assessment and other Arctic Council projects. The development and

resource users working together to enhance Arctic biodiversity monitoring to improve detection, understanding, prediction and reporting of important changes facing Arctic biodiversity.

The CBMP is collecting information from the existing extensive and varied monitoring efforts across the Arctic to provide more robust and timely information on what is happening in the Arctic environment. Harmonizing and integrating efforts to monitor the Arctic's living resources will allow decision makers to develop responses to challenges facing the Arctic environment in a more efficient and effective manner. The CBMP is currently guided by the CBMP Strategic Plan: 2018 – 2021. This is the third in a series of CBMP Strategic Plans and is intended to explain the overarching goals of the CBMP for the period 2018-2021, and to outline actions to deliver on those goals.

The CBMP coordinates marine, freshwater, terrestrial and coastal monitoring activities while establishing international linkages to global biodiversity initiatives including the UN Convention on Biological Diversity (CBD) and the Group on Earth Observations Biodiversity Observation Network (GEOBON). The CBMP emphasizes data management (through the Arctic Biodiversity Data Service), capacity building, reporting, coordination and integration of Arctic monitoring, and communications, education and outreach.



The CBMP takes an adaptive Integrated Ecosystem Approach to monitoring and data generation. This figure illustrates how management questions, conceptual ecosystem models, and existing monitoring networks guide the four CBMP Steering Groups (marine, freshwater, terrestrial, and coastal) in their development. Monitoring outputs (data) feed into the assessment and decision-making processes (data, communication and reporting). The findings feed back into the monitoring program.

Experts are currently developing and implementing coordinated and integrated Arctic Biodiversity

implementation of the CBMP has been further highlighted as an Arctic Council priority in the Kiruna (2013), Tromso (2009), Salekhard (2006), Reykjavik (2004), Inari (2002), Barrow (2000) and Iqaluit (1998) Declarations.

Monitoring Plans to help guide circumpolar monitoring efforts. Results will be channelled into effective conservation, mitigation and adaptation policies. These plans represent the Arctic's major ecosystems 1) marine; 2) freshwater; 3) terrestrial; and 4) coastal. The Coastal Plan is currently under development while the other Plans are being implemented. These umbrella Plans work with existing monitoring capacity to facilitate improved and cost-effective monitoring through enhanced integration and coordination.

Implementation activities include the collection and aggregation of existing monitoring information and capacity across the Arctic, identifying opportunities to fill gaps in monitoring, and working towards the publication of the State of the Arctic Marine, Freshwater and Terrestrial Biodiversity Reports. The first State of the Arctic Biodiversity Report, the marine report, was released and published in 2017. This will be followed by a freshwater and terrestrial report in 2019.

The *State of the Arctic Marine Biodiversity Report* identifies trends in key marine species and points to important gaps in biodiversity monitoring efforts across key ecosystem components in: sea ice biota, plankton, benthos, marine fishes, seabirds and marine mammals. Changes in these species likely indicate changes in the overall marine environment. Over 60 international experts in CAFF's Circumpolar Biodiversity Monitoring Program (CBMP) collected and sifted through existing data on key elements of the Arctic marine species and provided advice to improve Arctic biodiversity monitoring activities.

Work also continues to make data available through the Arctic Biodiversity Data Service (ABDS), an online, interoperable data management system that serves as a focal point dynamic source for up-to-date circumpolar Arctic biodiversity information and emerging trends. Satellite data is underutilized in the Arctic. There is a desire among the various science disciplines to use remote sensing to support ongoing biodiversity assessments and monitoring. In addition, remote sensing data also has value for site-specific and regional applications. CAFF, through the CBMP is creating a framework to harness remote sensing potential for use in Arctic biodiversity monitoring and assessment activities, and to produce a series of satellite-based remote sensing products focussing on the circumpolar Arctic. MODIS satellite products of relevance to Arctic processes are being converted to a more Arctic-friendly projection, facilitating a top-of-the-world analysis perspective. Satellite products are being developed for use by different stakeholder groups and products will be organized by terrestrial, marine, coastal, and freshwater disciplines. Landsat images will be used to generate additional remote sensing products at a finer scale.

It is important that monitoring programs develop the most effective reporting strategies if they are to inform decision making. To facilitate effective and consistent reporting, the CBMP has chosen a suite of indices and indicators that provide a comprehensive picture of the state of Arctic biodiversity – from species to habitats to ecosystem processes to ecological services. These indices and indicators are developed in a hierarchical manner, allowing users to drill down into the data from the higher-order indices to more detailed indicators. Indicators available or under development include Arctic Species Trend index; Arctic Migratory Bird index, Protected Areas index, Land cover change, and Linguistic Diversity.

Enhanced coordination of Arctic biodiversity monitoring via the CBMP is yielding an improved ability to detect important trends, link these trends to their underlying causes, predict future trends and scenarios for Arctic biodiversity, and thereby provide more timely and credible information to support responsible decision-making at multiple scales (local, regional, national and global). It is anticipated that this increased coordination will result in reduced costs, compared to the cost of multiple, uncoordinated approaches that stop at regional or national boundaries. While most Arctic biodiversity monitoring networks are, and will remain, national or sub-national in scope, there is immeasurable value in establishing circumpolar connections among monitoring networks. In addition, this coordination is resulting in more rapid uptake of new technologies and methodologies through increased dialogue.

The CBMP has been endorsed by the Arctic Council and the UN Convention on Biological Diversity. It is the biodiversity component of the Sustaining Arctic Observing Networks (SAON) and the official Arctic Biodiversity Observation Network of the Group on Earth Observations Biodiversity Observation Network (GEOBON).

Information from the efforts of the CBMP will flow through national processes as well as through appropriate international venues such as the Arctic Council and the UN Convention on Biological Diversity. This not only provides the best information to the most relevant policy actors, but also creates cost efficiencies in reporting activities. The continued implementation of CBMP comes at a critical time. The recent Conference of the Parties to the Convention on Biological Diversity (CBD) resulted in a strong recognition of the importance of Arctic biodiversity and of the Arctic Council work.

For more information please visit: www.cbmp.is or contact caff@caff.is.

Recent updates and reports:

- CBMP Strategic Plan: 2018 – 2021
- *State of the Arctic Marine Biodiversity Report*
- Arctic Freshwater Biodiversity Monitoring Plan
- Arctic Terrestrial Biodiversity Monitoring Plan
- Arctic Marine Biodiversity Monitoring Plan
- Arctic Coastal Biodiversity Monitoring Background Paper
- Arctic Biodiversity Data Service (ABDS)
- Arctic Protected Areas Indicator Report
- Linguistic Diversity

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Toward a Pan-Arctic Observing System: Analysis of Current Observational Gaps and Issues

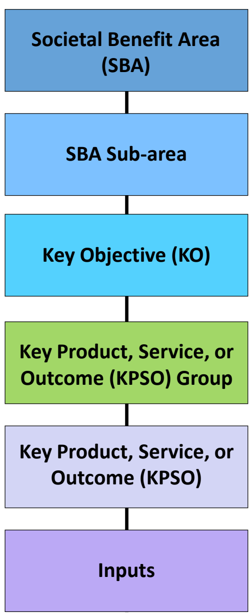
While many countries currently observe the Arctic's physical, biological, and human systems, gaps in observational coverage remain. In order to address these gaps globally and systematically, it is necessary to first understand what observations currently being used, by whom, and for what purposes. The 2017 *International Arctic Observations Assessment Framework* presents a common structure for understanding the purposes to which Arctic observations are applied.[1] The *Framework* was developed by an international group of Arctic subject matter experts (SMEs) and serves as a benchmark that can be used by nations to assess their own reliance on Earth observations on the achievement of Arctic objectives. It presents 12 Arctic societal benefit areas (SBA), 41 SBA sub-areas, and 163 key objectives to which Arctic observations contribute. This statement lays out a method to identify the observational gaps that would need to be addressed in order to achieve systematic observational coverage in the Arctic, also known as a Pan-Arctic Observing System.

In order to determine observational gaps, three pieces of information are needed: (1) objectives that articulate why Earth observations in the Arctic are needed, (2) information about how different observations contribute to each objective, and (3) information about how well these objectives are currently being achieved. By examining the extent to which each objective is met, it will be possible to determine when additional observations are needed to fully meet the objective. The *Framework* provides the first piece of information (the objectives), and because each objective was developed by an international group of SMEs with the intention of being broadly applicable across national boundaries, they are well-suited for an international gap analysis. An objective may not be achieved due to a lack of observations, issues with existing observations, or issues associated with the production, management, or dissemination of observations or derived products. Identifying which of these issues should be addressed is the key to improving the ability to meet Arctic objectives and provide societal benefits.

Given the set of Arctic objectives, the next steps are to gather the additional two pieces of information identified above: information about the contribution of observations to achieving each objective and how well each objective is currently being met. We discuss how a method used by the United States to assess the federal reliance on Earth observation assets can be adapted to gather this information. The United States Government conducts Earth Observation Assessments (EOAs) to understand the impact of individual Earth observation systems, sensors, networks, surveys, datasets, and sampling programs on meeting its key civil objectives. The process relies on a value tree analysis, which defines the ways that

[1] IDA Science and Technology Policy Institute and Sustaining Arctic Observing Networks. 2017. International Arctic Observations Assessment Framework. IDA Science and Technology Policy Institute, Washington, DC, U.S.A., and Sustaining Arctic Observing Networks, Oslo, Norway, 73 pp.

Earth observations are used to achieve societal benefits, identifies specific products and services that are currently used to meet the objectives, and then evaluates the contribution of individual Earth observations to developing that product or service. The value tree used in the EOA consists of six levels (Figure 1). Societal Benefit Areas (SBAs), which form the top level, are environmental, economic, and social domains in which public services and research provide societal benefit. SBA sub-areas are natural thematic subdivisions within each SBA. Key objectives (KOs) are activities that support national goals and can be clearly linked to Earth-observing systems, data, or products. Key products, services, and research outcomes (KPSOs) are the data, information, and analytical products or research findings that directly support progress toward meeting KOs. The inputs are the Earth observations needed to produce KPSOs. KPSOs that belong to the same category or class of information products or research area are organized into KPSO groups.



Societal Benefit Area (SBA): Environmental, economic, and social domains in which public services and research provide societal benefit.

SBA Sub-area: The major thematic component within an SBA; natural subdivision of the parent SBA

Key Objective (KO): An activity within a sub-area that is clearly supported by and can be linked to Earth-observing systems, data, and products

Key Product, Service, or Outcome (KPSO) Group: A group of KPSOs that belong to the same category or class of information products or research area

Key Product, Service, or Outcome (KPSO): A primary or important information product, service, or outcome required to make progress toward or meet a KO

Inputs: The data, information, and Earth-observing systems needed to produce KPSOs

Figure 1. EOA 2016 Value Tree Levels

The *Framework* establishes the top three levels of an international Arctic value tree. Nations and institutions can assess the extent to which these objectives are being achieved within their own context by determining the KPSO groups, KPSOs, and inputs that are used to achieve these objectives. Once this is accomplished, national or institutional experts can determine the extent to which the objectives are being achieved currently, and if any shortcomings are due to the insufficient production or provision of KPSOs or issues with underlying observation inputs (such as geographic coverage, spatial resolution, temporal frequency, etc.) or due to another limiting process such as data management. If multiple nations and institutions complete this process, the results can be shared and experts from each can collectively decide whether there is a gap in global or regional observational coverage or if there are other deficiencies that need to be addressed. This effort could be used to inform international, national, and institutional policies to address these gaps, maintain the continuity of observations, or share observational data and information products.

In order to reach the stage where collective inter-comparison among nations and institutions is possible, it is necessary for these groups to rigorously develop the bottom levels of the value tree (KPSO groups to inputs). Developing the KPSO Group and KPSO levels of the value tree allows for preliminary inter-comparison to understand if there are products or services that currently exist for each objective. Doing further elicitations with the SMEs that produce each identified KPSO will allow for a full tracing from an individual product to the observations relied upon to develop it. As an example of how a country or institution might build out further levels of the value tree using the Arctic *Framework*, one of the objectives within the “Weather Effects on Economic Productivity” sub-area of the “Weather and Climate SBA” is “Provide sector-specific weather predictions for economic productivity.” Each nation or institution could determine KPSO groups (perhaps one KPSO group per relevant sector, such as fishing, transportation, energy production, tourism, etc.) and the constituent KPSOs representing sector-specific weather predictions. An example of a KPSO Group could be “Weather predictions for transportation,” and example KPSO could include the “Special Marine Warning: Anchorage” produced by the U.S. National Weather Service or the “Weather forecast for shipping” produced by the Finish Meteorological Institute.

In the case of the EOA process, once the list of KPSOs is generated, elicitations with SMEs who produce the KPSO are conducted to generate a list of inputs needed. In the case of the sector-specific forecasts, SMEs would be asked about the inputs needed to produce each forecast. The list of inputs would likely include satellite observations, airborne meteorological observations, radar network information, and coastal buoy array data, among others, as well as modeled output. Because the output of a model may rely on additional observational inputs, to capture the full range of inputs contributing to the forecast, additional elicitations would need to be conducted with the SMEs that manage the identified models to generate a list of the inputs they rely on. Once each input to the forecast is traced down to all the observational inputs, the final list should be complete. At each elicitation step, information on the SME’s satisfaction with each of the underlying observational inputs should be collected based on a standardized scale (the scale that the U.S. uses in its EOA process is displayed below). This should be repeated for each KPSO. Together these two pieces, the list of inputs and satisfaction, provide information about the reliance on individual observational inputs as well as any issues with those observations in the context of KPSO production.

Performance / Satisfaction Scale		
100	Ideal	Meets all requirements and exceeds some
90	Fully Satisfied	Meets all requirements
80	Good	Meets all major requirements with minor limitations
70		
60	Fair	Meets most major requirements, with significant limitations
50		
40	Poor	Fails to meet many major requirements, but provides some value
30		
20	Very Poor	Fails to meet most major requirements, but provides minor value
10		
1	No Capability	Provides no value

Figure 2. Standardized Satisfaction Scale

To determine whether additional observations are needed to meet the objectives (as opposed to addressing issues with existing observations or KPSO provision), additional information should be gathered from experts with scientific, operational, and policy expertise who are able to address the application of KPSOs to the objective(s) in question. These experts should be asked to determine: (1) the extent to which the set of KPSOs listed, as a whole, are sufficient for achieving the objective, and (2) the adequacy of individual KPSO for meeting the objective. These experts should answer the following questions:

- Do KPSOs exist that help meet the objective in question?
- If not, is this due to a lack of observations or inadequacies in the production, management, or dissemination of existing observations?
- If not, is this due to the inadequacy of the KPSO(s) in meeting the objective?

This information, in tandem with the standardized KPSO SME satisfaction information can provide a robust understanding of observational gaps, as well inadequacies associated with existing KPSOs or their underlying observations.

By developing the value tree through each key objective, KPSO Group, and KPSO down to the underlying Earth observation inputs, and determining satisfaction and adequacy, it will be possible to identify where additional observations, modifications to existing observations, as well as improvements to products and services, are needed. These analyses can be combined across national and institutional boundaries to identify how the global Arctic community can work together to strengthen the existing Arctic observing network and collaboratively address gaps, continuity issues, and emerging challenges.

Scenarios of strategic investments in coordinated observing of Pacific walrus sea ice habitat

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Monitoring reductions in Arctic sea ice habitat plays a key role in improving understanding of the impacts of future habitat change on Arctic species populations. In the U.S., legislation such as the Endangered Species Act (ESA) provides support for conserving critical habitat for listed species, potentially providing an influx of additional research dollars to support monitoring key habitat. Arctic marine mammal species recently considered for listing under the ESA include the polar bear, ringed and bearded seals, and the Pacific walrus. In each case the listing determination was further subjected to additional litigation as a result of challenges to the initial listing decision. Arguably, the cost of litigation and delayed implementation of species habitat research further reduces opportunities to establish a robust sea ice habitat observing program, which can subsequently lead to more challenging species management in the future. This short statement explores two scenarios of sea ice habitat observing efforts for the Pacific walrus (*Odobenus rosmarus divergens*) to examine the long-term cost and benefits of a sustained, coordinated sea ice habitat monitoring program that is shared between the U.S. and Russia. The value of the approach used is not in identifying the exact costs of such an observing program (the dollar values used in the model assumptions are intended to be more illustrative than absolute), but rather, the approach demonstrates at a high level that early, coordinated, sustainable funding yields a more useful decision-making product on critical sea ice habitat.

Model methodology: A simplified walrus population model was developed to simulate the potential rate of walrus population decline related to anticipated declines in sea ice habitat. Given the high levels of uncertainty in quantifying current walrus population size, the model was used to identify the approximate time period when a 50% drop in population size was detected, after which it was assumed that ESA listing status would no longer be challenged, and the ESA-listed status would provide much-needed additional funding for sea ice habitat research. Two scenarios of funding coordination were investigated for developing an ice-habitat observing program: 1) **Non-coordinated** funding for observations between U.S. and Russia, but with more sustained funding in the U.S. once the Pacific walrus population drops by 50%; 2) **Coordinated** and sustained funding between the U.S. and Russia once the Pacific walrus population dropped by 50%, and occasional significant investments in observing the marginal ice zone before the walrus population shows significant declines.

Additional assumptions in the scenarios include: 1) during non-coordinated funding periods there was a 30% chance of a research project being funded in any given year that could inform sea ice habitat research; 2) in the event of sustained funding over consecutive years, the sustained annual funding would allow some expansion of the observing program, given that previous year's investments would continue to function for an additional 1 year after initial deployment; 3) a percentage of the overall potential sea ice habitat (including nearshore sea ice and pack ice) could be reasonably monitored at a fixed dollar value that was arbitrarily set, but well within the range of U.S. spending for listed marine mammal species (Gerber 2016), and shared equally between the U.S. and Russia (i.e. 50% potential habitat in Russia, 50% potential habitat in the U.S.); the cost of observing a given proportion of potential sea ice habitat remained fixed at the cost in 2017 dollars; 4) given that few Pacific walruses are observed east of Utqiaġvik, we assumed that the Canadian nearshore sea ice would remain negligible walrus habitat.

Results. The cumulative cost of a coordinated, sustained observing program remained higher than the scenario of the non-coordinated observing program through the year 2115, although the difference in cumulative cost shrinks over time (Fig. 1A). The coordinated, sustained funding model showed less fluctuations in anticipated funding at 5-year intervals, particularly after 2056 when the significant walrus population decline was simulated. As a result, the maximum annual cost beyond 2056 could remain substantially lower than the total annual cost in the non-coordinated model (Fig. 1B). The anticipated proportion of potential walrus habitat monitored could be maintained around 80% (fluctuating annually between 70-90%) once sustained, coordinated funding was implemented in 2056 in the coordinated scenario. In the non-coordinated scenario, the proportion of habitat monitored fluctuated between 47% and 85%, with a 10-year average of less than 70% of habitat monitored each year.

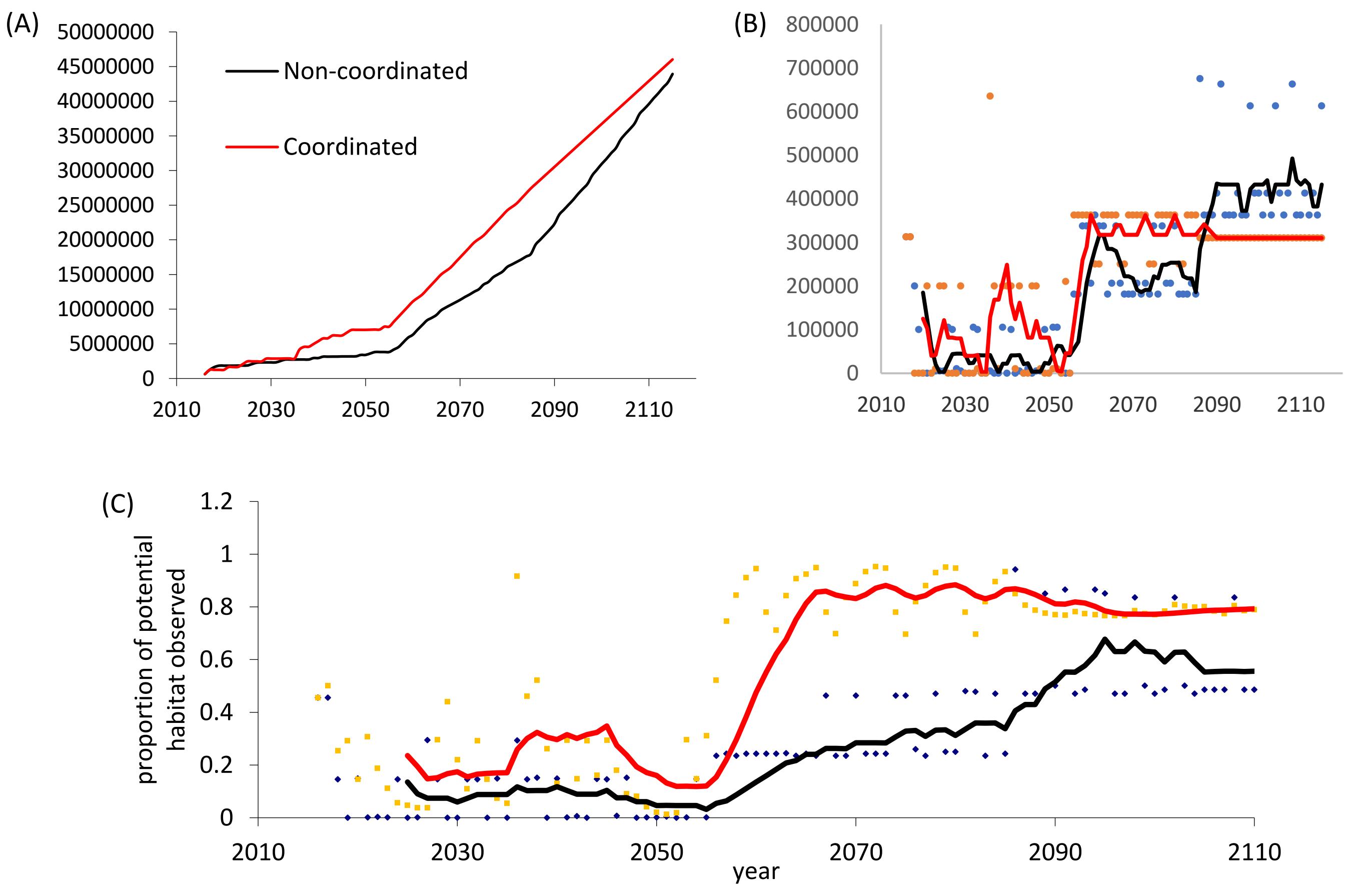

Figure 1. A) Cumulative cost of observing potential walrus sea ice habitat by scenario: non-coordinated (black) and coordinated (red); B) Annual cost of observing effort with 5-year average trendline; C) proportion of potential ice habitat covered by observing program with 10-year average trendline. All dollar amounts shown as 2017 dollars.

Conclusions: The scenarios present possible long-term outcomes of potential costs of a sustained observing program to inform serve management needs for the Pacific walrus. The coordinated, sustained funding scenario shows substantial improvement in the proportion of potential habitat monitored over time (~ 80%), and this could be achieved with more modest annual investments, whereas the non-coordinated scenario improved proportion of habitat monitored only during years when there was an influx of additional funding. Policies for coordinated sustained funding internationally is key to management of migratory Arctic species, and ideally such efforts should not only be triggered by species protections that occur after significant population declines as was the case in the scenarios presented here.

References

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Statement from the Partnership for Observation of the Global Oceans (POGO) on the need for and challenges facing sustained Arctic observations and their international coordination

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The Partnership for Observation of the Global Oceans (POGO) was founded in 1999 by directors of oceanographic institutions around the world as a forum to promote and advance the observation of the global ocean. POGO's membership includes most of the world's leading ocean science and technology institutions, whose expertise, experience and infrastructure provide the unique and long term capability to design, build, operate and innovate the global ocean observing system.

POGO's vision is to have by 2030, world-wide cooperation for a sustainable, state-of-the-art global ocean observing system that serves the needs of science and society. POGO-s mission is to:

1. Lead innovation and development of the crucial components of the ocean observing system.
2. Identify and contribute to the development of the key skills, capabilities and capacities needed to achieve the vision.
3. Work with governments, foundations and industry, to articulate the benefits to society and required funding to build and sustain the system.

Since 2016, POGO has been focussing at its annual meetings on the challenges (scientific, political and societal) facing sustained Arctic observations. The first workshop highlighted the degree of fragmentation in Arctic observations, caused by logistical and political problems, which are further complicated by the need to consider and work with the communities living in the Arctic. As a result, there is a lack of long-term observational data and, even where historical data sets exist, they are not easily accessible.

POGO members recognised the uniqueness of the Arctic in terms of its current geopolitical position (and, for example, the ongoing United Nations Convention on the Law of the Sea (UNCLOS) process) and the rapidity of change occurring there, as well as the relatively poor coverage of monitoring and observational data collected in the Arctic, due to logistical and transnational challenges to circumpolar monitoring activities, and the need for international coordination of observational efforts in the Arctic Ocean.

Organizations such as the International Arctic Science Committee (IASC) are working on improving coordination and also re-establishing monitoring programmes in the Arctic. It was highlighted that POGO has a role to play in this process but needs to liaise with organisations and programmes already active in the region to ensure that activities are complementary. POGO has strong connections to many other international organisations (including the Intergovernmental Oceanographic Commission and its Global Ocean Observing System (GOOS), and the Group on Earth Observations, within which POGO plays a lead role in the "Oceans and Society: Blue Planet" Initiative). POGO can therefore make a contribution towards enhancing communication and coordination among organisations and networks operating in the Arctic. Some first steps have been made through the participation of IASC and Sustaining Arctic Observing Networks (SAON) in the

2018 POGO Annual Meeting, initiating a dialogue that all parties are keen to pursue. The discussions also highlighted the need for an “Arctic GOOS”, which is currently lacking from the existing set of GOOS Regional Alliances.

In summary, POGO is keen to support ongoing Arctic efforts, such as the biennial Arctic Observing Summit (AOS), as well as their integration in global scale observing efforts (GOOS and GEOSS), in seeking to create a platform for coordination of monitoring and data collection.

The ocean is vital to the functioning of the whole Earth system, including life on Earth, and it is undergoing unprecedented and rapid change, most strikingly in the Arctic. The ocean plays a central role in shaping the Earth's climate and its variability through its fluid motions, its high heat capacity, and its ecosystems. Accordingly, it is vital to monitor and understand changes in the ocean, particularly in the polar regions, and their effects on weather and climate, and to improve the precision of climate models. Therefore, continuous, globally distributed ocean observations are essential to the scientific understanding of the changes underway, not least with the prospect of very rapid alterations of the system. Without a networked system of ocean observations, mitigation and adaptation strategies ensuring a sustainable human ocean future can be considered next to impossible.

By enabling a network of high quality, systematic, continuous global scale observations, we would acquire essential knowledge of the ocean's state and rates of change and variability. Such knowledge is needed to underpin:

- predictions and informed **responses to climate change and variability**, including major consequences such as sea level rise and changing weather patterns, IPCC 2013;

- the urgent demand for robust **ocean health and risk assessments**, and **data and information products**, on local, regional and global scales to support ecosystem based management, which is vital to sustaining the ocean's productive capacity especially in support of global food security through sustainable fisheries;

- the world's "blue economy" based on sustainable use of marine resources where, wisely managed, there are considerable opportunities not only for the world's advanced economies but also for sustainable development as recognized by the **United Nations Sustainable Development Goal (SDG) 14** to “conserve and sustainably use the oceans, seas and marine resources” as well as by other related SDGs. Such a future cannot be achieved without an improved knowledge of the environmental status of the oceans, which hinges on sustained, global ocean observations.

The challenge of building a sustained global ocean observing system is considerable. The concept is not new, and the building of the observational fundament for the oceans has been underway through international scientific and intergovernmental cooperation since the 1990s. However, the progress to completion of a sustained global ocean observation network is seriously encumbered by the lack of vital *in situ* measurements, especially in remote regions and under the ice-cover, as in the case of the Arctic Ocean,. It is now accepted that measurements need to span not only physical parameters but also biogeochemical, biological and ecosystem domains. The dearth of biological and biogeochemical measurements (carbon, acidity, biodiversity) for oceans, in general, and especially in the ice covered oceans, combined with the lack of high quality maps of the seafloor, currently make management of the oceans difficult.

Working with the Scientific Committee on Oceanic Research (SCOR) and the Scientific Committee on Antarctic Research (SCAR), POGO supported the establishment of the Southern Ocean Observing System (SOOS) in 2011. This has been very successful in bringing together the Southern Ocean observing community to work collectively to facilitate the collection and delivery of essential observations on dynamics and change of Southern Ocean systems to all international stakeholders (researchers, governments, industries), through design, advocacy and implementation of cost-effective observing and data delivery systems. Although there are additional challenges facing international coordination of Arctic observations, there are many lessons to be learnt from the experience of SOOS.