# Arctic Research Activities

Third Meeting of Scientific Experts on Fish Stocks in the Central Arctic Ocean

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Northwest Fisheries Science Center, Seattle, Washington

## Norwegian survey and project activity:

IMR will address the research challenge by review of historical data and literature, field observations, numerical modeling and analytical approaches. Initial observational data will be obtained by expanding already ongoing surveys, conducting a baseline study in 2016 utilizing data from IMR and PINRO surveys and from satellites and other auxiliary sources. The field activities will proceed in a step-wise manner, not necessarily using the entire methodological and instrumentation toolbox from day one. It will be necessary, particularly depending on the harsh and changing environmental conditions met in the Arctic Ocean and research vessel available, to initially rely on a set of core instrumentation and gear to be used. This also holds for the process oriented *in situ* and *ex situ* experiments to be conducted.

Today's scientific monitoring of the northern areas are mainly a joint Norwegian (IMR) and Russian (PINRO, Murmansk) effort. The monitoring program includes a joint ecosystem survey covering all trophic levels as well as chemical and physical properties of the entire Barents Sea during autumn. This survey is part of a monitoring strategy developed for the Barens Sea, including the northern shelf (Appendix A5). The suggested monitoring program seeks to establish a stable regulatory framework, securing that the monitoring program is carried out according to long-term plans (scientific, financial and organisational). Thus, there should be no need for annually to consider 1) the time allocation for standard surveys by the national cruise planning committees, 2) new survey objectives and design, and 3) estimate the cost. The long term plans should secure increased competence and continuation of expertise for involved leaders, scientists, technicians and users.

The monitoring program should include the following standard surveys and time frames, based on the present surveys (Norwegian Russian winter survey – NRWS, Norwegian spawning cod survey – NSCS, Russian acoustic winter survey – RAWS and Norwegian ground gear survey – NGGS):

- A joint Barents Sea ecosystem survey of at least 150 days in winter (BESS winter)
- A joint Barents Sea ecosystem survey of at least 160 days in autumn (BESS autumn)
- A joint ground gear survey covering the continental slope of at least 25 days in late autumn (JGGS late autumn)
- Use of the part of the summer international ecosystem survey for the Nordic Seas covering the Barents Sea in early summer (IESNS summer)

In table 1 is given a short description of the standard surveys suggested in the monitoring program for the Barents Sea and Arctic Ocean

The IMR is also developing a general monitoring strategy that will be guiding for the expansion of survey activity into the open Arctic Ocean. As part of the IMR activity, the survey activity in 2015 and 2016 will extend further northwards to also cover the ice free part of the waters under Norwegian jurisdiction of the Arctic Ocean. This will provide new information on species distribution and abundance for describing and understanding the variability of the Arctic Ocean ecosystem. In addition, the approach of covering the ice free part of the Arctic Ocean nearly at the same time as the shallower Barents Sea is covered, allows examining the interplay between the shelf and the deep Arctic Ocean, which is crucial for understanding both regions.

A detailed baseline study mapping also the ice-covered regions will be conducted using available vessel in 2016 that is able to operate in first year and to some degree in multiyear ice. A new ice breaker research vessel will be ready in 2017 and baseline studies will then be expanded. These studies will provide data for the partly or fully ice-covered regions, as well as determining northward extension ranges. Adding to the data from the 2014 and 2015, this gives a data set suitable for assessing the effect of reduction of the ice cover on the Arctic Ocean ecosystem. In more detail we will investigate inter annual variability in production and abundance of phyto- and zooplankton, the response of key zooplankton species to the available food, and the relation between key zooplankton species and the presence of important invertebrate, fish and marine mammals. The sampling strategy for the survey will be in line with that described for the Barents Sea ecosystem survey (Appendix A6 and Michalsen et al., 2013).

Table 1 shows the existing and suggested monitoring and give a short description of standard surveys.

| Existing monitoring | Suggested monitoring | Primary objectives | Secondary objectives | Additional objectives |
|---|---|---|---|---|
| NRWS (90 days)<br>NSCS (20 days)<br>RAWS (30days) | BESS-winter<br>150 days: NO-80 days, RU 70 days | - Demersal fishes: cod, haddock, Greenland halibut, redfishes | - Pelagic fishes: capelin, young herring, blue whiting<br>- Interspecies interaction<br>- Young groups of other commercial species | Oceanography |
| Data not used | IESNS summer | - Pelagic fishes: young herring, blue whiting | - Plankton | Oceanography |
| BESS-autumn (160 days) | BESS-autumn 160 days: NO-90days, RU-70 days | - Pelagic fishes: capelin, young herring, blue whiting<br>- Shrimps | - Young groups of other commercial species<br>- Demersal fishes: cod, haddock, Greenland halibut, redfishes, wolffishes<br>- Interspecies interaction<br>- Pollution | Oceanography<br>Plankton<br>Fish biodiversity<br>Bentos<br>Marine mammals<br>Sea birds |
| NGGS (20days)<br>RAWS | JGGS late autumn, at least 25 days | Demersal fishes: Greenland halibut, redfishes | -fish community | |

Collecting information from other previous and ongoing activities should also have a strong focus in the future work. The IMR and PINRO have conducted surveys to monitor ice dependent seal populations over several decades. Data from these surveys in combination with a continuation of the activities will enable assessment of the effect of the retreating sea ice on these pagophilic top predators. Deep-sea surveys along the Norwegian Sea continental slope, from 68°N to northwest of Spitsbergen at 80°N, have been run regularly by the IMR since 1992. Survey data and models could reveal possible distribution changes of commercial deep-sea fish species, and also whether these species are likely to extend their distribution, and in some cases spawning grounds, into the Arctic Ocean. Additionally deep-sea slope surveys can support the analysis. Utilizing data from satellites and other auxiliary sources will be used to supplement the survey data. It will also give valuable information for designing a long-term monitoring program. Review of historical data (e.g., Russian) and literature will be used to supplement the survey material. Literature review will be essential when exploring potential options for providing integrated, ecosystem-based advice for management of the Arctic Ocean. Further background information on research activities may be found in the report of IMR ecosystem activity in the Arctic Ocean (Appendix A7).

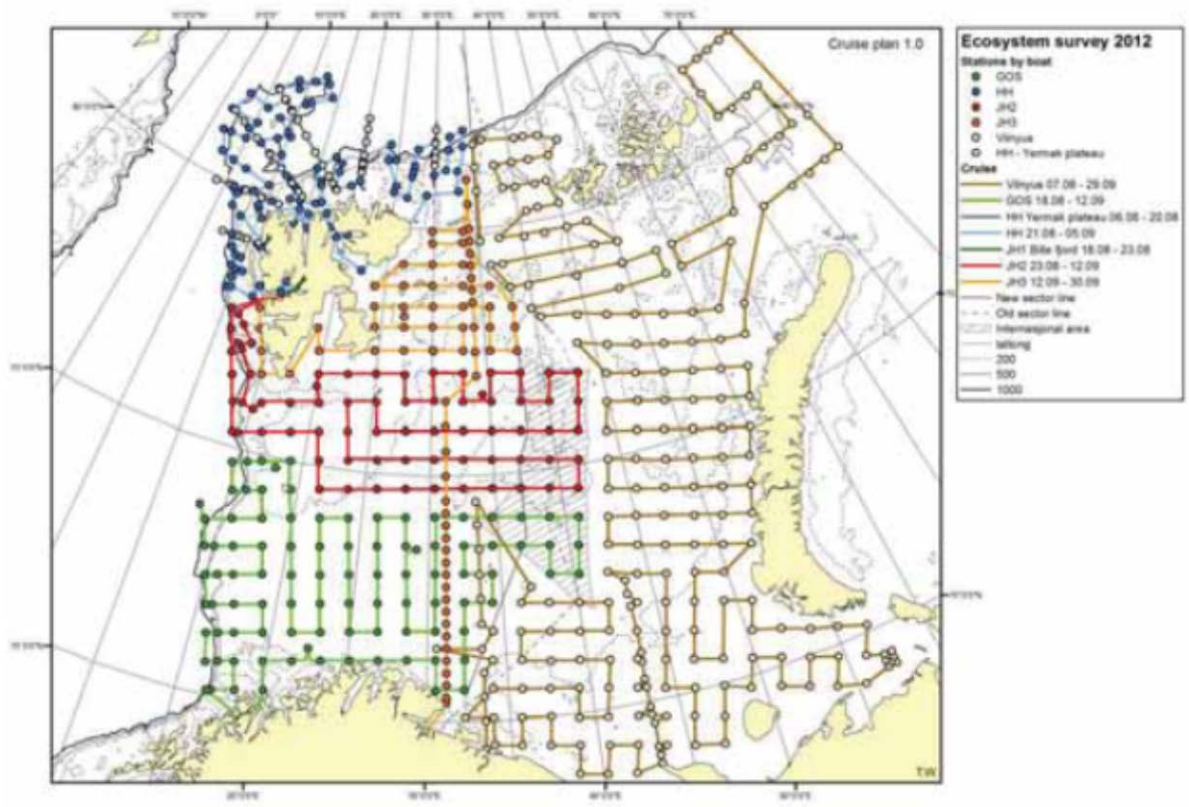



Figure 2. Map of the survey area for the BESS-autumn survey in 2012.

To improve the understanding of mechanisms that may transport biomass northwards and into the Arctic Ocean, individual-based larval drift modeling will be conducted to investigate drift of offspring from key fish species into the Arctic Ocean from potential future spawning sites. The model system utilizes an ocean model archive for two decades (Vikebø et al., 2010) and enables investigation of inter annual variability in environmental exposure and dispersal of individuals hatched at various sites. A

similar ocean model setup has been used for downscaling IPCC global climate models and the output of these will be utilized to investigate potential northward extension of favorable spawning grounds in a future climate. In addition, IMR operate the model system norwecom.e2e, which is a two-way coupled bio-physical model system including physics, primary and secondary production and fish IBM-modules (Hjøllo et al., 2012, Utne et al., 2012). Development of IBMs for *Calanus hyperboreus*, *Calanus glacialis* and *Calanus helgolandicus* are in progress. This will allow for modelling biogeography, population dynamics, and production of the different species under present and future climate scenarios. When ready, primary and secondary production in the Arctic Ocean can be evaluated from this model system.

In order to start the research expanding into the open Arctic Ocean, a strategic initiative on The Arctic Ocean Ecosystem (SI_ARCTIC) to develop research is started with extra funding from the Norwegian Ministry of Trade, Industry and Fisheries. The text of this document is collected from the project description of ths initiative, and the content of the work packages are given in Appendix A8.

Thus, IMR will expand existing knowledge on the impacts of climate change in the Arctic through an extensive observational program. Through the analyses performed and the knowledge added, answers to questions regarding whether the production of the Arctic Ocean will be sufficient to sustain commercial fish stocks will hopefully be given. All advice on management should build on scientific knowledge. Exploring potential options for providing integrated, ecosystem-based advice for management of the Arctic Ocean will be an important outcome of the activity, together with the designing of a long-term monitoring program.

Other activities: Nansen legacy: The Ministry of Research and Education has granted NOK 2.8 million to a SAK project for the purpose of preparing an overarching research plan to attain greater understanding of the marine system in the central and northern parts of the Barents Sea. The project requires cooperation, division of labor and concentration among the University of Tromsø (project leader), the University of Bergen, the University of Oslo, the Norwegian University of Science and Technology, the University Centre in Svalbard, the Norwegian Meteorological Institute, the Norwegian Polar Institute and the Institute of Marine Research. The project title is *SAK-Nansen's legacy*.

The overall objective is to formulate the research plan for a new national program to study the marine system in the central and northern parts of the Barents Sea. An important goal is to contribute new findings that will help meet Norway's significant need for knowledge in an area where little research has previously been done. The program is intended to enhance understanding of ecosystems and improve management in the same way as the PRO MARE project in the southern Barents Sea in the 1980s.

Intensified commercial activity necessitates greater fundamental knowledge about the marine biosphere and geosphere. This is required to ensure that our understanding of natural systems and processes is adequate to enable future risk assessments and knowledge-based management in these areas. The research plan will be a scientifically focused organizational framework for innovative collaboration, firmly grounded in the SAK principles.

The overall goal is to formulate a scientific plan for a research program targeting basic scientific knowledge to increase understanding of the marine bio- and geosphere in the central and northern parts of the Barents Sea.

Further information on the project may be found on the web page: http://nansenlegacy.org/en/

## Research and monitoring clusters

*The FRAM-centre:*

The Fram Centre is the short name for FRAM - High North Research Centre for Climate and the Environment. The Fram Centre is based in Tromsø, and consists of scientists from 21 institutions (Akvaplan-niva, CICERO, IMR, NGU, NINA, NORUT, NMI, NP, NIVA, SINTEF, Universities, UNIS ++) involved in interdisciplinary research and outreach in the fields of natural science, technology and social sciences. Several flagships are organized in the centre and they all focus on the northernmost areas of Arctic land and waters. Some of the flagships also perform field activities on the Arctic Ocean. The flagships are:

<u>Sea ice in the Arctic Ocean, technology and agreements</u>

Melting of sea ice in the Arctic greatly impacts the global climate. This flagship focuses on social and management challenges to fisheries, shipping and petroleum-related activities. New challenges and technological solutions pertaining to rescue and oil spill response are addressed.

Cod, harp seal and minke whale are the main top predators in the Barents Sea ecosystem and theitr ole has been investigated in the project "Dynamic interactions between large zooplankton (amphipods and krill) and seals: impacts of climate change". In the last decade, the abundance of cod has increased considerably, and is at a record high level. Also, the distributional area of cod has increased substantially towards the northern and northeastern parts of the Barents Sea. In spite of this, the growth and condition of cod has remained rather stable, although some decrease is seen in size at age of large, mature cod. During the same period, the abundance of harp seals has declined whereas the minke whale stock has been at a stable level. The body condition (blubber thickness) of these two mammal stocks has, however, decreased, with the strongest decrease observed for harp seals. A possible hypothesis to explain this is that cod outperform the marine mammal stocks in the competition for food (Bogstad et al. 2015). The main advantages for cod are most likely larger availability of food (mainly capelin) during winter-spring than for marine mammals, as well as a wider range of prey species being available to cod than to marine mammals. Harp seals are more dependent on prey items found close to the ice edge than the other two predator stocks are, which could partly explain why the performance of harp seals is worse than that of the two other main top predators in the area.

<u>Effects of climate change on sea and coastal ecology in the north</u>

Research in this program address the multiple ways climate change impacts the physical conditions of fjords and coasts and how, in turn, habitats and food supply are affected.

<u>Ocean acidification and ecosystems effects in Northern waters</u>

This flagship program contributes to a more complete understanding of ocean acidification. This process will affect the productivity of ecosystems, impacting ecosystem-based management and the exploitation of commercial resources, especially in the cold waters of the North, where the uptake of CO2 is substantial.

The main objectives may be as follows:

- Assess seasonal and interannual variability of the physical and chemical state ($CO_2$ system) of the Arctic Ocean (relatively unknown)
- Assess and quantify the main drivers for change in the state of ocean acidification and carbon system in the Arctic Ocean
- Investigate possible linkages between the chemical and physical characteristics of different marine areas with distribution and ”health” of aragonite forming organisms (Cold Water Corals, pteropods)

A large part of the research conducted to investigate trends and processes driving the acidification of the Arctic Ocean is field work. Since 2011 there have been annual field cruises for periods of weeks with research vessels in the area north of Svalbard, northeast of Greenland and in the fjords of Svalbard. On the surveys physical and chemical investigations are made on sea ice and of sea water, and collection of samples in the whole water column down to considerable depths has been made. Sampling of organisms with calcified organs are also done, e.g wing snail, in order to investigate the thickness of the shell and other organs.

Collaboration with the ”Polhavet flagship” and results from the Fram Strait data give an integrated picture of effects of climate change in Arctic Ocean. New data reveal low pH and low calcium carbonate saturation ($\Omega$) in polar outflow waters, and there are indications for pH decrease in Fram Strait (0 to 500 m. Northern Barents Sea data also show that polar waters already have low pH values (Fransson et al 2015a, Fransson et al 2015b)

Effects of climate change on terrestrial ecosystems, landscapes, society and indigenous peoples.

Changes in Northern terrestrial ecosystems are highly relevant to society, in particular for agriculture, forestry, reindeer herding and nature-based industries, species and area conservation, tourism and recreation. Issues related to climate adaptation in the North, as well the significance of climate change for Sámi culture and settlement are included this flagship.

Hazardous substances – effects on ecosystems and human health

Climate change reinforces the importance of filling the gaps in our understanding of the distribution of pollutants in the Arctic and their effects on ecosystems and human health. This flagship program also addresses the need for this knowledge to be incorporated in international agreements and processes.

Environmental impact of industrial development in the north (MIKON)

MIKON’s objective is to do research that will strengthen the knowledge base used by the authorities in efforts to limit the “footprint” of industrial activity in the High North, and ensure that new industrial activity takes place within a responsible environmental framework. The research within the MIKON program will take into consideration both existing business activities and visions/expectations of future developments.

Further information may be found at the web page: http://www.framsenteret.no/

*ARCTOS – Arctic Marine Ecosystem Research Network (arctosresearch.net)*

Mare incognitum

*Norwegian management plan (government.no/kld)*

Indicators and monitoring system – the monitoring group

Miljostatus.no

Ocean 3 – project (Appendix A9)

*The Ny-Ålesund centre for international arctic scientific research and environmental monitoring (KingsBay.no)*

Svalbard science forum (rcn.no/SSF) / RiS data base (researchinsvalbard.no)

## Iceland Arctic Research Activites

The Marine Research Institute (MRI) is the main body undertaking ocenaograhpic and fisheries research in Iceland. The most important role of the MRI is to provide advice to the government on catch levels and conservation measures for over 30 species of fish stocks exploited in the waters around Iceland. To meet this role MRI undertakes extensive environmental and fisheries monitoring the most important of is listed in table below.

Since 1950s temperature, salinity, nutrients have been monitored at a grid of 80-100 stations all around Iceland 4 times per year while phytoplankton, zooplankton is monitored at the same station grid in spring. These observations have demonstrated marked inter-annual and decadal fluctuations in temperature and other environmental factors in the waters around Iceland. Since around 1995 a warm period attributed to increased inflow of Atlantic water has been observed.

Inflow of Atlantic water has been found to increase nutrient availability and mixing which leads to increased primary production and secondary production. Increased Atlantic water also advects more zooplankton from southern waters. Higher temperature of Atlantic water "per se" further leads to increased growth/production of zooplankton. In combination this generally means better feeding conditions for pelagic fish.

In order to understand the factors determining the dynamics/variability of the Atlantic inflow extensive current measurements have been undertaken for almost two decades off the northwest coast of Iceland. These investigations have demonstrated that variability in flow is determined by winds while the drivers of the average flow of the Atlantic water are not fully understood.

Atlantic inflow increases nutrient availability and mixing which leads to increased primary production and increased primary production then to increased food for zooplankton. Inflow of Atlantic water on to the shelf north of Iceland markedly affects the production process at all levels in that area. Increased Atlantic water also advects more zooplankton from southern waters. Higher temperature of Atlantic water further leads to increased growth/production of zooplankton and increased production/biomss means better feeding conditions for pelagic fish

Capelin is the only fish stock exploited in Icelandic waters  that is of Arctic origin. The capelin is an important fishable resource while it is also food for other fish species, seabirds, whales. The capelin feeds during summer in the Sub-Arctic waters to the north of Iceland. When it returns to the northern shelf it is transporting great amounts of energy into the Icelandic shelf system. The stock size of capelin has been monitored since the early 1970s during acoustic surveys in autumn (October/November) and in winter (January) to provide advice for fishing. Since around 2000 the summer and autumn distribution of capelin has shifted farther to the west and north into East Greenland waters. Concurrently, autumn stock assessment surveys were difficult in some years and the fishing fleet failed to find fishable shoals. These events have been attributed to an increase in the flow of Atlantic water to the areas north of Iceland and increased temperature. In order to try to further understand the changes observed in the capelin stock MRI undertook extensive studies in the Iceland Sea during 2006-2008.

Since the Norwegian Spring Spawning herring started to recover in the middle of the 1990s it has been monitored annually in an extesive acoustic survey undertaken under ICES coordintion by Faroe Islands, Iceland, Norway and Russia. In recent years EU has also contributed vessels to this survey.

Since 2009 the Northeast Atlantic Mackerel (NEA Mackerel) stock has been assessed by ICES coordinated pelagic trawl survey carried out by Faroes Islands, Iceland and Norway.). The mackerel stock has shown marked changes distribution in recent years. During the summer of 2007 a marked change was evident in Icelandic waters when mackerel became more widely and uniformly distributed east of the country and westwards along the south coast. By 2010 mackerel was then distributed right around Iceland and this has led to extensive fishery within the Icelandic EEZ. From the above mentioned surveys and other information it is evident that a large part of the mackerel stock has extended its distribution by about 1200-1500 miles to west and 600 miles to north in recent years.

Icelandic Summer Spawning Herring (ISSH) has been surveyed acoustically in early winter since early 1970s.

The demersal fish stocks in Icelandic waters are mainly monitored in groundfish surveys which have been conducted in March since 1985 and in October since 1996. They are based on standardized sampling at about 600 stations from ca 50-500 m using bottom trawls. The main aim is to gather fishery independent indices on stock sizes of groundfish species together with information on various biological factors (length frequency distributions and spatial distribution, together with sexual maturity, age composition). The groundfish surveys do also provide very important biological data on less important and not exploited stocks.

MRI has since 1987 regularly along with cooperating institutes in the North Atlantic conducted extensive whale sighting surveys in order to obtain information on distribution and abundance of whales in Icelandic and nearby waters. The last and most extensive survey covering the whole of the North Atlantic and using ships and aeroplanes took place in 2007. This survey will be repeated in 2015 which is considered particularly important in light of environmental changes that are presently taking place in Icelandic waters and nearby waters.

All Icelandic fishing vessels fill out detailed logbook on each fishing operation. This includes catch/species, position, time duration of fishing operations, fishing gear used. Annually about 170 thousand fishing related operations registered. All these data are stored in MRI data base and form a part of MRI assesment work and research. Since 2009 the logbooks have been in an electronic from and are sent as such for screening and storing directly to MRI.

MRI has for decaded taken part in many international projects to investigating the both environment and biology of Icelandic and nearby waters. Most important is work coordinated by ICES and some of it has already been mentioned. In addition the following recent ones are worth mentioning. Hydrography: Arctic Subarctic Ocean Fluxes (ASOF), Thermo-Haline Overturning at risk (THOR), North Atlantic Climate (NACLIM). Biology/environment: Basin-scale Analysis, Synthesis and Integration (BASIN). Carbon absorbiton and release: Lamont-Doherty Earth Observatory USA, EU framework programs Carbo-Ocean, Carbo-Change).

**Main environmental and fisheries annual and long term monitoring surveys undertaken by MRI Iceland.**

| **Project** | **Time of year** | **Area** |
|---|---|---|
| Capelin | January | N, E, S |
| Environment | February | V, N, E, V |
| Demersal fish | March | V, N, E, S |
| NSS Herring (ICES coordinated) | May | E |
| Lobster/flatfish | May | S, V |
| Environment | May | V. N, E, S |
| NEA Mackerel (ICES coordinated) | July/August | V. N, E, S |
| Offshore shrimp | August | N |
| Environment | August | V. N, E, S |
| Capelin | October | N |
| Environment | November | V. N, E, S |
| Demersal fish | November | V. N, E, S |
| ISS Herring | December | V. N, E, S |

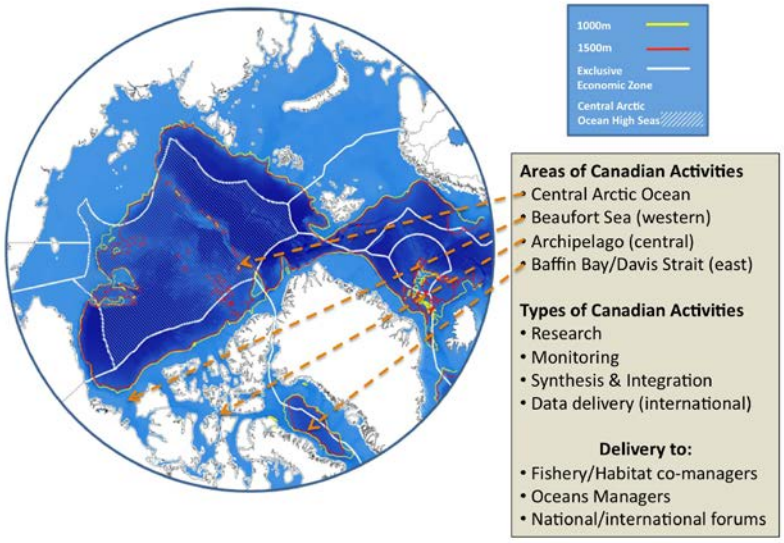
## Canadian Arctic Research and Monitoring Activities

### Introduction

Operational areas in which activities were conducted from 2012-2014 included Canadian Arctic waters as follows (Figure 1): Western Arctic – Beaufort Sea and waters adjacent to the northwestern margin of the Canadian Arctic Archipelago, Central Arctic Archipelago waters, and Eastern Arctic – Baffin Bay and Davis Strait waters south to include Hudson Strait. The former two areas are truly arctic in circumstances, whereas the latter is a mixture of arctic and sub-arctic ecological circumstances. In addition to activities in these areas, Canadian marine researchers also conducted activities in the high seas area of the Central Arctic Ocean, and participated in international missions in other areas. This document summarizes the salient activities pertinent to the workshop focused upon finfish and lower trophic levels, primarily with respect to activities delivered by government; brief mention is also made regarding activities delivered by university consortia, some of which may have relevance here. Where relevant the distinction is made between research and monitoring activities, however, most of this report focuses upon the former. Examples of ongoing synthesis and integrative, and data delivery activities are also provided. Knowledge acquisition (research) and synthesis activities underpin the provision of advice to environmental managers, and national and international forums. These activities also provide baseline data and advice for development and delivery of monitoring programs.

From the standpoint of the Central Arctic Ocean (CAO) and adjacent shelf seas, the Canadian Arctic marine systems are, for the most part, 'downstream' of the system. That is, Coriolis forcings and other physical processes generally move water masses from the northwest central polar region onshore towards the Canadian Arctic Archipelago. These are counter clockwise movements of deepwater masses occurring as the Atlantic water mass (~450-900m depths) and the Arctic Bottom water (1000m depth). Above this and offshore is the Beaufort Gyre which moves surface waters and ice generally in a clockwise fashion towards areas further west. Between these offshore situations and the continental coast in the west, Pacific Water entering through the Bering Strait, sea-ice summer melt water and freshwater sources are entrained and move generally towards the east (i.e., into Canadian coastal waters). Accordingly, from the Canadian perspective, changes, occurrences and activities in the CAO have significance in that they may affect domestic seas. Water and ice that enter the western edges of the Archipelago move eastwards to outflow in Baffin Bay and Davis Strait thence southwards along the Canadian coast into the Labrador Sea, thus further influencing processes in these 'downstream' areas. Moreover, water and ice flowing from the Arctic basin through Nares Strait between Canada and northern Greenland further influence the eastern regions of the Canadian system, as do North Atlantic inflows along the west Greenland coast. Thus Canada has a vested interest in and is very cognizant of how circumstances and activities in the CAO may affect its Arctic areas. Development and delivery of international and national programs to understand the CAO and its influences are encouraged by Canada.

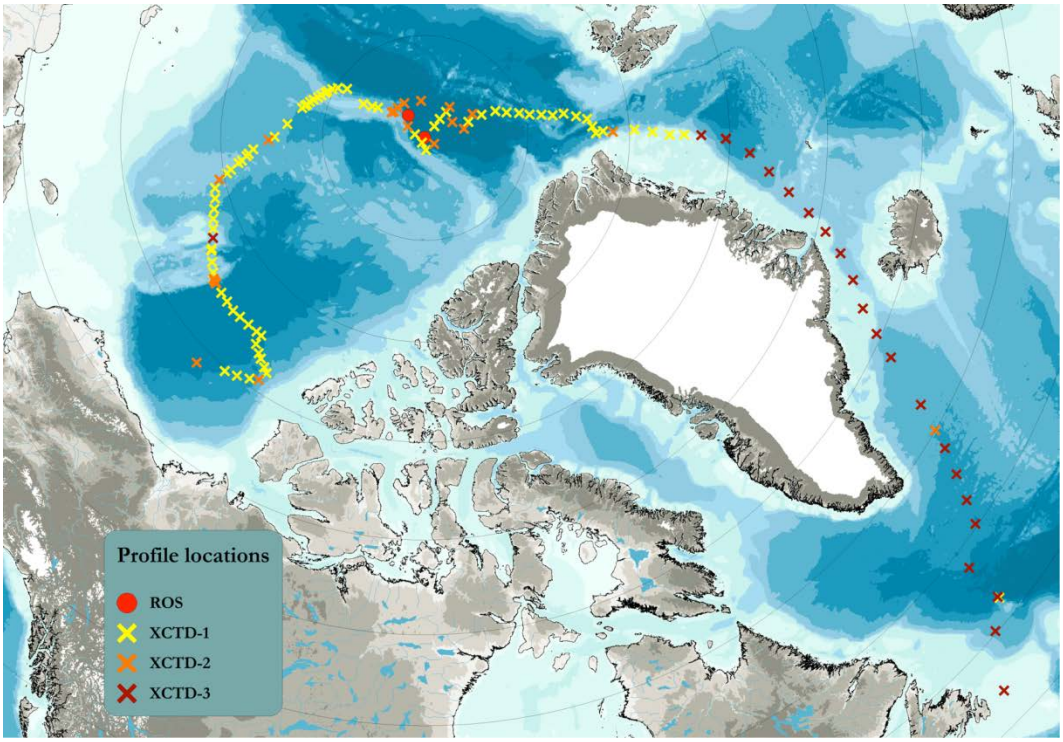
Figure 1. Areas of Recent Canadian Activitly




## Overview of Research Activities

**1. Oceanographic Data Collection in the Central Arctic Ocean, J. Eert, Institute of Ocean Sciences.**
During a polar mission by the CCGS *Louis S. St. Laurent* (Figure 2), physical and geochemical measurements were taken Aug-Sept 2014 to determine water mass distribution and ocean circulation. Underway measurements included: seawater loop system - salinity, temperature, chlorophyll, CDOM, oxygen saturation and data on geo-position, weather, sounder depths and ice (cameras). Two stations were occupied near the geographic north pole and CTD/rosette casts (ROS, Figure 2) conducted with 46 water bottles to be analyzed for TIC, pCO2, salinity, oxygen, nutrients, CDOM, Bacteria, Barium & O-18. Additionally, en route 126 expendable CTD (XCTD) casts as part of Pan-Arctic Climate Investigation (collaboration between JAMSTEC & DFO) were deployed to gather data.

Figure 2. Ship track and locations of particular activities during 2014 polar mission.




**2. Lower Trophic Level Research in West and Central Locations, C. Michel, Freshwater Institute.**

Research in the Beaufort Sea (2012-2014) included water mass description (nutrients, $O_{18}$, particulate organic matter (if not previously defined), fatty acids, stable isotope tracers) and indicators of the amount and fate of primary productivity (chlorophyll, dissolved organic matter, microbial communities and productivity). This work was linked directly with the Beaufort Regional Environmental Assessment Marine Fishes Project noted below. Additionally, ca. 100 ice stations have been occupied in Canadian Arctic Archipelago (2010-2013) to estimate production and food web linkages in first- and multi-year ice (Figure 3).

This research program also participated in an examination of primary production in the high Arctic through collaboration in the 2014 SUBICE (under-ice blooms) cruise in the Chukchi Sea (Arrigo, Stanford). Goals were to determine the fate of ice-associated production, for example, the potential re-direction of energy away from higher-trophic levels and into microbial systems.

Researchers from this program will in May 2015 participate in the TRANSSIZ program involving a seasonal sea ice transit (Svalbard area) aboard the *Polarstern* (in collaboration with AWI Germany). The research goal of the expedition is to understand cryo-pelagic-benthic coupling on the Barents Shelf and Nansen basin and thus develop better predictions of primary production in an ice-free Arctic Ocean.

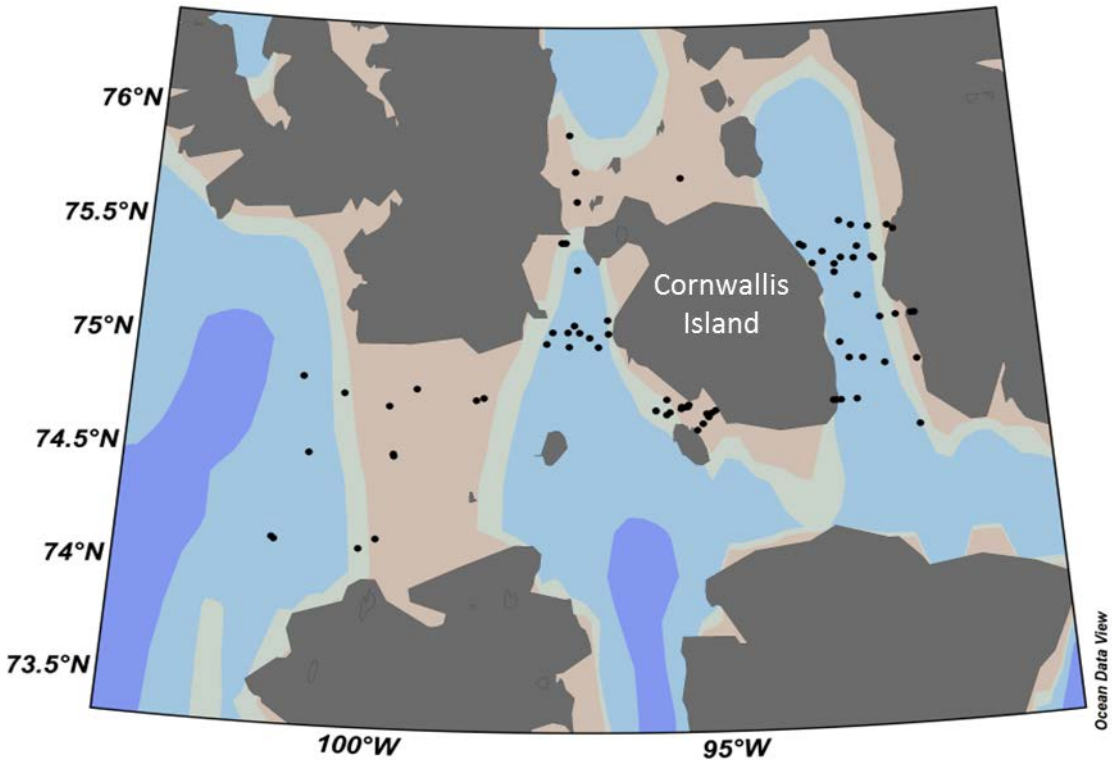



Figure 3. First-year sea-ice sampling stations in the Canadian Arctic Archipelago 2010-2013, Sea-ice BIOTA program, C. Michel, freshwater Institute.

3. **Beaufort Sea Marine Fishes Project, J. Reist, Freshwater Institute.**

This activity is focused upon developing knowledge of the offshore marine fishes of the Canadian Beaufort Sea (CBS). Field years included 2012, 2013 and 2014 during which an ice-strengthened fishing vessel (F/V *Frosti*) was deployed for 4-6 weeks in the CBS to sample fishes (e.g., bottom trawl, hydroacoustic biomass estimation, midwater trawl), planktonic and benthic invertebrate diversity, pelagic and benthic (substrate) habitats, and determine ecosystem structure and function in the offshore area (i.e., beyond shelf-break at >200m depths). Additionally, the research was linked with previous shelf (<150m) research (2003-2009) through the re-occupation of stations on the shelf. As well, the findings will be linked with those from coastal ecosystems in this area through the use of ecosystem 'tracers' (i.e., diets, stable carbon and nitrogen analyses, fatty acids analyses). Work extended from the Alaskan border eastwards into Amundsen Gulf and northwards to ice limits at about 73$^{o}$N latitude; depths sampled typically were from ~40-1000m, however, successful bottom trawling was also conducted at 1515m depth in 2013 (Figure 4). Findings to date include substantively increased geographic, offshore and deep-water spatial coverage from previous knowledge with respect to fishes, plankton, epifauna and infauna. As well, longer time series are now available for stations on key transects and stations on the shelf from which inter-annual variability may be assessed. Initial findings include: a) incremented known marine fish diversity from 52 to 68 species (in addition to the 20 anadromous fishes present); b) the marine fish community is depth-structured with certain species

being closely associated with particular habitats and zones (Figure 5); c) there appears to be moderately high inter-annual variability in Arctic Cod biomass and habitat usage (ice associated?); and, d) wind- and ice-moderated(?) episodic upwellings along the slope concentrate biota in several key areas.

Figure 4: Fish occurrence records for the Canadian Beaufort Sea (and by extension sampling locations for the BREA Marine Fishes Project, yellow points).

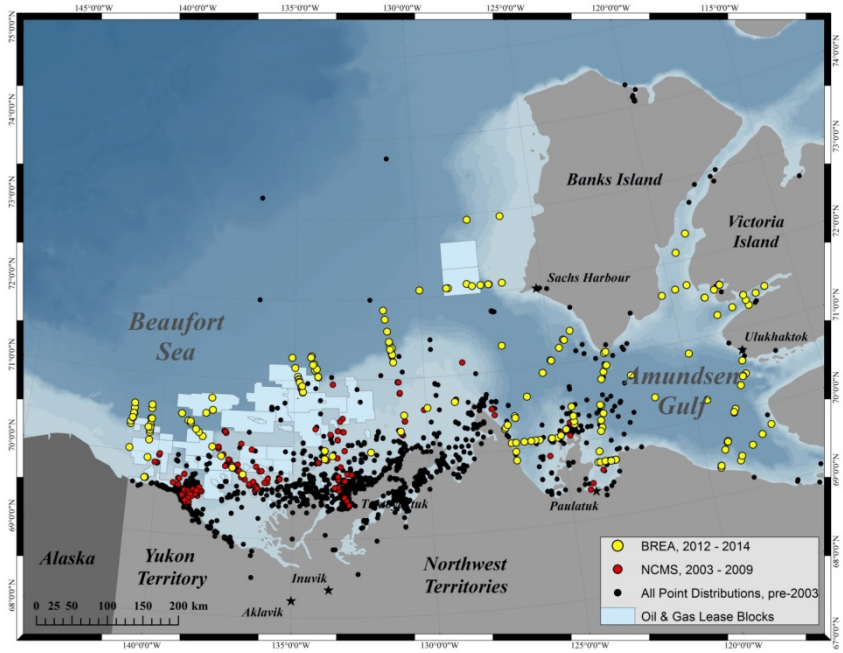
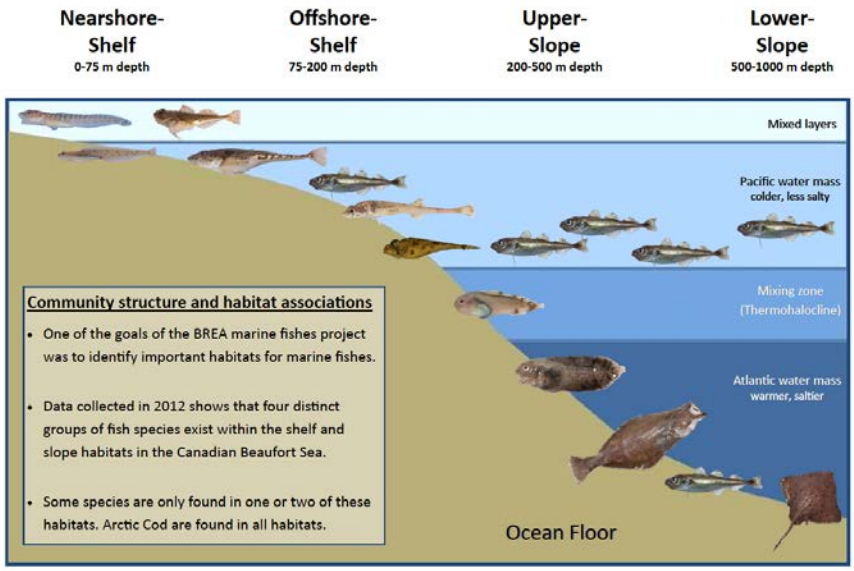



Figure 5: Preliminary results indicating the structuring of the fish community in the CBS by depth zones.



4. **Coastal Research and Monitoring in the Canadian Beaufort Sea, J. Reist (fishes) & L. Loseto (protected areas, beluga linkages), Freshwater Institute.**

Six coastal sites (3 estuarine/3 marine) in the southern Canadian Beaufort Sea are regularly sampled and monitored for fishes or beluga whales (hunter captured) and basic oceanographic parameters. Research activities aim to understand local drivers for fish composition and diversity, establish baselines for monitoring programs associated with stock assessment of anadromous fishes and for marine protected areas, monitor ongoing health of beluga whales harvested in the area, and to establish linkages between coastal, shelf and offshore components of the overall ecosystem. Investigation of capelin abundance and linkages with offshore studies is being conducted in Darnley Bay (near the community of Paulatuk). Similarly an Arctic Coastal Ecosystem Study (ACES) focuses upon the anadromous and marine fish community at Shingle Point immediately west of the Mackenzie River delta.

From the Canadian perspective the western Arctic (CBS and presently ice-bound areas of the northwestern Archipelago) have two significant associations with the Central Arctic Ocean (CAO). These are: 1) inputs from the CAO occur through deepwater processes (e.g., Atlantic Water Mass at depths between 450 and 1000m, and Arctic Bottom Water at depths >1000m in the Canada Basin are both advected onshore and up in the water column in shallower areas); and 2) shifts or perturbations in the CAO ecosystem may have consequences to nearshore transboundary organisms (i.e., beluga, bowheads, Arctic Cisco, Dolly Varden, Pacific salmons). Accordingly, ongoing research and monitoring to better understand these and document changes, particularly in the offshore areas is required.

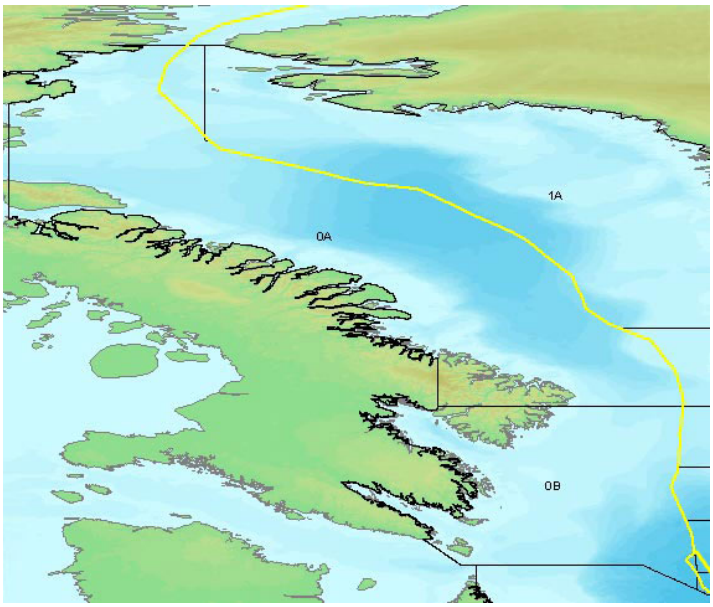
Figure 6. Canadian Beaufort Sea Coastal Research & Monitoring Activities.

5. **Multi-species offshore research survey and fisheries monitoring Baffin Bay/Davis Strait (BB-DS) and Hudson Strait, M. Treble & K. Hedges, Freshwater Institute.**

A multi-species bottom trawl survey is conducted annually using an ice-strengthened research vessel (RV *Pâmuit*). During 2012-2014 the area surveyed in a given year alternated between NAFO Division 0A (including Shrimp Fishing Area 1) and Division 0B and the Western Assessment Zone within Hudson Strait. Stations were selected randomly across depths with a Cosmos trawl used to sample depths 100-

1000m and an Alfredo trawl for 400-1500m. This work supports the assessment and monitoring of commercially fished stocks of Greenland Halibut and northern shrimp. Surveys have been conducted biennially in Division 0A since 1999. Catch and biological data are collected for demersal fishes and invertebrates. Oceanographic data is collected (salinity, temperature) on each tow and along cross-shelf transects near Broughton Island and Cape Christian. Distribution, abundance and biological data on Greenland Halibut and northern shrimp are incorporated into NAFO Scientific Council and Canadian Science Advisory Secretariat reports. Data, particularly those associated with by-catch species, once verified are shared on Ocean Biogeographic Information System (OBIS).

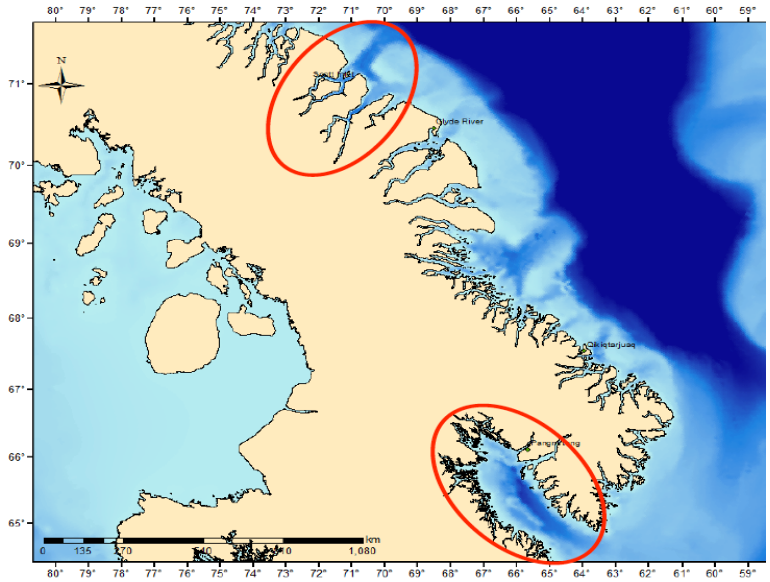
Figure 7. NAFO areas 0A and 0B in the eastern Canadian Arctic.




**6. Inshore surveys in the Eastern Arctic, K. Hedges, Freshwater Institute.**

Greenland Halibut sub-groups occur in fjords on the eastern margins of Baffin Island. An ice-based long-line winter inshore fishery based upon this and other potential resources has been ongoing, however, survey knowledge regarding the scope of possible resources has been limited. A program for inshore surveys, developed in partnership with the Government of Nunavut, has been developed. Additional partnerships with the Ocean Tracking Network (see below) to investigate key by-catch species have also been developed. In Scott Inlet (Clyde River area of north-central Baffin Island) (Figure 8), test fishing and biological stock assessment activities focused on Greenland Halibut are underway; and tracking studies of Greenland Halibut, Greenland Shark and Arctic Skate are also developed. In the Cumberland Sound area of southern Baffin Island, a **c**ommunity-based commercial winter Greenland Halibut fishery occurs and research into developing a summer fishery (depth-stratified long-line survey) is occurring. Additional research in this area includes Greenland Halibut movements (Ocean Tracking Network & DFO) and research into Capelin on southern Baffin Island with respect to population abundance and range changes (DFO & U Manitoba).

Figure 8. Research activities on inshore fishery resources in Baffin Island (northern oval is Scott Inlet; southern oval is Cumberland Sound).




Planned research activities in the near future include expanding inshore fisheries research regarding assessment into more westerly areas of the eastern Archipelago and to also conduct biodiversity surveys in northern and more westerly areas.

7. **Baffin Bay Benthic Biodiversity Research & Monitoring, E. Kenchington, Bedford Institute of Oceanography and others.**

As noted in the introduction, these areas of the eastern Canadian Arctic represent, in part, the downstream ends of influences from a changing Arctic Ocean. In addition, Baffin Bay and Davis Strait are influenced by changes in the North Atlantic with those effects being transferred by prevailing currents and water mass movements northwards along western Greenland, across the bay to the Canadian Archipelago eastern edge, thence southwards. Thus, distinguishing effects of transport through the Archipelago (i.e., indirect trickle-down changes from the CAO) from effects due to North Atlantic changes is challenging. Documenting benthic diversity and productivity represent initial steps to do so for this component of the ecosystem.

The relationships between benthic assemblages and seabird presence in Lancaster Sound (Bouchard Marmen, Kenchington, Archambault) on the northern end of Baffin Island was investigated in 2012 through comparison of benthos in areas with and without seabird colonies. Findings indicate that diversity of benthos was similar but infaunal density was lower near to seabird colonies. Benthic biodiversity, epifaunal density and community structure seem to be driven by other environmental factors such as food supply proxies and sediment type.

Discovery of relatively unique benthic areas with high diversity in Davis Strait has led to the closure of an area to bottom trawling (box outline in central bay on Figure 9). Documentation and monitoring of the benthic diversity in this area was conducted in 2013 using Circumpolar Biodiversity Monitoring Protocols through photographic transects and grabs. The spatial diversity and density of biota was estimated, taxon photos and identification conducted to the lowest taxonomic level with confirmation through DNA barcoding. These data and findings will be uploaded to the Arctic Council Data Portal (as per the Canadian CBMP protocol).

Figures 9 – Ship track for 2013 and benthic survey areas (dots in box in centre of bay).

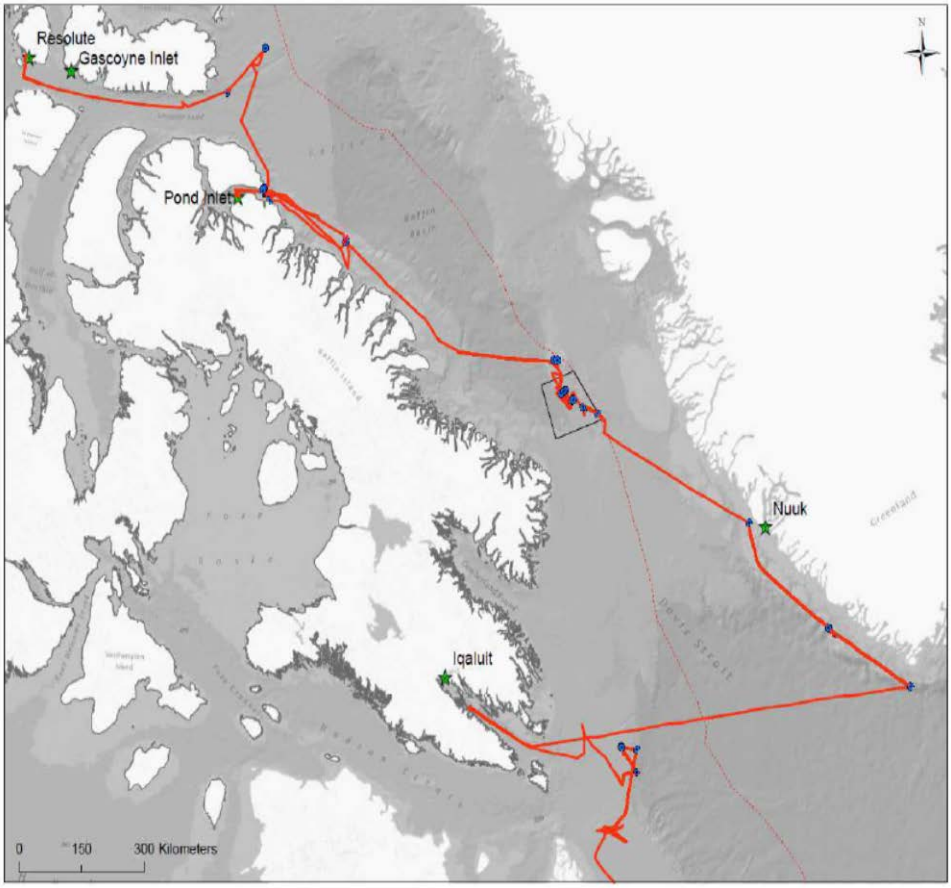
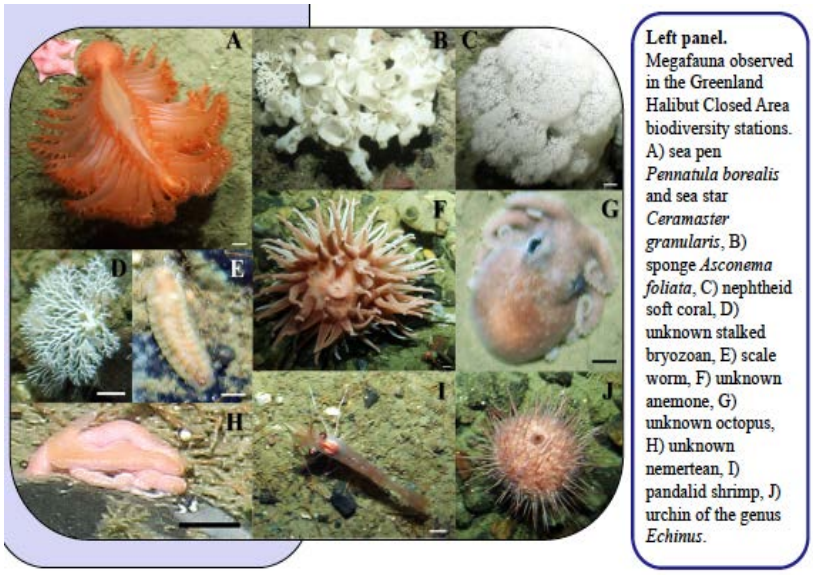


Figure 10 – Examples of benthic invertebrates present in the Baffin Bay/Davis Strait area.




**Left panel.** Megafauna observed in the Greenland Halibut Closed Area biodiversity stations. A) sea pen *Pennatula borealis* and sea star *Ceramaster granularis*, B) sponge *Asconema foliata*, C) nephtheid soft coral, D) unknown stalked bryozoan, E) scale worm, F) unknown anemone, G) unknown octopus, H) unknown nemertean, I) pandalid shrimp, J) urchin of the genus *Echinus*.

8. **Marine Aquatic Invasive Species (AIS) Research & Monitoring (Howland, Freshwater Institute and others 2012-present).**

Increased Canadian Arctic destinational and transpolar shipping is anticipated in the future as declines and changes in summer sea ice occur. Accordingly, risk associated with vessel-mediated transfers of biota is increased. This research aims to increase baseline knowledge and early detection of non-indigenous organisms in Arctic Ports (Canadian Aquatic Invasive Species Network), inventory existing biota and compare that to existing information to document changes (if any). Research being under-taken includes the development (preliminary phases only of multi-species environmental DNA (eDNA)) assays. Results to date indicate that ~20% of identified taxa were newly reported for the location but origins are uncertain (i.e., previously unsampled vs introduced).

A second research theme includes assessing the risk of invertebrate colonizing through climate changes. This includes modeling of risk (i.e., vector, biology) linked to ecology (and projected changes). Eight species have potential high risk for range extension and/or invasions.

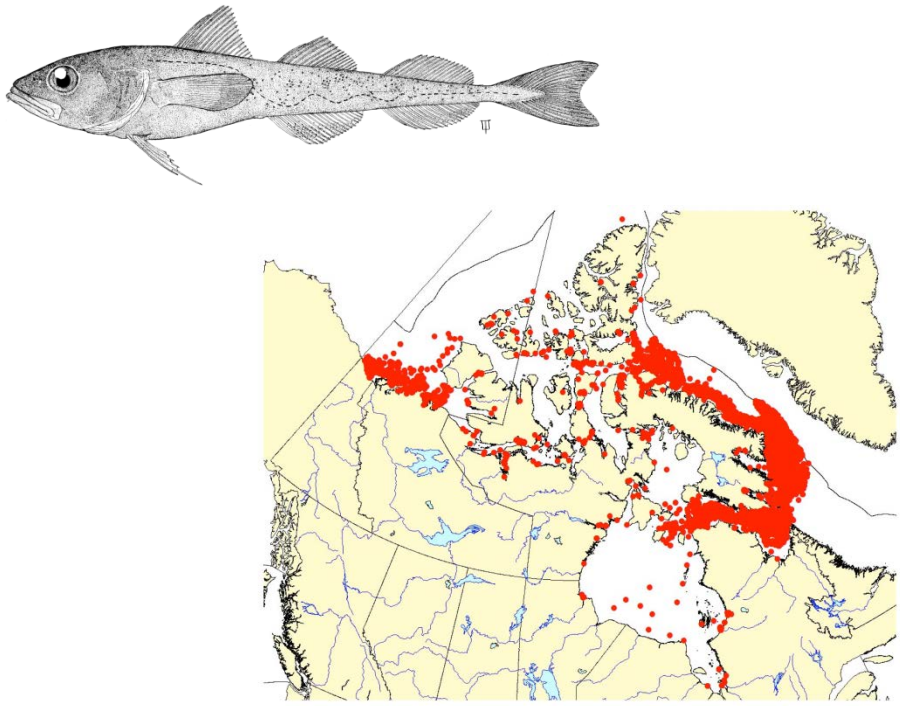
A third research theme examines the ecological risks of Ballast Water Exchange; this work has concluded that existing eastern areas are high risk thus suggests new areas for this activity beyond 1000m. This work further concludes that there are no feasible areas in Beaufort Sea area for Ballast Water Exchange. Related to this theme, research regarding ballast water as an AIS Pathway is being undertaken with the examination of ballast water from arriving ships conducted for both the Churchill (Hudson Bay) and Deception Bay (Northern Quebec).

**9. Information Synthesis and Integration Activities.**

*Central Arctic Ocean Knowledge* – A number of information synthesis and integration activities are underway within Canada with relevance to the Arctic Ocean and adjacent seas. These include:

- Distribution, diversity & habitat associations of marine fishes in Canadian Beaufort Sea (DFO Manuscript report presently as a draft, publication in late 2015) produced as part of the BREA Marine Fishes Project reporting.
- Marine Fishes of Arctic Canada – a guide developed by Coad (Canadian Museum of Nature) & Reist (DFO), with the final draft presently in revision. This will include identification keys, illustrations, descriptions & point distributions; plus bibliography (electronic) and published database of distributions (late 2015 date) (see Figure 12 for an example).
- Summaries of biota for the Central Arctic Ocean (CAO) and adjacent areas of Canada: Fishes of CAO (abundance, roles, Canadian shelf linkages), Benthic ecosystem of CAO (bottom types, benthos), Fishes & benthos of Chukchi Cap
  (all as draft contract reports; to be integrated and synthesized, publication in 2016).

Figure 12. Arctic Cod illustration and point distribution map for Canadian Arctic waters – draft from Coad & Reist, Marine Fishes of Arctic Canada.



*Knowledge Regarding Marine Protected Areas in the Canadian Arctic* – Delineation of marine protected areas (MPAs) in the Canadian Arctic is underway to protect and conserve important marine species and their habitats (for additional information see this website;

http://www.dfo-mpo.gc.ca/oceans/marineareas-zonesmarines/mpa-zpm/index-eng.htm). To date, one area has been designated and a second is nearing completion of the process to do so. Other areas are under discussion for consideration for development as MPAs.

Both the Tarium Niryutait Marine Protected Area (TNMPA) and the Anuniaqvia niqiqyuam Area of Interest (ANAOI) are in the Beaufort Sea area of the western Arctic (http://www.beaufortseapartnership.ca/tnmp_area.html).

Two key activities underpin the development and ongoing delivery associated with MPAs. First, in the context of information synthesis all relevant scientific background information in brought together as and Ecological Overview and Assessment report. An example for the ANAOI is: http://www.beaufortseapartnership.ca/documents/ANAOI%20synth.pdf.

Second, as part of the ongoing monitoring of the MPAs, assessment of potential monitoring parameters (e.g., key indicators associated with the environment and species) is conducted and synthesized into an ongoing monitoring program (those for the TNMPA are summarized in the following publications):

http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2010/2010_094-eng.html

http://www.dfo-mpo.gc.ca/CSAS/Csas/publications/sar-as/2010/2010_059_e.pdf

http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2012/2012_113-eng.html

http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2012/2012_061-eng.html

http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2012/2012_091-eng.html

**10. Recent reporting – Additional Information.**

Recent reporting by Canadians of relevance to the CAO and adjacent seas include the following:

- Arctic Biodiversity Assessment (Fishes & Marine Ecosystems chapters) http://www.arcticbiodiversity.is ;
- Arctic Biodiversity Congress (Dec 2014) presentations on Fish research in Beaufort Sea & Baffin Bay/Davis Strait and Benthos in Baffin Bay/Davis Strait, http://www.arcticbiodiversity.is/congress;
- Gordon Polar Marine Conference (March 2015) presentation regarding C:N ratios in sea ice & water column; https://www.grc.org/programs.aspx?id=14833;
- Marine Fishes in Arctic Report Card (2013) http://www.arctic.noaa.gov/report13/marine_fish.html; and,
- Arctic Ocean Acidification (2013), http://www.amap.no/documents/doc/amap-assessment-2013-arctic-ocean-acidification/881.
- An upcoming special issue of Polar Biology (late 2015) will focus upon Arctic/Polar cod with several relevant Canadian papers.

## 11. Other (non-governmental) Canadian Activities.

The following organizations also conduct research in the Canadian (and global Arctic); although activities are not enumerated in detail here, linkages exist between these programs and DFO as well as between DFO scientists and various universities. Programs include:

- ArcticNet: http://www.arcticnet.ulaval.ca with many publications produced and data archived through Polar Data Catalogue;

- Ocean Tracking Network: Projects 4.10. Fish and marine mammal interactions in the high Arctic, 4.11. Deep-water Arctic marine fishes: Developing commercial fisheries and interactions with marine mammals, and 4.13. Tracking anadromous adult salmonids in Canada's three oceans to evaluate the sustainability of catch-and-release angling practices – behavioural and physiological perspectives on estuarine fisheries. http://oceantrackingnetwork.org
- Canadian Healthy Oceans Network: http://chone.marinebiodiversity.ca

**12. Delivery of Data from Canadian Arctic Science Activities.**

Data developed by DFO Science Research and Monitoring programs are archived in various ways. At present this is program-dependent. Various mechanisms and sites include the following:

- Polar Data Catalogue: Beaufort Sea Marine Fishes (i.e., metadata and first-order data) – usually <6 months; https://www.polardata.ca;
- Oceanographic and lower trophic data collected by researchers from Fisheries and Oceans Canada are maintained on a database (DFO ISDM/MEDS); http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/index-eng.html;
- By-catch Data from Baffin Bay and Davis Strait offshore: OBIS, http://www.iobis.org and Stock Assessment Data/reports: NAFO, http://www.nafo.int;
- Internal DFO data reports: Detailed 2nd (biological) and 3rd order (e.g., lab analyses of trophic markers) – usually no longer than 2 years (or before);
- Other Internal DFO reports: Technical Reports and Manuscript Reports
  (Data, Technical & Manuscript reports available at http://waves-vagues.dfo-mpo.gc.ca/waves-vagues/);
- Canadian Science Advisory Secretariat (formal advisory documents) (available at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm;
- Other: Arctic Council Data Portal - http://arcticdata.is.

In addition to the above, the development and delivery of knowledge regarding Arctic marine diversity is conducted through the Canadian Arctic Marine Biodiversity Plan (Pomerleau et al. referenced below as CAFF Monitoring report 13) of the Circumpolar Biodiversity Monitoring Program in regards to the following Focal Ecosystem Components: sea-ice biota, plankton, benthos, fishes, sea-birds & marine mammals. This activity takes a regional ecosystem-based approach: Beaufort Shelf, Lancaster Sound, Western Hudson Bay, Hudson Strait, Southeast Baffin Bay, Nares Strait/North Baffin Bay and works through the ongoing Marine Expert Networks (e.g., marine fishes).

- The Canadian activity is outlined in CAFF Monitoring Series Report No. 13, Sept. 2014 (http://www.caff.is/marine/marine-monitoring-publications/278-canadian-arctic-marine-biodiversity-plan-2014-2017).
- Indicators for CBMP Marine Canada are outlined in Nelson, R.J. 2012. Development of indicators for Arctic Marine Biodiversity Monitoring in Canada. Canadian Science Advisory Secretariat Research Document 2012/123.
- Both government and university Canadian researchers are also involved in ongoing assessments led through various Arctic Council working groups: 'State of the Arctic Marine Biodiversity (SAMBR)' writing workshop (CAFF led); and, Adaptation Actions for a Changing Arctic (AACA) for the Baffin Bay/Davis Strait and Beaufort Sea sub-regions (AMAP led).

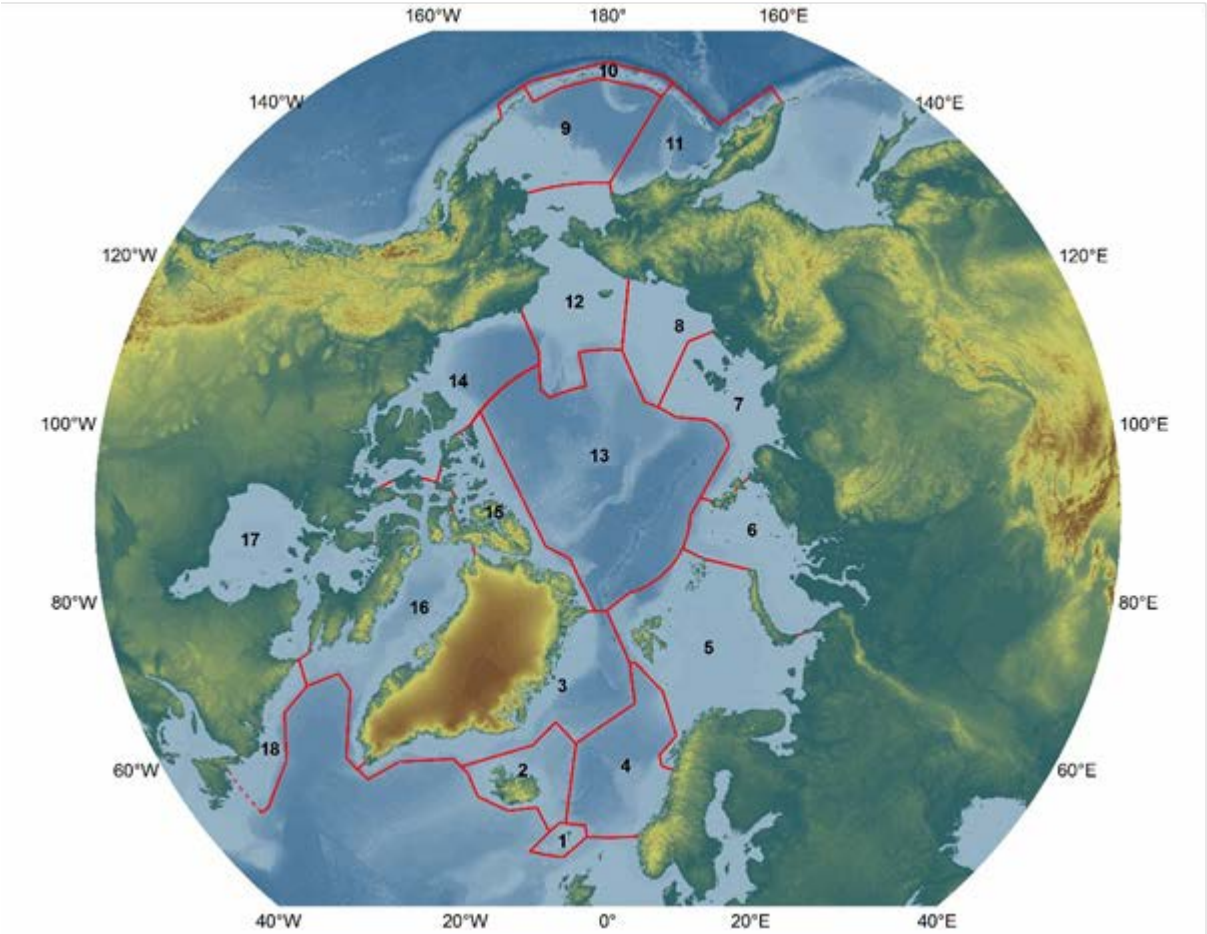
## U.S. survey and project activity:

### *Introduction*

#### ***Integrated Ecosystem Assessment (IEA)***

http://www.noaa.gov/iea/

As developed within NOAA, Integrated Ecosystem Assessment, IEA, is an iterative science-based process that provides products to resource managers who are operating under the principles of ecosystem based management, EBM, and as an application to exploited fish stocks, Ecosystem Based Fishery Management, EBFM. NOAA Fisheries, Alaska Fisheries Science Center, is implementing EBFM in four Arctic Large Marine Ecosystems, LMEs, as an active part of the NOAA Integrated Ecosystem Assessment Program. Under the US Arctic Research and Policy Act (ARPA 1982) the waters of the US arctic occur in the following LMEs; Aleutian Archipelago (10), East Bering Sea (9), Northern-Bering Chukchi Seas (12), and Beaufort Sea (14). The fisheries in the Bering Sea were perhaps the first in the United States to be managed under an ecosystem-level annual harvest cap implemented about three decades ago. Under the ecosystem-level cap, the North Pacific Fishery Management Council, NPFMC, limits annual harvests of all fish species to no more than two million metric tons. NPFMC is also guided in its management decisions by an Alaska Marine Ecosystems Considerations Report, which is an annual snapshot of ecosystem indicators and their time trends. In addition, estimates of the risks posed to twenty-two types of fish habitats, such as rocky coastal habitats, by twenty risk factors, such as ecotourism. The synthesized ecosystem level information is synthesized into a written report which is factored into the decisions on total allowable catch, TAC, made by the NPFMC each year. Observations from physics, through primary and secondary production are also used to estimate the impacts of climate change on fish species in a vertically integrated coupled biophysical model driven by IPCC climate projections. The upper trophic level component of the biophysical model is known as Forage and Euphausiid Abundance in Space and Time, FEAST. FEAST exchanges information on distribution and abundance of upper trophic level organisms with the lower trophic level model and the economic and spatial fishery predictions model in this vertically integrated series of models. At the base of the models are the IPCC climate scenarios, which drive the physical oceanographic model which in turn drives the lower trophic level model that interacts with FEAST. Work is continuing to extend FEAST beyond the eastern Bering Sea LME to make predictions about the impact of climate change on other species and other locations.




Revised Map of 18 Arctic LMEs (version 17 April 2013). The revisions resulted in 18 LMEs for the Arctic by addition of a new LME in the Bering Sea area: the *Aleutian Archipelago LME*.

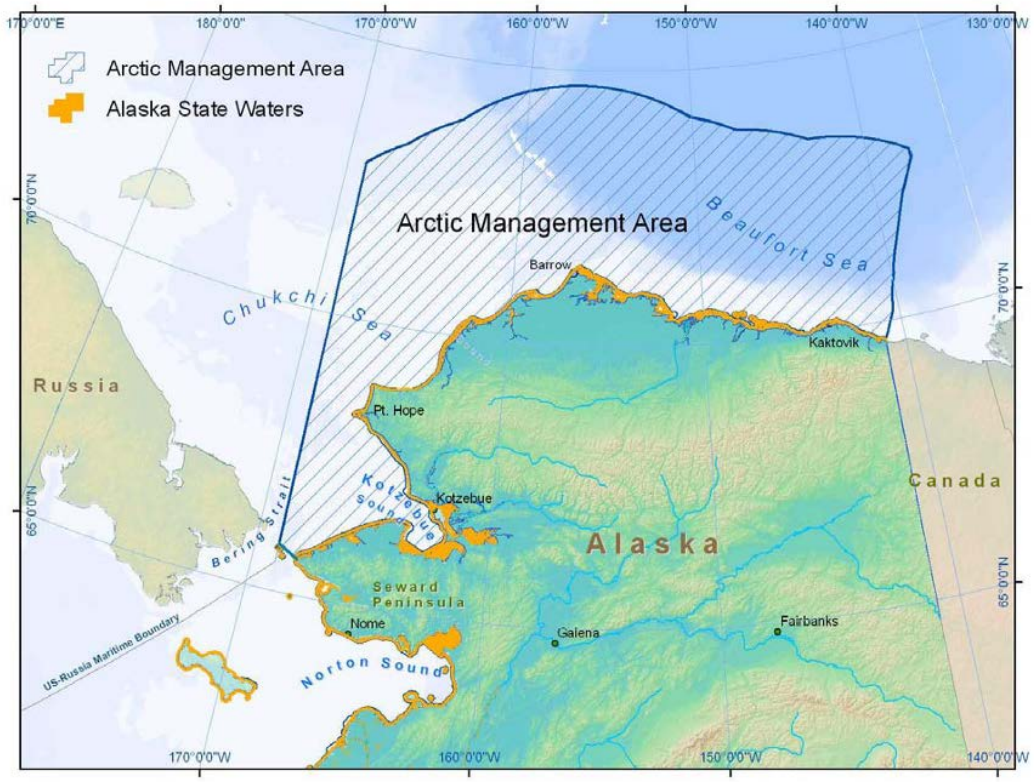
### *Arctic Fishery Management Plan*

http://www.npfmc.org/wp-content/PDFdocuments/fmp/Arctic/ArcticFMP.pdf

This Fishery Management Plan (FMP) governs commercial fishing for most species of fish within the Arctic Management Area.1 The FMP management area, the Arctic Management Area, is all marine waters in the U.S. Exclusive Economic Zone of the Chukchi and Beaufort Seas from 3 nautical miles offshore the coast of Alaska or its baseline to 200 nautical miles offshore, north of Bering Strait (from Cape Prince of Wales to Cape Dezhneva) and westward to the 1990 United States/Russia maritime boundary line and eastward to the United States/Canada maritime boundary. The FMP governs commercial fishing for all stocks of fish, including all finfish, shellfish, or other marine living resources, except commercial fishing for Pacific salmon and Pacific halibut, which is managed under other authorities. The FMP was approved by the Secretary of Commerce on August 17, 2009. Pursuant to Title II of the Magnuson-Stevens Act (MSA), there is no allowable level of foreign fishing for the fisheries covered by this FMP. While fishing vessels and fish processors of the U.S. have the capacity to harvest and process up to the level of optimum yield of all species subject to other Council FMPs, Council policy as articulated in this Arctic FMP is to prohibit all types of commercial harvests of all fish resources of the Arctic Management Area until sufficient information is available to support the sustainable management of a commercial fishery. The FMP implements the principles of ecosystem based fishery management, EBFM, consistent with the missions and policies of the US Department of Commerce, NOAA and NOAA Fisheries. Under EBFM a fish stock may be harvested only to the extent that information is in hand to determine if National Standard One of the MSA (prevent overfishing) is being implemented. The absence of sufficient information on National Standard One may preclude any harvesting, which is the case in the Arctic FMP. Note that EBFM is an integral part of NMFS' Integrated Ecosystem Assessment (see preceding section).

Under the Magnuson-Stevens Act, the North Pacific Fishery Management Council (Council) is authorized to prepare and submit to the Secretary of Commerce for approval, disapproval, or partial approval, an FMP and any necessary amendments for each fishery under its authority that requires conservation and management. The Council's policy is to proactively apply judicious and responsible fisheries management practices, based on sound scientific research and analysis, to ensure the sustainability of fishery resources, to prevent unregulated fishing, and to protect associated ecosystems for the benefit of current users and future generations. As part of its policy, the Council intends to consider and adopt, as appropriate, measures that prevent unregulated fishing, apply the Council's precautionary, adaptive management policy through community-based or rights-based management, apply ecosystem-based management principles that protect managed species from overfishing and protect the health of the entire marine ecosystem, and where appropriate and practicable, include habitat protection and bycatch constraints. All management measures will be based on the best scientific information available. Given this intent, the fishery management goals are to provide sound conservation and sustainability of the fish resources, provide socially and economically viable fisheries for the well-being of fishing communities, minimize human-caused threats to protected species, maintain a healthy marine resource habitat, and incorporate ecosystem-based considerations into management decisions. This management policy recognizes the need to balance competing uses of marine resources and different social and economic goals for sustainable fishery management, including protection of the long-term health of the

ecosystem and the optimization of yield from its fish resources. This policy will use and improve upon the Council's existing open and transparent process of public involvement in decision-making.




## *US Arctic Research*

There are at least 14 different Arctic research projects/efforts in the US recently completed or currently underway. They are described in detail later in this document. An important collaborative program involving many of these individual projects is the Distributed Biological Observatory (DBO). The DBO is envisioned as a change detection array along a latitudinal gradient extending from the northern Bering Sea to the Barrow Arc. Data collected at DBO sites includes measurement/samples/observations of physical oceanography, chemical oceanography, production, phytoplankton, zooplankton, benthic fauna, marine mammals, marine birds and fish.

Research and/or funding institutes/agencies for US Arctic research include: University of Alaska Fairbanks, University of Washington, North Pacific Research Board, NOAA Alaska Fisheries Science Center, NOAA Pacific Marine Environmental Laboratory, NOAA National Marine Mammal Laboratory, North Slope Borough, Bureau of Ocean and Energy Management, US Fish and Wildlife Service, US Geological Survey, Community Coastal Impact Assistance Program, Department of Fisheries and Oceans Canada, State Research and Design Institute for Fishing Fleet (Giprorybflot), ConocoPhillips, Shell Exploration, Statoil USA, and Olgoonik Fairweather LLC.

US Arctic field research projects are carried out on the Chukchi Sea and Beaufort Sea shelves. No recent, current or ongoing studies are conducted in Central Arctic Ocean, outside the US EEZ. Most of the at-sea

projects are conducted in waters > 20 m deep, although a few study the fish communities of the nearshore (< 20 m deep) and lagoons.

Objectives for US Arctic research are several fold. The goal of many studies is to understand the distribution of marine fishes and shellfishes. Some studies are also designed to collect baseline data on the habitat, abundance, distribution and species composition of fish. A number of studies, supported by BOEM, are to assess the oceanography and ecology of areas of potential oil and gas development. One new project, the Arctic Marine Biodiversity Observing Network, aims to close current gaps in biodiversity observation in the Arctic. Another, the Marine Arctic Ecosystem Study, is designed to identify cultural, historic and subsistence resources which could be sensitive to human activities.

Focal study organisms for US Arctic research include taxa of potential commercial interest in the Arctic such as Arctic cod (*Boreogadus saida*), walleye pollock (*Gadus chalcogrammus*), flatfish (Pleuronectidae), and snow crab (*Chionoecetes opilio*). Many studies are ecosystem surveys and thus also include collections of data on ocean circulation and physics, water chemistry, microbes, phytoplankton, zooplankton, benthic invertebrates (epi- and infaunal), sediment characteristics, other fish taxa (e.g., capelin, salmon, saffron cod), seabirds and marine mammals.

There is a substantial US Arctic research effort aimed specifically at marine mammals. The objectives of some marine mammal studies are to document the distribution and relative abundance of whales in areas of potential industrial activity and to relate changes in those variables to oceanographic conditions, indices of potential prey density, and anthropogenic activities. Some studies are conducted to describe the annual migration of bowhead whales across the Alaskan Arctic, significant inter-year differences, and long-term trends in the spatial distribution and timing of the migration. Other studies document the relative abundance, spatial and temporal distribution, and behavior of a suite of marine mammal taxa (cetaceans, ice seals, walruses, and polar bears).

Finally, there are a number of data synthesis projects involving data on physics, fish, and marine mammals. Some projects synthesize recent studies, while others draw on historical data.

### *Distributed Biological Observatory (DBO)*

Contact: Sue Moore, NOAA, sue.moore@noaa.gov

Funding: NOAA, National Science Foundation

http://www.arctic.noaa.gov/dbo/

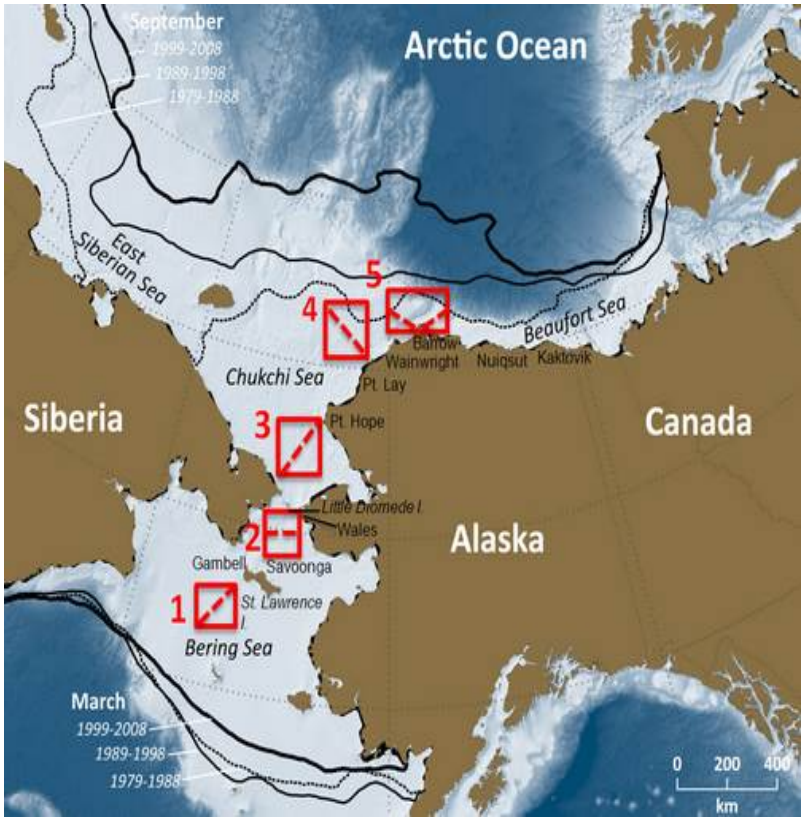
The “Distributed Biological Observatory (DBO)” is envisioned as a *change detection array* along a latitudinal gradient extending from the northern Bering Sea to the Barrow Arc. DBO sampling is focused on transects centered on locations of high productivity, biodiversity and rates of biological change. The DBO sampling framework was initially tested during the successful 2010 Pilot Study, which consisted of international ship occupations of two of the DBO sites, one in the SE Chukchi Sea and one across upper Barrow Canyon. Provisional results of the 2010 Pilot Study were the central topic at the December 2010 PAG meeting in Tokyo, Japan, and at the March 2011 DBO workshop in Seoul, Korea, held immediately prior to the international Arctic Science Summit Week. Approximately 90 people attended the one-day DBO workshop in Seoul, including invited speakers who presented ideas for efforts to expand the DBO

concept to the Eastern Arctic. In addition, provisional data sets were presented and planning efforts for the 2011 Pilot Study were initiated.

A pilot study focused on sampling two of the five DBO regions was launched in 2010. Subsequently the U.S. Interagency Arctic Research Policy Committee (IARPC), comprised of representatives from 13 Federal agencies, developed a five year plan (2013-2017) focused on seven research themes, with further development of the DBO included under the first theme: Sea ice and Marine Ecosystems. Since 2012, a US DBO Implementation Team (IT) has met via monthly teleconference, with the overarching goal of implementing sampling in all five DBO regions by 2015. Currently, the DBO IT consists of 37 participants, 25 from seven Federal agencies and 12 non-Federal partners.

Data collected at DBO sites includes measurement/samples/observations of physical oceanography, chemical oceanography, production, phytoplankton, zooplankton, benthic fauna, marine mammals, marine birds and fish. Two new DBO regions have been added to the Beaufort Sea at longitudes 152° W and 143° W.

The DBO IT is now focused on bringing together data from 2010-2013 sampling efforts, to demonstrate the value-added of this national and international, sampling shared-data approach to the investigation of biological responses to a rapidly changing Arctic marine ecosystem. Expanding from the Pacific Arctic sector, the DBO will also serve as a framework for international research coordination via the Arctic Council Circumpolar Biodiversity Monitoring Program (CBMP), and is recognized as a task of the pan-arctic Sustaining Arctic Observing Network (SAON) program.




Map of US Arctic Seas showing DBO sites

Recent publications

Grebmeier, J.M., *Biological community shifts in Pacific Arctic and sub-Arctic seas*, 2012, Annual Review of Marine Science, Vol. 4. (in press). Note the paper will appear first as a web article in fall 2011 (http://www.annualreviews.org/toc/marine/forthcoming)

Grebmeier, J. M., Moore, S. E., Overland, J. E., Frey, K. E., and Gradinger, R., EOS Trans. AGU, 91, 18, doi:10.1029/2010EO180001, 2010

## *Arctic Ecosystem Integrated Survey (Eis)*

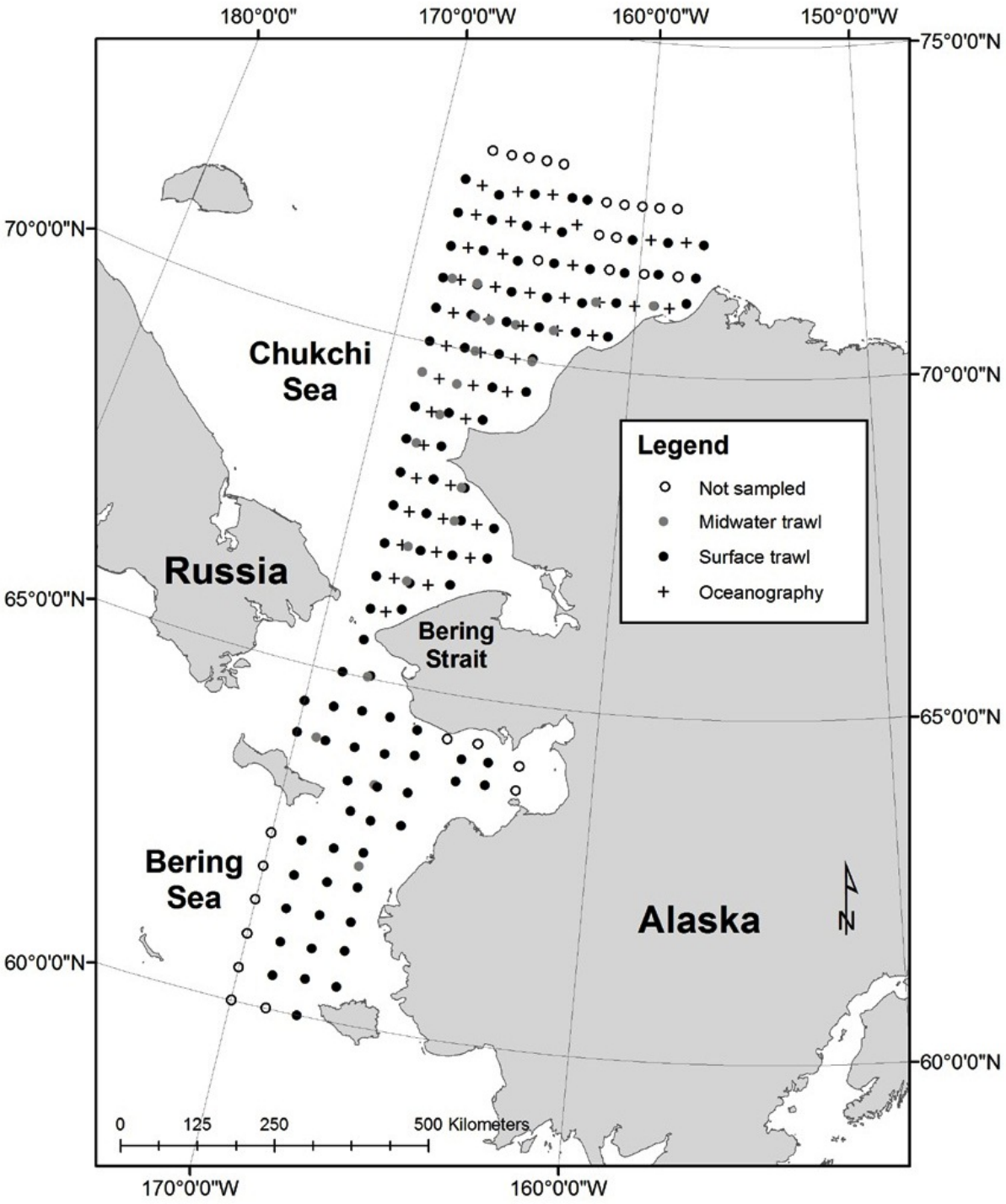
Contacts: Arctic Eis Program Manager Jared Weems, jdweems@alaska.edu; Lead Principal Investigators Ed Farley (@noaa.gov) and Franz Mueter fmueter@alaska.edu

Funding: BOEM, Coastal Impact Assistance Program, NOAA (in kind).

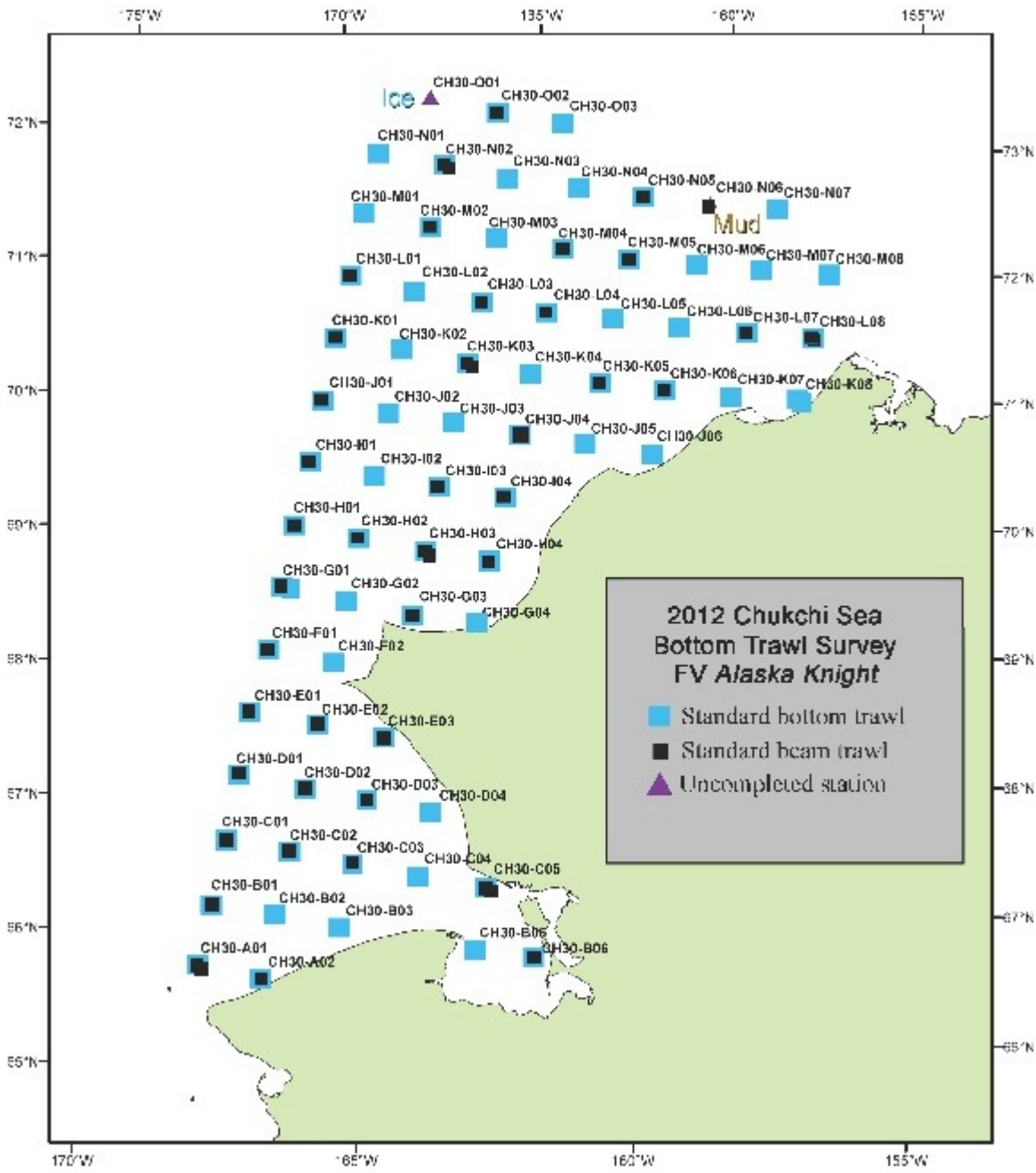
Conducting Agencies: University of Alaska Fairbanks and NOAA, and USFWS for seabird component

https://web.sfos.uaf.edu/wordpress/arcticeis/

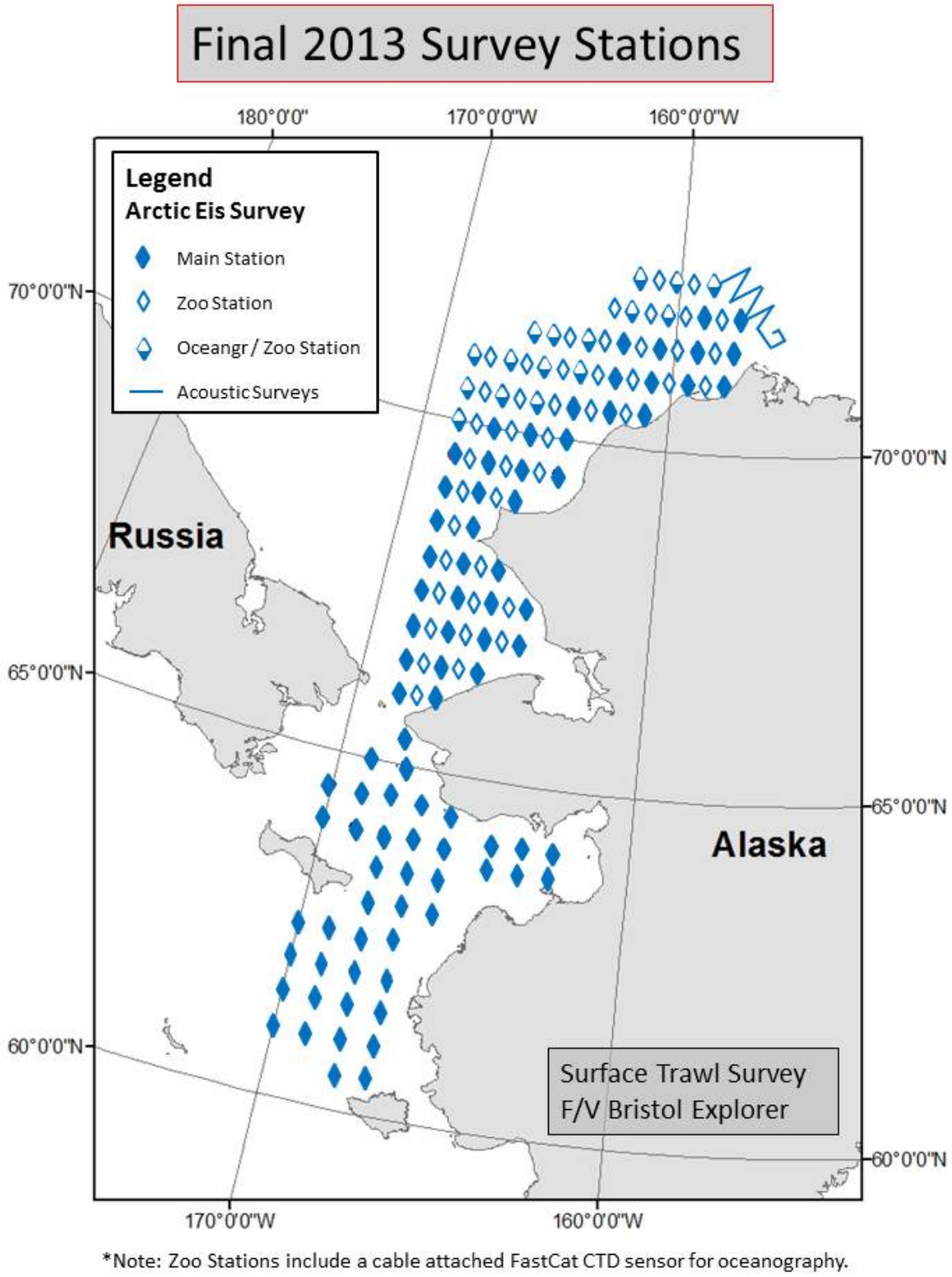
The Arctic Eis Project is a 2-year comprehensive field study of the water masses, circulation and biological resources of the northeastern Bering Sea and Chukchi Sea marine ecosystems from August through September in 2012 and 2013. Our baseline data collection and analysis helps define the regional structure, function, and ecology of the plankton, fish and shellfish communities under current climate and habitat conditions. Three scientific cruises and 164 sea days were used to collect data and samples on the oceanography, small plankton, pelagic and demersal fish, and benthic invertebrates. Oceanographic results show consistently warmer, less saline waters along the Alaska coast and cooler, saltier waters offshore on the northern Bering and Chukchi shelves. Zooplankton distribution and abundance appears to relate to oceanographic conditions (habitat); though large copepod s were prevalent throughout. Surface trawls from the upper water column found that jellyfish, herring and capelin were relatively abundant in the southern region (60$^{o}$N to 70$^{o}$N), while smaller juvenile Arctic cod and jellies were the most abundant north of 70$^{o}$N latitude. Of note, the 2013 juvenile and immature Chinook salmon catch in the Northern Bering Sea was nearly ten-fold larger than in 2012 and appears to be one of the best regional survey catches in the last decade. On the Chukchi sea floor in 2012, fish (mostly Arctic and saffron cod) accounted for less than 4% of the catch weight per unit area, with most of the biomass consisting of various invertebrate species, headlined by green sea urchins and snow crab. Final results from our ecosystem-wide analyses will provide a benchmark against which to assess the impacts of potential oil and gas development and climatic change on the polar marine environment in the future. Efforts to organize an Arctic Eis 'Special Issue' within a respected peer-reviewed journal are ongoing (Deep Sea Research).




The 2012 surface trawl cruise station map while on board the F/V Bristol Explorer. (Credit: AFSC)




The 2012 bottom trawl cruise station map while on board the F/V Alaska Knight. (Credit: AFSC)




The 2013 surface trawl cruise station map while on board the F/V Bristol Explorer. (Credit: AFSC)

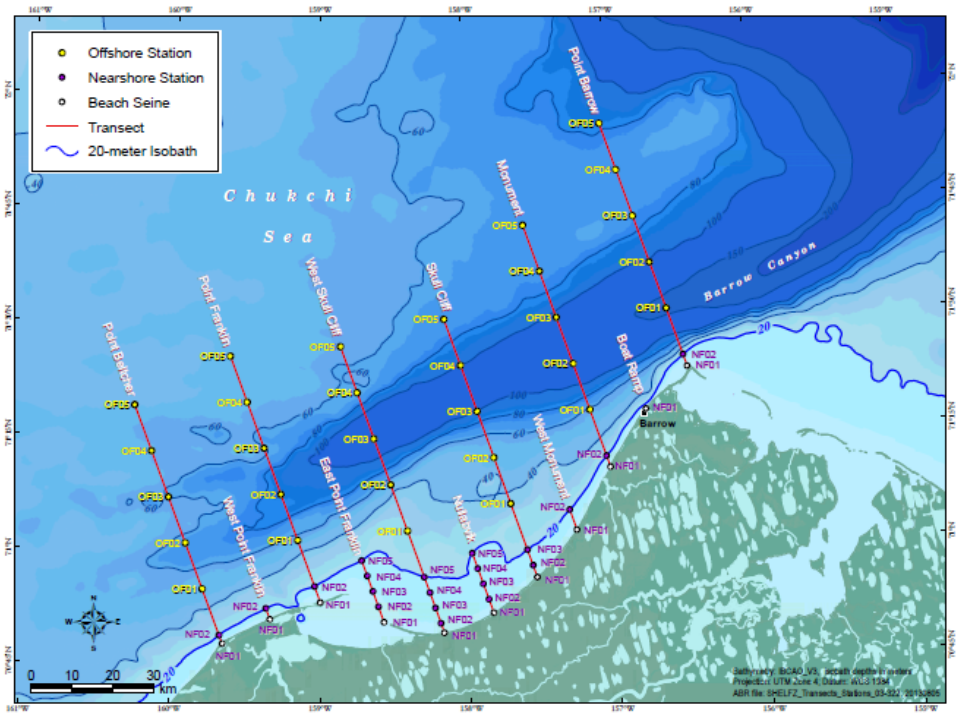
## *Shelf Habitat and Ecology of Fish and Zooplankton (SHELFZ)*

Contact: Leandra de Sousa, North Slope Borough Department of Wildlife Management, leandra.sousa@north-slope.org

Funding: Coastal Impact Assistance Program

The SHELFZ project is a North Slope Borough Department of Wildlife Management (NSB-DWM) initiative, funded by the Coastal Impact Assessment Program through the United States Fish and Wildlife Service (USFWS). This objectives of this study are to: 1) Collect baseline data on the habitat, abundance, distribution and species composition of zooplankton and fish in the Chukchi Sea; 2) Identify similarities and differences between nearshore (< 20 meters water depth) and offshore (> 20 meters water depth) zooplankton and fish communities in the Chukchi Sea.

The project duration is from May 2013-December 2016. Field sampling and data collection occurred in August and September 2013, sample processing and analyses are ongoing and will continue through December 2015 and report writing will be completed in October 2016. Data collected include: zooplankton and fish net samples, fisheries acoustics, fish diet and energetics, and hydrography (conductivity, temperature, depth). Cooperating agencies include: University of Alaska Fairbanks, University of Washington, AFSC-Seattle, AFSC-Juneau. This is the first survey in which nearshore (< 20 m isobath) and offshore data (> 20 m isobath) have been concurrently collected for fish, zooplankton, fisheries acoustics, and water mass properties along Alaska's Chukchi Sea coast. This study contributes new baseline information to our understanding of the ecology of nearshore and offshore habitats.




Station and transect locations for nearshore (purple) and offshore (yellow) components of the SHELFZ 2013 survey. Depth contours are in meters.

### *Chukchi Sea Environmental Studies Program (CSESP)*

Contact: Sheyna Wisdom, Olgoonik Fairweather LLC, sheyna.wisdom@fairweather.com

Funding: ConocoPhillips, Shell Exploration, Statoil USA

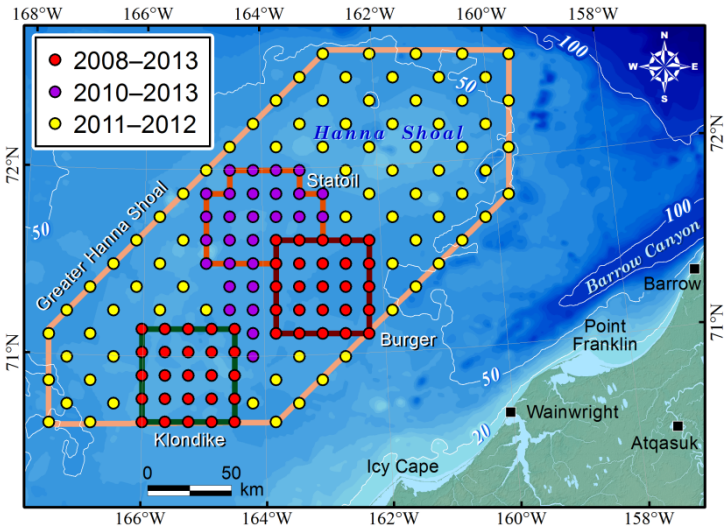
www.chukchiscience.com

In February 2008 the Bureau of Ocean Energy Management (BOEM) held Lease Sale 193 of blocks in federal waters of the northeastern Chukchi Sea. ConocoPhillips (COP) obtained 98 lease-blocks within two main former well-site areas, Klondike and Burger. Shell Exploration & Production Company (Shell) obtained 275 lease-blocks near the Crackerjack, Shoebill, and Burger well sites. Statoil USA Exploration & Production (Statoil) obtained 16 lease-blocks north of Burger. In the open-water seasons of 2008 and 2009, COP operated, on behalf of itself and Shell, an integrated ecosystem-based environmental studies program to collect baseline data in the Chukchi Sea. Starting in 2010, Olgoonik Fairweather LLC (OF) began to operate the Chukchi Sea Environmental Studies Program (CSESP), jointly funded by COP, Shell, and Statoil.

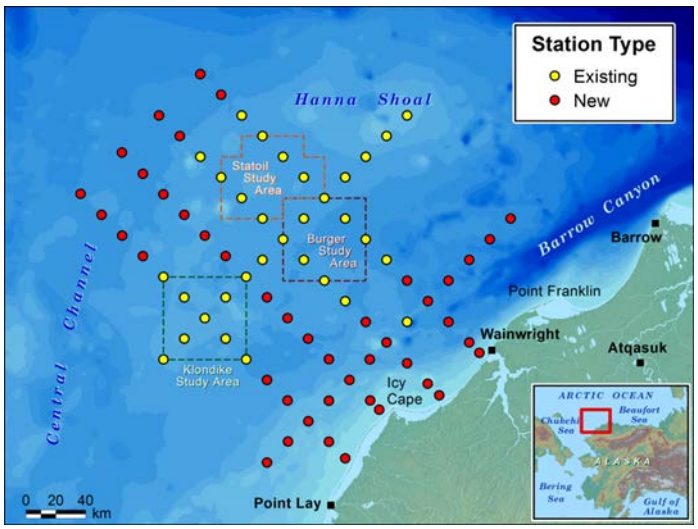
The CSESP includes various disciplines of the marine ecosystem, including physical oceanography, ocean acidification (new in 2010), plankton ecology (zooplankton and primary productivity), benthic ecology (infaunal and epibenthic communities), seabird ecology, marine mammal ecology. In addition, several types of instruments (sub-surface and surface moorings) are deployed to measure current and ice velocities, profiling of ice, air, and water parameters, and passive acoustic monitoring.

The overall purpose of the CSESP is to provide to COP, Shell, and Statoil necessary baseline information about the marine environment in their respective lease areas that can be used in applications for permits, in National Environmental Policy Act (NEPA) compliance documents, and in other documents and to help manage these resources and plan for mitigation. This study will provide valuable information for the regulatory agencies to conduct realistic evaluations on the potential impacts of oil and gas activities and, thus, issue permits with reasonable stipulations and guidance. It also will contribute to the overall knowledge of the northeastern Chukchi Sea marine ecosystem.

In 2008 and 2009, the program consisted of two prospect-specific study areas: “Klondike” for COP and “Burger” for Shell. In 2010, an additional prospect-specific study area (“Statoil”) was added north of Burger for Statoil. In 2011 and 2012, the program was expanded to a regional survey that encompassed the three prospect-specific study areas plus areas to the west, east, and north, including Hanna Shoal. The study design for 2011 and 2012 was based on the systematic station and transect grid used during the 2008–2010 CSESP but was expanded to a coarser scale to cover a greater area in a shorter amount of time. The 2013 program includes the sample grid and general timing from 2010, surveying only the prospect-specific study areas of Klondike, Burger, and Statoil. The finer transect scale in the prospect-specific study areas is maintained to allow for interannual data continuity. Additionally, a transect including stations to be sampled for physical oceanography will be surveyed, as logistics and time allow, in support of the Distributed Biological Observatory (DBO) program managed by NOAA and the Pacific Arctic Group. For the 2014 program, the physical and biological oceanographic sample stations occur along six monitoring lines around and intersecting each previous years prospect-specific study area.




CSESP sampling stations 2008-2013




CSESP sampling stations 2014

<u>Recent publications</u>

Day, Robert H., Thomas J. Weingartner, Russell R. Hopcroft, Lisanne a.M. Aerts, Arny L. Blanchard, Adrian E. Gall, Benny J. Gallaway, et al. 2013. "The offshore northeastern Chukchi Sea, Alaska: A complex high-latitude ecosystem." *Continental Shelf Research* 67 (September): 147-165. doi:10.1016/j.csr.2013.02.002. http://linkinghub.elsevier.com/retrieve/pii/S0278434313000514.

### *Arctic Marine Biodiversity Observing Network (AMBON)*

Program managers: Catherine Coon (BOEM), catherine.coon@boem.gov, Gabrielle Canonico (NOAA), gabrielle.canonico@noaa.gov

Lead PI: Katrin Iken, University of Alaska Fairbanks, kbiken@alaska.edu

http://www.boem.gov/BIO-1501/

Through the National Oceanographic Partnership Program (NOPP), multiple agencies including NOAA, NASA, BOEM, and the USGS sent out a request for proposals to initiate an integrated Marine BON demonstration project. The bureaus requested proposals for one or more broadly coordinated demonstration projects in U.S. coastal waters that demonstrate how an end-to-end marine BON can be developed. “End-to-end” refers to integration of observations and historical data across multiple scales of diversity (genetic to ecosystem, microbes to whales), time (instants to centuries), and space (in situ to satellite remote sensing).

The objective of this study for the Alaska Region is to build on emerging distributed biological observatories (DBOs) by developing a prototype ecosystem-based marine biodiversity network over offshore oil and gas lease areas in the Chukchi Sea, monitoring multiple trophic levels and species, and informed by historical data and past modeling efforts. Such a network will: expand upon planned and recently-launched observing sites, systems, and programs; employ innovative techniques for data discovery and methods that dynamically interrelate data sets and add value to existing monitoring data; collaborate with the U. S. Integrated Ocean Observing System (U.S. IOOS) participants and funding agencies to optimize data management and modeling capabilities.

The period of performance for AMBON 2015-2018. Data will be collected on bird and marine mammal distribution, water column properties, microbes and small eukaryotic plankton, zooplankton, sediment characteristics, meiofauna, macrofauna, epifauna and fish.

## *Russian-American Long-term Census of the Arctic (RUSALCA)*

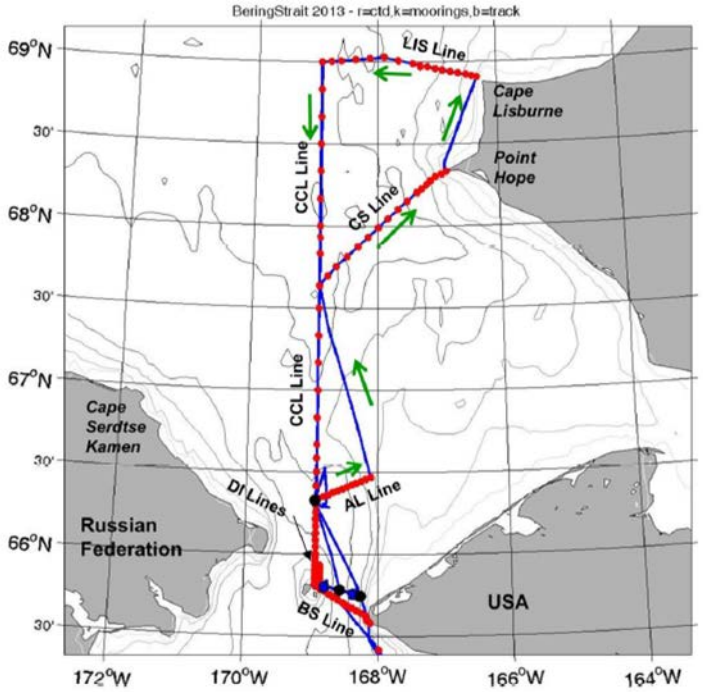
U.S. Contact: Kathy Crane, NOAA, kathy.crane@noaa.gov

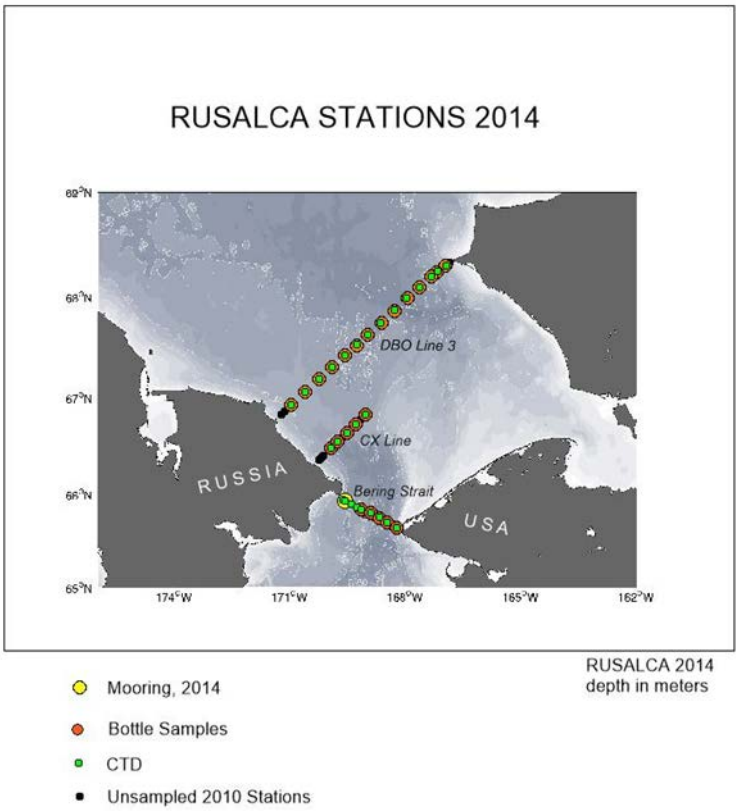
http://www.arctic.noaa.gov/rusalca/

July 23, 2004 marked an historic day in Arctic research and exploration as well as Russian-U.S. relations. On this date the Russian research ship, the Professor Khromov, left Vladivostok, Russia packed with U.S.and Russian, funded scientists to begin a 45-day collaborative journey of exploration and research in the Arctic. Stemming from a 2003 Memorandum of Understanding for World Ocean and Polar Regions Studies between NOAA and the Russian Academy of Sciences, this cruise was the first activity under the Russian-American Long-term Census of the Arctic (RUSALCA). The Initial Expedition to the Bering and Chukchi Seas (Arctic Ocean), was conducted July 23 – September 6, 2004. This initial cruise was a collaborative U.S – Russian Federation oceanographic expedition to the Arctic seas regions shared by both countries: the Bering and Chukchi Seas. Expeditions have been conducted annually from 2014 to the present. Field sampling/observations include moorings for oceanography, bio-optics, whale acoustics and ocean acidification; CTD sections and water samples; phytoplankton and zooplankton net tows; infaunal and epibenthic invertebrate sampling; benthic fish trawls;  marine mammal and seabirds observations.

In 2013-2014 moorings were deployed, CTD sections and water samples were taken, and marine mammal and seabird observations were made.

***BERING STRAIT 2013 MOORING CRUISE MAP:*** *Ship-track, blue.  Mooring sites, black. CTD stations, red.  Grey and green arrows indicate direction of travel (grey during mooring operations, green during CTD operations).  Depth contours every 10m from the International Bathymetric Chart of the Arctic Ocean (IBCAO) [Jakobsson et al., 2000].  Lower panels mooring detail: - black solid=recovered and redeployed; black with blue center =recovered, not redeployed.*




RUSALCA STATIONS 2014
69°N
68°N
67°N
66°N
65°N
174°W
171°W
168°W
165°W
162°W
DBO Line 3
CX Line
Bering Strait
RUSSIA
USA
RUSALCA 2014
depth in meters
Mooring, 2014
Bottle Samples
CTD
Unsampled 2010 Stations

## *Arctic Coastal Ecosystem Survey (ACES)*

Contact: Ron Heintz, NOAA Alaska Fisheries Science Center, ron.heintz@noaa.gov

Funding: BOEM, North Pacific Research Board, North Slope Borough

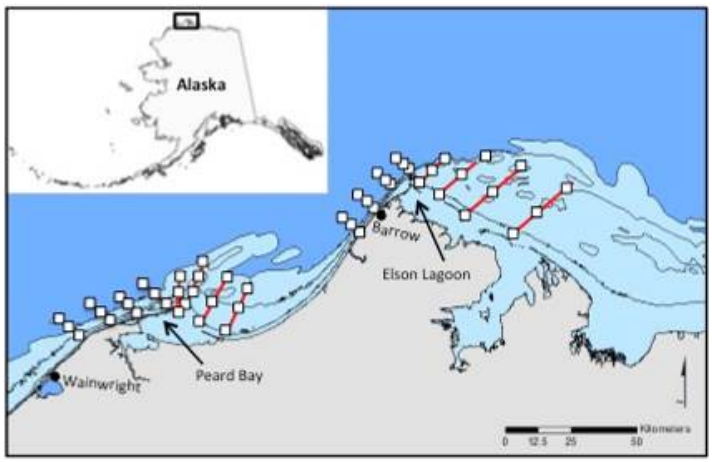
The Arctic shoreline comprises a matrix of shallow lagoons and barrier islands on the edge of an expansive shallow shelf. Despite this area's importance for subsistence fisheries and as foraging habitat for protected marine mammals and seabirds it's contribution to Arctic productivity is unknown (Craig et al., 1982; NPFMC 2009). Further, it is unwise to assume that Arctic barrier island systems function in the same manner as lower latitude systems, particularly given that fast ice conditions in lagoons have the capacity to extend through the entire water column (Johnson and Richardson 1981; Dunton et al. 2006) displacing or injuring animals (Craig 1984; Conlan et al. 1998), and potentially resetting the pelagic ecosystem annually. Thus, it is unknown what role these lagoons serve (i.e., nursery areas) or if these shallow habitats can be classified as essential fish habitat as suggested by the North Pacific Fishery Management Council (NPFMC 2009) under the Sustainable Fisheries Act of 1996. This is in large part because their shallow nature defies traditional survey methods (Craig et al., 1982; Fechhelm et al. 2008; Jarvela and Thorsteinson 1999; Johnson et al. 2010). Nevertheless, retreating sea ice, oil/gas exploration, increased marine transportation and potential oil spills are obvious and imminent threats in these areas (Johnson 1983; AMAP 2007). Arctic Coastal Ecosystem Survey (ACES) is a multi-faceted field and laboratory-based survey aimed at improving our understanding of the importance of these habitats in structuring the distribution, abundance and condition of invertebrates and fishes by combining active and passive collections from small shallow-draft vessels and a novel autonomous sampling platform.

ACES is designed to patterns in the distribution, demographics, trophic position and nutritional status of forage fish near Pt. Barrow, along the nearshore Chukchi and Beaufort Seas including Elson Lagoon, Alaska. These data are related to biological and physical conditions observed near the Chukchi and Beaufort coasts and Elson Lagoon. The physical features to be measured include salinity, temperature, current direction and speed, wind direction and speed and bathymetry. Biological features include the community composition, abundance, distribution and quality of zooplankton prey available to forage fish.

Subsamples of the catches are retained for age, condition and trophic analyses that are poorly documented for Arctic species. Fish condition is related to the habitat in which fish are sampled. Subsamples of dominant fish and macro-zooplankton species by habitat and station are retained for analysis of their biochemical content, including proximate composition (lipid, protein, water) and caloric content. These parameters describe an organism's nutritional quality for predators as well as reflect the health and condition of the organism itself. The trophic relationships between organisms sampled in each habitat will be characterized using stomach content and isotopic analysis. Dependence of primary prey sources is likely to be variable across habitat types and spatial and depth gradients, and will also vary with predator life-history strategy, thus contrast among these components will facilitate a firm understanding of the food web structure of these coastal ecosystems. Sagittal otoliths are extracted and cleaned of tissue, and annular rings on the left otolith from each individual will be used to assign ages, while preserving the second (right) otolith for use in opportunistic microchemical analysis.

2013-2014 field seasons

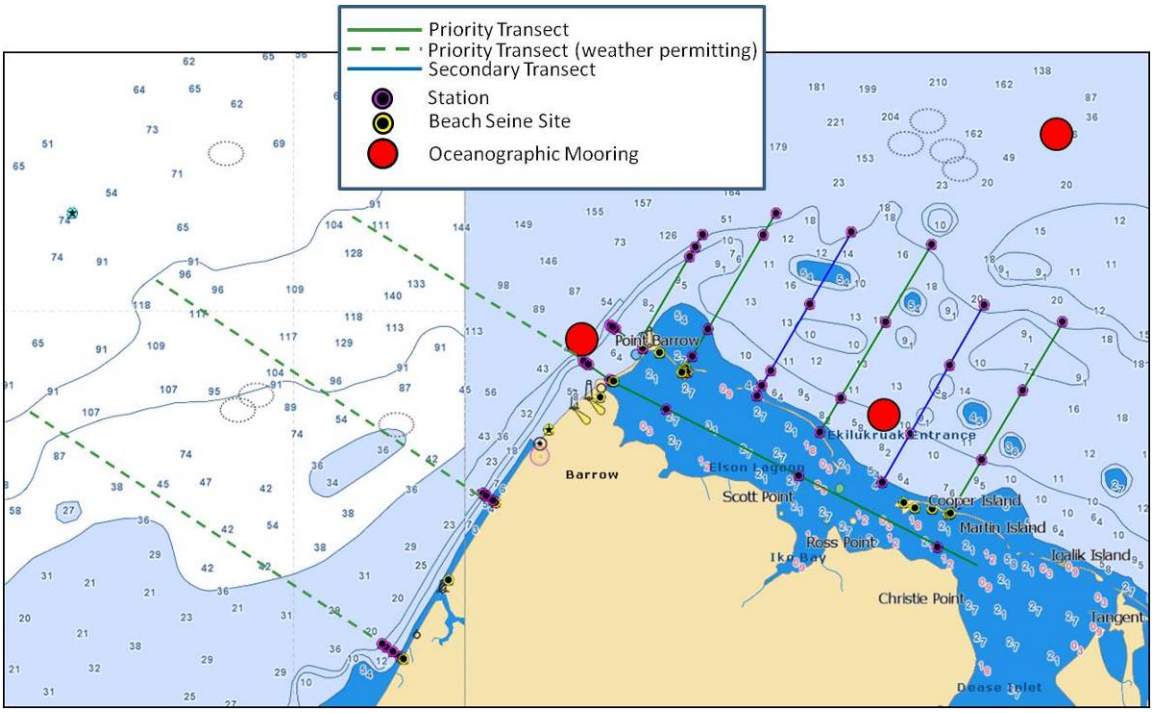
This project sampled lagoon habitats and nearshore habitats near Barrow and Wainwright, Alaska during the summers of 2013 and 2014 to characterize the patterns and use of these habitats by nekton and their primary prey items. Sampling consisted of a combination of direct biological capture (seines, traps, and trawls) and remote acoustic collections at both inshore and nearshore stations. Lagoon stations comprise several habitat types (mainland edge, lagoon center, barrier-island edge; Craig et al. 1985) while nearshore transects comprised discrete sampling stations along a depth gradient perpendicular to shore out to the 15m isobath, with transects separated by approximately 10km (Figure 1). The nearshore component was structured to complement stations sampled by the University of Alaska Arctic EIS Program with planned collections as close to shore as the 25 m isobaths.




Regional station map of Barrow and Wainwright, AK illustrating acoustic transects (red lines) overlaid with trawling and plankton sampling stations (white squares) for 2013-2014 field seasons. Isobaths represent 5 m depth contours.

2014-2015 field seasons

In 2014-2015 ACES investigators will couple observations of the temporal dynamics of forage fish and their prey resources along transects located on both sides of Point Barrow and within Elson Lagoon with oceanographic measurements. Transects in the Beaufort will extend to the 30 m contour, those in the Chukchi will extend as far over the Barrow Canyon as is deemed safe with the existing vessels. The complete set of transects was sampled twice in 2014 and will be sampled as many as three times in 2015, depending on the timing of ice retreat and experience in 2014. In 2014 acoustic, zooplankton and fish sampling was conducted from a vessel provided by BOEM under the ACES project. In 2015 a vessel supplied by NOAA will be used for the sampling.




Locations of transects to be sampled on the Chukchi and Beaufort Sea coasts and in Elson Lagoon during 2014 and 2015. Secondary transects will be sampled as time permits. Dotted lines over the Barrow Canyon show proposed transects to be conducted as conditions permit. Oceanographic mooring locations are approximated

<u>Recent publications</u>

Boswell K., Norcross B., Li C. 2015. Arctic coastal ecosystems: Evaluating the functional role and connectivity of lagoon and nearshore habitats. NPRB Project #1229, Semiannual Report. 19p.

Vollenweider J., Heintz R. 2015. Distribution and Habitat Use of Fish in the Nearshore Ecosystem of the Beaufort and Chukchi Seas. BOEM Project # AK-12-06, Annual Report. 28p.

### *Alaska Monitoring and Assessment Program (AKMAP) Survey of Estuaries within the National Petroleum Reserve-Alaska*

Contact: Kate Wedemeyer (BOEM), kate.wedemeyer@boem.gov

http://www.boem.gov/akstudies/

http://www.sfos.uaf.edu/cmi/

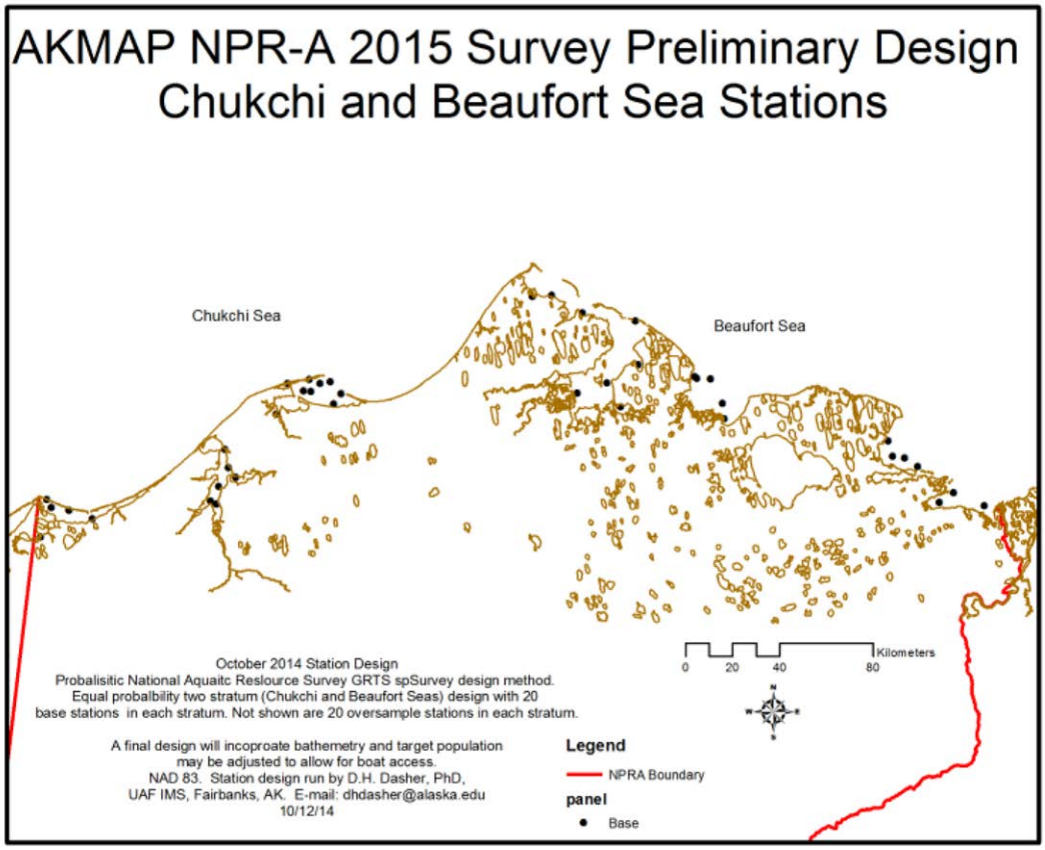
An aquatic resource survey of estuaries within the National Petroleum Reserve-Alaska (NPR-A) is being conducted by the Alaska Department of Environmental Conservation (ADEC) under the Alaska Monitoring Assessment Program (AKMAP). This survey is based on sampling designs developed with an integrated approach that uses multiple indictors to allow for assessment, evaluation, understanding and forecasting at different spatial scales. The AKMAP surveys allow for statistical inferences to be made for the entire population or region, such as NPR-A estuaries, that can be used to support baseline assessments of ecological condition, cumulative impacts, trends over time and for use in probabilistic risk assessments. The funding provided by BOEM will double the number of sites to be surveyed.

The goal of this project is to expand the existing AKMAP surveys to include up to 20 additional sampling stations, which will allow for a more robust statistical analysis, and to incorporate a sediment chemistry analysis into the project. The specific objectives of the AKMAP program include:

- Estimate the areal extent of NPR-A estuaries that meet or do not meet ADEC and Environmental Protection Agency (EPA) water quality criteria in regard to ecological conditions (sediment, water column, biological).
- Assess whether areal extent and magnitude of ecological conditions vary between the NPR-A Chukchi and Beaufort estuaries.
- Evaluate potential connections between biological responses and contaminant exposure, including relationships between diversity and abundance of macroinvertebrates and habitat conditions, such as sediment grain size, at each station, or contaminant concentrations, including sediment trace metals and polycyclic aromatic hydrocarbons.
- Assess potential differences between regional reference conditions established by the entire survey and the same indicators measured temporally at potentially impacted stations, such as areas near oil seeps.

AKMAP NPR-A will use four NCCA indices of condition – water quality (pH, dissolved oxygen, temperature, salinity, nutrients, total suspended solids, light transmittance, chlorophyll a), sediment quality (hydrocarbons, trace metals, total organic carbon), benthic community condition, and fish tissue contaminants.

This project is currently in procurement. The Final Report will be due January 2017.




Preliminary Design Showing 40 Base Stations

### *Bureau of Ocean Energy Management (BOEM)*
### *Beaufort Sea Fish Surveys*

Contact: Kate Wedemeyer, BOEM, kate.wedemeyer@boem.gov

Agencies/Institutions: BOEM, University of Alaska Fairbanks, Canada Department of Fisheries and Oceans

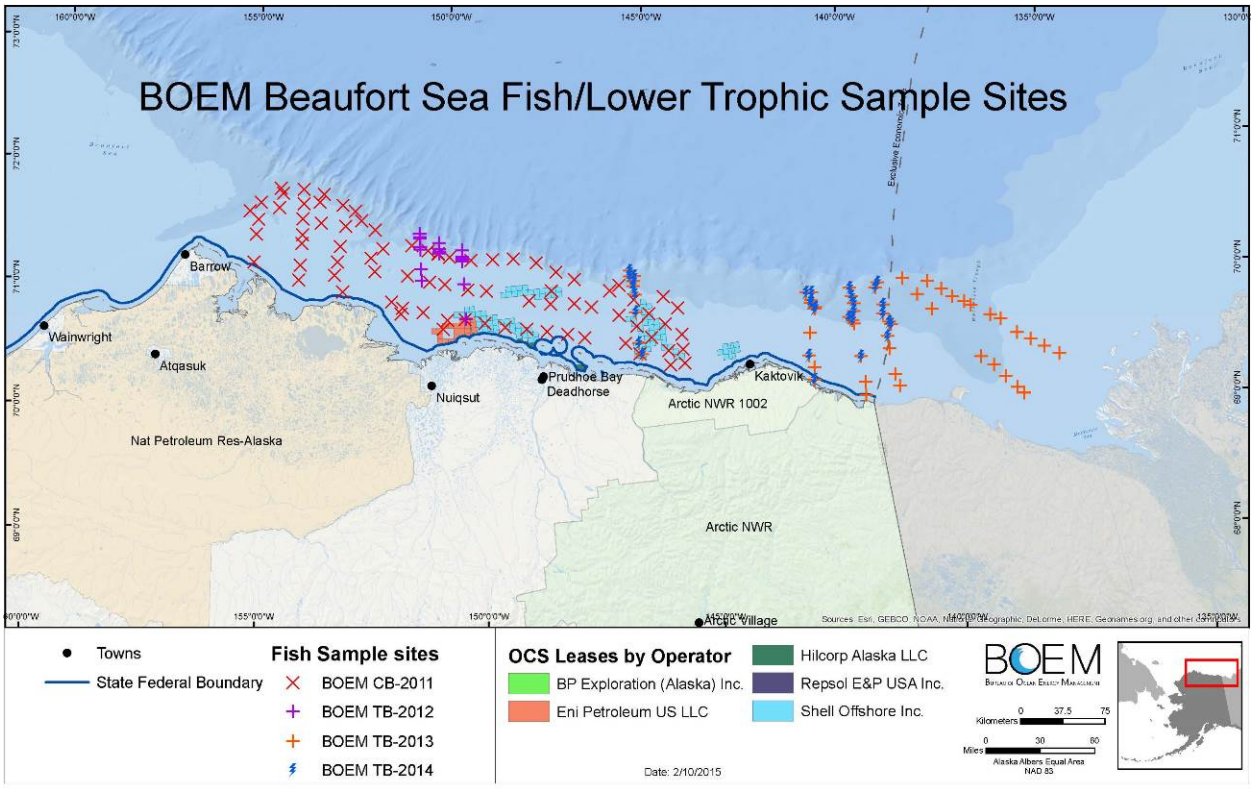
http://www.boem.gov/bio-1204/

Information needs in the eastern Beaufort Sea are growing, especially in light of new emphasis on marine spatial planning, EFH consultation, food web modeling and Arctic climate change issues. Currently, NEPA analysts must rely on limited historical data and extrapolation to analyze potential development impacts on eastern Beaufort Sea marine fish and lower trophic communities. A 2008 MMS fish survey in the western Beaufort (Rand and Logerwell 2010) documented unexpected diversity, including several commercial fish species (cod, pollock, crab) previously unknown in the region. We need better information in the eastern Beaufort about what fish species inhabit the lease area, as well as baseline information about abundance, distribution, habitat, and seasonal and inter-annual variability of fish and invertebrates in the understudied lower foodweb. Additional oceanographic information about currents, upwelling, and hydrographic structure through fine-scale CTD resolution is needed to document biological habitats.

This transboundary survey effort, jointly-funded with the Canadian Department of Fisheries and Oceans (DFO), Central and Arctic Region, shares a research vessel, as well as expertise and methods. Costs are shared in proportion to area surveyed.

Project period of performance in 2012-2016. The survey samples fish, invertebrates, and related biological and oceanographic habitat characteristics between longitudes 141° and 147° in the U.S. and into Canadian waters to ~138° (across the Canadian border to Herschel Island and the Mackenzie canyon). Field surveys are performed every other year in order to reduce autocorrelation of climate conditions and to refine sampling strategy based on analysis of first year data. Field sampling occurs in years 1 and 3. This study includes additional field surveys in both the under-ice and open water seasons to provide a better understanding of variability and collect additional habitat characteristics; collect invertebrates in both the water column and benthos; collect CTD data to document hydrographic structure; and collect and analyze ecological (e.g. energetics, isotope, genetic and otolith) samples for a foodweb model.

Another component of this project is an Arctic cod genomics and genetics study. This project's goal is to identify genetic and genomic differences that might change BOEM's approach to Arctic cod NEPA analyses from evaluating a single pan-mictic population to evaluating as several geographic sub-populations. The subpopulations, if they exist, might well exhibit differential survival in warming Arctic waters. This study will guide field sampling, primarily in the BOEM field study "US-Canada Transboundary Fish and Lower Trophic Communities" and will use genetic/genomic techniques to analyze the collected field samples.




### *ANIMIDA: The Arctic Nearshore Impact Monitoring in Development Area (ANIMIDA)*

Contact: Dan Holiday (BOEM), dan.holiday@boem.gov

Funding: BOEM

http://www.boem.gov/uploadedFiles/BOEM/Environmental_Stewardship/Environmental_Studies/Alaska_Region/Alaska_Studies/FE_1114b.pdf

The Arctic Nearshore Impact Monitoring in Development Area (ANIMIDA) (1999-2003) and continuation of ANIMIDA (cANIMIDA) (2004-2007) started in 1999 and has provided baseline data and monitoring results for chemical contamination, turbidity, Boulder Patch productivity, and subsistence whaling in the vicinity of oil industry development in the Beaufort Sea OCS.

Objectives:

- Sediment chemistry monitoring emphasizing hydrocarbon and priority metal concentrations
- Improve the cANIMIDA conceptual model of suspended sediment interactions, loading, and export from the ANIMIDA area
    - Delineate and quantify the offshore dispersion of river runoff and suspended sediments during the spring melt,
    - Trace the dispersion of suspended sediments into deeper, outer shelf water,

    - Refine sourcing techniques for suspended sediments particularly in the expanded eastern ANIMIDA area
    - Expand the chemical analyses of suspended sediments to include hydrocarbon composition
    - Estimate the contribution of shoreline erosion, Mackenzie River runoff, and offshore waters to suspended sediment load and composition
- Development of a conceptual model of bioaccumulation and trophic interaction in ANIMIDA biota
    - Monitor bioaccumulation of contaminants in selected species
    - Contaminant monitoring for amphipod and bivalve samples
    - Develop and initiate a contaminant monitoring program for deeper water benthic biota found in this expanded ANIMIDA study area. Include mid-Beaufort Distributed Biological Observatory stations as part of the monitoring program

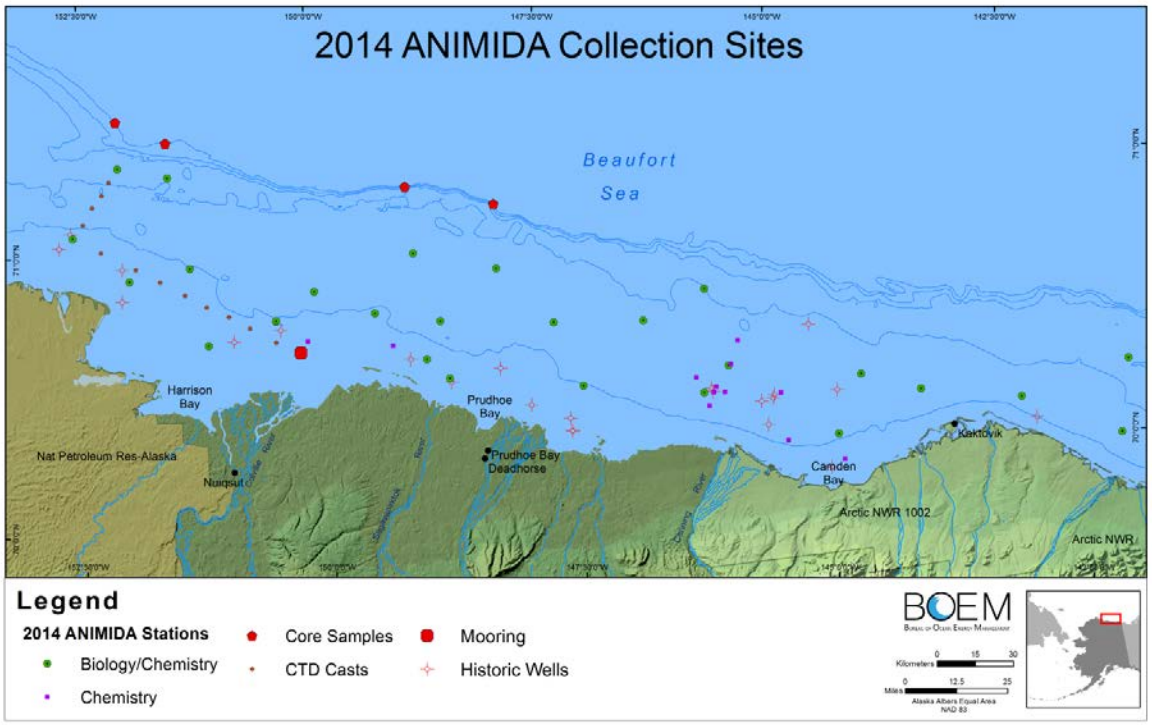
Methods:

Sediment and biota sampling will be scheduled such that stations sampled in eastern, central, and western Beaufort in ANIMIDA/cANIMIDA will be resampled at least once and that new deeper eastern Beaufort Region stations around Sivulliq and Torpedo would sampled at least twice (to form a baseline). Focus will be on potential oil and gas development areas and contaminants in sediments and benthic biota, as well as distribution and abundance of benthic biota.

Chemical fingerprinting and ratio techniques developed in ANIMIDA/cANIMIDA will be used to characterize sources of suspended sediments. Profiles for turbidity, salinity, temperature and current would be obtained from numerous sites around the pertinent project area at the time of sampling. The choice of elemental and isotope parameters to be analyzed for suspended sediment will be designed to maximize the potential for discriminating among different sources of particles. A variety of dispersion models and predictive tools should be considered.

The study will use the cANIMIDA conceptual food web model to help guide development of specific objectives for this task, increase statistical viability of the results with the goal of longer-term strategy for biological contaminant monitoring, and will make improvements to this conceptual model based on study findings.

This new project is a 4 years project with the first field season in 2014.

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### *BOEM Marine Arctic Ecosystem Study (MARES)*

Contact: Carol Fairfield (BOEM), carol.fairfield@boem.gov

http://www.boem.gov/press11212014/

A new study focused on the Beaufort Ecosystem has just been awarded. The geographical scope of this study is the continental shelf and slope of the southeastern Beaufort Sea between the Mackenzie River (and Tuktoyatuk Peninsula) mouth (in collaboration with Canadian scientists and agencies) to at least Barrow, Alaska. The study area extends from the coastline to the 1000 m isobath. More will be revealed in the coming weeks but the first few task orders will be initiated to in FY 15 and will likely have a marine mammal component.

The objectives of this study are:

• Identify and delineate areas of high biological productivity, as well as relative sensitivities and resiliencies to changes in environmental conditions within ecosystem components. This includes a detailed description of different trophic levels and their composition in terms of species abundance, distribution, and behavior in both ice free and ice covered habitat.

• Identify cultural, historic and subsistence resources which could be sensitive to human activities, such as increased shipping, intensified offshore energy development, and expanded tourism.

• Provide a qualitative and quantitative description of the biogeochemical-physical interactions and feedback processes in ice free and ice covered areas.

• Provide a detailed spatio-temporal description of ocean currents at different depths along the Beaufort continental shelf, including ice covered areas.

Methods: Proposed studies will emphasize an integrated, or ecosystems approach to data collection or synthesis. Each study will be based on the application of appropriate scientific methodologies, coordinating observational and modeling efforts, while focused on essential processes, functions and interactions among organisms and their environment. Proposed studies will recognize that humans, with their cultural diversity, are an integral component of ecosystems, and will accommodate appropriate methods of integration where possible, including access to traditional knowledge with active involvement of Alaska Natives in research planning and execution. Proposed studies will also seek to advance, where appropriate, the use of technology and instrumentation in monitoring and understanding complex ecosystem processes.

### *Chukchi interdisciplinary whale projects*

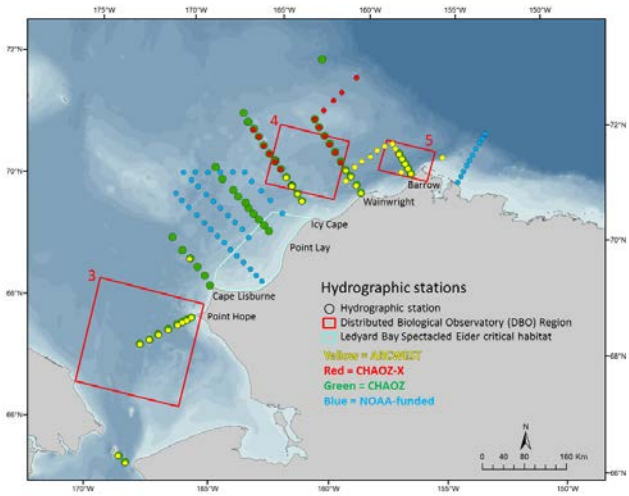
Contact: Catherine Berchok (NOAA), catherine.berchok@noaa.gov

Agencies: NOAA Fisheries, Pacific Marine Environmental Laboratory, BOEM

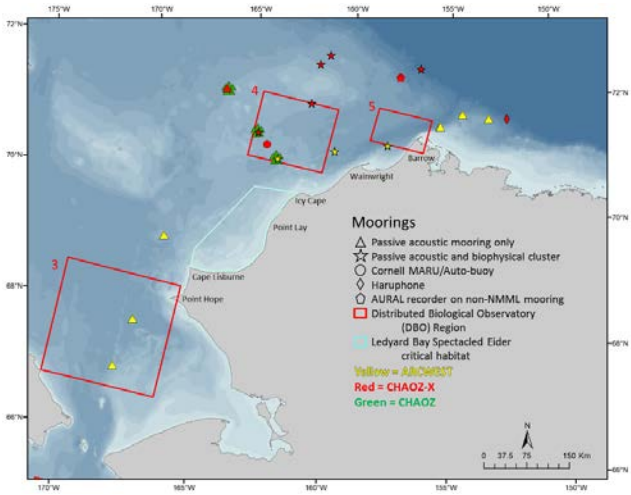
Three interdisciplinary projects are being conducted in the US Arctic to document the distribution and relative abundance of whales in areas of potential industrial activity. The studies are designed to collect information to relate changes in those variables to oceanographic conditions, indices of potential prey density, and anthropogenic activities. The projects are:

- CHAOZ: Chukchi Acoustics, Oceanography, and Zooplankton Study (Chukchi lease area), 2010-2015
- CHAOZ – X: CHAOZ Extension Study (Waters feeding Hanna Shoal), 2013-2017
- ARCWEST: Arctic Whale Ecology Study (Waters feeding Barrow Arch), 2012-2017

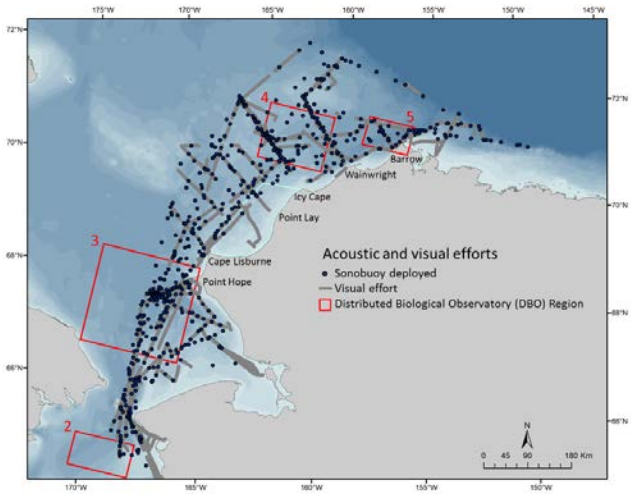
Project effort includes biophysical sampling stations; long-term biophysical/passive acoustic mooring clusters; and marine mammal visual surveys and passive acoustic monitoring and bird surveys. In addition, work on climate modeling, noise modeling, marine mammal tagging, and photo-id are undertaken.




Location of hydrographic stations during interdisciplinary whale projects




Location of moorings during interdisciplinary whale projects




Location of acoustic and visual survey efforts during interdisciplinary whale projects

## *Aerial Surveys of Arctic Marine Mammals (ASAMM)*

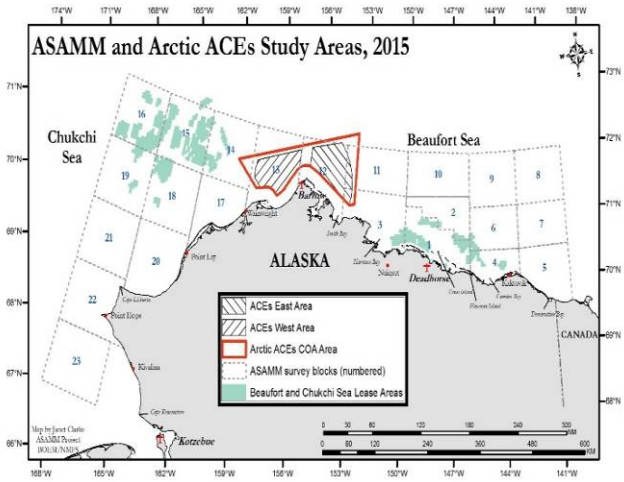
Contact: Megan Ferguson (NOAA), megan.ferguson@noaa.gov; Janet Clarke, janet.clarke@leidos.com

Collaborators: BOEM (funding agency), National Marine Fisheries Service, North Slope Borough Department of Wildlife Management, US Fish and Wildlife Service, US Geologic Service

http://www.afsc.noaa.gov/nmml/ cetacean/bwasp/index.php

These surveys are conducted in the Western Beaufort Sea and Northeast Chukchi Sea, and represent a 35 year time series (1979 to present). Field work in 2015 will be conducted in July-October. The objectives of these surveys are:

- Describe the annual migration of bowhead whales across the Alaskan Arctic, significant inter-year differences, and long-term trends in the spatial distribution and timing of the migration
- Document relative abundance, spatial and temporal distribution, and behavior of marine mammals (cetaceans, ice seals, walruses, and polar bears)
- Provide an objective wide-area context for understanding marine mammal ecology in the Alaskan Arctic, to help inform management decisions and interpret results of other small-scale studies




Location of ASSAM survey blocks (numbered) in the Chukchi and Beaufort Seas

## *Ecology of ice-associated seals*

Contact: Michael Cameron (NOAA National Marine Mammal Laboratory), michael.cameron@noaa.gov

Collaborating agencies: BOEM, NOAA National Marine Mammal Laboratory, State Research and Design Institute for Fishing Fleet

<u>Bering Okhotsk Seal Surveys (BOSS)</u>

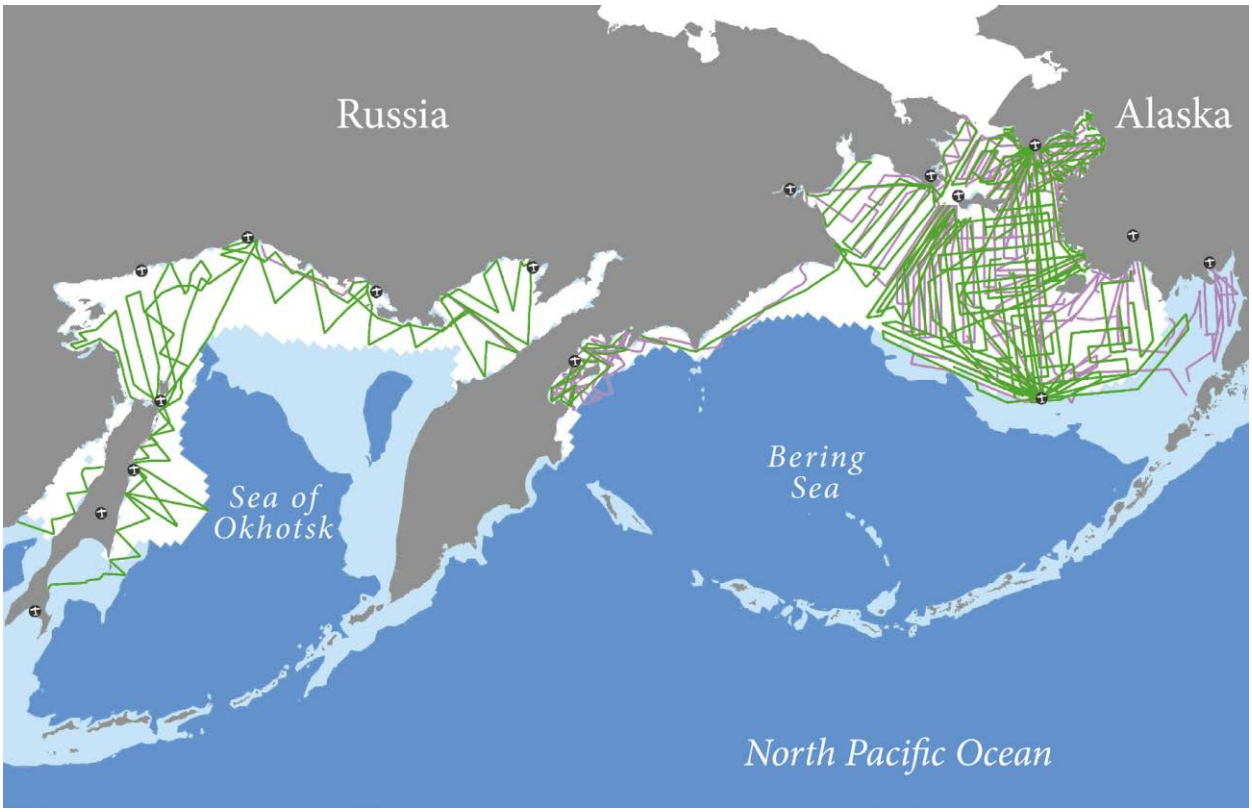
http://www.afsc.noaa.gov/quarterly/jas2013/jas13featurelead.htm

Bearded, spotted, ribbon, and ringed seals are key components of Arctic marine ecosystems and they are important subsistence resources for northern coastal Alaska Native communities. Obtaining reliable

abundance estimates for ice-associated seals is vital for developing sound plans for management, conservation, and responses to potential environmental impacts of oil and gas activities and climate change. The Bering Okhotsk Seal Surveys (BOSS) project addressed the most critical need for fundamental assessment data on ice-associated seals (also known as ice seals) in the Bering and Okhotsk Seas.

Scientists at NOAA's National Marine Mammal Laboratory's (NMML) Polar Ecosystems Program (PEP) collaborated with colleagues from the State Research and Design Institute for Fishing Fleet ("Giprorybflot") in Saint Petersburg, Russia, to conduct synoptic aerial surveys of ice-associated seals in the Bering and Okhotsk Seas. Conducting spring-time surveys in those areas will yield abundance estimates for the entire population of ribbon seals, and all but a small fraction of the spotted seal population. For bearded seals, the surveys included the large and important fraction of the population that overwinters and breeds in the Bering and Okhotsk Seas. The U.S. Bureau of Ocean Energy Management provided critical financial support in 2012 and 2013 to complete the U.S. surveys of the central and eastern Bering Sea.

Two years of survey effort were required to achieve adequate precision (CV= 0.1) for abundance estimates and to ensure that sufficient periods of suitable weather occurred during survey periods. Aerial surveys for bearded, spotted, ribbon, and ringed seals were conducted in spring 2012 and 2013. In the United States and Russia combined, the teams flew more than 47,000 nautical miles (nmi) (90,000 km) of survey track. The completion of this project marks the largest survey of ice-associated seals ever completed and will provide the first comprehensive estimates of abundance for bearded, spotted, ribbon, and ringed seals in the Bering Sea and Sea of Okhotsk.



BOSS 2012 (pink) and 2013 (green) survey track lines in the Bering and Okhotsk seas covering more than 90,000 km (56,000 miles) completed during the joint U.S.-Russian survey effort. The 500-m isobath is in light blue and April 2013 ice extent is in white.

Ecology of Ice-Associated Seals in the Central Bering Sea

The National Marine Mammal Laboratory's (NMML) Polar Ecosystems Program (PEP) conducted an ice-seal research cruise in the central Bering Sea during 4 April to 1 May 2014, aboard the NOAA Ship *Oscar Dyson*. One of the primary objectives for the cruise was to deploy satellite-linked tags on ribbon and spotted seals, which are closely associated with sea ice during this time of year. The data collected by the satellite-linked tags will, together with information collected during similar cruises since 2005, provide information on the timing of hauling out (critical for calculating abundance estimates from aerial surveys) and dive behavior and seasonal movements (useful in identifying important habitat).

PEP researchers captured, handled, and released 19 ribbon, 8 spotted, and 2 bearded seals, for a total of 29 individuals. Seals were captured on ice floes with hand-held landing nets. Satellite transmitters were attached to 14 ribbon and 5 spotted seals. Most of the transmitters were SPOT tags (Wildlife Computers, Redmond, WA), attached to the seals' hind-flippers, that provide long-term movement data and haul-out timelines but only when the seals are hauled out with their flippers exposed. The remaining transmitters were SPLASH tags (Wildlife Computers, Redmond, WA) that provide more detailed information about locations at sea and diving behavior. SPLASH tags must be glued to the hair on the seals' back or head.

## *Data synthesis projects*

Contact: Heather Crowley (BOEM), heather.crowley@boem.gov

Synthesis of Arctic Research (SOAR) – Physics to marine mammals in the Pacific Arctic

Project leads: Sue Moore (NOAA), sue.moore@noaa.gov; Phyllis Stabeno (NOAA PMEL), phyllis.stabeno@noaa.gov

http://www.arctic.noaa.gov/soar/

The Synthesis Of Arctic Research (SOAR) brings together a multidisciplinary group of Arctic scientists and residents to explore and integrate information from completed and ongoing marine research in the Pacific Arctic. Our goal is to increase scientific understanding of the relationships among oceanographic conditions, benthic organisms, lower trophic prey species (forage fish and zooplankton), seabirds, and marine mammal distribution and behavior in the Pacific Arctic. The SOAR project is supported by the Bureau of Ocean Energy Management (BOEM), and will assist in their evaluation of oil and gas development in the Arctic.

The SOAR project aims to create a platform for collaboration among scientists and Alaska Arctic residents. The SOAR has the overarching goal of using available data, analytical and modelling approaches to identify and test hypotheses that cross scientific disciplines. The geographic area is the Pacific Arctic, including the northern Bering, Chukchi and Beaufort seas, with time frames extending from days to decades.

The three primary objectives of the SOAR program are to:

1. increase scientific understanding of the biophysical environment;
2. enhance capability to predict future conditions; and
3. effectively transmit findings of the synthesis to local residents, resource managers, science societies, and the general public.

*Publications*

Mathis, J.T., S.R. Cooley, N. Lucey, S. Colt, J. Ekstrom, T. Hurst, C. Hauri, W. Evans, J.N. Cross, and R.A. Feely. 2014. "Ocean Acidification Risk Assessment for Alaska's Fishery Sector." Progress in Oceanography (July). doi:10.1016/j.pocean.2014.07.001. http://linkinghub.elsevier.com/retrieve/pii/S0079661114001141.

Citta, John J, Lori T Quakenbush, Stephen R Okkonen, Matthew L Druckenmiller, Wieslaw Maslowski, Jaclyn Clement-Kinney, John C George, et al. 2014. "Ecological characteristics of core-use areas used by Bering – Chukchi – Beaufort ( BCB ) bowhead whales , 2006 – 2012." *Progress in Oceanography*: 2006-2012. doi:10.1016/j.pocean.2014.08.012.

Logerwell, E.A., M. Busby, C. Carothers, S. Cotton, J. Duffy-Anderson, E. Farley, P. Goddard, R. Heintz, B. Holladay , J. Horne, S. Johnson, B. Lauth , L. Moulton, D. Neff , B. Norcross, S. Parker-Stetter, J. Seigle, T. Sformo. 2015. *Accepted*. Fish communities across a spectrum of habitats in the western Beaufort Sea and Chukchi Sea. Progress in Oceanography.

<u>Recent and Historical Distribution and Ecology of Demersal Fishes in the Chukchi Sea Planning Area (OCS Study BOEM 2012-073)</u>

www.data.boem.gov/PI/PDFImages/ESPIS/5/5291.pdf

Prior to this study, fish survey information in the Chukchi Sea was limited to a few historical surveys conducted from 1959 through 1992 and in 2004, and collection data from most of these surveys were not readily accessible in electronic format. The objectives of this report were to make historical haul-catch databases available in georeferenced electronic format and to conduct scientific cruises in 2007 and 2008 to collect new fish data to provide a current ecological perspective that could be compared with historical records and could serve as a baseline for future comparisons.

<u>Retrieval of Historical Arctic Fisheries Survey Data (OCS Study BOEM 2012-084)</u>

This study retrieved additional historical data. It is part of a multifaceted BOEM effort to integrate historical and current study data sets from both the Chukchi and Beaufort Seas into comparable formats and fields for analyses. The data is also being enrolled in OBIS (http://www.iobis.org/) and available in AOOS (http://www.aoos.org/).

<u>Ecological Analysis of Western Beaufort Sea Data (OCS Study BOEM 2014-014)</u>

Data collected in the western Beaufort Sea in 2008 is compared to data collected in 2011.

### *References cited*

AMAP. 2007. Arctic oil and gas 2007. Arctic Monitoring and Assessment Programme, Oslo, Norway. 70p. Accessed at http://www.amap.no/oga/.

Conlan, K.E., H.S. Lenihan, R.G. Kvitek, J.S. Oliver. 1998. Ice scour disturbance to benthic communities in the Canadian High Arctic. Marine Ecology Progress Series. 166:1–16.

Craig, P.C., W.B. Griffiths, L. Haldorson, and H. McElderry. 1982. Ecological Studies of Arctic Cod (*Boreogadus saida*) in Beaufort Sea Coastal Waters, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 39:395-406.

Craig, P.C. 1984. Fish Use of Coastal Waters of the Alaskan Beaufort Sea: A Review. Transactions of the American Fisheries Society. 113:265-282.

Duffy, J Emmett, L. A. Amaral-Settler, D.G. Fautin, G. Paulay, T.A. Rynearson, H.M. Sosik, and J.J. Stachowicz. 2013. "Envisioning a Marine Biodiversity Observation Network." *BioScience* 63 (5): 350-361. doi:10.1525/bio.2013.63.5.8.

Dunton, K.H., T. Weingartner, and E.C. Carmack. 2006. The nearshore western Beaufort Sea ecosystem: Circulation and importance of terrestrial carbon in arctic coastal food webs. Progress in Oceanography. 71: 362–378.

Fechhelm, R.G., B.W. Williams, M.J. Daigneault, and M.R. Link. 2008. Year 25 of the long-term monitoring of nearshore Beaufort Sea fishes in the Prudhoe Bay region, 2007. Report for BP Exploration (Alaska) Inc. by LGL Alaska Research Associates, Inc., Anchorage, Alaska. 80 p.

Jarvela, L.E., and L.K. Thorsteinson. 1999. The Epipelagic Fish Community of Beaufort Sea Coastal Waters, Alaska. Arctic. 52:80-94.

Johnson, S.R., W.J. Richardson. 1981. Beaufort Sea barrier island-lagoon ecological process studies: birds. US Dep. Commerce, NOAA, OCSEAP Final Report 7, pp. 109–383.

Johnson, L. 1983. Assessment of the effects of oil on arctic marine fish and marine mammals. Canadian Technical Report of Fisheries and Aquatic Sciences. Report:1200, viii +15p.

Johnson, S.W., J.F. Thedinga, A.D. Neff, and C.A. Hoffman. 2010. Fish fauna in nearshore waters of a barrier island in the western Beaufort Sea, Alaska. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-AFSC-210, 28 p.

NPFMC (North Pacific Fishery Management Council). 2009. Fishery Management Plan for Fish Resources of the Arctic Management Area. Anchorage, AK: NPFMC, 147 pp.

Rand, K, and E A Logerwell. 2010. "The first survey of the abundance of benthic fish and invertebrates in the offshore marine waters of the Beaufort Sea since the late 1970s." *Polar Biology* 34: 475-488. doi:10.1007/s00300-010-0900-2.

## *Bibliography*

### *Recent project publications*

Bluhm B. and Iken K. 2013. Population assessment of snow crab, Chionocetes opilio, in the Chukchi and Beaufort Seas: Preliminary findings. (Oral) 28th Lowell Wakefield Symposium: Responses of Arctic Marine Ecosystems to Climate Change, March 2013, Anchorage, AK.

Boswell K., Norcross B., Li C. 2015. Arctic coastal ecosystems: Evaluating the functional role and connectivity of lagoon and nearshore habitats. NPRB Project #1229, Semiannual Report. 19p.

ChanBell L., Iken K. and Bluhm B. 2013. Lower trophic level food web structure on the Beaufort Slope: a preliminary analysis. Poster, Alaska Marine Science Symposium, January 2013, Anchorage, AK.

Citta, John J, Lori T Quakenbush, Stephen R Okkonen, Matthew L Druckenmiller, Wieslaw Maslowski, Jaclyn Clement-kinney, John C George, et al. 2014. "Ecological characteristics of core-use areas used by Bering – Chukchi – Beaufort ( BCB ) bowhead whales , 2006 – 2012." *Progress in Oceanography*: 2006-2012. doi:10.1016/j.pocean.2014.08.012.

Day, Robert H., Thomas J. Weingartner, Russell R. Hopcroft, Lisanne a.M. Aerts, Arny L. Blanchard, Adrian E. Gall, Benny J. Gallaway, et al. 2013. "The offshore northeastern Chukchi Sea, Alaska: A complex high-latitude ecosystem." *Continental Shelf Research* 67 (September): 147-165. doi:10.1016/j.csr.2013.02.002. http://linkinghub.elsevier.com/retrieve/pii/S0278434313000514.

Grebmeier, J.M., *Biological community shifts in Pacific Arctic and sub-Arctic seas*, 2012, Annual Review of Marine Science, Vol. 4. (in press). Note the paper will appear first as a web article in fall 2011 (http://www.annualreviews.org/toc/marine/forthcoming)

Grebmeier, J. M., Moore, S. E., Overland, J. E., Frey, K. E., and Gradinger,R., EOS Trans. AGU, 91, 18, doi:10.1029/2010EO180001, 2010

Grey, B. 2013. Comparing the Feeding Ecologies of three abundant Fish Species in the Chukchi and Beaufort Seas. Poster, Lowell Wakefield Symposium: Responses of Arctic Marine Ecosystems to Climate

Logerwell, E.A., M. Busby, C. Carothers, S. Cotton, J. Duffy-Anderson, E. Farley, P. Goddard, R. Heintz, B. Holladay , J. Horne, S. Johnson, B. Lauth , L. Moulton, D. Neff , B. Norcross, S. Parker-Stetter, J. Seigle, T. Sformo. 2015. *Accepted*. Fish communities across a spectrum of habitats in the western Beaufort Sea and Chukchi Sea. Progress in Oceanography.

Mathis, J.T., S.R. Cooley, N. Lucey, S. Colt, J. Ekstrom, T. Hurst, C. Hauri, W. Evans, J.N. Cross, and R.a. Feely. 2014. "Ocean Acidification Risk Assessment for Alaska's Fishery Sector." Progress in Oceanography (July). doi:10.1016/j.pocean.2014.07.001. http://linkinghub.elsevier.com/retrieve/pii/S0079661114001141.

Norcross, B. 2013. Beaufort Sea marine Fish Surveys in the U.S.-Canada Transboundary Area. Lowell Wakefield Symposium: Responses of Arctic Marine Ecosystems to Climate Change. March 27, 2013

Norcross, B.L., and L.E. Edenfield. 2012. U.S. Beaufort Sea fish communities. Oral presentation, U.S.-Canada Northern Oil and Gas Research Forum, November 2012, Anchorage, AK.

Norcross, B.L. and L.E. Edenfield. 2013. Beaufort Sea marine fish surveys. Oral presentation, 28th Lowell Wakefield Symposium: Responses of Arctic Marine Ecosystems to Climate Change, March 2013, Anchorage, AK.

Norcross, B. et al. 2012. U.S. Canada Transboundary Survey. U.S.-Canada Oil and Gas Research Conference, Nov 12-15, 2012, Anchorage, Alaska.

Reist, Majewsky, Loseto. 2012. Canada BREA program fish survey. U.S.-Canada Oil and Gas Research Conference, Nov 12-15, 2012, Anchorage, Alaska.

Smoot et al. 2013. Toward a contemporary baseline for zooplankton communities in the American Beaufort Sea. (Poster) Alaska Marine Science Symposium, January 2013, Anchorage, AK.ge. March 27, 2013

Vollenweider J., Heintz R. 2015. Distribution and Habitat Use of Fish in the Nearshore Ecosystem of the Beaufort and Chukchi Seas. BOEM Project # AK-12-06, Annual Report. 28p.

### *Aerial surveys of marine mammals*

Clarke, J.T., A.A. Brower, C.L. Christman, and M.C. Ferguson. 2014. Distribution and relative abundance of marine mammals in the northeastern Chukchi and western Beaufort Seas, 2013. Annual Report, OCS Study BOEM 2014-018. National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, NOAA.

Clarke, J.T., C.L. Christman, A.A. Brower, and M.C. Ferguson. 2013a. Distribution and relative abundance of marine mammals in the northeastern Chukchi and western Beaufort Seas, 2012. Annual Report, OCS Study BOEM 2013-00117. National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, NOAA.

Clarke, J.T., C.L. Christman, A.A. Brower, and M.C. Ferguson. 2012. Distribution and relative abundance of marine mammals in the Alaskan Chukchi and Beaufort Seas, 2011. OCS Study BOEM 2012-009. Rep. from National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, for U.S. Bureau of Ocean Energy Management. 344 pp.

Clarke, J.T., C.L. Christman, A.A. Brower, M.C. Ferguson, and S.L. Grassia. 2011a. Aerial surveys of endangered whales in the Beaufort Sea, fall 2010. OCS Study BOEMRE 2011-035. Rep. from National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, for U.S. Bureau of Ocean Energy Management, Regulation and Enforcement. 119 pp.

Clarke, J.T., C.L. Christman, M.C. Ferguson, and S.L. Grassia. 2011b. Aerial surveys of endangered whales in the Beaufort Sea, fall 2006-2008. OCS Study BOEMRE 2010-042. Rep. from National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, for U.S. Bureau of Ocean Energy Management, Regulation and Enforcement. 229 pp.

Clarke, J.T., C.L. Christman, M.C. Ferguson, S.L. Grassia, and A.A. Brower. 2011c. Aerial surveys of endangered whales in the Beaufort Sea, fall 2009. OCS Study BOEMRE 2010-040. Rep. from National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, for U.S. Bureau of Ocean Energy Management, Regulation and Enforcement. 92 pp.

Clarke, J.T., M.C. Ferguson, C.L. Christman, S.L. Grassia, A.A. Brower, and L.J. Morse. 2011d. Chukchi Offshore Monitoring in Drilling Area (COMIDA), Distribution and Relative Abundance of Marine Mammals: Aerial Surveys. OCS Study BOEMRE 2011-06. Rep. from National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, for U.S. Bureau of Ocean Energy Management, Regulation and Enforcement. 286 pp.

Monnett, C. and S.D. Treacy. 2005. Aerial surveys of endangered whales in the Beaufort Sea, fall 2002-2004. OCS Study MMS 2005-037. Anchorage, AK: USDOI, MMS, Alaska OCS Region. 153 pp.

Treacy, S.D. 2002a. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 2000. OCS Study MMS 2002-014. Anchorage, AK: USDOI, MMS, Alaska OCS Region. 111 pp.

Treacy, S.D. 2002b. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 2001. OCS Study MMS 2002-061. Anchorage, AK: USDOI, MMS, Alaska OCS Region. 117 pp.

USDOI, MMS. 2008. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 2005. OCS Study MMS 2008-023. Anchorage, AK: USDOI, MMS, Alaska OCS Region. 96 pp.

## *BOEM Fish and Lower Trophic Study Publications*

Beaufort Sea:

Loggerwell, Elizabeth, Rand, Kimberly, Parker-Stetter, Sandra, Horne, John, Weingartner, Tom and Bluhm, Bodil. 2010. Beaufort Sea Marine Fish Monitoring 2008: Pilot Survey and test of Hypotheses. BOEMRE 2010-048. Anchorage, AK: USDOI, MMS, Alaska OCS Region, pp 262.

Gray, B. P., 2014. Region, depth, and size-based comparisons of three fish species' diets across the Chukchi and Beaufort seas. University of Alaska-Fairbanks. In prep.

Konar, Brenda, Ravelo, Alexandra. 2012. Epibenthic Community Variability on the Alaskan Beaufort Sea Continental Shelf BOEM 2013-01148. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 43 pp.

Konar, Brenda. 2012. Recovery in a High Arctic Kelp Community. BOEM 2012-011. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 24 pp.

Bluhm, Bodil, Huettmann, Falk, Norcross, Brenda. 2014. Ecological Analysis of 2008 Western Beaufort Sea Data. BOEM 2014-014 . Anchorage, AK: USDOI, MMS, Alaska OCS Region.

Thorsteinson, Lyman K, Milton S. Love, Catherine W Mecklenburg, Nancy E Elder, T. Anthony Mecklenburg. 2014. Arctic Marine Fish Ecology Catalog BOEM 2014-16. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 781 pp.

Carouthers 2013 Subsistence Use and Knowledge of Salmon in Barrow and Nuiqsut, Alaska [Reference being supplied by Chris Campbell]

Talbot, Sandra L, George K. Sage, Sarah A. Sonsthagen, Megan C. Fowler. 2014. Arctic Cod Pilot Genomics Study: Preliminary Results from Analyses of Mitochondrial DNA. BOEM 2014-050. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 29pp.

Murphy, Stephen M., Mueter, Franz J., and Braund, Stephen R. 2007. Variation in the Abundance of Arctic cisco in the Colville River: Analysis of Existing Data and Local Knowledge, volumes I and II MMS 2007-042. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 240 pp.

Zimmerman, Christian E, Vanessa R von Biela. 2014. Investigation of Population of Origin and Migration of Arctic Cisco found in the Colville Rive, Alaska using Molecular and Otolith Tools Tools. BOEM 2014-019. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 107 pp.

Talbot, Sandra L., George K. Sage, Sarah A. Sonsthagen, Megan C. Fowler2014 Arctic Cod Pilot Genomics Study: Preliminary Results from Analyses of Mitochondrial DNABOEM 2014-050. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 29pp.

Chukchi Sea:

Barber, W. E., Smith, R. L., Weingartner, T.J. 1993. Fisheries Oceanography of the Northeast Chukchi Sea. MMS-93-0051. Anchorage, AK: USDOI, MMS, Alaska OCS Region, ~ 250 pp.

Feder, H.M. 1977. Trawl Survey of the Benthic Epifauna of the Chukchi Sea and Norton Sound. In: Environmental Assessment of the Alaskan Continental Shelf, Annual Reports 10:452-482 RU 0502. Outer Continental Shelf Environmental Assessment Program. OCSEAP Alaska Office, Juneau. 30pp.

Frost, K. J., Lowry, L. F. 1983. Demersal fishes and invertebrates trawled in the northeastern Chukchi and western Beaufort seas 1976 – 1977. U.S. Dep. Commer., NOAA Tech. Rep. NMFS-SSRF-764, 22 p.

Barber, W. E., R. L. Smith, M. Vallarino, and R. M. Meyer. 1997. Demersal fish assemblages of the northeastern Chukchi Sea, Alaska. Fish., Bull. 95:195-209.

Frost, K. J., and L. F. Lowry. 1983. Demersal fishes and invertebrates trawled in the northeastern Chukchi and western Beaufort seas 1976 – 1977. U.S. Dep. Commer., NOAA Tech. Rep. NMFS-SSRF-764, 22 p.

Jarvela, L. E., and L. K. Thorsteinson. 1999. The Epipelagic Fish Community of Beaufort Sea Coastal Waters, Alaska. Arctic, 52(1):80-94.

Thorsteinson, Lyman K., Jarvela, Laurie E., Hale, David A.. 1992. Arctic Fish habitat Use Investigations: Nearshore Studies in the Alaskan Beaufort Sea, Summer 1990 OCS Study MMS 92-0011 Anchorage, AK: USDOI, MMS, Alaska OCS Region, 166 pp.

## *APPENDIX 5: U.S. ARCTIC RESEARCH PLAN:*
## *Intersection with BOEM Environmental Studies*

This table is organized to display recent BOEM-directed research as it supports the national Arctic Research Plan FY2013-2017, issued by the Executive Office of the President, National Science and Technology Council, February 2013. The Arctic Research Plan was produced by the Interagency Arctic Research Policy Committee (IARPC) in recognition of responsibilities described in the Arctic Research Policy Act of 1984. IARPC activities are chaired by the National Science Foundation and serve to coordinate science and technology policy across diverse Federal institutions. Chapter 3 of the Arctic Research Plan (ARP) discusses each numbered item identified in the table below, and can be accessed from the White House web portal here. The Arctic Research Plan directly supports the Implementation Plan for the National Strategy for the Arctic Region, issued in January 2014.

| ARP Item | Research Topic | BOEM Partner | BOEM Funding | Study Duration | Key Words |
|---|---|---|---|---|---|
| **3.1** | **Understand Sea-ice Processes, Ecosystem Processes, Ecosystem Services, and Climate Feedbacks In The Beaufort and Chukchi Seas And The Contiguous Arctic Ocean** | | | | |
| **3.1.1** | **Develop a framework of observations and modeling to support forecasting of sea-ice extent on seasonal to annual scales for operational and research needs** | | | | |
| | Characterization of the Circulation on the continental Shelf Areas of the Northeast Chukchi and Western Beaufort Seas | UAF | $5,056,252 | 2012 - 2016 | high frequency radar, ocean currents, gliders, drifters, Barrow Canyon |
| | Ecosystem Observations in the Chukchi Sea: Biophysical Mooring and Climate Modeling | NOAA | $2,068,928 | 2010 - 2015 | ice coverage, forecast |
| | Enhanced Verification and Interpretation of Freeze-up Conditions for the Northeast Chukchi Shelf: Field Observations and Process Studies; Freeze-up Forecasts | UAF | $1,995,000 | 2014 – 2019 | sea ice forecasting, sea ice hind cast, freeze-up, Burger drill site |
| | Application of High Frequency Radar to Potential Hydrocarbon Development Areas in the Northeast Chukchi Sea | UAF | $1,056,322 | 2009-2014 | surface currents, Barrow Canyon, circulation |
| | Mapping and Characterization of Recurring Polynyas and Landfast Ice in the Chukchi Sea | UAF | $461,404 | 2009 - 2012 | ice leads, landfast ice, breakouts |
| | Satellite-Tracked Drifter Measurements in the Northeast Chukchi Sea | UAF | $459,892 | 2011- 2015 | ocean currents, current velocities |
| | Development and Testing of a Low-Cost Satellite Tracked Ice Drifter for Arctic Alaska | UAF-CMI | $433,409 | 2014 - 2017 | ice velocities, model validation |
| | Development of an accurate model of the Beaufort and Chukchi Ice Drift and Dispersion for Forecasting Spill Trajectories and Providing Decision Support for Spill Response | UAF-CMI | $359,078 | 2013 -2016 | spill response, ice velocities, ice deformation, convergence zone |
| | Adaptation of Arctic Circulation Model | Rutgers | $349,999 | 2010 - 2012 | ocean currents, ice coverage, hind cast |
| **3.1.2** | **Identify study sites in the Beaufort and Chukchi Seas and the contiguous Arctic Ocean where climate feedbacks are active** | | | | |
| | Bowhead Whale feeding Variability in the Western Alaskan Beaufort Sea: Oceanography and Feeding (BOWFEST) | NOAA/ Others | $8,095,000 | 2006 - 2013 | feeding, variability, behavior, Cross Island, Barrow , aircraft, tagging |
| | Hanna Shoal Ecosystem Study | UT-Austin | $5,665,144 | 2011 - 2016 | food web, ocean currents, species distribution, diversity |
| | Characterization of the Circulation on the Continental Shelf Areas of the Northeast Chukchi and Western Beaufort Seas | UAF | $5,056,252 | 2012 - 2016 | high frequency radar, ocean currents, gliders, drifters, |

| ARP Item | Research Topic | BOEM Partner | BOEM Funding | Study Duration | Key Words |
|---|---|---|---|---|---|
| | | | | | Barrow Canyon |
| | Arctic Whale Ecology Study: Use of the Chukchi Sea by Endangered Baleen and other Whales (ARCWEST) | NOAA | $4,502,000 | 2012 - 2017 | Smith Bay, Barrow Canyon, whale distribution, habitat, Barrow arch, nutrients |
| | Chukchi Acoustic, Oceanography and Zooplankton Study: Hanna Shoal (Extension of CHAOZ) | NOAA | $3,933,671 | 2014 – 2017 | passive acoustic, zooplankton detection, TAPS-6 |
| | ANIMIDA III: Contaminants, Sources, and Bioaccumulation | Olgoonik/ Fairweather | $2,700,000 | 2013 - 2017 | monitoring, sediment, bivalves, amphipods, hydrocarbons |
| | Ecosystem Observations in the Chukchi Sea: Biophysical Mooring and Climate Modeling | NOAA | $2,068,928 | 2010 - 2015 | ice coverage, forecast |
| | Application of High Frequency Radar to Potential Hydrocarbon Development Areas in the Northeast Chukchi Sea | UAF | $1,056,322 | 2009-2014 | surface currents, Barrow Canyon, ocean currents |
| | Biogeochemical Assessment of the OCS Arctic Waters: Current Status and Vulnerability to Climate Change | UAF-CMI | $756,704 | 2008 - 2014 | north Aleutian Basin, hydrographic, climate, net ecosystem production |
| | Toward a Predictive Model of Arctic Coastal Retreat in a Warming Climate, Beaufort Sea, Alaska | NOPP | $577,586 | 2006-2010 | coastal erosion, bluff retreat, wave modeling, thermal modeling |
| | Mapping and Characterization of Recurring Polynyas and Landfast Ice in the Chukchi Sea | UAF | $461,404 | 2009 - 2012 | ice leads, landfast ice, breakouts |
| | Wading Shorebirds Habitats, Food Resources, Associated Infauna, Sediment Characteristics and Bioremediation Potential of Resident Microbiota of Deltaic Mudflats | UAF | $365,236 | 2011 - 2015 | population structure, chemical footprint, Jago River, Okpilak River, Canning River |
| | ANIMIDA III: Arctic Kelp Communities in the Beaufort Sea: Sentinels of Long-Term Change | UT-Austin | $128,774 | 2014 – 2017 | cANIMIDA, Camden Bay, chemical finerprint, biota, sediments |
| | Sea Level Measurements along the Alaskan Chukchi and Beaufort Coasts | UAF-CMI | $72,178 | 2014 - 2017 | ocean currents, storm surges |
| **3.1.3** | **Complete deployment of a Distributed Biological Observatory in the Arctic Ocean to create long-term data sets on biological, physical, and chemical variability, change, and ecosystem response** | | | | |
| | Hanna Shoal Ecosystem Study | UT-Austin | $5,665,144 | 2011 - 2016 | food web, ocean currents, species distribution, diversity |
| | Passive Acoustic Detection and Monitoring of Endangered Whales in the Arctic (CHAOZ) | NOAA | $4,304,300 | 2010 - 2015 | tracking, cetaceans, climate modeling, hydrophone array, biophysical moorings |
| | Chukchi Acoustic, Oceanography and Zooplankton Study: Hanna Shoal (Extension of CHAOZ) | NOAA | $3,933,671 | 2014 – 2017 | passive acoustic, zooplankton detection, TAPS-6 |
| | Chukchi Sea Offshore Monitoring in Drilling Area: Chemistry and Benthos | UT-Austin | $2,887,495 | 2008 - 2012 | benthic biota, food web, sediment, contaminants |
| | ANIMIDA III: Contaminants, Sources, and Bioaccumulation | Olgoonik/ Fairweather | $2,700,000 | 2013 - 2017 | monitoring, sediment, bivalves, amphipods, hydrocarbons |
| | Arctic Marine Biodiversity Observing Network for Ecosystem Monitoring (Chukchi Sea) | Industry/ NOAA | $1,500,000 | 2014 - 2019 | microbes, plankton, meiofauna, epibenthic, fishes, birds, mammals, food web |
| **3.1.4** | **Develop integrated ecosystem research in the Beaufort and Chukchi Seas** | | | | |
| | Distribution and Relative Abundance of Marine | NOAA | $14,586,585 | 2011 - 2016 | pinnipeds, cetaceans, |

| ARP Item | Research Topic | BOEM Partner | BOEM Funding | Study Duration | Key Words |
|---|---|---|---|---|---|
| | Mammals in the Chukchi Sea and the Fall Migration of Bowhead Whales in the Beaufort Sea | | | | migration, satellite-track, tags, aerial, abundance |
| | Hanna Shoal Ecosystem Study | UT-Austin | $5,665,144 | 2011 - 2016 | food web, ocean currents, species distribution, diversity |
| | Passive Acoustic Detection and Monitoring of Endangered Whales in the Arctic (CHAOZ) | NOAA | $4,304,300 | 2010 - 2015 | tracking, cetaceans, climate modeling, hydrophone array, biophysical moorings |
| | Chukchi Acoustic, Oceanography and Zooplankton Study: Hanna Shoal (Extension of CHAOZ) | NOAA | $3,933,671 | 2014 – 2017 | passive acoustic, zooplankton detection, TAPS-6 |
| | Chukchi Sea Offshore Monitoring in Drilling Area: Chemistry and Benthos | UT-Austin | $2,887,495 | 2008 - 2012 | benthic biota, food web, sediment chemistry, contaminants |
| | ANIMIDA III: Contaminants, Sources, and Bioaccumulation | Olgoonik/ Fairweather | $2,700,000 | 2013 - 2017 | monitoring, sediment, bivalves, amphipods, hydrocarbons |
| | ANIMIDA III: Arctic Kelp Communities in the Beaufort Sea: Sentinels of Long-Term Change | UT-Austin | $623,661 | 2012 - 2017 | boulder patch, Liberty Prospect, ambient light, Camden Bay |
| | Distribution of Fish, Crab and Lower Trophic Communities in the Chukchi Sea Lease Area (Arctic Ecosystem Integrated Survey) | UAF/NOAA | $2,600,000 | 2012 - 2016 | ecology, demersal, pelagic, invertebrate, food-web |
| | Trophic Links: Forage Fish, their Prey, and Ice Seals in the Northeast Chukchi Sea | UAF-CMI | $532,173 | 2009 - 2013 | food web, isotope, fish, seal, benthic, demersal, pelagic, arctic cod |
| | Genomics of Arctic Cod: A Sentinel Species in a Changing Environment | USGS | $300,000 | 2014 - 2017 | genetics, genomics, transcriptomics, arctic cod, boreogadus saida |
| | Distribution and Habitat Use of Fish in the Nearshore Ecosystem of the Beaufort and Chukchi Sea | NOAA | $184,000 | 2012 - 2016 | nearshore habitat diversity, diet, temperature, salinity, Peard Bay, baseline |
| | Epifaunal Communities in the Central Beaufort Sea | UAF-CMI | $123,310 | 2008 - 2012 | epibenthic, abundance, species, biomass, trawl, voucher specimens |
| | Population Connectivity and Larval dispersal in Bering, Chukchi and Beaufort Sea Snow Crab Populations: Estimating Spatial Scales of Disturbance Impacts | UAF-CMI | $19,787 | 2009 -2011 | population structure, genetic variation, microsatellite, mitochondrial, phylogenetic |
| **3.2** | **Understand Terrestrial Ice Processes, Ecosystem Processes, Ecosystem Services, And Climate Feedbacks In The Arctic** | | | | |
| **3.2.1** | **Perform glacial-process studies targeting specific dynamic regimes** | | | | |
| | Toward a Predictive Model of Arctic Coastal Retreat in a Warming Climate, Beaufort Sea, Alaska | NOPP | $576,586 | 2006-2010 | coastal erosion, bluff retreat, wave modeling, thermal modeling |
| | Mapping Sea Ice Overflood Using Remote Sensing from Smith Bay to Camden Bay | D.F. Dickins | $478,017 | 2006 - 2009 | strudel scour, strudel holes, North Slope |
| | Evaluating Chukchi Sea Trace Metals and Hydrocarbons Sourced from Nearby Coastal Rivers | UAF-CMI | $232,760 | 2012 - 2014 | polycyclic aromatic hydrocarbons, bedload samples |
| **3.2.2** | **Coordinate and integrate terrestrial ecosystem research efforts** | | | | |
| | Marine Mammal/Physical Oceanography Synthesis (SOAR - Synthesis of Arctic Research) | NOAA | $1,798,459 | 2011 - 2016 | riverine, traditional knowledge, oceanography, marine mammals |
| | Demography and Behavior of Polar Bears | USGS | $1,480,767 | 2009 - 2014 | coastline, habitat, |

| ARP Item | Research Topic | BOEM Partner | BOEM Funding | Study Duration | Key Words |
|---|---|---|---|---|---|
| | Summering on Shore in Alaska | | | | Barter Island, Cross Island, demographic, behavior |
| | ShoreZone Mapping of the North Slope of Alaska | Nuka | $554,121 | 2011 - 2015 | imagery, groundtruthing, geomorphic, nearshore habitat, mapping |
| | Wading Shorebirds Habitats, Food Resources, Associated Infauna, Sediment Characteristics and Bioremediation | UAF | $365,236 | 2011 - 2016 | macrofauna assemblage, littoral zone, interstitial, invertebrates, shorebirds |
| | Shorebirds and Infaunal Abundance and Distribution on Delta Mudflats along the Beaufort Sea | USGS | $237,169 | 2011 - 2015 | invertebrate, foraging, shorebirds, sediment, chemical footprint |
| | Synthesis of Time-Interval Changes in Trace Metals and Hydrocarbons in Near shore Sediments of the Alaskan Beaufort Sea: A Statistical Analysis | UAF-CMI | $82,184 | 2006 - 2007 | hydrocarbons, contaminants, sediments, nearshore, mercury |
| | Biodegradation and Transport of Crude Oil in Sand and Gravel Beaches of Arctic Alaska | UAF-CMI | $56,310 | 2013 - 2017 | viscosity, sediments, soil profile, wave action, porosity, density |
| **3.2.3** | **Identify and study key sites where climate feedbacks are active, including permafrost, snow, hydrates, and glaciers** | | | | |
| | **Not Jurisdiction of BOEM** | | | | |
| **3.2.4** | **Investigate the frequency and severity of wildland fires in the Arctic** | | | | |
| | **Not Jurisdiction of BOEM** | | | | |
| **3.2.5** | **Conduct socio-economic research to understand ecosystem services as increased warming changes the Arctic tundra** | | | | |
| | COMIDA: Impact Monitoring for Offshore Subsistence Hunting | Stephen Braund | $999,805 | 2009 - 2013 | marine mammal, fish, harvest, climate, sea ice |
| | The Study of Sharing Networks to Assess the Vulnerabilities of Local Communities to Oil and Gas Development Impacts in Arctic Alaska | UAF | $785,000 | 2007 - 2013 | subsistence, Wainwright, Kaktovik, Venetie, Iñupiat |
| | Social Indicators in Coastal Alaska: Arctic Communities | Stephen Braund | $669,656 | 2011 - 2012 | cultural, health, climate, subsistence |
| | MAG-PLAN Modification: New Data Collection, Testing and Streamlining of OCS Economic Impact Model for Alaska | Northern Economics | $588,857 | 2011 - 2012 | modeling review board, economic impact model, cost function |
| | Subsistence Mapping of Nuiqsut, Kaktovik and Barrow : Past and Present Comparison | Stephen Braund | $399,994 | 2004 - 2007 | Iñupiat, harvest, traditional knowledge |
| | Continuation of Impact Assessment for Cross Island Whaling Activities - Beaufort Sea | ASCR | $328,507 | 2008 - 2013 | Iñupiat, Nuiqsut, bowhead whale, subsistence, migration, hunting |
| | Subsistence Use and Knowledge of Salmon in Barrow and Nuiqsut | UAF-CMI | $119,459 | 2009-2013 | Inupiat, fishing, traditional knowledge |
| **3.3** | **Understand Atmospheric Surface Heat, Energy, And Mass Balances** | | | | |
| **3.3.1** | **Improve understanding of short-lived climate forcers (SLCFs); source regions, direct and indirect effects, and net impact on Arctic warming** | | | | |
| | Ecosystem Observations in the Chukchi Sea: Biophysical Mooring and Climate Modeling | NOAA | $2,068,928 | 2010 - 2015 | ice coverage, forecast |

| ARP Item | Research Topic | BOEM Partner | BOEM Funding | Study Duration | Key Words |
|---|---|---|---|---|---|
| | Beaufort and Chukchi Seas Mesoscale Meteorology Model | UAF | $1,784,735 | 2006 - 2012 | forecasting model, winds, meteorological stations, buoys |
| | Arctic Air Quality Impact Assessment Modeling | ERG | $1,751,036 | 2013 - 2016 | pollutants, air quality |
| | Biogeochemical Assessment of the OCS Arctic Waters: Current Status and Vulnerability to Climate Change | UAF-CMI | $756,704 | 2008 - 2014 | Bering Sea, hydrographic, climate, net ecosystem production |
| | Adaptation of Arctic Circulation Model | Rutgers | $349,999 | 2010 - 2012 | ocean currents, coupled air-sea-ice, 30-year hindcast |
| | Sea Level Measurements along the Alaskan Chukchi and Beaufort Coasts | UAF-CMI | $72,178 | 2014 - 2017 | ocean currents, storm surges |
| **3.3.2** | **Improve understanding of processes that control the formation, longevity, and physical properties of Arctic clouds, including the effects of—and sensitivities to—aerosols** | | | | |
| | Beaufort and Chukchi Seas Mesoscale Meteorology Modeling | UAF | $1,784,735 | 2006 - 2012 | forecasting, model, winds, meteorological stations, buoys |
| | Arctic Air Quality Impact Assessment Modeling | ERG | $1,751,036 | 2013 - 2016 | pollutants, air quality |
| **3.3.3** | **Develop an integrated understanding of Arctic atmospheric processes, their impact on the surface energy budget, and their linkages with oceanic, terrestrial, and cryospheric systems** | | | | |
| | Circulation, Cross-Shelf Exchange, Sea Ice, and Marine Mammal Habitats on the Alaskan Beaufort Sea Shelf | NOPP | $2,948,000 | 2007-2009 | Changing ice conditions, satellite observations, wind-forcing |
| | Enhanced Verification and Interpretation of Freeze-up Conditions for the Northeast Chukchi Shelf: Field Observations and Process Studies; Freeze-up Forecasts | UAF | $1,995,000 | 2014 - 2019 | sea ice, forecasting, hind cast, freeze-up, Burger |
| | Arctic Air Quality Impact Assessment Modeling | ERG | $1,751,036 | 2013 - 2016 | pollutants, air quality |
| | Biogeochemical Assessment of the OCS Arctic Waters: Current Status and Vulnerability to Climate Change | UAF-CMI | $756,704 | 2008 - 2012 | Bering Sea, hydrographic, climate, net ecosystem production |
| | Adaptation of Arctic Circulation Model | Rutgers | $349,999 | 2010 - 2012 | ocean currents, coupled air-sea-ice, 30-year hindcast |
| | Sea Level Measurements along the Alaskan Chukchi and Beaufort Coasts | UAF | $72,178 | 2014 - 2017 | ocean currents, storm surges |
| **3.4** | **Integrate And Continue To Deploy A National Arctic Observing System And Promote International Cooperation To Create A Circumpolar Arctic Observing System** | | | | |
| **3.4.1** | **Facilitate observing-system design for the Arctic** | | | | |
| | Distribution and Relative Abundance of Marine Mammals in the Chukchi Sea and the Fall Migration of Bowhead Whales in the Beaufort Sea | NOAA | $14,586,585 | 2011 - 2016 | pinnipeds, cetaceans, migration, satellite-track, tags, aerial, abundance |
| | Bowhead Whale feeding Variability in the Western Alaskan Beaufort Sea: Oceanography and Feeding (BOWFEST) | NOAA/ Others | $8,095,000 | 2006 - 2013 | feeding, variability, behavior, Cross Island, Barrow , aircraft, tagging |
| | Marine Arctic Ecosystem Study (MARES) | Stantec NOPP | $5,000,000 | 2014-2019 | Mackenzie plume, water column properties, shelf/slope exchange, marine mammal tagging |
| | U.S.-Canada Transboundary Fish and Lower Trophic Communities | UAF | $5,191,125 | 2012 - 2016 | food web, DBO, arctic cod, Canada |
| | Characterization of the Circulation on the Continental Shelf Areas of the Northeast Chukchi and Western Beaufort Seas | UAF | $5,056,252 | 2012 - 2016 | high frequency radar, ocean currents, gliders, drifters, |

| ARP Item | Research Topic | BOEM Partner | BOEM Funding | Study Duration | Key Words |
|---|---|---|---|---|---|
| | | | | | Barrow Canyon |
| | Arctic Whale Ecology Study: Use of the Chukchi Sea by Endangered Baleen and other Whales (ARCWEST) | NOAA | $4,502,000 | 2012 - 2017 | Smith Bay, Barrow Canyon, distribution, habitat, Barrow Arch, nutrients |
| | COMIDA: Factors Affecting the Distribution and Relative Abundance of Endangered Whales: Passive Acoustic Detection and Monitoring of Endangered Whales in the Arctic | NOAA | $4,304,300 | 2010 - 2015 | marine mammals, zooplankton, TAPS-6 |
| | Chukchi Acoustic, Oceanography and Zooplankton Study: Hanna Shoal (Extension of CHAOZ) | NOAA | $3,933,671 | 2014 – 2017 | passive acoustic, zooplankton detection, TAPS-6 |
| | ANIMIDA III: Contaminants, Sources, and Bioaccumulation | Olgoonik/ Fairweather | $2,700,000 | 2013 - 2017 | monitoring, sediment, bivalves, amphipods, hydrocarbons |
| | Distribution of Fish, Crab and Lower Trophic Communities in the Chukchi Sea Lease Area (Arctic Ecosystem Integrated Survey) | UAF/NOAA | $2,600,000 | 2012 - 2016 | ecology, demersal, pelagic, invertebrate, food-web |
| | Beaufort Sea Marine Fish Monitoring: Pilot Survey in the Central Beaufort Sea | UAF | $1,764,252 | 2010 - 2015 | food web, isotope, Barrow Canyon, arctic cod, benthic, pelagic, demersal |
| | Ice Seal Movements and Foraging: Village-based Satellite Tracking of Ringed and Bearded Seals | ADF&G | $1,174,994 | 2013 - 2017 | pinnipeds, tagging, Kotzebue, habitat, ice seal committee, bathymetry, ice edge |
| | Application of High-Frequency Radar to Potential Hydrocarbon Development Areas in the Northeast Chukchi Sea | UAF | $1,056,322 | 2009 - 2014 | surface currents, Barrow Canyon, Barrow , Wainwright, Point Lay, upwelling |
| | COMIDA: Impact Monitoring for Offshore Subsistence Hunting | Stephen Braund | $999,805 | 2009 - 2013 | Iñupiat, Point Lay, Wainwright, gps, sea ice, traditional knowledge |
| | Study of Sharing Networks to Assess the Vulnerabilities of Local Communities to O&G Development Impacts in Arctic Alaska | UAF | $785,000 | 2007 - 2013 | subsistence, Wainwright, Kaktovik, Venetie, Iñupiat |
| | Abundance Estimates of Ice Associated Seals: Bering Sea Populations that Inhabit the Chukchi Sea during Open-Water Period | NOAA | $713,010 | 2012 - 2014 | Russia, logistics support |
| **3.4.2** | **Assess local-resident priorities for addressing change** | | | | |
| | Quantitative Description of Potential Impacts of OCS Activities on Bowhead Whale Hunting and Subsistence in the Beaufort Sea | EDAW | $702,445 | 2001 - 2006 | Iñupiat, Barrow , Kaktovik, Nuiqsut, Savoonga, household survey |
| | Social Indicators in Coastal Alaska: Arctic Communities | Stephen Braund | $669,659 | 2011 - 2012 | household survey, traditional knowledge, health, subsistence |
| | Trophic Links: Forage Fish, Their Prey, and Ice Seals in the northeast Chukchi Sea | UAF-CMI | $532,173 | 2009 - 2014 | food web, isotope, fish, seal, benthic, demersal, pelagic, arctic cod |
| | Subsistence Mapping of Nuiqsut, Kaktovik and Barrow : Past and Present Comparison | Stephen Braund | $399,994 | 2004 - 2007 | Iñupiat, harvest, traditional knowledge |
| | Aggregate Effects Research & Environmental Mitigation Monitoring of Oil Operations in the Vicinity of Nuiqsut | Stephen Braund | $373,298 | 2009 - 2013 | Iñupiat, Nuiqsut, oil, gas, subsistence, harvest, mitigation |
| | Continuation of Impact Assessment for Cross Island Whaling Activities - Beaufort Sea | ASCR | $328,507 | 2008 - 2013 | Iñupiat, Nuiqsut, bowhead, subsistence, gps, harvest, hunt |

| ARP Item | Research Topic | BOEM Partner | BOEM Funding | Study Duration | Key Words |
|---|---|---|---|---|---|
| | Researching Technical Dialogue with Alaskan Coastal Communities: Analysis of the Social, Cultural, Linguistic, and Institutional Parameters of Public/Agency Communication Patterns | EDAW | $299,878 | 2004 - 2009 | NEPA analysis, linguistics, Iñupiat, development, focus groups |
| | Dispersal Patterns and Summer Ocean Distribution of Adult Dolly Varden from the Wulik River, Alaska, using Satellite Tags. | UAF-CMI | $146,510 | 2012 – 2013 | fish, distribution, migration, subsistence, |
| | Subsistence Use and Knowledge of Beaufort Salmon Populations | UAF-CMI | $119,459 | 2009 - 2012 | Iñupiat, traditional knowledge, Barrow, Nuiqsut, whitefish |
| **3.4.3** | **Combine in-situ and remotely sensed observations of sea ice with local community and traditional knowledge** | | | | |
| | Crude Oil Infiltration and Movement in First-year Sea Ice: Impacts on Ice-associated Biota and Physical Constraints | UAF-CMI | $298,214 | 2014 - 2017 | oil spill, temperature, salinity, brine channel network, sea ice |
| | Distribution and Abundance of Select Trace Metals in Chukchi and Beaufort Sea Ice | UAF-CMI | $262,073 | 2013 - 2016 | trace metals, sea ice, laboratory, seawater, Camden Bay |
| | Traditional Knowledge Implementation: Accessing Arctic Community Panels of Subject Matter Experts | Pending | | | |
| **3.4.4** | **Conduct long-term monitoring of key outlet glaciers and tidewater glaciers** | | | | |
| | **Not Jurisdiction of BOEM** | | | | |
| **3.4.5** | **Monitor the biological and physical state of the Arctic marine environment** | | | | |
| | Distribution and Relative Abundance of Marine Mammals in the Chukchi Sea and the Fall Migration of Bowhead Whales in the Beaufort Sea | NOAA | $14,586,585 | 2011 - 2016 | pinnipeds, cetaceans, migration, satellite-track, tags, aerial, abundance |
| | Hanna Shoal Ecosystem Study | UT-Austin | $5,665,144 | 2011 - 2016 | oceanography, benthic biota, food web, sediment chemistry, contaminants |
| | Marine Arctic Ecosystem Study (MARES) | Stantec NOPP | $5,000,000 | 2014-2019 | Mackenzie plume, water column properties, shelf/slope exchange, marine mammal tagging |
| | COMIDA: Factors Affecting the Distribution and Relative Abundance of Endangered Whales: Passive Acoustic Detection and Monitoring of Endangered Whales in the Arctic | NOAA | $4,304,300 | 2010 - 2015 | marine mammals, zooplankton, biophysical conditions |
| | Chukchi Acoustic, Oceanography and Zooplankton Study: Hanna Shoal (Extension of CHAOZ) | NOAA | $3,933,671 | 2014 – 2017 | passive acoustic, zooplankton detection, TAPS-6 |
| | Chukchi Sea Offshore Monitoring in Drilling Area: Chemistry and Benthos | UT-Austin | $2,887,495 | 2008 - 2012 | benthic biota, food web, sediment, contaminants |
| | ANIMIDA III: Contaminants, Sources, and Bioaccumulation | Olgoonik/ Fairweather | $2,700,000 | 2013 - 2017 | monitoring, sediment, bivalves, amphipods, hydrocarbons |
| | Satellite Tracking of Bowhead Whales: Habitat Use, Passive Acoustic and Environmental Monitoring | ADF&G | $2,699,857 | 2012 - 2015 | tagging, Saint Lawrence, Point Hope, Canada, sensors, monitoring, ambient |
| | Distribution of Fish, Crab and Lower Trophic Communities in the Chukchi Sea Lease Area (Arctic Ecosystem Integrated Survey) | UAF/NOAA | $2,600,000 | 2012 - 2016 | ecology, demersal, pelagic, invertebrate, food-web |
| | Beaufort Sea Marine Fish Monitoring: Pilot Survey in the Central Beaufort Sea | UAF | $1,764,252 | 2010 - 2014 | food web, isotope, Barrow Canyon, arctic cod, benthic, pelagic, demersal |

| ARP Item | Research Topic | BOEM Partner | BOEM Funding | Study Duration | Key Words |
|---|---|---|---|---|---|
| | Ice Seal Movements and Foraging: Village based Satellite Tracking and Acoustic Monitoring of Ringed, Bearded, and Spotted Seals | ADF&G | $1,174,994 | 2013 - 2017 | satellite, telemetry, habitat, mapping |
| | COMIDA: Impact Monitoring for Offshore Subsistence Hunting | Stephen Braund | $999,805 | 2009 - 2013 | Chukchi Sea, Iñupiat, harvest, Point Lay, Wainwright, boat tracks, traditional knowledge |
| | Biogeochemical Assessment of the OCS Arctic Waters: Current Status and Vulnerability to Climate Change | UAF-CMI | $756,704 | 2008 - 2014 | Bering Sea, hydrographic, climate, net ecosystem production |
| | ANIMIDA III: Arctic Kelp Communities in the Beaufort Sea: Sentinels of Long-Term Change | UT-Austin | $623,661 | 2012 - 2017 | boulder patch, Liberty Prospect, ambient light, Camden Bay |
| | Trophic Links: Forage Fish, Their Prey, and Ice Seals in the northeast Chukchi Sea | UAF-CMI | $532,173 | 2009 - 2014 | food web, isotope, diet, fish, seal, benthic, demersal, pelagic, arctic cod, |
| | Genomics of Arctic Cod: A Sentinel Species in a Changing Environment | USGS | $300,000 | 2014 - 2017 | genetics, genomics, transcriptomics, arctic cod, Boreogadus saida |
| **3.4.6** | **Assess the effects of clouds and atmospheric constituents on surface radiation balance** | | | | |
| | **Not Jurisdiction of BOEM** | | | | |
| **3.4.7** | **Assess the impact of terrestrial warming and permafrost thawing on the carbon cycle** | | | | |
| | **Not Jurisdiction of BOEM** | | | | |
| **3.4.8** | **Improve data access** | | | | |
| | Distribution of Fish, Crab and Lower Trophic Communities in the Chukchi Sea Lease Area (Arctic Ecosystem Integrated Survey) | UAF/NOAA | $2,600,000 | 2012 - 2016 | ecology, demersal, pelagic, invertebrate, food-web |
| | Marine Mammal/Physical Oceanography Synthesis (SOAR - Synthesis of Arctic Research) | NOAA | $1,798,459 | 2011 - 2016 | traditional knowledge, oceanography, marine mammals |
| | Enhancement of the Environmental Studies Program Information System and the Multipurpose Marine Cadastre to Provide Environmental Studies Program Data | NOAA | $1,700,000 | 2012 - 2015 | geoespis, database, noaa-csc, geospatial web portal |
| | Synthesis of Information on the Socioeconomic Effects of Oil and Gas Activities in Alaska | Stephen Braund | $349,249 | 2001 - 2006 | sociocultural, subsistence, economy, Exxon Valdez |
| | Developing BOEM's Access to Protected Species Occurrence Data for Impact Analysis and Rulemaking | USGS, NOAA, Duke | $180,000 | 2014-2016 | bowhead whale, distribution, density, OBIS |
| | Alaska Marine Science Symposium (co-sponsor) | NPRB | $100,000 | 2010 - 2014 | workshop, environmental studies program |
| | Joint Funding Opportunities in Existing Marine Fish Studies: Beaufort Sea Fish and their Trophic Linkages--Literature Search and Synthesis | UAF | $23,578 | 2012 - 2012 | fish, prey, food web |
| | Arctic Research Synthesis Conference | BGES | Pending | 2014 - 2015 | workshop, information transfer |
| **3.4.9** | **Engage indigenous observers and communities in monitoring environmental parameters** | | | | |
| | Social Indicators in Coastal Alaska: Arctic Communities | Stephen Braund | $669,659 | 2011 - 2014 | marine mammal, fish, subsistence, harvest, |
| | ShoreZone Mapping of the North Slope of Alaska | Nuka | $554,121 | 2011 - 2015 | imagery, groundtruthing, geomorphic, nearshore habitat, mapping |
| | Subsistence Mapping of Nuiqsut, Kaktovik and Barrow : Past and Present Comparison | Stephen Braund | $399,994 | 2004 - 2007 | Iñupiat, harvest, traditional knowledge |

| ARP Item | Research Topic | BOEM Partner | BOEM Funding | Study Duration | Key Words |
|---|---|---|---|---|---|
| | Aggregate Effects Research & Environmental Mitigation Monitoring of Oil Operations in the Vicinity of Nuiqsut | Stephen Braund | $393,490 | 2009 - 2013 | Iñupiat, oil, gas, subsistence, harvest, mitigation |
| | Analysis of Variation in Abundance of Arctic Cisco in the Colville River | ABR | $345,520 | 2004 - 2007 | traditional knowledge, Iñupiat, Nuiqsut, fish |
| | Sea Level Measurements along the Alaskan Chukchi and Beaufort Coasts | UAF-CMI | $72,178 | 2014 - 2017 | ocean currents, storm surges |
| | Traditional Knowledge Implementation: Accessing Arctic Community Panels of Subject Matter Experts | Pending | | | |
| **3.5** | **Integrate Arctic Regional Models** | | | | |
| **3.5.1** | **Inventory Arctic modeling activities** | | | | |
| | Enhanced Verification and Interpretation of Freeze-up Conditions for the Northeast Chukchi Shelf: Field Observations and Process Studies; Freeze-up Forecasts | UAF | $1,995,000 | 2014 - 2019 | sea ice forecasting, sea ice hind cast, freeze-up, Burger |
| | Development of an accurate model of the Beaufort and Chukchi Ice Drift and Dispersion for Forecasting Spill Trajectories and Providing Decision Support for Spill Response | UAF-CMI | $359,078 | 2013 -2016 | spill response, oil trajectories, ice velocities, ice deformation, convergence zone |
| | Loss of Well Control Occurrence and Size Estimators for Alaska OCS | Bercha | $298,540 | 2012 -2014 | risk assessment, oil spill, offshore, onshore |
| | Update to the Fault Tree for Oil-spill Occurrence Estimators needed Under the Forthcoming BOEM 2012-2017, 5-Year Program | Bercha | $229,840 | 2011 - 2016 | risk assessment, arctic conditions |
| | Development of a Very High-resolution Regional Circulation Model of Beaufort Sea Nearshore Areas | Pending | | | barrier islands, eddies |
| **3.5.2** | **Encourage coordinated approaches that better represent Arctic processes in Earthsystem models** | | | | |
| | **Not Jurisdiction of BOEM** | | | | |
| **3.5.3** | **Build Arctic and subsystem models for coupling with regional and global approaches** | | | | |
| | Beaufort and Chukchi Seas Mesoscale Meteorology Model | UAF | $1,784,735 | 2006 - 2012 | weather, forecasting, model, surface winds, meteorology, buoys |
| | Adaptation of Arctic Circulation Model | Rutgers | $349,999 | 2010 - 2012 | ocean currents, ice coverage, hind cast |
| | Development of a Very High-resolution Regional Circulation Model of Beaufort Sea Nearshore Areas | Pending | | | barrier islands, eddies |
| **3.5.4** | **Develop models of Arctic land ice mass loss, connections to ocean and atmospheric variability, and implications for sea level** | | | | |
| | **Not Jurisdiction of BOEM** | | | | |
| **3.5.5** | **Increase Arctic model resolution to improve prediction and inform future research and observations** | | | | |
| | Beaufort and Chukchi Seas Mesoscale Meteorology Model | UAF | $1,784,735 | 2006 - 2012 | forecasting model, winds, meteorological stations, buoys, WRF |
| | Development of an accurate model of the Beaufort and Chukchi Ice Drift and Dispersion for Forecasting Spill Trajectories and Providing Decision Support for Spill Response | UAF-CMI | $359,078 | 2013 -2016 | spill response, oil trajectories, ice velocities, ice deformation, convergence zone |
| | Adaptation of Arctic Circulation Model | Rutgers | $349,999 | 2010 - 2012 | ocean currents, ice coverage, hind cast |
| | Development of a Very High-resolution Regional Circulation Model of Beaufort Sea Nearshore Areas | Pending | | | |

| ARP Item | Research Topic | BOEM Partner | BOEM Funding | Study Duration | Key Words |
|---|---|---|---|---|---|
| **3.5.6** | **Use insights from models to inform process research; use process research to evaluate and improve models** | | | | |
| | Marine Mammal/Physical Oceanography Synthesis (SOAR - Synthesis of Arctic Research) | NOAA | $1,798,459 | 2011 - 2016 | riverine, traditional knowledge, oceanography, marine mammals |
| | Enhanced Verification and Interpretation of Freeze-up Conditions for the Northeast Chukchi Shelf: Field Observations and Process Studies; Freeze-up Forecasts | UAF | $1,995,000 | 2014 - 2019 | sea ice forecasting, sea ice hind cast, freeze-up, Burger |
| | Beaufort and Chukchi Seas Mesoscale Meteorology Model | UAF | $1,784,735 | 2006 - 2012 | forecasting model, winds, meteorological stations, buoys, WRF |
| | Arctic Tracer Release Experiment: Applications for Mapping Spilled Oil in Arctic Waters | UAF | $1,249,977 | 2013 - 2016 | dispersed dye , drifters, high frequency radar, gliders, drifters, NOAA |
| | Development of an accurate model of the Beaufort and Chukchi Ice Drift and Dispersion for Forecasting Spill Trajectories and Providing Decision Support for Spill Response | UAF-CMI | $359,078 | 2013 -2016 | spill response, oil trajectories, ice velocities, ice deformation, convergence zone |
| | Adaptation of Arctic Circulation Model | Rutgers | $349,999 | 2010 - 2012 | ocean currents, ice coverage, hind cast |
| | Characterization of the Circulation on the continental Shelf Areas of the Northeast Chukchi and Western Beaufort Seas | UAF | $5,056,252 | 2012 - 2016 | high frequency radar, ocean currents, gliders, drifters, Barrow Canyon |
| | Ecosystem Observations in the Chukchi Sea: Biophysical Mooring and Climate Modeling | NOAA | $2,068,928 | 2010 - 2015 | ice coverage, forecast |
| | Application of High Frequency Radar to Potential Hydrocarbon Development Areas in the Northeast Chukchi Sea | UAF | $1,056,322 | 2009-2014 | surface currents, Barrow Canyon, circulation |
| | Mapping and Characterization of Recurring Polynyas and Landfast Ice in the Chukchi Sea | UAF | $461,404 | 2009 - 2012 | ice leads, landfast ice, breakouts |
| | Satellite-Tracked Drifter Measurements in the Northeast Chukchi Sea | UAF | $459,892 | 2011- 2015 | ocean currents, current velocities |
| | Development and Testing of a Low-Cost Satellite Tracked Ice Drifter for Arctic Alaska | UAF-CMI | $433,409 | 2014 - 2017 | ice velocities, model validation |
| | Development of a Very High-resolution Regional Circulation Model of Beaufort Sea Nearshore Areas | Pending | | | |
| **3.5.7** | **Integrate Arctic climate-model results with observational validation and verification to understand the principal drivers and uncertainties of Arctic climate changes** | | | | |
| | Ecosystem Observations in the Chukchi Sea: Biophysical Mooring and Climate Modeling | NOAA | $2,068,928 | 2010 - 2015 | ice coverage, forecast |
| | Enhanced Verification and Interpretation of Freeze-up Conditions for the Northeast Chukchi Shelf: Field Observations and Process Studies; Freeze-up Forecasts | UAF | $1,995,000.00 | 2014 - 2019 | sea ice forecasting, sea ice hind cast, freeze-up, Burger |
| | Satellite-Tracked Drifter Measurements in the Northeast Chukchi Sea | UAF | $459,892 | 2011- 2015 | ocean currents, current velocities |
| | ShoreZone Mapping of the North Slope of Alaska | Nuka | $554,121 | 2011 - 2015 | imagery, groundtruthing, geomorphic, nearshore habitat, mapping |
| **3.6** | **Assess Strengths And Vulnerabilities Of Arctic Communities Facing The Impacts Of Climate Change And Assist In Developing Adaptation Strategies And Tools To Maximize Sustainability, Well-Being, And Cultural And Linguistic Heritage** | | | | |

| ARP Item | Research Topic | BOEM Partner | BOEM Funding | Study Duration | Key Words |
|---|---|---|---|---|---|
| **3.6.1** | **In collaboration with local communities, develop methods for assessing community sustainability and resilience and determine the efficiency of current adaptation strategies** | | | | |
| | The Study of Sharing Networks to Assess the Vulnerabilities of Local Communities to Oil and Gas Development Impacts in Arctic Alaska | UAF | $785,000 | 2007 - 2013 | subsistence, Wainwright, Kaktovik, Venetie, Iñupiat |
| | Social Indicators in Coastal Alaska: Arctic Communities | Stephen Braund | $669,659 | 2011 - 2014 | marine mammal, fish, subsistence, harvest |
| | Aggregate Effects Research & Environmental Mitigation Monitoring of Oil Operations in the Vicinity of Nuiqsut | Stephen Braund | $373,298 | 2009 - 2013 | Iñupiat, oil, gas, subsistence, harvest |
| **3.6.2** | **Identify the current vulnerabilities of Arctic communities and ecosystems to climate change and explore their interactions with socio-economic and other stressors** | | | | |
| | Social Indicators in Coastal Alaska: Arctic Communities | Stephen Braund | $669,659 | 2011 - 2014 | traditional knowledge, climate change, subsistence, economy, |
| | Aggregate Effects Research & Environmental Mitigation Monitoring of Oil Operations in the Vicinity of Nuiqsut | Stephen Braund | $393,490 | 2009 - 2013 | Iñupiat, Nuiqsut, oil, gas, subsistence, harvest, mitigation |
| | Analysis of Variation in Abundance of Arctic Cisco in the Colville River: Study | ABR | $345,520 | 2004 - 2007 | traditional knowledge, Iñupiat, Nuiqsut, arctic cisco, climate change |
| **3.6.3** | **Develop projections of future climate scenarios and demographic conditions to forecast potential strengths and weaknesses of human and ecological systems in the Arctic** | | | | |
| | North Slope Borough Economy: 1975 to Present | Northern Economics | $145,255 | 2005 - 2006 | employment, income, demography |
| | Social Indicators in Coastal Alaska: Arctic Communities | Stephen Braund | $669,659 | 2011 - 2014 | communities, economic, cultural, subsistence, Arctic Council |
| **3.6.4** | **Assist Arctic communities in documenting, revitalizing, and strengthening indigenous languages and cultural heritage** | | | | |
| | A Year in the Life of a Bowhead Whale: An Animated Film | UAF-CMI | $87,587 | 2012 – 2014 | Alaska Museum of the North, animated film, production, storyboarding |
| | Traditional Knowledge Implementation: Accessing Arctic Community Panels of Subject Matter Experts | Pending | | | |
| **3.7** | **Understand Factors That Impact Human Health In The Arctic, Including Infectious And Non-Communicable Diseases, Climate Change, Environmental Contamination, And Behavior And Mental-Health Disorders** | | | | |
| **3.7.1** | **Continue to expand circumpolar surveillance and research for infectious diseases, non-communicable diseases, trauma, injury, sanitation services, and indoor air quality to help prevent morbidity and mortality** | | | | |
| | **Not Jurisdiction of BOEM** | | | | |
| **3.7.2** | **Continue interagency collaboration to monitor the impacts of climate change and environmental contaminants on human health and wildlife** | | | | |
| | Chukchi Sea Offshore Monitoring in Drilling Area (COMIDA): Chemistry and Benthos | UT-Austin | $2,887,495 | 2008 - 2012 | benthic biota, food web, sediment chemistry, contaminants |
| | ANIMIDA III: Contaminants, Sources, and Bioaccumulation | Olgoonik/ Fairweather | $2,700,000 | 2013 - 2017 | long term monitoring, sediment, bivalves, amphipods, hydrocarbons |
| | Arctic Air Quality Impact Assessment Modeling | ERG | $1,751,036 | 2013 - 2016 | pollutants, air quality |
| | Analysis of Variation in Abundance of Arctic Cisco | ABR | $345,520 | 2004 - 2007 | traditional knowledge, |

| ARP Item | Research Topic | BOEM Partner | BOEM Funding | Study Duration | Key Words |
|---|---|---|---|---|---|
| | in the Colville River: Study | | | | Iñupiat, Nuiqsut, fish, climate change |
| | Sensitivity to Hydrocarbons and Baselines of Exposure in Marine Birds on the Chukchi and Beaufort Seas | UAF-CMI | $194,676 | 2013 - 2016 | marine birds, crude oil, cytochrome p450, 7-ethoxyresorufin-*O*-deethylase |
| | ANIMIDA III: Arctic Kelp Communities in the Beaufort Sea: Sentinels of Long-Term Change | UT-Austin | $128,774 | 2014 – 2017 | cANIMIDA, Camden Bay, chemical finerprint, biota, sediments |
| **3.7.3** | **Continue to support investigator-initiated research in major health priority areas such as mental health including substance abuse and suicide, obesity, diabetes, and cancer** | | | | |
| | **Not Jurisdiction of BOEM** | | | | |
| **3.7.4** | **Continue to engage indigenous communities and tribal groups in research activities and projects in the Arctic** | | | | |
| | Bowhead Whale feeding Variability in the Western Alaskan Beaufort Sea: Oceanography and Feeding | NOAA/ Others | $8,095,000 | 2006 - 2013 | feeding, variability, behavior, Cross Island, Barrow , aircraft, tagging |
| | Satellite Tracking of Bowhead Whales: Habitat Use, Passive Acoustic and Environmental Monitoring | ADF&G | $2,699,857 | 2012 - 2015 | tagging, Saint Lawrence, Point Hope, Canada, |
| | Distribution of Fish, Crab and Lower Trophic Communities in the Chukchi Sea Lease Area (Arctic Ecosystem Integrated Survey) | UAF/NOAA | $2,600,000 | 2012 - 2016 | ecology, demersal, pelagic, invertebrate, food-web |
| | Ice Seal Movements and Foraging: Village based Satellite Tracking and Acoustic Monitoring of Ringed, Bearded, and Spotted Seals With the TEK component, this should be included here | ADF&G | $1,174,994 | 2013 - 2017 | Traditional knowledge, satellite telemetry, habitat, satellite mapping |
| | COMIDA: Impact Monitoring for Offshore Subsistence Hunting | Stephen Braund | $999,805 | 2009 - 2013 | Iñupiat, harvest, Point Lay, Wainwright, climate, sea ice, traditional knowledge, |
| | The Study of Sharing Networks to Assess the Vulnerabilities of Local Communities to Oil and Gas Development Impacts in Arctic Alaska | UAF | $785,000 | 2007 - 2013 | subsistence, Wainwright, Kaktovik, Venetie, |
| | Social Indicators in Coastal Alaska: Arctic Communities | Stephen Braund | $669,659 | 2011 - 2014 | communities, economic, cultural, subsistence, Arctic Council |
| | Subsistence Mapping of Nuiqsut, Kaktovik and Barrow : Past and Present Comparison | Stephen Braund | $399,994 | 2004 - 2007 | Iñupiat, harvest, traditional knowledge |
| | Analysis of Variation in Abundance of Arctic Cisco in the Colville River: Study | ABR | $345,520 | 2004 - 2007 | traditional knowledge, Iñupiat, Nuiqsut, fish, climate change |
| | Continuation of Impact Assessment for Cross Island Whaling Activities - Beaufort Sea | ASCR | $328,507 | 2008 - 2013 | Nuiqsut, subsistence, Nuiqsut Whalers Association, Alaska Eskimo Whaling Commission |
| | Sea Level Measurements along the Alaska Chukchi and Beaufort Coasts | UAF-CMI | $72,178 | 2014 - 2017 | ocean currents, storm surges |