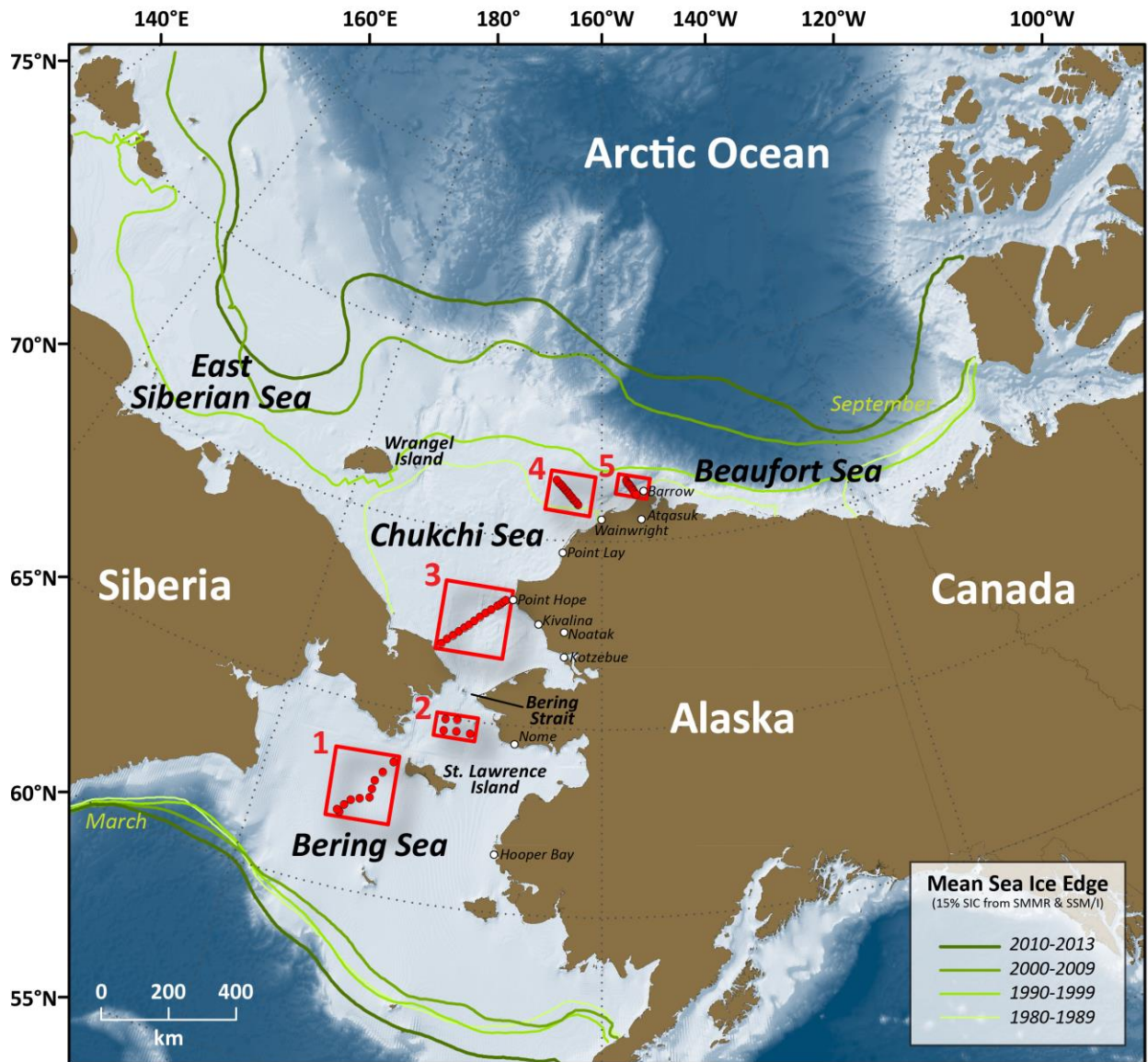


DISTRIBUTED BIOLOGICAL OBSERVATORY: IMPLEMENTATION PLAN, 2015-2024

Prepared by the IARPC DBO Collaboration Team

MAY 2016



Original DBO Regions

DISTRIBUTED BIOLOGICAL OBSERVATORY: Implementation Plan, 2015-2024**CONTENTS**

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Introduction

In 2009, in response to dramatic loss of summer sea ice and other physical changes influencing biological communities, a Distributed Biological Observatory (DBO) was proposed as a change detection array to measure *biological responses* to physical variability along a latitudinal gradient extending from the northern Bering Sea to the Beaufort Sea in the Pacific Arctic sector (Grebmeier et al. 2010). By design, DBO sampling was focused on five regions of demonstrated high productivity, biodiversity and rates of change (Fig. 1). The DBO concept was vetted at numerous scientific meetings and has been included in various US arctic research planning documents, including the National Oceanographic and Atmospheric Administration (NOAA) Arctic Strategic Plan, the United States Geological Survey (USGS) 'Science Needs' Report, the Bureau of Ocean Energy Management (BOEM) Alaska Region Research Plan, the Interagency Arctic Research Policy Committee (IARPC) 5-Year Research Plan, the National Ocean Policy Strategic Plan, and the National Strategy for the Arctic Region (NSAR)¹.

In 2010, a pilot DBO program was initiated and focused on developing standardized sampling in regions 3 and 5 (Fig. 1). International participation was coordinated by the Pacific Arctic Group (<http://pag.arcticportal.org/>), with US national participation facilitated by the NOAA (<http://www.arctic.noaa.gov/dbo/>). In 2012, the National Science Foundation/Arctic Observing Network (NSF/AON) program awarded a 5-year research grant to a collaborative team from the University of Maryland Center for Environmental Science (UMCES), Clark University and the Woods Hole Oceanographic Institution (WHOI) to provide support for standardized sampling in all five DBO regions. That same year, the IARPC developed a 5-year plan focused on seven research themes (<http://www.iarpcollaborations.org/plan/index.html>). The DBO Collaboration Team (CT) was formed under the first IARPC theme, *Sea Ice and Marine Ecosystems* and has been meeting via teleconference to complete ten milestones intended to guide the DBO from a pilot phase to the implementation of decadal-scale sampling; more details at: <http://www.iarpcollaborations.org/teams/Distributed-Biological-Observatory-milestones>.

This Draft Implementation Plan has been prepared in response to the only remaining milestone, specifically:

Milestone 3.1.3h: *Starting in 2015, DBO partners execute decadal-scale plans and prepare periodic assessments on the physical and ecological state of the Pacific Arctic marine environment using not only DBO data, but also data from BOEM, NPRB, AOOS and other sources. The decadal-scale implementation plan will update and augment DBO regions and transects to accommodate interest in sampling expansion and support full implementation of the DBO.*

¹ see **Web Links** to all research planning documents

Pilot Phase, 2010-2014

International Cruise Planning and Reporting

NOAA'S coordination and support by the Pacific Arctic Group (PAG) has been essential to the success of the DBO pilot phase. The PAG is a consortium of international institutions and individuals having a Pacific perspective on Arctic science (<http://pag.arcticportal.org/>). Organized under the aegis of the International Arctic Science Committee (IASC), the PAG has as its central mission to serve as a Pacific Arctic regional partnership to plan, coordinate, and collaborate on science activities of mutual interest. The PAG meets each spring and autumn and has taken a leadership role in coordinating international and industry-based contributions to DBO sampling, including the provision of ship time at no-cost (Fig. 2). These international contributions to DBO sampling have provided an unprecedented capability to track inter- and intra-annual variability in DBO regions. An annual listing of DBO cruises is developed each year at the PAG spring meeting and is available on both the PAG and NOAA DBO websites (<http://www.arctic.noaa.gov/dbo/cruise-data>). The results of each year's sampling are reported at the PAG autumn meeting and form the basis for science presentations given at various national and international forums.

US Interagency and Academic Partners

The DBO CT has benefitted from strong support and collaboration from a number of US agencies and academic partners (Fig. 3). An abbreviated listing of contributions is provided below, accompanied by web links to sources of additional information.

NSF AON: Conducts standardized sampling in all five DBO regions, 2012-2017 <http://arctic.cbl.umces.edu/>; also, contributions to DBO sampling from other AON-supported projects, various NSF-research platforms and the provision of a temporary physical oceanographic data portal at WHOI

see Lee Cooper presentation to the DBO CT
<http://www.iarpccollaborations.org/members/documents/2164>

UCAR: Provision of a DBO Data Agreement and Data Archive at the University Corporation for Atmospheric Research (UCAR), Earth Observing Laboratory (EOL)
https://www.eol.ucar.edu/field_projects/dbo

see Jim Moore presentation to the DBO CT
<http://www.iarpccollaborations.org/members/documents/1576> and

see Don Stott presentation to the DBO CT
<http://www.iarpccollaborations.org/members/events/2319>

NASA The development of DBO-focused satellite visualization products as part of the Cryosphere Science Research Portal
<http://neptune.gsfc.nasa.gov/csb/index.php?section=270>

see Joey Comiso presentation to the DBO CT

<http://www.iarpccollaborations.org/members/documents/1318>

NASA also contributed to DBO sampling during the 2010 ICESCAPES program

<http://www.nasa.gov/topics/earth/features/icescape2010.html>

NOAA OAR: Core US management support and coordination of international contributions to the DBO, via the PAG; and contributions to DBO sampling during the RUSALCA program - the only international DBO program to sample in the Russian Exclusive Economic Zone
<http://www.arctic.noaa.gov/rusalca/>

NMFS: Chair of the IARPC DBO CT, and contributions to DBO sampling during various multidisciplinary research programs in the northern Bering and Chukchi seas, e.g.

BASIS: http://www.afsc.noaa.gov/abl/mesa/mesa_basis.php,

Arctic Eis: <https://web.sfos.uaf.edu/wordpress/arcticeis/>

NOS: Opportunistic contributions to DBO sampling via NOAA ship *Fairweather* and coordination of the Arctic Marine Biodiversity Observing Network (AMBON; <http://ambon-us.org>). AMBON is co-supported by NOAA and BOEM through the National Oceanographic Partnership Program (NOPP); Shell Exploration and Production Company contributed to funding the first-year of the AMBON project (<http://ambon-us.org/field-work/>)

BOEM Alaska Environmental Studies Program: Contributions to DBO sampling, via support of research projects conducted by NOAA OAR and NMFS, in the Chukchi and Beaufort Seas (e.g. CHAOZ, ArcWest), and via awards to numerous academic partners in support of studies such as ANIMIDA, cANIMIDA, ANIMIDA III, COMIDA², Hanna Shoal, AMBON; see Dan Holiday presentation to the DBO CT
<http://www.iarpccollaborations.org/members/documents/1956>

for research project summaries, see DBO 2nd Data Workshop final report

http://www.arctic.noaa.gov/dbo/sites/default/files/atoms/files/2nd%20DBO%20data%20workshop%20report_Final-2.pdf

also see BOEM Alaska Region Environmental Studies page:

<http://www.boem.gov/About-BOEM/BOEM-Regions/Alaska-Region/Environment/Environmental-Studies/Index.aspx>

Future contributions to sampling in DBO Beaufort Sea regions are anticipated, via the Marine Arctic Ecosystem Study (MARES) program

see Guillermo Auad presentation to the DBO CT

<http://www.iarpccollaborations.org/members/documents/2533>

²See Acronyms List

AOOS Provision of web-based assets including mapping and visualization tools, and a password-protected DBO Data Workspace
<https://workspace.aos.org/group/23134/projects>

AOOS also provides linkage to the coordinated observing activities of IOOS, including both national (17 Fed agencies) and global (GOOS) outreach <http://www.aos.org/>

Partial support for a long-term biophysical mooring (UAF) in the NE Chukchi Sea, and potential for future support for moorings in the northern Bering and Beaufort seas as ‘anchors’ to DBO transect lines

NPRB Support for long-term biophysical mooring (UAF) in the northeast Chukchi Sea, and potential for future contributions to sampling in DBO Chukchi Sea regions, via a new integrated ecosystem research program in the Arctic, <http://www.nprb.org/arctic-program>

Key Products: Workshops, Data Agreement, Data Archive, Presentations and Papers

There have been numerous special sessions and presentations on the DBO at multiple science and policy venues since the inception of the pilot phase. While a full-listing goes beyond the scope of this document, some of the key meetings (including three DBO Data Workshops) are provided here: <http://www.arctic.noaa.gov/dbo/workshop-products>. Several significant products have resulted from these meetings, including:

- DBO Data Policy and Release Guidelines: http://dbo.eol.ucar.edu/data_policy-dbo.html
 - UCAR/EOL DBO Data Archive: https://www.eol.ucar.edu/field_projects/dbo
 - Satellite products for the DBO: <http://neptune.gsfc.nasa.gov/csb/index.php?section=270>
 - AOOS DBO Workspace <https://workspace.aos.org/group/23134/projects>
 - Presentations: AGU & OSM Meeting(s) and the annual Alaska Marine Science Symposium
 - Peer-reviewed publications: Nishino et al. (2016); Itoh et al. (2015); Grebmeier et al. (2015);
- NOTE – planning is underway for DBO Special Issue of *Deep Sea Research II*.

Implementation Phase, 2015-2024

Expansion to Eight DBO Sampling Regions: 2 Bering + 3 Chukchi + 3 Beaufort

In 2013, increasing interest in the DBO led to the initiation of discussions within the IARPC CT to extend DBO sampling to regions in the Beaufort Sea. Primary contributors to these discussions were NSF/AON-UMCES, BOEM/Alaska Region, NOAA/NMFS & OAR and Fisheries and Oceans Canada. To the extent possible, Beaufort Sea sampling transects and regions were centered on areas of high productivity and biodiversity, as in the northern Bering and Chukchi Seas. Other factors considered in selection of the new regions included: (i) availability of long-term data; (ii) linkages to other programs; and (iii) willingness of IARPC CT and other partners to participate in DBO sampling and data sharing. In 2014, draft maps of provisional DBO sampling sites were prepared and circulated among the IARPC CT, PAG, participants at the 2nd DBO Workshop and

other interested colleagues for discussion and revision. By 2015, three new DBO regions were agreed upon for the Beaufort Sea, with locations embedded in a web-accessible map, (<http://www.arctic.noaa.gov/dbo/dbo-stations>). The IARPC DBO CT agreed that expansion of standardized sampling into the Beaufort Sea was a significant step in the process of developing a decadal-scale implementation plan.

Annual Cycle for Field Season Planning, Data Sharing and Reporting: 5 steps

Since the inception of the DBO, the PAG semi-annual meetings have been essential to field season planning, provisional data exchange and collaboration on science products on an international basis. The annual cycle for of DBO activities (Fig. 4) proceeds in five steps:

- (i) **PAG Spring Meeting:** coincides with the Arctic Science Summit Week (ASSW) of IASC, and includes a review of ongoing studies in the Pacific Arctic region and the initiation of the annual DBO Sampling Table where *planned* DBO sampling is tabulated and auxiliary research projects that can provide DBO-related data are identified.
- (ii) **DBO Cruises:** ship-based sampling is completed on various cruises from July-October, and DBO-related sampling is completed on various auxiliary projects. In addition to core variables already sampled, there is high interest in routine dissolved inorganic carbon and alkalinity sampling to track ocean acidification (OA) on DBO transects, and to contribute findings to the nascent OA Alaska-regional network (<http://www.oceanacidification.noaa.gov/EngagementActivities/USRegionalNetworks.aspx>), via partnership with the AOOS.
- (iii) **PAG Fall Meeting:** often coincides with related arctic science meetings and provides an opportunity to report *actual* DBO cruise sampling and related outcomes from auxiliary projects. During the implementation phase, a new goal of submission of metadata to the UCAR/EOL website will be established.
- (iv) **DBO Data Workshops:** three DBO Data Workshops have provided an opportunity for presentation of provisional results, multi-disciplinary discussions and planning for the data archiving (<http://www.arctic.noaa.gov/dbo/workshop-products>). During the implementation phase, an annual DBO Data Workshop has been identified as a key activity in support of data integration, analysis and archiving.
- (v) **DBO Products:** this has included science presentations and community outreach at various annual science meetings (e.g. AGU, OSM, AMSS) and during informal discussions with agency and academic leaders. During the implementation phase, the goal of augmenting community outreach to include active participation by local observers of biological change will be sought, via linkages with established community observing networks (e.g. CONAS, ELOKA, C2O2, LEO²).

This annual cycle of DBO activities has proven very effective during the pilot phase and is anticipated to foster success during the DBO implementation phase. As noted above, three

important additions to the cycle for the implementation phase include: (1) a requirement for all DBO contributors to upload metadata to the EOL DBO data archive during or immediately after the PAG autumn meeting; (2) the convening of an annual DBO Data Workshop, and (3) the goal of building connections with existing community-based observation programs, as described below.

Building Connections with Existing Community-based Observation Programs

The development of a decadal implementation plan seems an opportune time for the DBO to foster connections to existing community-based observation programs in an effort to link offshore observations of biological change to local observations and indigenous knowledge. One approach to this goal would be to identify communities close to existing DBO transect lines where local observations are already underway: e.g., Gambell, Savoonga, Wales, Diomedea, Point Hope, Point Lay, Wainwright, Barrow and Kaktovik. A second step would be to initiate dialog with existing local observation programs to explore areas of synergy between coastal and DBO sampling, which could be identified and acted upon.

Over the past decade of rapid environmental change, several community-based programs have been initiated to foster the inclusion of local knowledge and observations in assessments of shifts in Arctic ecosystems (e.g., Sigman, 2015). Four examples include the US-based CONAS, LEO and ELOKA programs, and the Canadian-led CACCON (Circumpolar Arctic Coastal Communities Observatory Network) program:

- The Community Based Observation Network for Adaptation and Security (CONAS) consists of systematic observations made by subsistence hunters, fishermen and other leaders from eight coastal communities in the Bering Sea (<http://www.bssn.net>). The existing network is comprised of 3 villages in Chukotka and 5 in Alaska, including Gambell and Savoonga on St. Lawrence Island (near DBO regions 1 and 2). The CONAS is funded by the NSF, and is now planning to expand northwards, to include coastal villages along the Chukchi and Beaufort seas, and has expressed an intention to partner with the DBO and AOOS (<http://www.uidaho.edu/caa/programs/research/crc/research/conas>).
- The Local Environmental Observer (LEO) network is a consortium of local observers and topic experts who share knowledge about unusual animal, environment, and weather events. These observations are based on local and traditional knowledge, and the experience of network members. LEO was launched in 2012, based on the work of the Alaska Native Tribal Health Consortium (ANTHC) Center for Climate and Health, to investigate connections between climate change, environmental impacts, and human health. In 2015, the ANTHC and Resource Data Inc. developed LEO App to increase access and improve data management and analytical features of the network. That same year, the LEO Network was selected as a model program under the United States Chairmanship of the Arctic Council, to help raise awareness and improve communication about climate change in the circumpolar region.

- The Exchange for Local Observations and Knowledge of the Arctic (ELOKA) was launched during the 2007-09 IPY, with funding from NSF/Arctic Social Science program, to facilitate the collection, preservation, exchange, and use of local observations and knowledge of the Arctic. ELOKA continues to support a number of community-based observations and includes a long list of partner organizations including AOOS (<http://eloka-arctic.org/>).
- The Circumpolar Arctic Coastal Communities Observatory Network (CACCON ~"Catch-ON") is a new initiative aiming to build knowledge hubs to support, sustain and share adaptation for coastal communities (<http://caccon.org/>).

There are many other community-based programs where synergistic connections to the DBO might be fostered. Of note, the AOOS is developing an online *Atlas of Community-Based Monitoring* to provide basic information about phenomena being monitored, methods used, geographic range, and time frame of sampling (<http://www.aos.org/alaska-community-based-monitoring/>). The atlas is being developed by the Inuit Circumpolar Council-Canada in partnership with Brown University, the ELOKA, and Inuit Tapiriit Kanatami's Inuit Qaujisarvingat: Inuit Knowledge Centre. Future plans call for the atlas to interface with the Sustaining Arctic Observing Networks (SAON) program to facilitate connections among community-based monitoring projects to foster a more defined network.

Periodic Assessment of the State of the Pacific Arctic Marine Environment

The overarching goal of a decadal-scale DBO implementation plan is to establish guidelines for the *periodic assessment of the physical and ecological state of the Pacific Arctic marine environment* (ref: Milestone 3.1.3h). The DBO was launched in 2010 with just such a goal in mind; that is, to assess how bio-diverse 'hotspots' of marine organisms are responding to rapid physical changes in the Pacific Arctic region. As mentioned earlier, an annual DBO workshop is considered an essential activity in support of this goal. Annual workshops would serve as forums where assessment guidelines could be developed, discussed and approved. All US agencies contributing to the DBO effort should explicitly recommend and financially support the participation of their Principal Investigators in this annual DBO workshop.

A general timeline for steps in the development of a Pacific Arctic Regional Marine Assessment (PARMA) are provided for discussion and revision (Fig. 6):

PRODUCT	Target Date
Annual DBO Workshop	2016-2023
PARMA Guidelines: development and vetting	2016-2017
Special Issue of DSR II: "DBO – results since 2010"	2017
Produce the 1st Pacific Arctic Regional Marine Assessment	2018
Revise PARMA @ 3-year intervals	2021, 2024

Long-term Future of the DBO – National and International Linkages

2019

IARPC-IASC Panel Review @ 3-year intervals

2020, 2023

Possible IARPC-coordinated support for the DBO Implementation Phase**US Agency Contributions**

- **NSF** –support of core US DBO sampling in all regions, *and* support of the DBO Data Archive, conditioned on successful peer review; initiate a DBO Program Office &/or as a DBO-LTER (Long Term Ecological Research) framework.

- **NASA** – further refinement of DBO Cryosphere products, as needed. Note that satellite sea surface height and sea surface salinity are currently being added to augment existing data products. Also, NASA may provide coordination of sampling from shipboard programs (e.g. Arctic-COLORS), and an upscaling of DBO results using a model in conjunction with satellite observations.

- **NOAA** –continue US leadership and participation in the PAG; continue DBO sampling during the RUSALCA and AMBON cruises, on AFSC cruises *and* with NOS-charting assets (e.g. *Fairweather*) whenever possible; support and host an annual DBO workshop; publish the Executive Summary of the PARMA as a contribution to the Arctic Report Card.

- **BOEM** – through contributions to AMBON, the LEO network and other marine-related research programs (e.g., CHAOZ, ArcWest, ALTIMA), continue support of DBO sampling in the Pacific Arctic whenever possible.

- **AOOS** – continue support of long-term biophysical mooring in the NE Chukchi Sea and initiate support for biophysical moorings in the Beaufort and northern Bering Seas; enhance DBO Workspace and linkages to DBO Data Archive; assist in the development of visualization products; support linkages between the DBO and a regional OA Network.

- **NPRB** – continue support of long-term biophysical mooring in the NE Chukchi Sea, as part of the Long-Term Monitoring Program; initiate DBO sampling during research programs funded via the Arctic Program.

- **ONR** – initiate DBO sampling during physical research programs in the Pacific Arctic whenever possible.

- **Academic Contributions**
Universities – research & provision of peer-reviewed science, via support from US Agencies; streamline funding processes through programs such as the NOPP, LTER, and NOAA/Cooperative Institutes.

- **Potential Industry Contributions**

NOPP – following the AMBON example, development of an inter-agency + industry call for a 10-year program of DBO support, in response to Integrated Ecosystems Assessment (IEA) goals common to all contributors.

- **International Support and Coordination**

PAG – continued support of semi-annual meetings, cruise coordination and data delivery
 IASC – initiate inclusion of DBO review @ annual meeting of IASC-Marine Working Group
 Arctic Council – CAFF/CBMP; PAME, especially the Ecosystem Approach to Management (<http://pame.is/index.php/projects/ecosystem-approach>); AMAP and other working groups.

Contributions to the National Strategy for the Arctic Region

The National Strategy for the Arctic Region (NSAR) Implementation Plan¹ identifies three lines of effort, **two** of which are particularly germane to the implementation phase of the DBO, specifically: *Pursue Responsible Arctic Region Stewardship*, and *Strengthen International Cooperation*.

The DBO directly supports responsible stewardship of the arctic region by providing science-based observations as a basis for effective management and policy decisions. Activities of the DBO are summarized in the NSAR report under the ‘Stewardship’ line of effort, demonstrating the key nature of systematic observation of biophysical properties to the goals of integrated ocean resource management.

The DBO also strengthens international cooperation by providing the foundation for countries to engage in a common approach to oceanographic observations. The activities of the DBO, coordinated by the PAG, directly support the ‘One Arctic’ theme, at the foundation of goals established by the US during the Chairmanship of the Arctic Council. In addition, the fact that DBO regions are ‘embedded’ in the US contribution to the Arctic Council CAFF/CBMP program further strengthens international cooperation.

References

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Itoh, M., Pickart, R.S., Kikuchi, T., Fukamachi, Y. + 9 authors. 2015. Water properties, heat and volume fluxes of Pacific water in Barrow Canyon during summer 2010. *Deep-Sea Research I* 102: 43-54.

Nishino, S., Kikuchi, T., Fujiwara, A., Hirawake, T., Aoyama, M. 2016. Water mass characteristics and their temporal changes in a biological hotspot in the southern Chukchi Sea. *Biogeosciences* 13: 2563-2578.

¹Web Links

BOEM Arctic Region Research Plan: <http://www.boem.gov/About-BOEM/BOEM-Regions/Alaska-Region/Environment/Environmental-Studies/Index.aspx>

IARPC 5-Year Plan: <http://www.iarpcollaborations.org/plan/index.html>

NOAA Arctic Action Plan: <http://www.arctic.noaa.gov/features/action-plan.html>

NSAR: www.whitehouse.gov/sites/default/files/docs/implementation_plan_for_the_national_strategy_for_the_arctic_region_-_fi....pdf

USGS Evaluation of Science Needs for OCS Development in Alaskan Seas: <http://pubs.usgs.gov/circ/1370/>

²ACRONYMS

AGU	American Geophysical Union
ALTIMA	Arctic Long-Term Integrated Mooring Array
AMBON	Arctic Marine Biodiversity Observing Network
AMSS	Alaska Marine Science Symposium
ANIMIDA	Arctic Nearshore Impact Monitoring in Development Area
A-OK	Alaska Arctic Observatory and Knowledge Hub
AON	Arctic Observing Network
AOOS	Alaska Ocean Observing System
AFSC	Alaska Fisheries Science Center
ArcWest	Arctic Whale Ecology Study
BOEM	Bureau of Ocean Energy Management
C2O2	Coastal Community Ocean Observers
CACCON	Circumpolar Arctic Coastal Communities Observatory Network
CAFF	Conservation of Arctic Flora and Fauna
CBMP	Circumpolar Biodiversity Monitoring Program
CHAOZ	Chukchi Acoustics, Oceanography and Zooplankton Study
Clark U	Clark University
COMIDA	Chukchi Sea Offshore Monitoring in Drilling Area
CONAS	Community Based Observation Network for Adaptation and Security
CT	Collaboration Team
DBO	Distributed Biological Observatory

DSR II	Deep Sea Research Part II
ELOKA	Exchange for Local Observations and Knowledge of the Arctic
EOL	Earth Observing Laboratory
FIT	Florida Institute of Technology
GOOS	Global Ocean Observing System
IARPC	Interagency Arctic Research Policy Committee
IASC	International Arctic Science Committee
IOOS	Integrated Ocean Observing System
LEO	Local Environmental Observer Network
NASA	National Aeronautics and Space Administration
NMFS	National Marine Fisheries service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NOPP	National Oceanographic Partnership Program
NPRB	North Pacific Research Board
NSAR	National Strategy for the Arctic Region
NSF	National Science Foundation
OAR	Oceanic and Atmospheric Research
ODU	Old Dominion University
ONR	Office of Naval Research
OSM	Ocean Sciences Meeting
OSU	Oregon State University
PAG	Pacific Arctic Group
PAME	Protection of the Arctic Marine Environment
PARMA	Pacific Arctic Regional Marine Assessment
SIWO	Sea Ice for Walrus Outlook
UAF	University of Alaska Fairbanks
UCAR	University Corporation for Atmospheric Research
UMCES	University of Maryland Center for Environmental Science
URI	University of Rhode Island
USGS	United States Geological Survey
UW	University of Washington
WHOI	Woods Hole Oceanographic Institution

Figures

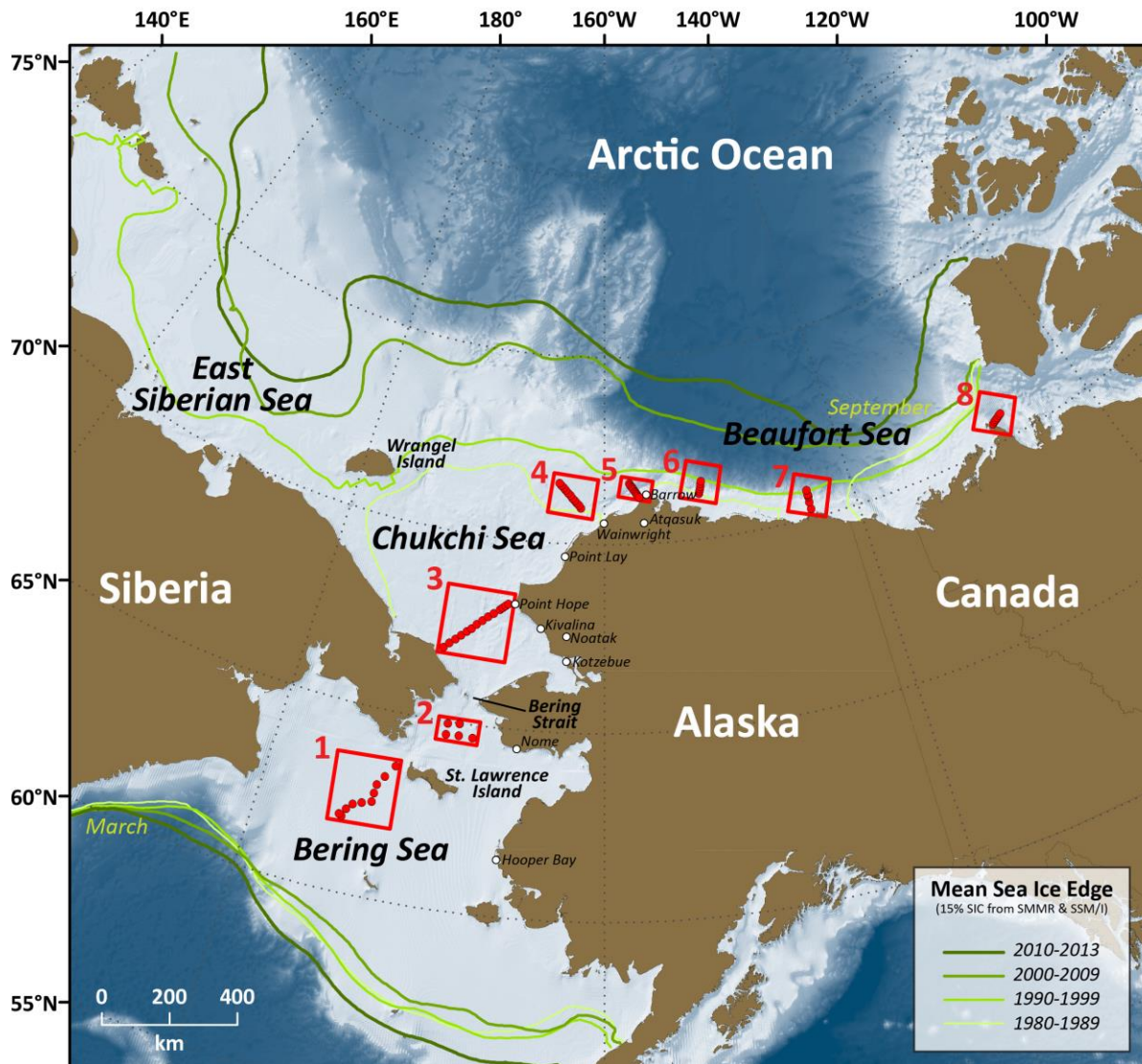


Figure 1. The Distributed Biological Observatory (DBO) focuses multidisciplinary sampling at oceanographic stations in eight regions: five regions extending across a latitudinal gradient from the northern Bering Sea through the Chukchi Sea, and three regions of high productivity and biodiversity across a longitudinal gradient in the Beaufort Sea.



	Country	Ship Name
	Russia	<i>Professor Khromov</i>
	Korea	<i>Aaron</i>
	China	<i>Xuelong</i>
	Japan	<i>Oshuru-Maru, Mirai</i>
	Canada	<i>Sir Wilfrid Laurier, Louis S. St. Laurent, Amundsen</i>
	USA	<i>Healy, Oscar Dyson, Aquila, Annika Marie</i>
Industry	Shell, ConocoPhillips	<i>Norseman II, Westward Wind</i>

Figure 2. Pacific Arctic Group (PAG) international partners contributing to sampling of the DBO.



Figure 3. Government agency and academic partners collaborating in support of the DBO.

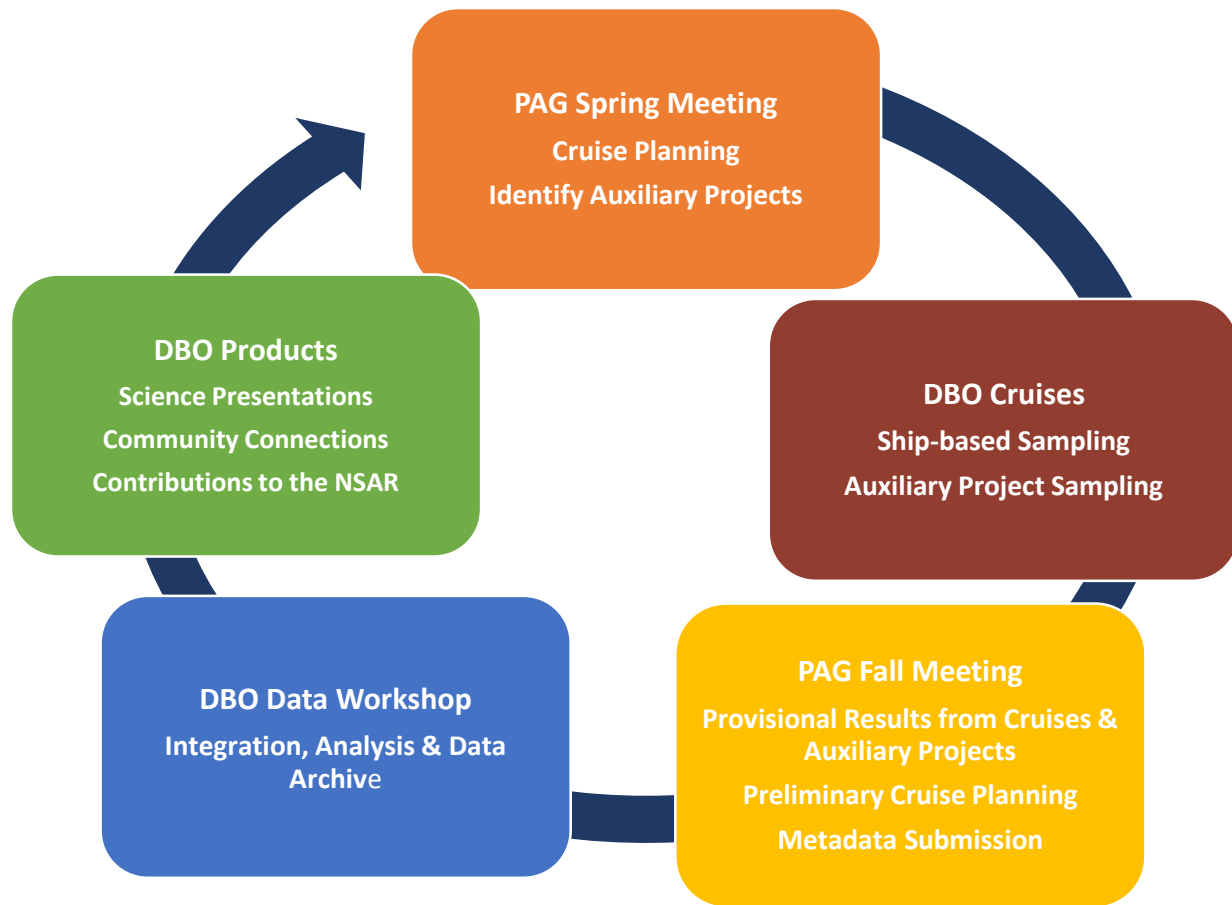


Figure 4. Annual cycle for implementation of the DBO, from planning to products.

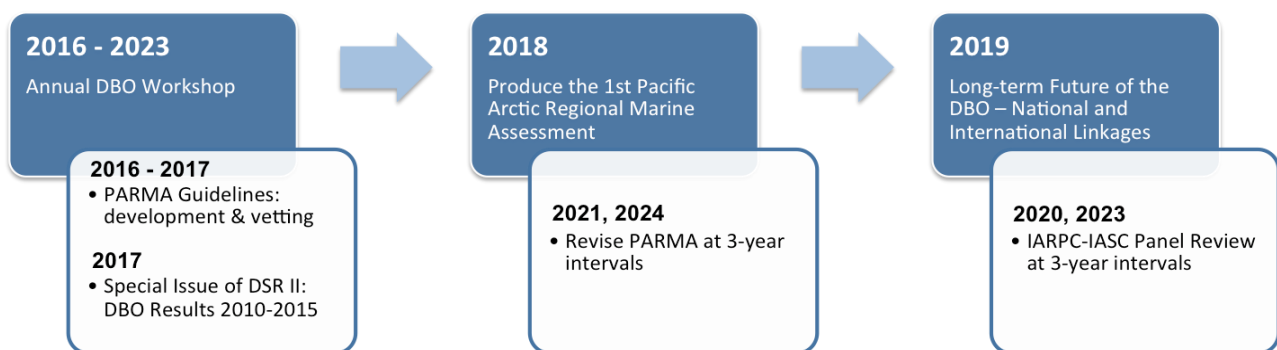


Figure 5. Timeline for the development of a Pacific Arctic Regional Marine Assessment (PARMA).