Part Three

Ecological and Human Environment

Part Three

Overview

Chapters 9 and 10 examine the current knowledge on key ecological and human environment considerations and the capacity of industry, and policy and regulatory decision-makers to prudently explore and develop oil and gas resources in a manner that is protective of the Arctic ecosystem and human environment.

Chapter 9 summarizes the current information that is available to document and interpret existing conditions within the Arctic ecosystem (with specific focus on the U.S. Arctic), understand the rate and trajectory of changes in the environment, and predict or evaluate the impact(s) of exploration and development activities upon ecological resources. Chapter 10 documents the ways in which the peoples of the Arctic interact with and depend upon their environment; the interplay between development and cultural, health, and economic well-being; and the changing patterns of current human use of the Arctic environment that is undergoing change. The objective of these chapters is to describe the existing understanding of the physical, biological, and human components and functional interrelationships that exist within the Arctic ecological and human environments and to identify opportunities to improve upon information to facilitate prudent exploration and development.

This evaluation of Arctic ecological and human environment data was conducted with attention to those data that are most relevant to oil and gas activities and responsible management. Opportunities have been identified that could enhance capabilities to:

- Support operational planning and implementation that are informed by and protective of ecological resources and human interactions and dependencies upon their environment
- Identify measures that can assist in avoidance, reduction, and/or mitigation of impacts
- Aid in the evaluation of risks and potential impacts
- Enhance capacities to responsibly manage resources and systems
- Inform and facilitate regulatory decision-making and permitting that is both protective of resources and their use and accommodates prudent oil and gas exploration and development.

The process of identifying opportunities for ecological and human research has drawn heavily upon the work products of multiple prior research planning and evaluation efforts that have been conducted over the last two decades to identify and prioritize research. Multiple research recommendations were reviewed and evaluated to identify common themes and stakeholder priorities. The working groups that developed these opportunities included industry specialists, representatives of the stakeholder communities, academia, and resource agency scientists. Workshops were also held in Washington, D.C., and Fairbanks, Alaska, to review findings and early recommendations with key stakeholders and to build consensus around conclusions.

Opportunities identified in this study are listed in the following table. These opportunities are grouped into two broad categories, namely research theme and facilitation recommendations that can enhance capacities to accomplish effective research programs through data sharing, planning, coordination, and collaboration. Priorities have been assessed based upon the immediacy of industry activities that would

Chapter	Category	Enhancement Opportunity	Supports Exploration, Production, or Both	Priority
9	Research Facilitation	Trustee agencies, such as U.S. Fish & Wildlife Service and the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS), could execute multi-year population assessments and monitoring of key Arctic species including the Pacific walrus, ice seals, polar bears, bowhead and beluga whales.	Both	H
9	Research Facilitation	Under its legislative mandate to coordinate scientific data that will provide a better understanding of the ecosystems of the North Slope of Alaska, the North Slope Science Initiative (NSSI) should work with trustee agencies, industry, and other stakeholders to define, develop, and maintain an ecological monitoring program to detect and interpret change in the Arctic ecosystem.	Both	H
9	Research Theme	The U.S. Department of Energy (DOE), other governmental entities, the National Laboratories, and industry should execute additional studies of fate and effects of oil under Arctic conditions and upon Arctic species: toxicity of oil, oil residue, and dispersants to key Arctic species, including Arctic cod and plankton, the rate and extent of biodegradation of oil in Arctic environments, and the interactions of oil with under-ice communities.	Both	H
9	Research Facilitation	The federal government (National Marine Fisheries Service) should work collaboratively with industry and other stakeholders to develop a coordinated strategy for industry and government research on interactions between energy development and key species. • Specifically, the improved understanding of the response of ice dependent species to specific industry activities (ice management, seismic, drilling, etc.) will inform operational planning and permitting as well as designations and management of critical habitats. • NMFS should join the Bureau of Ocean Energy Management (BOEM) in participation as an observer in the Sound and Marine Life Joint Industry Programme.	Both	H
9	Research Theme	The U.S. National Security Strategy for the Arctic Region states that it is vital to "increase understanding of the Arctic through scientific research and traditional knowledge" while at the same time "pursue[ing] innovative arrangements" to ensure "faster progress through a well-coordinated and transparent national and international exploration and research agenda." • An important tool to enhance this understanding as well as to implement integrated Arctic management is the enhanced use of the NSSI. It is recommended that NSSI establish appropriate protocols and gather best practices for the effective collection and integration of traditional knowledge, existing science, community engagement, and resource management. NSSI should engage all key stakeholders to develop appropriate methodologies and improvements in this integrated management model.	Both	H
10	Research Facilitation	An updated Social Impacts Assessment protocol is needed, to improve consistency and ability to integrate baseline data across agencies, industry, and communities and to be consistent with other Arctic nations. • The Department of State, via the Senior Arctic Official and the Arctic Council Sustainable Development Working Group, should update the Social Impacts Assessment protocol, leveraging the state of Alaska's coordinated framework for a Health Impact Assessment, recently developed by the Alaska Department of Natural Resources and Department of Health, in partnership with federal agencies, the Alaska Native Tribal Health Consortium, and local boroughs. • The Council for Environmental Quality should include this updated protocol in the existing Energy Information Administration protocol under the National Environmental Policy Act (NEPA).	Both	H
10	Research Facilitation	The NSSI provides scientific information on both environmental and social science to its 14 federal, state, and local government members and to the public. Enhancement of NSSI capabilities in social science would help provide crucial information for both industry and governments, and provide improved coordination on human environment research activities.	Both	H
9	Research Facilitation	Industry, government, and academia should work to establish data sharing agreements and promote use of platforms such as Alaska Ocean Observing System and the University of Alaska Fairbanks/NSSI catalog.	Both	H

List of Recommendations from Ecological and Human Environment Chapters

Chapter	Category	Enhancement Opportunity	Supports Exploration, Production, or Both	Priority
9	Research Facilitation	Establish an annual forum or mechanism for routine sharing of information among industry, agencies, and researchers. New opportunities exist to work collaboratively, share resources, and plan strategically, to facilitate maximum outcomes from the resources invested. Such a forum should also strive to create and enhance mechanisms for providing financial and logistic resources to support scientific research of mutual interest.	Both	M
9	Research Facilitation	While recognizing the value and extent of existing relevant scientific knowledge, strengthen and support scientific research efforts to improve the quantity and quality of information upon which permit decisions are based. To ensure that research activities are adequately focused on the information needed for science-based permitting and regulatory actions, regulators should clearly identify, prioritize, and communicate specific information needs to all stakeholders.	Both	M
9	Research Facilitation	Develop a multi-stakeholder private-public partnership, or a cooperative approach, to fund and oversee applied environmental research and monitoring relevant to economically and ecologically sustainable oil and gas development in the Alaskan Arctic. A cooperative approach will promote and support strategic research rather than research linked to individual development projects and permits. Broad integration of the accumulating data is essential to provide a strong management basis for the Arctic.	Both	M
9	Research Facilitation	DOE should facilitate a workshop aimed to identify research priority topics focused at the winter/dark periods, so as to facilitate data collection from these periods. This will assist stakeholders and government increase the understanding of ecological processes in this less studied period.	Both	M
9	Research Theme	Industry, government, and academia should work to improve the understanding of the response of ice-dependent species to specific industry activities (ice management, seismic surveys, drilling, etc.) and this will inform operational planning and permitting as well as designations and management of critical habitats.	Both	M
9	Research Facilitation	DOE, BOEM, and NMFS should follow the studies and outcomes of the International Association of Oil and Gas Producers' Sound and Marine Life Joint Industry Programme.	Exploration	M
9 & 10	Research Theme	NSSI should work with its member organizations, industry, and indigenous peoples to provide leadership in the development of protocols to identify and improve methods for the collection of traditional and local knowledge and for incorporating this knowledge with western science, evaluation of potential impacts, and operational planning.	Both	M
10	Research Facilitation	The resource agencies of the federal government should work with the state of Alaska, local stakeholders, and industry to develop a framework to identify changes in cultural sustainability patterns as a product of the interplay of culture, economy, health, and environment. While numerous studies and programs examine these areas individually, more work is needed to examine the synergies and trade-offs among them in order to approach sustainability in a systematic way.	Both	M
10	Research Facilitation	The federal government should establish a programmatic mechanism for long-term monitoring of contaminant levels and disease indicators in subsistence foods within the Arctic. This effort should be informed by and consistent with the Arctic Council's Arctic Monitoring and Assessment Program and should work closely with the subsistence community to obtain samples of harvested tissues.	Both	M
10	Research Facilitation	Resource agencies, including Department of Interior and Department of Commerce, should work with the state of Alaska, local stakeholders, and industry to develop strategies that optimize the processes of consultation and engagement of Arctic communities to be as useful and meaningful as possible while limiting the burden on local communities.	Both	M
9	Research Facilitating Initiative	DOE should champion a collaborative effort through the Interagency Arctic Research Policy Committee with trustee agencies, industry, and other stakeholders to define, develop, and maintain an integrated ecological monitoring program to detect and assess change, including cumulative impacts of development, including transportation and industrial activities, in the Arctic ecosystem, such as a Distributed Biological Observatory.	Both	M

List of Recommendations from Ecological and Human Environment Chapters (continued)

benefit from additional information related to each theme or upon the need for facilitation of research initiatives and an assessment of priority is given.

In the process of developing the research and technology recommendations listed in the table, the investigative teams identified 13 ecological and 5 human environment research themes that are relevant to exploration and development activities in the Arctic. While the high-level recommendations are derived from these 18 themes, or from strategies that would facilitate implementation of research within these themes, the themes collectively represent a range of investigative topics that would facilitate prudent exploration and development of the Arctic in a manner that supported responsible decision-making, protective of the ecological environment and consistent with cultural and economic sustainability. The 13 themes for ecological characterization are:

1. Understanding and documentation of current conditions
2. Marine sound and biological resources
3. Ecological fate and effects of energy-related discharges in the Arctic
4. Interactions between ice-dependent species and oil and gas exploration and development activities
5. Population and habitat changes of biological resources
6. Range and efficacy of mitigation measures
7. Methods for assessing and forecasting cumulative impacts and risks
8. Ecosystem characteristics during winter periods
9. Habitat restoration and rehabilitation
10. Air quality
11. Integrating traditional and local knowledge
12. Emerging technologies for monitoring ecological change
13. Oil spill prevention and response.

The 5 themes for characterization of the human environment include:

1. Sociocultural demographic and wellness patterns
2. Subsistence use patterns
3. Traditional knowledge
4. Protection of food security through evaluation of contaminants in subsistence foods
5. Fate and effect of oil spills.

Chapter 9

The Ecological Environment

INTRODUCTION

This chapter examines the current status of drivers and efforts for achieving a characterization of the Arctic ecological environment and recommends themes of continuing investigation. It provides a history of ecological investigations and assessments that have established the existing bases for decision-making. In addition to a history of Western scientific investigation and research that has been, at times, intensive, and stretches back more than 60 years, there is a rich history of traditional knowledge that informs Western science and current knowledge and understanding on the state and changes in the Arctic. The chapter provides a brief high-level description of Arctic ecosystems for which an understanding is important to support prudent development of oil and gas resources.

As is described in this chapter, much is known about the ecology of the U.S. Arctic based on decades of past and current research, and collaborations by many governments, academic, industry, and indigenous organizations and individuals.

The scope of this assessment is predominantly focused on the U.S. Arctic; however, information and research from the broader pan-Arctic is drawn on where relevant. Published peer reviewed literature and government, academic, and industry reports, assessments, and research studies are drawn on to support the findings on areas that should be considered for future research, assessment, or study. Recommendations are provided on these focus areas, along with identified responsible organizations.

A number of government bodies[1] have conducted assessments of the scientific data necessary to inform decisions in the U.S. Arctic. The findings in these reports indicate that there is a substantial amount of information, including foundational information on geology, ecology, and subsistence, available for Arctic ecosystems and resource management and to pursue resource development while protecting the environment.

Sufficiency of data to allow robust permits and regulatory decisions that are based in rigorous science and capable of withstanding stakeholder scrutiny is a key element of the adequacy of information. For oil and gas exploration and development in the Arctic to be successful, permits and regulatory positions must also allow efficient operations to effectively support prudent exploration and development activities.

CHAPTER OBJECTIVES

Prudent exploration and development in the Arctic requires operating safely within an ecological setting that consists of highly specialized biological organisms that thrive in the presence of extreme physical conditions. Despite historic events such as the hunting and near extirpation of some species of marine mammals, the Arctic ecosystem has not been subject to large-scale alteration or degradation as a result of human activities. It is currently, however, undergoing physical and biological responses related to changes in climate and varying levels of human development. The combined popular perception of Arctic ecological resources as being at once unique, pristine, and at risk raises the bar for responsible operation that is informed by an understanding of Arctic ecosystems and the interaction between these resources and the processes and activities related to energy exploration and development.

Though few conservation policies and regulations are specific to the Arctic, the ecological resources of the Arctic are protected by a broad array of traditional, state, national and international conservation and environmental measures. These measures are generally applied rigorously within the Arctic through a regulatory construct that is well established and has been functioning effectively in relation to oil and gas exploration and development for several decades. Oil and gas operations in both land and sea environments of the U.S. Arctic must acquire numerous federal, state, and local permits and demonstrate compliance with them through monitoring and reporting. Many of these permits are directly applicable to the protection of ecological resources and processes. Even those permits that are not directly related to ecological resources often require consultation with the trustee agencies and review of potential impacts under the National Environmental Policy Act (NEPA). As such, nearly all aspects of permitting of all activities within the U.S. Arctic are predicated upon demonstration of an understanding of the ecological resources present, the potential interactions between activities and resources, and mitigation measures that are effective.

Holland-Bartels and Pierce[2] evaluated data adequacy around several key themes (i.e., marine mammals and anthropogenic noise, cumulative impacts, and oil spill lessons learned) and made a number of recommendations for additional research. Sufficiency of data to allow robust permits and regulatory decisions that are based on rigorous science and capable of withstanding scientific and stakeholder scrutiny is only one measure of the adequacy of information. If oil and gas exploration and development in the Arctic are to be successful, permits and regulatory requirements must also allow efficient operations, to effectively support prudent exploration and development activities. Permits that are overly restrictive may not provide the operational latitude to successfully explore or develop energy resources, but may also not provide protection to ecological resources or their use. Precaution, whether officially mandated in regulation, or representing a standard of practice of regulatory agencies, induces agencies to issue permits that err on the side of reducing the potential for impacts where the extent of such potential is not well understood. The application of precaution is increasingly supported by international agreements and by legal precedent within the United States.[3,4] The standard of applying protection or mitigation measures, unless they can be demonstrated to be unnecessary, potentially creates a significant challenge in terms of the adequacy of information necessary to support permits that are appropriately protective of ecological resources and allow successful exploration and development in the Arctic. Insufficient data can cause permits to be denied, delayed unnecessarily, awarded with unnecessary constraints, or successfully challenged through litigation.

In recent years, numerous efforts have been made, both within scientific and governmental bodies and among multiple stakeholders, to ascertain the current state and trends in ecological science of the Arctic. Recently the National Research Council (NRC) sought to identify the emerging questions in a changing Arctic,[5] which included a significant focus on ecological resources and processes. The Bureau of Ocean Energy Management (BOEM) funds a very extensive annual Arctic Studies Program[6] that is designed to address data gaps and has strong applicability to pending pre- and post-lease decisions and management. These evaluations of science needs have identified key areas where additional studies could benefit decision-making.

Through the processes of review of recommendations derived from more than 100 research review and planning documents (described in the section titled "Review of Key Research and Planning Documents" later in this chapter, followed by analysis of regulatory drivers for ecological data needs), the NRC study has identified a number of recurrent investigative themes through which resource stewardship, effective and efficient regulatory decision-making, and responsible development can continue to be enhanced. As such, the results of these review processes reflect the cumulative and common recommendations of a number of organizations, including the National Academy of Sciences, the National Science Foundation, and the U.S. Arctic Research Commission, that had been established to answer the question of what research is needed on Arctic ecological resources. To the broad range of potential research opportunities that can be undertaken on Arctic ecology, this study applied an additional filter to identify the key areas for supporting prudent development of oil and gas resources in the Arctic. Specific themes have been used to categorize the potential studies and assess priorities. The resulting 13 research themes have also been vetted through a dialogue with key stakeholders and participants in this effort, including representatives of tribal organizations and native corporations of the North Slope through workshops in Washington, D.C. and Fairbanks, Alaska.

Under the heading "Identified Common Themes of Continuing Research Related to Decision-Making," later in this chapter, 13 subsections delve into the different themes that have been identified from the review of existing information. These themes are as follows:

1. Understanding and documenting current conditions
2. Marine sound and biological resources
3. Ecological fate and effects of energy-related discharges in the Arctic
4. Interactions between ice-dependent species and oil and gas exploration and development activities
5. Population and habitat changes of biological resources
6. Range and efficacy of mitigation measures
7. Methods for assessing and forecasting cumulative impacts and risks
8. Ecosystem characteristics during winter periods
9. Habitat restoration and rehabilitation
10. Air quality
11. Integrating traditional and local knowledge
12. Emerging technologies for monitoring ecological change
13. Oil spill prevention and response

All of these identified research themes are currently being addressed to some degree by a variety of investigative programs operated internationally and nationally, and by both the public and private sectors. A number of countries have Arctic research programs and have articulated the priorities of these programs. In most cases, these research programs are not specifically focused on oil and gas exploration and development. Within the United States, a large portion of the research conducted tends to be oriented toward various trustee responsibilities of government agencies, or the mandates for academic inquiries of public and private institutions. This includes Arctic research funded by the National Aeronautics and Space Administration (NASA) and National Science Foundation (NSF). The oil and gas companies also play a significant role in the acquisition and delivery of environmental data and execution of research studies in the Arctic.

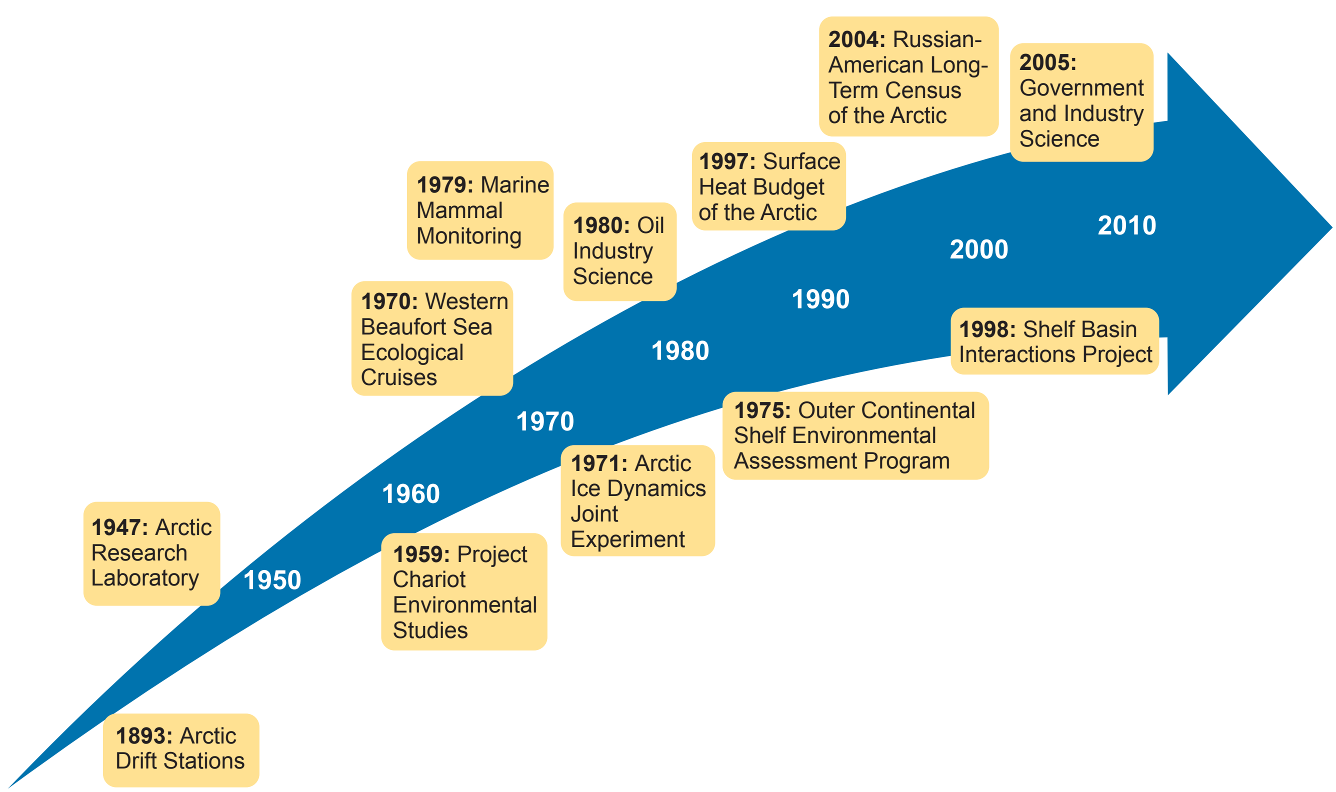
Recommendations for research and environmental technology priorities to advance the characterization of the Arctic ecology are based upon the findings from examination of identified research needs, common investigative themes related to energy exploration and development, and existing research programs.

REVIEW OF EXISTING ECOLOGICAL UNDERSTANDING

Historical Scientific Programs in the U.S. Arctic

Humans have observed, studied, and communicated information about the seasonal patterns of the physical environment and biological inhabitants of the Arctic for thousands of years. Our current ecological understanding of the U.S. Arctic, aided in part by Alaska Native traditional knowledge, has been driven by basic scientific inquiry supported through academia, government institutions, and by various commercial endeavors, particularly oil and gas exploration and development. Early knowledge of the ecology of the region was derived from the scientific curiosity of members of exploration teams looking for new global travel routes and potentially useful or exploitable natural resources. The U.S. and Canadian Arctic were heavily exploited by commercial whaling fleets beginning in 1848.[7] Despite the devastation inflicted on whale populations, whale distribution and habitat records kept by whalers provided a great deal of ecological information about whales.[8,9,10] Schrader and Peters crossed the North Slope coastal plain in 1901 under the auspices of the U.S. Geological Survey (USGS) collecting geological and botanical information and were the first to apply the term "Arctic Coastal Plain" to the region.[11] Leffingwell, also under the aegis of the USGS, studied the geology and mapped the coast of the area in the lower Canning River/Flaxman Island region and westward to Prudhoe Bay in 1901, from 1909-1912 and 1913-1914.[12] Elsewhere in the Arctic, Norwegian drift stations measured Arctic temperatures starting in 1893 and the Soviets established Arctic stations in 1923. Recognition of the strategic value of the U.S. Arctic in terms of both its location and its resources led to intensive interest by the military. Various scientific studies associated with these efforts and the increased accessibility of the area following establishment of the Naval Arctic Research Laboratory in 1947 began a period of extensive study of the U.S. Arctic's physical and biological systems.

In the past 100 years, scientists have utilized ever-advancing technology to expand knowledge of the Arctic resulting in a robust understanding of the physical environment, biological resources, various ecosystem processes, as well as the human inhabitants of the Arctic. Historical data are just as important today as they were when first collected because investigations continuously expand on the scientific foundations built by others. Historical data also provide a basis for comparison and allow for detecting environmental change and impacts. The sequence of scientific programs summarized in this section is illustrated on the timeline in Figure 9-1. The sequence begins with the earliest Arctic drift stations and ends with recent investigative activities by the U.S. government and the oil and gas industry. These programs serve as an important scientific foundation for current and future environmental studies and impact assessments. Frozen-in ships or camps on pack ice and ice islands were the first reliable means of conducting ongoing Arctic investigations. Over the course of 100 years, these Arctic drift stations provided substantial physical and biogeographic information.[13] Some of the earliest temperature measurements in the Arctic, for example, were acquired in 1893 with shipboard measurements taken by Fridtjof Nansen and his crew onboard the purpose-built *Fram,* which drifted within the transpolar current from 1893 to 1896.[14] The earliest known attempt to scientifically study the oceanography of the Beaufort Sea Shelf was conducted by the Canadian Arctic Expedition (1913-1918) from the *Karluk* and other vessels. The *Karluk,* not suited for the Arctic, was destroyed when trapped by sea ice; the expedition ended with the loss of the vessel, data, and several scientists. Efforts to understand the Arctic, however, did not end. By the 1930s and 1940s, Russian, American, and Canadian expeditions to the Beaufort and Chukchi Seas had already



Source: Shell.

Figure 9-1. *Generalized Timeline of Research for the U.S. Arctic* determined the major characteristics of temperature, salinity, chemical nutrient distributions, and that Bering Sea water flowed northward through the Bering Strait into the Arctic Ocean.

In 1947, the U.S. Navy formally established the Arctic Research Laboratory, later renamed the Naval Arctic Research Laboratory (NARL), in Barrow, Alaska. For more than 60 years, the laboratory has been an important center for Arctic science and technology development in the United States. By the early 1950s, NARL research projects focused on a broad spectrum of Arctic science issues, including cold region physiology, sea ice dynamics, oceanography, and marine biology. The early marine biological work went far beyond collecting and identifying organisms: it included biogeographical, reproductive, and ecological analyses including planktonic sampling, tundra ecology, cold region physiology, geology and geophysics, sea ice dynamics, oceanography, marine biology, and mammalogy. Similarly, Russian studies for the Chukchi Sea can be traced to the 1930s.

The United States began experimental ice floe drift stations in 1950 followed by establishment of the T3 station in 1952 on Fletcher's Ice Island. While generally focused on military interests, studies spanned a wide range of disciplines including hydrography (mapping the physical features of oceans, seas, coastal areas, lakes, and rivers), bathymetry (study of the underwater depth of the ocean floor), marine biology, sea ice studies, and meteorology.

In 1958, the U.S. Atomic Energy Commission's Project Chariot began to explore excavation of a harbor south of Point Hope along the Chukchi Sea coast. This project implemented 40 separate investigations of baseline conditions in the area[15] including oceanography,[16] zooplankton,[17] benthic organisms (such as sea stars, oysters, clams, sea cucumbers, brittle stars, and sea anemones),[18] and fish.[19] These studies represent a fundamental contribution to the current understanding of the Arctic marine and terrestrial ecosystems and pioneered the concept of project-specific environmental studies and impact assessment still used today. The biological oceanography sampling was focused on marine biota from the seafloor as well as within the water column.[20,21] The methods employed during this time are still comparable to the methods used today and allow evaluations of different descriptive data sets over time.

The Western Beaufort Sea Ecological Cruises occurred between 1970 and 1972 in the Chukchi and Beaufort Seas. This program was the origin for the long-term practice of conducting Arctic oceanography from U.S. Coast Guard (USCG) icebreakers that continues to this day.[22] Numerous surveys of marine biota were conducted; phytoplankton, zooplankton, benthic invertebrate, and marine fish species were collected at numerous stations.[23] Much of the data from the Ecological Cruises, such as trace metal sediment chemistry, has been assimilated into various data repositories.

Sea ice science and the coordinated investigation of oceanographic and meteorological parameters were first conducted in the early 1970s as part of the Arctic Ice Dynamics Joint Experiment (AIDJEX). This program resulted in an improved knowledge and understanding of sea ice in the Arctic and how ice floes move and change in response to the influence of ocean currents and atmospheric winds.[24] More details on these and other ice studies have been covered in Chapter 5 of this report.

The largest and most comprehensive environmental studies program of the offshore Arctic began in 1975 with the Outer Continental Shelf Assessment Program and continued until 1988. These studies and syntheses are recognized as a key source for Arctic baseline information today. The accumulated knowledge contained within Assessment reports and archived datasets provides a crucial basis for predicting and mitigating potential impacts of offshore development in the U.S. Arctic Outer Continental Shelf (OCS). Many of the projects started during this program continued to advance through the 1980s, 1990s, and 2000s as part of the U.S. Minerals Management Service and BOEM Environmental Studies Programs.

Studies on marine and coastal birds, marine mammals, and the effects of offshore oil and gas industry sound on marine mammals have been undertaken in northern Alaskan waters since the mid-1970s. The surveys have resulted in a unique long-term dataset on marine mammal distribution, relative abundance and density, migration patterns, and general behavior. From the 1970s through the early 1990s, a substantial amount of offshore science, including marine mammal monitoring, was also conducted by the oil and gas industry. The areas of focus for industry were quite broad and reflected a desire to actively use and apply environmental information in operations and engineering design.

The U.S. government, through several federal agencies and the NSF, has collected extensive data on the U.S. Arctic OCS. Currently, much of this research has been tracked and coordinated by NOAA (National Oceanic and Atmospheric Administration) and NSF through the development of an Arctic Observing Network. Federal agencies that have conducted important science programs in the Arctic marine ecosystem include National Marine Fisheries Service, NASA, USCG, BOEM, USGS, U.S. Fish and Wildlife Service (USFWS), and the Department of Defense.

The environmental baseline studies and scientific research programs described in this chapter have been incorporated into numerous impact assessments conducted to assess the potential negative impacts as well as positive benefits of oil and gas exploration activities in the offshore Arctic environment and to identify mitigation options and strategies.

Description of the Ecological Setting of the Alaskan Arctic, with Emphasis on the Offshore

The discovery of commercially recoverable oil on Alaska's North Slope at Prudhoe Bay was announced in 1968, which catalyzed the exploration and development of oil and gas resources, both onshore and offshore, for commercial and strategic purposes. This exploration spurred additional study by U.S. government agencies as well as the North American oil and gas industry throughout the 1970s and 1980s. The Naval Arctic Research Laboratory served as a base for numerous studies of the Arctic tundra[25] as well as large-scale multidisciplinary programs. Notable among these were the Tundra Biome project conducted as part of the International Biological Program[26,27,28,29] on the coastal tundra and the Research of Arctic Tundra program conducted inland from Barrow at Atqasuk.[30] These studies characterized the basic patterns of structure and function of Alaskan tundra and aquatic communities and studies of controls on fundamental ecosystem processes such as photosynthesis and decomposition were initiated.

In anticipation of potential broader oil and gas development in the Alaskan Arctic, the USGS conducted environmental studies on the National Petroleum Reserve in Alaska (NPR-A) between 1976 and 1979.[31] The U.S. Department of Energy conducted the Response, Resistance, Resilience, and Recovery of Arctic Ecosystems project near Toolik Lake in the Brooks Range, and from 1980 to 1985 the USFWS conducted baseline studies of fish and wildlife populations in the 1002 Area of the Arctic National Wildlife Refuge (ANWR).

In the Alaskan offshore areas, the Western Beaufort Sea Ecological Cruises (1970-1972) surveyed existing marine conditions and biota,[32] and AIDJEX studied the oceanography, meteorology, and sea ice dynamics of the Beaufort Sea. The Outer Continental Shelf Environmental Assessment Program (OCSEAP) began in 1975 and covered a wide range of topics, including chemistry, geology, sea ice dynamics, oceanography, meteorology, Arctic biology, marine mammals, birds, marine fish, benthic communities, intertidal environment, plankton, microbiology, seabirds, and socioeconomics. Some of these programs have continued through the years, providing long-term data sets that span decades. The Bowhead Whale Aerial Survey Program began during OCSEAP and continues today as the Aerial Survey of Arctic Marine Mammals. This long-term dataset provides important information on the distribution, movements, behavior, and relative abundance of the bowhead whale and other marine mammal species that inhabit the Beaufort and Chukchi Seas.[33,34,35,36,37,38,39,40,41,42,43,44,45,46]

In addition to government sponsored programs, the oil and gas industry, either as independent companies or as industry associations such as the Arctic Petroleum Operators Association and the Alaska Oil and Gas Association, facilitated or directly sponsored large research and monitoring programs in Arctic Alaska. The greatest intensity of work took place in the oil fields near Prudhoe Bay throughout the 1980s to the 2000s. These studies overlapped temporally and spatially with development in the oil fields, characterizing existing conditions and measuring responses of the biota to development activities.[47]

Oil production began in 2001 in the Beaufort Sea with the Northstar field, the first offshore oil and gas production facility in the Alaskan Arctic. Numerous industry-sponsored studies were conducted during exploration and development of Northstar,[48,49,50,51] and it prompted additional work by agencies, including bowhead feeding in the eastern Alaskan Beaufort Sea, conducted from 1997 through 2000;[52] the Arctic Nearshore Impact Monitoring in the Development Area (ANIMIDA) from 2001 to 2005; and the continuation of that program as cANIMIDA from 2005 to 2009 in the Beaufort Sea. Since 2005, the Study of the Northern Alaska Coastal System (SNACS), the Bowhead Whale Feeding Ecology Study (BOWFEST), and the National Oceanographic Partnership Program (NOPP) have studied the interaction of oceanography, bowhead whales, and their prey at the boundary between the Chukchi and Beaufort Seas.[53,54,55] In the Chukchi Sea, the Western Arctic Shelf-Basin Interactions (SBI) study was conducted from 2002 through 2004,[56] and the Russian-American Long-Term Census of the Arctic (RUSALCA) began in 2004.[57] The Chukchi Sea Offshore Monitoring in Drilling Area (COMIDA) program has conducted broad-scale marine mammal surveys since 2008,[58] building on earlier work in the area as part of the Bowhead Whale Aerial Survey Program (described above), and the COMIDA-CAB program[59] focused on chemistry and benthos (CAB). In 2010, the Chukchi Acoustic, Oceanographic, and Zooplankton (CHAOZ) study conducted by NOAA and funded by BOEM began studying factors responsible for the distribution of marine mammals in the Chukchi Sea that were listed as "endangered" under the U.S. Endangered Species Act.

Since 2006, renewed interest in the offshore areas of both the Beaufort and Chukchi Seas has driven large-scale monitoring and research programs conducted by the oil and gas industry. These have included marine mammal monitoring and mitigation studies during industry operations[60] as well as the Chukchi Sea Environmental Studies Program (CSESP), which investigates a wide range of physical and biological components of the offshore system. This in turn has led to increased efforts by local, state, and federal government agencies, which were already funding a number of baseline research efforts. Notable among these are bowhead whale tagging studies conducted by the Alaska Department of Fish and Game (ADF&G);[61] walrus tagging studies conducted by the USGS;[62] ringed and bearded seal tagging studies conducted by NOAA, the North Slope Borough, and the Northwest Arctic Borough; the Pacific Marine Arctic Regional Synthesis;[63] and numerous other smaller-scale studies. Collectively, these studies have begun to provide a comprehensive and detailed understanding of various physical and biological ecosystem-level processes and components of the U.S. Arctic.

The sections below provide a brief description of the ecological setting in the Alaskan Arctic developed through decades of research studies by government agencies, academic institutions, and the oil and gas industry. While the sections highlight various studies, reviews, and synthesis efforts that have been conducted, it is not intended to be exhaustive and serves only as a starting place for exploring the extensive literature, databases, and wealth of knowledge associated with each of the topics addressed.

Marine Ecosystems

The Chukchi and Beaufort Seas are the northernmost seas bordering Alaska and are integral parts of the greater Arctic Ocean. They are connected ecologically and oceanographically to global water circulation patterns via the Bering Strait to the Pacific Ocean and via the Arctic Ocean. Each of these seas is of considerable strategic and economic value to the United States, largely due to extensive oil and gas reserves and potentially undiscovered deposits. As a result, they are at the center of a large scientific research focus.

Chukchi Sea Oceanography

Seasonal changes in Chukchi Sea water properties are established by the annual cycles of sea ice formation and ablation (i.e., melting, evaporation, sublimation, erosion of ice), heat loss and wind-driven mixing of the water column (exchange of water among varying depths, mixing across thermoclines or salinity gradients, etc.), and transport of waters through the Bering Strait from the North Pacific Ocean. Transport of water through the Bering Strait in summer and early fall is primarily northward, driven by the pressure gradient between the North Pacific Ocean and the North Atlantic Ocean, and consists of three major water masses:[64,65] the cold, salty, nutrient-rich Anadyr Water; the warm, fresh, nutrient-poor Alaskan Coastal Water; and the Bering Shelf Water.[66]

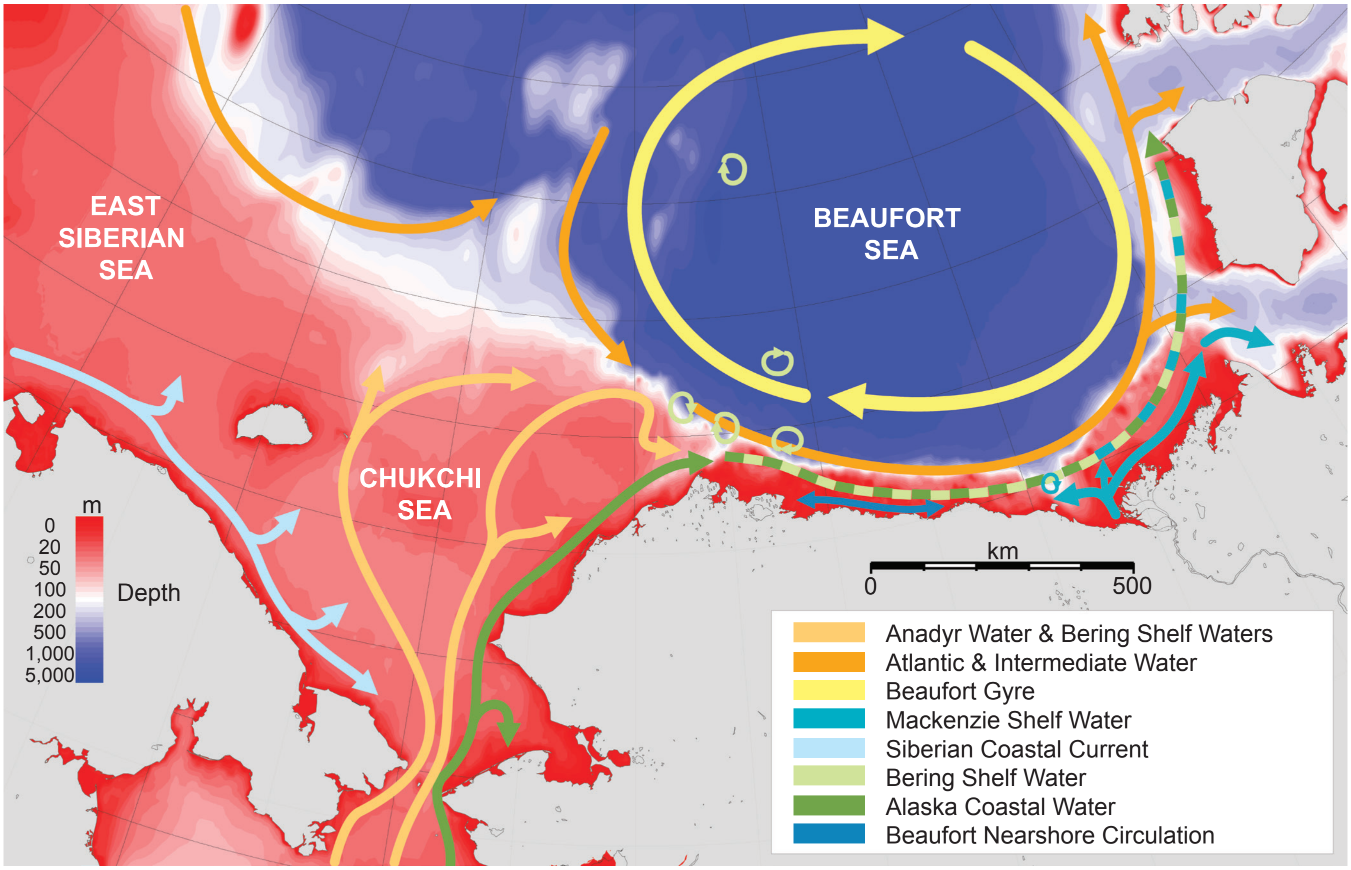
As the North Pacific waters enter the Chukchi Sea, their direction and speed are affected by topographic features of the shallow, broad continental shelf (Figure 9-2).[67,68,69,70,71,72] The temperature, salinity, and nutrient composition of these waters are modified by heat exchange with the atmosphere and, in some

Source: Shell Alaska.

Figure 9-2. *The Chukchi Sea Outer Continental Shelf and Primary Oceanographic Features*

places, by interaction with other water masses (Figure 9-3), such as those that form seasonally from sea ice melt water; the Siberian Coastal Current;[73] upwelling continental slope waters,[74] which intrude onto the shelf; or recurring polynyas, the open water areas surrounded by pack ice.[75]

These interactions funnel warm Pacific Ocean water into the valleys and channels, creating north-south oriented melt-back embayments[76] (open bodies of water surrounded on three sides by ice) and variation in nutrient and carbon loads among seafloor habitats in valleys, canyons, and around shoals.[77,78,79,80,81] Despite the large-scale factors that drive these typical circulation patterns, strong Arctic windstorms can reverse the flow over broad portions of the shelf, including the Bering Strait, and create significant variation in circulation strength and direction.[82,83]



Source: Tom Weingartner and Seth Danielson, University of Alaska Fairbanks.

Figure 9-3. *Summary of the Circulation and Water Masses in the Chukchi and Beaufort Seas*

In summary, the inflow of North Pacific water through the Bering Strait, coupled with topographic features of the Chukchi continental shelf, greatly influence the seasonal distribution of sea ice, regional hydrology (movement and quality of the water), circulation features, and biogeochemical oceanography of the Alaskan Chukchi Sea. Water flowing through the Bering Strait is a major source of heat and salt transport into the Chukchi Sea and the Arctic as a whole. Water transport through the Bering Strait serves as a conveyor belt for the dissolved and suspended carbon, nitrogen, and other nutrients that fuel the rich benthic communities of the Chukchi Sea.

Beaufort Sea Oceanography

The oceanographic characteristics of the Alaskan Beaufort Sea differ substantially from those of the Chukchi Sea because of its smaller, narrower continental shelf; the comparatively smaller and less direct impact of Pacific water inflow through the Bering Strait; more extensive sea ice distribution; and the influence of oceanic and coastal boundaries.

The oceanic boundaries of the Alaskan Beaufort Sea consist of the eastern boundary that adjoins the Mackenzie River Delta; the western boundary, which connects to the Chukchi continental shelf; and the offshore boundary along the shelf break and slope, which controls water exchanges between the deep-ocean basin and the shelf proper. The coastal boundary connects the inner shelf to the coastal discharge from rivers across the North Slope of Alaska. Exchanges across these boundaries are modulated by winds, topography, and the annual freeze-thaw cycle.

The Beaufort Sea continental shelf can be covered by sea ice throughout the year, but it is typically ice-free inshore of the 20 meter depth contour during the summer months. In recent years, however, the entire shelf has been ice free at some point during summer. Landfast ice (anchored to the shoreline and seafloor) begins to form along the coast in October[84] and typically covers about 25% of the shelf area.[85,86,87] The seaward edge of this immobile ice deforms into pressure ridges and grounded ice keels that gouge the seafloor and form masses of grounded ice called *stamuki* (refer to Chapter 5). *Stamuki* protect the inner shelf and landfast ice from pack ice forces[88,89,90] and inhibit exchange between nearshore and offshore waters[91] during much of the year.

Circulation in the Beaufort Sea is controlled largely by the winds that force upwelling, downwelling, and cross-shelf transport, depending on the direction, strength, and duration of the winds. These forces create a complex distribution of water masses that reflects the effects of ice melt, solar heating, remnant winter water, and the various hydrographic contributions from the Chukchi Sea, Mackenzie Shelf, coastal freshwater discharge and exchanges across the shelf break.[92,93,94,95,96,97,98,99,100,101]

As with the Chukchi Sea, the water-mass properties of the Alaskan Beaufort Sea undergo a pronounced annual cycle. By mid-fall, ocean temperatures begin to decrease rapidly because of the cold air temperature. Ice begins to form initially in inshore areas, and somewhat later offshore. Throughout winter, the shelf consists of nearly homogenous saline waters at the freezing point. Water temperatures remain at the freezing point until breakup begins the following summer, and do not rise much above freezing over the middle and outer shelf, even during the summer as nearshore waters warm. This pattern has shown variability in recent years, as open water has occurred nearshore as late as November and December. In late fall, shelf salinities increase rapidly, and then more gradually through the winter, because of the expulsion of salt from growing sea ice.

Planktonic Communities

Understanding of planktonic communities in the Chukchi and Beaufort Seas has improved considerably over the past decade.[102,103,104] Regional community composition is considered well documented,[105] although reduced summertime ice cover may influence composition. Copepods (tiny crustaceans) dominate in abundance, biomass, and species diversity. Larvaceans (solitary free-swimming plankton) and meroplankton (organisms that are planktonic for only part of their life cycle, such as the larvae of sea stars, sea urchins, or most fish, for example) are also important contributors to community abundance and biomass in the Chukchi Sea.[106,107]

The zooplankton community of the southern Chukchi Sea is predominantly Pacific in character during ice-free periods of the year.[108] As North Pacific water flows into the Chukchi Sea through the Bering Strait, large quantities of nutrients, phytoplankton, and zooplankton enter the region. Species assemblages vary with the water masses with which they are associated.[109,110,111] Springer et al. suggested that Bering Sea zooplankton and entrained (swept along in water currents) phytoplankton communities carried into the Chukchi Sea annually by these water masses are responsible for the greater pelagic productivity of the Chukchi Sea when compared to other adjoining regions of the Arctic Ocean.[112] This pelagic, or open-ocean, productivity is consumed by higher trophic levels (i.e., creatures higher on the food chain) such as planktivorous fishes, seabirds, or whales, and is exported to the seafloor where it supports rich benthic communities, or is advected northward into the deep Arctic basins.[113,114]

Plankton in the Beaufort Sea is widely distributed with the greatest production [biomass] in the coastal zone due largely to the relatively high nutrient inputs and warmer water along the coast.[115] Nutrients from the Bering Sea enter the western Beaufort Sea from the Chukchi Sea through Barrow Canyon. Upwelling in this area creates aggregations of zooplankton[116] that are fed upon each year by migrating bowhead whales in September and October. Similarly, topographically driven upwelling in the Mackenzie Canyon in the eastern Beaufort Sea, may be an important source of nutrients and zooplankton.[117,118,119] In addition, the prevailing easterly winds support year-round upwelling over the Beaufort shelf break,[120] which transports nutrient-rich deepwater onto the outer shelf. Farther east, in the Eastern Beaufort Sea, large inputs of nutrients and carbon associated with freshwater inflow of the Mackenzie River discharge and wind-driven currents transport nutrients westward along the coast, driving the biological character of the Mackenzie Shelf.[121] This flow supports zooplankton communities along the coast, including areas near Barter Island, which also are used annually by bowhead whales. Richardson[122] and Richardson and Thomson[123] reported extensive patches of zooplankton composed mostly of copepods, with the greater abundance of these organisms in nearshore and inner shelf waters when compared to offshore waters.

Epontic, or ice-associated, or living on the underside of ice, invertebrate and algal communities are also widely distributed across the Arctic, particularly along the sea ice edge, and can be relatively concentrated and productive.[124] Various fishes feed on these epontic species, although the magnitude of their annual contribution to the food web is not entirely understood.[125]

Benthic Communities

Large-scale regional studies in the Chukchi Sea since the mid-2000s built on earlier Outer Continental Shelf Assessment Program studies and have documented benthic community types and species composition on a regional scale,[126,127,128] and on more local scales in areas of oil and gas interest.[129,130] These studies, along with other efforts to integrate knowledge of the area,[131] have increased understanding of the process-level controls of benthic community diversity, dynamics, and the role of these communities in the structure of the Chukchi Sea ecosystem.

Variation in benthic communities in the Alaskan Arctic seas are driven by physical processes that determine sea-ice dynamics and disturbance regimes, current speeds and locations of oceanographic fronts, water mass primary and secondary production, and delivery of food to the benthos.[132,133,134,135,136,137,138,139,140] Grebemeier et al. suggest that pelagic-benthic coupling, in particular, is a defining process for understanding the spatial variability seen in the benthic communities in the Chukchi Sea as unconsumed seasonal primary production sinks to the benthos.[141]

Studies of carbon cycling demonstrate linkages between primary production in the water column and the distributions of invertebrate fauna in the Chukchi Sea. Pelagic grazers (sea creatures of the open ocean) are reduced in the Chukchi Sea due to an absence of deepwater, overwintering habitat for zooplankton, consequently the reduced grazing results in a large influx of phytoplankton detritus to the benthos.[142,143] Abundant and diverse benthic infaunal[144] (creatures that burrow into the sea bottom) and epifaunal (those that attach to the sea bottom) communities (Figure 9-4)[145,146] are supported by this abundance of unconsumed production and include large, energy-rich prey for marine mammals.

Sea ice dominates the benthic and coastal habitats in the Beaufort Sea. Due to the prevalent ice cover and narrow continental shelf area, the benthos and coastline are highly disturbed or modified and support

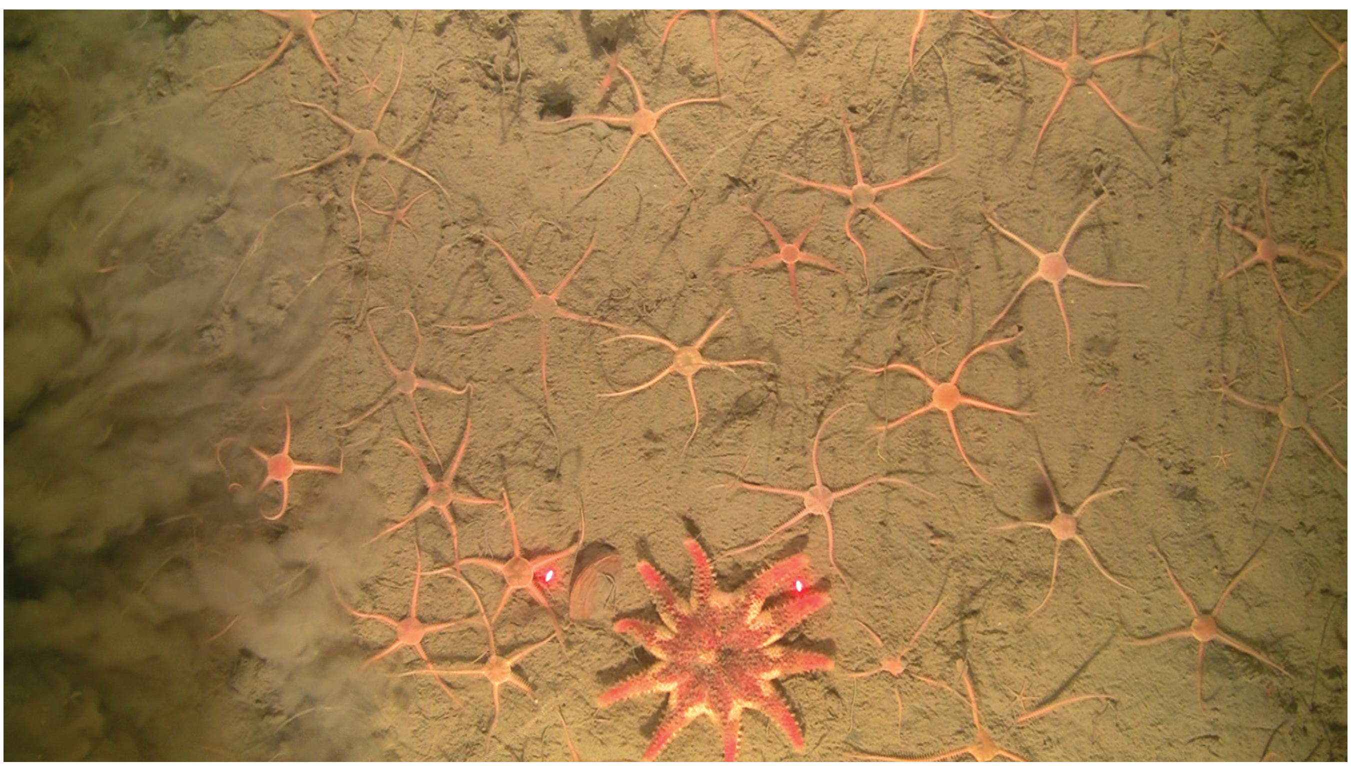


Photo: Chukchi Sea Environmental Studies Program – Olgoonik/Fairweather.

Figure 9-4. *High Abundance of Benthic Organisms on the Floor of the Chukchi Sea* few large organisms. Typical organisms include isopods (jointed crustaceans), amphipods (tiny shrimp-like creatures such as scud), and small clams, often widely distributed.[147,148,149] Substrates consist primarily of silty sands, which are gouged frequently by ice keels. In general, benthic production is low but tends to be lower in the eastern, deepwater portions of the Beaufort Sea and somewhat higher in the western portion where nutrient-rich waters from the Chukchi Sea have greater influence.

Dense kelp beds grow in a few areas of the Beaufort Sea composed of hard substrate that are protected from ice gouging. The Boulder Patch is the largest of these kelp beds and is located inside the barrier islands in Stefansson Sound.[150] This biologically complex, species-rich area contains about 300 infaunal and epibenthic (living on the surface of seafloor sediments) species.[151] The total biomass of the area is an order of magnitude greater than for most areas of the Beaufort Sea continental shelf. The kelp plants are long lived and the community spreads slowly, restricted by long periods with no light during winter, low light levels under the ice cover in spring particularly when sediment is present in the ice, and light attenuation in the water column during summer due to depth and sediment load.[152,153] Other smaller areas of kelp have been reported including some small patches in the Camden Bay area though no other large areas are known within the Alaskan Beaufort Sea.

Fish

No large-scale commercial fisheries operate north of the Bering Strait, which limits knowledge of some marine fish species and communities in the Chukchi and Beaufort Seas. Early work was reviewed and updated by Reynolds in Fish Ecology in Arctic North America.[154] Gallaway and Fechhelm reviewed anadromous (spawn in freshwater, live in saltwater, e.g., salmon, smelt, shad, striped bass, and sturgeon) and amphidromous (born in freshwater or estuaries, drift into the ocean as juveniles, then return to freshwater to live; e.g., Dolly Varden, some mullets, and some goby) fishes of the Beaufort Sea,[155] and Moulton and George provided a review of freshwater fishes in the Arctic oil and gas field region.[156] Recent studies have characterized current fish species and communities in the Chukchi Sea and the Arctic in general.[157,158,159,160] Close connections have been suggested between the distribution of fish species and the oceanographic characteristics of the water masses.[161,162,163]

Scientific collection of fish indicates that Arctic cod are the most abundant demersal species (bottom-dwelling, such as rays, flounder, sole, and others).[164] Cods (Gadidae), sculpins (Cottidae), eelpouts (Zoarcideae), and righteye flounders (Pleuronectidae) are the typical fish families. The relatively low species richness reported for the Chukchi Sea demersal fish communities is consistent with the latitudinal diversity gradient phenomenon described by Hildebrand.[165] Arctic cod is an important prey species for many bird, marine mammal, and other fish species.[166]

In the Beaufort Sea, marine fishes prefer the colder, more saline coastal water seaward of the nearshore brackish-water zone formed by inflow from rivers along the coast. As summer progresses, river input decreases and these waters become more saline. During this time marine and migratory fishes share these nearshore waters to feed on epibenthic fauna and to spawn. Arctic cod are generally concentrated along the interface between the nearshore water and the colder marine waters. Marine fishes in the area primarily feed on invertebrates, relying heavily on planktonic crustacean such as amphipods, mysids (tiny shrimp-like crustaceans, commonly called opossum shrimp), isopods, and copepods. Some fish species, such as flounders, feed on bivalve mollusks while sculpins feed on juvenile Arctic cod.[167] As nearshore ice thickens in winter, marine fishes move seaward of the bottom-fast ice and continue to feed.

Common marine fishes in the nearshore areas include fourhorn sculpin and capelin.[168,169,170] Saffron cod, Arctic flounder, and snailfish also occur sporadically in low numbers in the nearshore areas. Common marine fishes further offshore include Arctic cod and kelp snailfish.[171,172,173]

Migratory, diadromous fishes inhabit many of the lakes, rivers, streams, interconnecting channels, and coastal waters of the Beaufort Sea. These fishes spawn and overwinter in rivers and streams, but migrate to coastal waters to feed each summer, annually cycling between freshwater and marine environments.[174] Fish feed intensively on invertebrates in the nearshore waters during summer, accumulating fat and protein reserves needed to survive the long winters.[175,176,177,178,179] The distribution of diadromous (migrating between saltwater and freshwater) fishes in the Beaufort Sea is dominated by population centers in the Mackenzie River system in Canada and the Colville River and Arctic Coastal Plain systems of Alaska. The four most common species in the nearshore Beaufort Sea include Arctic cisco, least cisco, broad whitefish, and Dolly Varden (Figure 9-5), but also include Bering cisco, rainbow smelt, humpback whitefish, and inconnu.[180,181] These fishes are an important subsistence food source for Alaska Natives in coastal villages.

Freshwater fishes inhabit many of the rivers, streams, and lakes on the Arctic Coastal Plain. Species include lake trout, Arctic grayling, Alaska blackfish, northern pike, longnose sucker, round whitefish, burbot, ninespine stickleback, slimy sculpin, and Arctic lamprey.[182] Small streams provide corridors for moving between sites used for spawning, nurseries, feeding, and overwintering.[183] Juvenile fishes prefer warmer, shallow-water habitats available during periods without ice.[184] Waters with emergent and submerged vegetation are often used for spawning and rearing, particularly if overwintering sites are nearby.[185] Larger, deeper lakes with outlets and suitable spawning areas are more likely to support fish. Lakes less than 2 meters deep usually do not support resident fish, although they may be used during summer for feeding, rearing, or access corridors to other waters.[186] Freshwater fishes feed on terrestrial and aquatic insects and their larvae, zooplankton, clams, snails, fish eggs, and small fishes.[187,188] Freshwater fishes spawn from early spring to early fall in suitable gravel or rubble, with the exception of burbot, which spawn under ice in late winter.[189] At the onset of winter, Arctic freshwater fishes move to deeper areas of lakes, rivers, and streams to survive the winter ice and low oxygen conditions.

Birds

Several million birds of more than 70 species use the marine and coastal environments of the Beaufort and Chukchi Seas annually.[190] Nearly all of these species are migratory and are present for all or part of the period from May to early November (Figure 9-6). One notable exception is the black guillemot, which nests on Cooper Island ~40 kilometers east of Barrow in the Beaufort Sea and overwinters in open water leads within the pack ice of the Chukchi and Beaufort Seas. The nesting colony on Cooper Island was first described by Divoky et al.[191] and has been monitored intensively each year for the past 40 years. It is viewed as a benchmark standard for long-term monitoring studies.

Photo: ExxonMobil Production Alaska Inc.

Figure 9-5. *Dolly Varden Captured by Net for Population Study on North Slope*

Photo: ExxonMobil Production Alaska Inc.

Figure 9-6. *Canada Geese During Summer on Edge of Wetlands*

Habitat use and abundance of birds in terrestrial areas of the North Slope are well documented.[192,193] Aerial surveys in the Beaufort Sea have documented widespread use of the nearshore and offshore waters along most of the coastline and into the northern Chukchi Sea during the open water period (Figure 9-7). Birds occur out to at least 70 kilometers offshore where open water is available.[194,195,196]

At least 34 different seabird nesting colonies have been identified along the Alaskan Chukchi Sea coast between Point Hope and Barrow,[197] and the USFWS has conducted long-term monitoring studies of nesting birds on the Alaska Coastal Plain since 1986.[198,199]

Photo: Chukchi Sea Environmental Studies Program – Olgoonik/Fairweather.

Figure 9-7. *Common and Thick-Billed Murres*

Islands in river deltas and barrier islands provide nesting habitat for waterfowl and marine birds in the Beaufort Sea region. Numerous studies have documented nesting areas throughout much of the Arctic coastal plain. Brood rearing, molting, and staging in the post-nesting periods occur in large lakes, lagoons, and bays. Post-breeding adults concentrate in shoreline areas prior to migration in late July and early August. Parents with fledged young follow this pattern several weeks later, and eventually juveniles form large flocks in mid- to late-August.[200] Most birds have departed offshore areas by mid-September as they migrate south to wintering areas.

Marine bird habitat use and the processes that drive offshore distributions are less well characterized, and considerable interannual variation has been documented in the Chukchi Sea.[201] Birds using the waters of the Chukchi and Beaufort Seas during the open water season include waterfowl, loons, phalaropes, gulls and terns, procellarids (such as petrels), and alcids (e.g., auks, murres, and puffins), although species diversity is greater in the Chukchi Sea. These waters provide important staging and feeding areas, and processes that influence seasonal prey distribution also influence the distribution and abundance of birds across the area.[202]

During spring migration, species such as long-tailed duck, king eider, common eider, and brant migrate along a broad front that includes inland, coastal, and offshore routes from early May to mid-June[203,204,205] using open water areas off river deltas and in leads that largely determine the migration path and distribution of loons, waterfowl, and seabirds at this time of year. These areas are occupied until local nesting areas are free of snow in June.[206,207,208,209,210]

Like the other groups of organisms described above, marine birds also display habitat preferences often determined by water mass characteristics and water column structure that enhance preferred prey abundance and accessibility.[211,212,213] The influx of nutrients and oceanic plankton via the northward movement of water through the Bering Strait support fish and planktonic communities in the waters of the Chukchi Sea important to marine birds. Bird species may specialize in prey, such as planktivorous or piscivorous seabirds, and those that have more flexible diets. Variation in water masses as described earlier creates variation in the abundance and types of prey that are available, and appears to account for at least some of the large seasonal variations in the numbers of birds utilizing the area, particularly planktivorous birds.[214]

Marine Mammals

Marine mammal populations of the Alaskan Arctic are some of the most intensely studied populations in the world, primarily because of interest in oil and gas resources coupled with the importance of these species to Alaska Native cultures and subsistence activities. As a result, a great deal is known about the life history, distribution, and behavior of marine mammals in the Alaskan Chukchi and Beaufort Seas.

Pacific walruses, bearded seals, bowhead whales, beluga whales, and gray whales all use the Arctic waters offshore of Alaska and undergo long-distance migrations that traverse large areas of the Chukchi or Beaufort Seas or both. Only small numbers of Pacific walruses and gray whales enter the Beaufort Sea; however, beluga and bowhead whales make their way into the Beaufort Sea where they spend the summer feeding. These waters are also used extensively by ringed and spotted seals, polar bears, and by smaller numbers of other marine mammal species.

Pacific walruses, bearded seals, and gray whales are bottom feeders that rely on the productivity of the benthic communities in the Chukchi Sea. The distributions of these species overlap closely with areas that support high biomass of preferred benthic prey species.[215,216,217] In the Chukchi Sea, gray whales preferentially feed on amphipods, which dominated benthic habitats in areas where gray whales were routinely sighted.[218] Areas where amphipods were not found had few gray whale sightings despite similar effort surveying for whales.[219] Similarly, benthic communities sampled in areas where walruses are typically abundant,[220] such as those around Hanna Shoal, were found to have high bivalve and polychaete (bristleworms) abundance, which are preferred prey of walruses.[221]

Although walrus distribution in the Chukchi Sea is closely tied to prey distribution and availability, walruses are also influenced greatly by the distribution or absence of sea ice (Figure 9-8). Female and immature walruses overwinter in the Bering Sea and move northward with the sea-ice front as it recedes into the Chukchi Sea where the walruses spend the summer. Walruses typically haul out on sea ice above the Chukchi Sea continental shelf between feeding bouts. In most years since 2007, sea ice has receded off the continental shelf into deeper waters and caused walruses to abandon the remaining ice and haul out onshore.[222,223,224] Haul out locations in 2007 occurred in multiple locations along the Chukchi Sea coast but in more recent years walruses have aggregated in a single large haul out near the village of Point Lay.[225] Tagging studies suggest that walruses stay with the ice as long as possible, but once it retreats beyond the shelf break they begin to move to shore.[226] Results from tagging studies also indicate that they may be swimming out to many of their preferred offshore feeding areas from shore in these years,[227] though some evidence also suggests they may be utilizing areas closer to shore as well.[228]

The Bering-Chukchi-Beaufort (BCB) stock of bowhead whale is among the most studied populations of marine mammals in the world (Figure 9-9). The pre-exploitation (pre-whaling) population of bowhead whales in the Bering, Chukchi, and Beaufort Seas is estimated to have been 10,400 to 23,000 individuals.

Photo: Chukchi Sea Environmental Studies Program.

Figure 9-8. *Pacific Walruses Observed During Chukchi Sea Environmental Studies Program*

Commercial whaling activities in the late-1800s and early-1900s may have reduced this population to as few as 3,000 animals.[229] Up to the early 1990s, the population size was believed to be increasing at a rate of about 3.2% per year.[230] A census in 2001 yielded an estimated annual population growth rate of 3.4% from 1978 to 2001 and a population size (in 2001) of ~10,470 animals (George et al.;[231] revised to 10,545 by Zeh and Punt[232]). A photo identification-based population estimate, from data collected in 2004, indicated the population to be 12,631,[233] which further supported the estimated 3.4% population growth rate. Most recently, Givens et al. estimated the population to be 16,892 individuals in 2011.[234] Recent population estimates and relatively high annual growth rates have led some to question whether the BCB stock of bowhead whales remains endangered.[235]

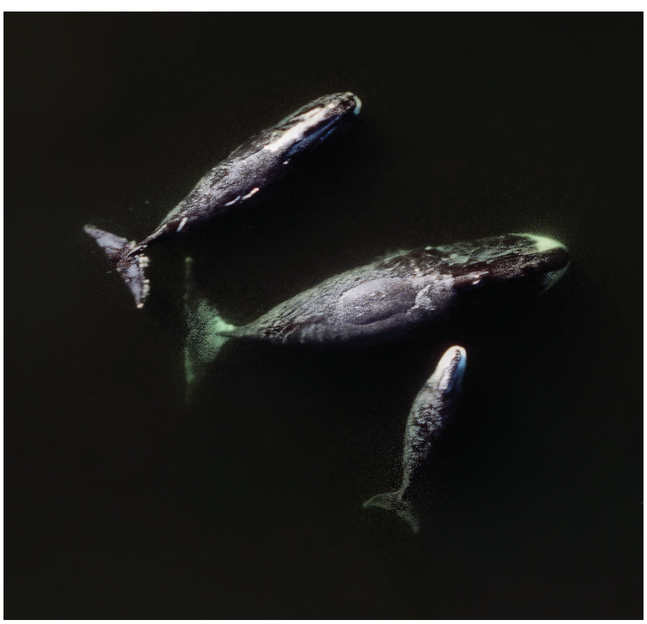


Photo: LGL Alaska.

Figure 9-9. *Adult and Immature Bowhead Whales*

The majority of the BCB bowhead whale population migrates annually from wintering areas in the Bering Sea through the Chukchi Sea in spring (March through June), making their way into the eastern Beaufort Sea where they summer (mid-May through September) on feeding grounds in the Mackenzie River Delta and Amundsen Gulf. Each fall, individuals migrate westward across the Alaskan Beaufort Sea and back to their wintering grounds (September through March) in the Bering Sea Gulf.[236,237,238] This pattern is not absolute, however, as increased observations both through aerial surveys and satellite tagging studies indicate that some portions of the bowhead population spend part of the summer feeding in the Chukchi Sea and the Alaskan Beaufort Sea.[239]

Bowheads feed primarily in the eastern Beaufort Sea during summer but also feed opportunistically in various areas along the Alaskan Beaufort Sea coast during their fall migration when oceanographic conditions support accumulations of prey species.[240,241,242] These sites occur sporadically across the eastern portion of the Alaskan Beaufort Sea but form regularly in an area east of Barrow where whales congregate in most years before migrating westward through the Chukchi Sea.[243,244,245] Occasional feeding has also been reported in the Chukchi Sea in areas near Point Franklin. Recent satellite tagging data suggest that most bowheads travel across the Chukchi Sea to the Chukotka Peninsula where they feed along the Russian coast before continuing south to wintering grounds.[246]

Northern stocks of beluga whales migrate seasonally with the formation and melting of pack ice. The two beluga whale stocks found in the Alaskan Arctic overwinter in the Bering Sea and move to coastal bays, estuaries, and rivers for calving and molting in the spring.[247,248] The eastern Chukchi Sea population spends part of the summer in the Chukchi Sea congregating in lagoons and nearshore waters along the Chukchi Sea coast, especially Omalik and Kasegaluk lagoons.[249,250] The Beaufort Sea population migrates through the Chukchi Sea into the Beaufort Sea, concentrating along the shelf break in the Beaufort Sea, to the pack-ice edge, or into the pack-ice, although they are sometimes seen in nearshore habitats. Tagged beluga whales were tracked above 80° N and far into 100% ice cover.[251] Many belugas continue into the eastern Beaufort Sea and Amundsen Gulf, where they summer. Other whales remain in the Alaskan Beaufort Sea near the ice edge and in waters near the shelf break where the continental shelf recedes to the deep ocean of the Canadian Basin. Aerial surveys conducted as a part of the Aerial Survey of Arctic Marine Mammal program also report concentrations of belugas close to the coastline in the western Beaufort Sea during the summer.

Other cetacean species that are found in the Chukchi Sea planning area include gray whales, minke whales, fin whale, humpback whales, killer whales, and harbor porpoise. Gray whales are found feeding in high densities with calves, particularly in the nearshore environment between Barrow and Point Lay. Distribution of the minke, fin, humpback, and killer whale stocks is only known for small portions of their range. Additionally harbor porpoise distribution is in a similar state for animals observed in parts of the Alaskan Arctic. These species do, however, seem to be found in increasing numbers in recent years.[252,253]

Bearded seals are found in relatively low numbers throughout the Chukchi and Beaufort Seas though they are somewhat more common in nearshore waters. Seasonal movements are directly related to the advance and retreat of sea ice and to water depth. During winter, most are found in the Bering Sea. As ice recedes each spring, they migrate north through the Bering Strait into the Chukchi Sea. During summer they are found near the fragmented ice margin and nearshore areas of the Beaufort and Chukchi Seas. Bearded seals, like walruses, are benthic feeders and exploit similar habitats to those used by walruses. They are generally associated with drifting sea ice in shallow waters that provide access to benthic food organisms.[254,255] Bearded seals are typically solitary but may become concentrated in nearshore pack-ice habitats in spring where females give birth on stable portions of the ice.[256]

Spotted seals are found primarily in the Bering and Chukchi Seas during summer months, but some individuals range into the Beaufort Sea[257,258] from July until September. At this time of year, spotted seals frequent bays, lagoons, and estuaries, haul out on land part of the time, but also spend extended periods at sea. In summer, they are rarely seen on the pack ice except when ice is very near shore. In the Chukchi Sea, spotted seals haul out in Kasegaluk Lagoon and at Icy Cape from mid-July until freeze-up in late October or November. Relatively low numbers of spotted seals are present in the Beaufort Sea. A small number of spotted seal haul outs are (or were) located in the central Beaufort Sea in the deltas of the Colville River and previously the Sagavanirktok River.[259] As the ice cover thickens with the onset of winter, spotted seals leave the northern portions of their range and move south into the Bering Sea where they overwinter along the ice edge.[260] Spotted seals eat a variety of schooling fish (Pollock, capelin, Arctic cod, and herring), as well as bottom dwelling fish such as flounder, halibut, and sculpin.[261] They are also known to feed on crabs and octopus. Spotted seals are able to forage to depths of 305 meters. Juveniles eat smaller prey than adults, consuming amphipods, krill, and other small crustaceans.

Ringed seals live year-round in the ice-covered waters of the Arctic. They are found throughout the circumpolar oceans of the Northern Hemisphere and are the most common and widely dispersed seal species in the Arctic. During cold periods of heavy sea-ice cover, ringed seals use the claws on their front flippers to excavate breathing holes and birthing lairs for pupping in the ice.[262] Lairs are used for birthing, nursing, and weaning pups from mid-March through April.[263,264] Mating occurs and pups are weaned in late April or May. During late April through June, ringed seals are distributed throughout their range from the southern ice edge northward. When the ice retreats to the north, ringed seals remain in the Beaufort, Chukchi, and Bering Seas throughout the open water season. In open water they tend to occur in patches, likely associated with the fish they prey upon. Ringed seals feed on polar and Arctic cod, other fish, and a variety of planktonic crustaceans.[265] Physiological adaptations help them make deep, sustained dives searching for prey. Ringed seals are the primary prey of polar bears and are also occasionally eaten by walruses and killer whales.

The polar bear is the largest species of bear.[266] They have a circumpolar distribution in the Northern Hemisphere and occur in most ice-covered seas, including the Bering, Chukchi, and Beaufort Seas.[267] In general, their distribution is limited to that of the sea ice though they occasionally occur on land and rarely inland of the coast (Figures 9-10 and 9-11). Long-distance north-south movements generally reflect seasonal melting and refreezing of sea ice.[268,269] Bears will move from summer pack ice to coastal sea ice as soon as it reforms in shallow areas in the fall.[270]

Polar bears breed between March and June following weaning of the young.[271] Female polar bears reach breeding age late in life (5 to 6 years old) compared to many animals, have small litters and high parental investment in their young.[272, 273] Pregnant females excavate dens in snowdrifts on pack ice or land in November and December.[274, 275, 276, 277] Denning habitats are characterized by topographic features such as ice ridges in pack ice, river banks, or coastal bluffs that catch snow in the autumn and early winter, and tend to occur near the coast. Cubs are born in late December to early January and females remain with the cubs in dens until March or April[278] returning to the sea ice in the spring as soon as the cubs are able. Cubs stay with their mothers until they are weaned at about 2.5 years of age.[279] Once cubs are weaned females can breed again.

Polar bears eat mostly ringed seals, bearded seals, and to a lesser extent walruses and other marine mammals.[280,281] Polar bears primarily eat energy-rich seal blubber, allowing them to quickly put on

Photo: ExxonMobil Production Alaska Inc.

Figure 9-10. *Polar Bear Image Captured on Wildlife Camera Deployed to Assess Wildlife Presence*

Photo: LGL Alaska.

Figure 9-11. *A Polar Bear Photographed from the Drilling Rig* Frontier Discoverer *During a 2012 Open Water Season*

large amounts of fat so as to survive extended periods without food when necessary. Polar bears have an extremely acute sense of smell and routinely search out and excavate seal birthing lairs to prey on the seal pups. They also stalk adult seals at breathing holes and at haul out sites. Many individuals scavenge whale carcasses at subsistence hunting sites near Kaktovik and on Cross Island, and are also attracted to dump sites and camps where food waste is not properly handled.[282]

Terrestrial Ecosystems

The North Slope of Alaska spans roughly 230,000 square kilometers north of the crest of the Brooks Range. It encompasses the drainage basins that empty into the Beaufort and Chukchi Seas as the land slopes gradually from the Brooks Range northward to the Arctic Ocean. The Arctic Slope can be broken into three physiographic provinces: the Brooks Range, the Arctic Foothills, and the Arctic Coastal Plain, which differ in topography, geology, climate, and history and as a result also in flora and fauna.

Variations in slope and topography in the Brooks Range create large differences in microclimatic and soil properties, resulting in diverse habitats for plants and animals. Floodplains of the larger rivers are dominated by shrub thicket while the valley bottoms contain sedge meadows and tundra dominated by willow and dwarf-birch shrub communities. The slopes support dry meadow and heath communities often dominated by species of *Dryas*. Above elevations of 1,800 meters, vascular plants (i.e., most trees and flowering plants) are found only in protected sites; at higher elevations, only discontinuous nonvascular plants such as lichen are found.

The Foothills to the north of the Brooks Range consist of more rolling terrain. Tussock tundra dominated by *Eriophorum vaginatum* and a rich assemblage of shrubs covers vast areas of the Foothills. Dry meadows and fellfields (screes with seasonal plants growing among the rocks) occur on the drier exposed ridges, and sedge-dominated meadows and willow thickets are found in the wetter valleys and swales.

The Coastal Plain is composed of nearshore marine, fluvial, alluvial, and Aeolian deposits of mid-to-late Quaternary age.[283,284] Large elliptical thaw lakes cover up to 40% of the land surface of the northern part of the Coastal Plain[285] near Barrow, but are less prevalent to the east in the NPR-A and near Prudhoe Bay. The lakes become oriented and elongated due to differential erosion at their north and south ends driven by prevailing winds. Lakes, river terraces, ice wedge polygons, and occasional pingos (conical or asymmetric dirt-covered ice hills formed by the freeze-thaw cycle in permafrost) provide topographic relief on the Coastal Plain. Along the coastline, relief is typically 2 to 5 meters with occasional bluffs and cliffs that may be 20 meters in height. The generally low topographic relief and the presence of permafrost cause poor soil drainage. Rivers generally originate in the Foothills and Brooks Range, and meander widely through the Coastal Plain to the ocean. The largest river crossing the Coastal Plain, the Coleville River, drains 60,000 square kilometers of the Foothills and the western Coastal Plain.[286]

The coastal climate has long, dry, cold winters and short, moist, cool summers. At Barrow, the sun is above the horizon continuously from May 10 to August 2, and below the horizon from November 18 to January 24. Air temperature remains below freezing for 9 months of the year and can fall below freezing at any time during the summer as well. The microclimate is influenced by the insulating snow cover in winter and the underlying permafrost. A gradual warming trend usually begins in April but snowmelt does not typically begin until June.

The vascular plants of the North Slope of Alaska consist of about 574 taxa, most of which occur in the Foothills. Species richness is greatest in the Foothills and least on the Coastal Plain for vascular plants and cryptogams (plants and fungi that produce by spores, rather than seeds). The plant communities differ substantially across the Coastal Plain due to differences in parent material (soil and underlying geology) and topography. The Barrow Peninsula is dominated by wet, acidic soils whereas soils near Prudhoe Bay to the east are influenced by carbonates contributed by the Sagavanirtok and Kuparuk Rivers, which result in more alkaline substrates.[287] The Barrow area is dominated by thaw lakes that support sedgegrass meadows of *Carex aquatilis, Eriphorum angustifolium,* and *Dupontia fisheri,* and *Sphagnum* moss species that grow well in the acidic soils.[288] *Sphagnum* mosses are uncommon to the east of Barrow, and numerous exposed and well-drained habitats occur on coarse textured soils along river banks, gravel bars, dunes, and pingos.[289,290] Small areas of salt marsh also occur along the coastline in areas of salt water intrusion. These areas may support only a few species of plants, often with a mosaic pattern maintained by ephemeral deposition of peat eroded along the shoreline or sand during storm events, unlike the zonation typical of salt marshes in lower latitudes.[291,292]

The North Slope is well known for its vertebrate wildlife resources, which include fish and birds (described previously) and mammals.[293] Mammals inhabiting the Arctic Slope include Dall sheep, wolves, grizzly and polar bears, moose, caribou, wolverines, weasels, Arctic and red foxes, and numerous other small mammal species such as lemmings and voles. Musk oxen, eliminated from the North Slope in the 1800s, were reintroduced into the Arctic National Wildlife Refuge (ANWR) beginning in 1969, and the population has survived and grown since. Caribou form three major herds that roam across the North Slope; these are the Western Arctic Herd, the Central Arctic Herd, and the Porcupine Herd. Caribou winter in the Foothills near the Brooks Range and migrate north to the coast during summer seeking relief from insects.[294] Calving occurs in several locations during movement from the foothills to the coast.[295] The herds are frequently seen in some oil and gas production areas.

Arctic foxes are the most common furbearing mammal on the North Slope and are highly adapted for survival in cold, seasonal environments.[296] They have also adapted well to the presence of humans in the oil fields near Prudhoe Bay,[297] although recent studies show that their numbers have declined dramatically near the oil fields as red fox numbers have increased. Microtine rodents include collard and brown lemming, and inland from the coast these two species occur together with the tundra vole. The red-backed mouse is present in the Foothills region, and singing voles are present in the rocky habitats of the southern Foothills and Brooks Range.[298]

The invertebrates of the North Slope are dominated by insects, arachnids, and crustaceans. The most abundant groups are the soil mites (Acari) and springtails (Collembola), which are critical agents in organic matter decomposition, soil production, and

Photo: ExxonMobil Production Alaska Inc.

Figure 9-12. *Wildlife Time-Lapse Camera Deployed to Capture Presence of and Habitat Use by Wildlife*

nutrient cycling.[299,300,301] Chironomid larvae are the most common benthic invertebrates in tundra ponds, and zooplanktonic invertebrates are also common, usually dominated by crustaceans, particularly *Daphnia* and fairy shrimp.[302,303,304,305] In vegetated areas, snails, stone fly nymphs, caddisfly larvae, cranefly larvae, and diving beetle larvae are also common.[306,307,308] These invertebrate organisms support fish and bird populations using the terrestrial and freshwater habitats of the coastal tundra.

Overall, there has been an extensive set of data collected on the broad range of species occurring across the North Slope and the nearshore and offshore habitats. Continuation of many of these studies, and subsequent impact assessments and research will continue to build this pool of knowledge (see Figure 9-12).

REVIEW OF RESEARCH PLANS, ANALYSIS REPORTS, AND REGULATORY DRIVERS

Review of Key Research and Planning Documents

This section summarizes a representative selection of ecological studies occurring in the Arctic from the perspectives of a broad range of stakeholders. There have been numerous monitoring and research projects that have occurred in the Arctic over the past decades, and this review is not intended to represent a comprehensive list of all of the research; rather, it is focused on those projects or activities related to prudent development of oil and gas in the offshore U.S. Arctic. Some of the original science in the Arctic began as early as the 1800s and has continued at an increasing pace since that time—and encompasses a significant variety of ecological aspects. This depth and breadth of science puts the Arctic—and Alaska in particular—in a unique position to have a strong base of understanding of the ecology of the region. If the research is assessed and the gaps filled, it will offer the oil and gas exploration and development industry a greater fact-base from which to make critical ecological, human, and economic decisions in developing any identified hydrocarbon resources in a prudent and environmentally protective manner. To exhibit the breadth of research undertaken or underway, a range of documents and websites were reviewed, including:

- Policy documents (i.e., ranging from overarching country policies to federal agency policies)
- Agency or regional strategic plans

- Agency or regional study or research implementation plans
- Regional assessments
- Syntheses of research
- Issue-specific research reports.

An extensive list of documents and webpages have been reviewed for this assessment. This review was focused on the following key aspects:

- List of key science issues or questions that were the subject of Arctic ecological research
- Entities involved in research or those that have identified future research needs
- Regulatory drivers associated with the science issues or questions identified (also see Table 9-1)
- Future research opportunities to address questions or needs related to prudent development of oil and gas in the Arctic.

Scientific research questions were organized into six broad categories, namely:

- Biological and environmental
- Climate change
- Oil spills
- Support technology
- Physical oceanography
- Mitigation.

Each of these broad categories, except mitigation, also have tiered subcategories as shown in Figures 9-13 and 9-14. To demonstrate the amount of ecological research by science issue, these figures provide the number of documents by research question or topic. As shown in the figures, past and current research is indicated in green, and future research opportunities are presented in gold.

The amount of baseline data collected as shown in Figure 9-13 reflects the amount of research that has occurred in the Arctic, and the amount of information that is available to industry, natural resource managers, scientists, and other stakeholders in order to inform decisions and understand the Arctic ecosystem. The regulatory permitting requirements necessary for Arctic oil and gas exploration and development have in part driven this level of research as well as future opportunities for baseline data collection, particularly in the United States. Notable in Figure 9-14 is less dedicated research on mitigation for actual or potential impacts. Research on mitigation is often included in comprehensive agency reporting rather than standalone research.

Regulatory Drivers for Ecological Data Collection

U.S. Arctic research funded by the private sector is driven in part by regulations, laws, and authorizations required by regulatory agencies with trust responsibilities, along with the need of industry to be able to assess any impacts and measure the effectiveness of mitigations and management. In order to obtain the required permits or authorizations needed for oil and gas exploration or development, project proponents often must demonstrate an understanding of the baseline environmental conditions and the potential impacts associated with proposed activities. In addition to data collection associated with specific proposed actions, agencies encourage or even require implementation of long-term research and monitoring in order to distinguish effects from oil and gas operations from other anthropogenic impacts and from changes due to natural processes.

Table 9-1 shows the number of permits required by government agencies to explore and develop oil and gas in Alaska's Arctic. The table includes the relevant research topics or questions that correspond to those listed in Figures 9-13 and 9-14. Alaska Department of Environmental Conservation and Alaska Department of Natural Resources Division of Mining Land and Water require the greatest number of permits. Research supports the permitting process and provides the necessary data for decision-making, mitigation planning, and implementation. Notable is the frequency of repeated research questions across multiple permits, such as oil spills, wildlife, birds, marine mammals, and others.

Research Support for the Regulatory Life Cycle

In the United States, development projects can be broken down into four phases:

- Pre-feasibility

- National Environmental Policy Act (NEPA) compliance and documentation
- Permitting
- Mitigation and monitoring.

Research is needed at varying stages of a project life cycle depending on the specific regulation or authorization required and the environmental aspects being undertaken. This research must incorporate traditional knowledge to support oil and gas activity (studies, site investigations, construction, and operations), permits, and authorizations. For this reason, it is difficult to generalize about any standard length of time to collect and analyze research data, given the variability among projects and the specific location, environmental conditions, project components, agency coordination, stakeholder inputs, and other factors that can influence these phases. For example, a Section 103 permit under the Clean Water Act requires approximately 2 years lead time for processing, and would require some level of baseline research in support of the permit application. A Temporary Land Use Permit from Alaska's Department of Natural Resources, however, may require only a few months to prepare, apply for, and obtain. The timing of research studies in support of permits or authorizations varies depending on the type of approval needed. Each agency has a published schedule for when to submit permit applications and the specific requirements for the application (which may require data obtained through research over a range of seasons).

Monitoring and research are important aspects of permitting and authorizing Arctic oil and gas development as they provide critical information necessary for regulatory agencies to make decisions on which actions to allow and what mitigations may be necessary to protect resources. Streamlining the permitting process will involve coordinating with agencies throughout the research, monitoring, and permitting process to continue sharing knowledge about the status of Arctic resources in order to make prudent decisions about oil and gas development.

IDENTIFIED COMMON THEMES OF CONTINUING RESEARCH RELATED TO DECISION-MAKING

There is a broad range of potential research opportunities that can be undertaken in the Arctic on its ecology. To identify the key areas that are particularly important for supporting prudent development of oil and gas resources in the Arctic, specific themes have been used to categorize the potential studies and assess priorities. The following sections delve into the different themes that have been identified from the review of existing information.

Theme 1: Understanding and Documentation of Current Conditions

Description of the Theme

One of the most essential groundings for regulatory policy and natural resource management are the data that establish existing environmental conditions within an area. These data are sometimes referred to as baseline or current conditions, and consist of an inventory of existing ecological resources, characterization of the physical environment, and examination of biotic interactions (interactions between living things, e.g., predator-prey, herbivore-plant, competition, and symbiosis) and abiotic interactions (interactions between living things and the environment, e.g., temperature, light, pH, salinity, etc.). They provide a basis for examining the current wellbeing of resources and for projecting potential change that may result from both natural and anthropogenically induced variability. Existing conditions may reflect patterns of species movement and the use of an area or habitat. They may also reflect the current status and trends of species and identify the existing bounds of variability of both biotic and abiotic parameters.

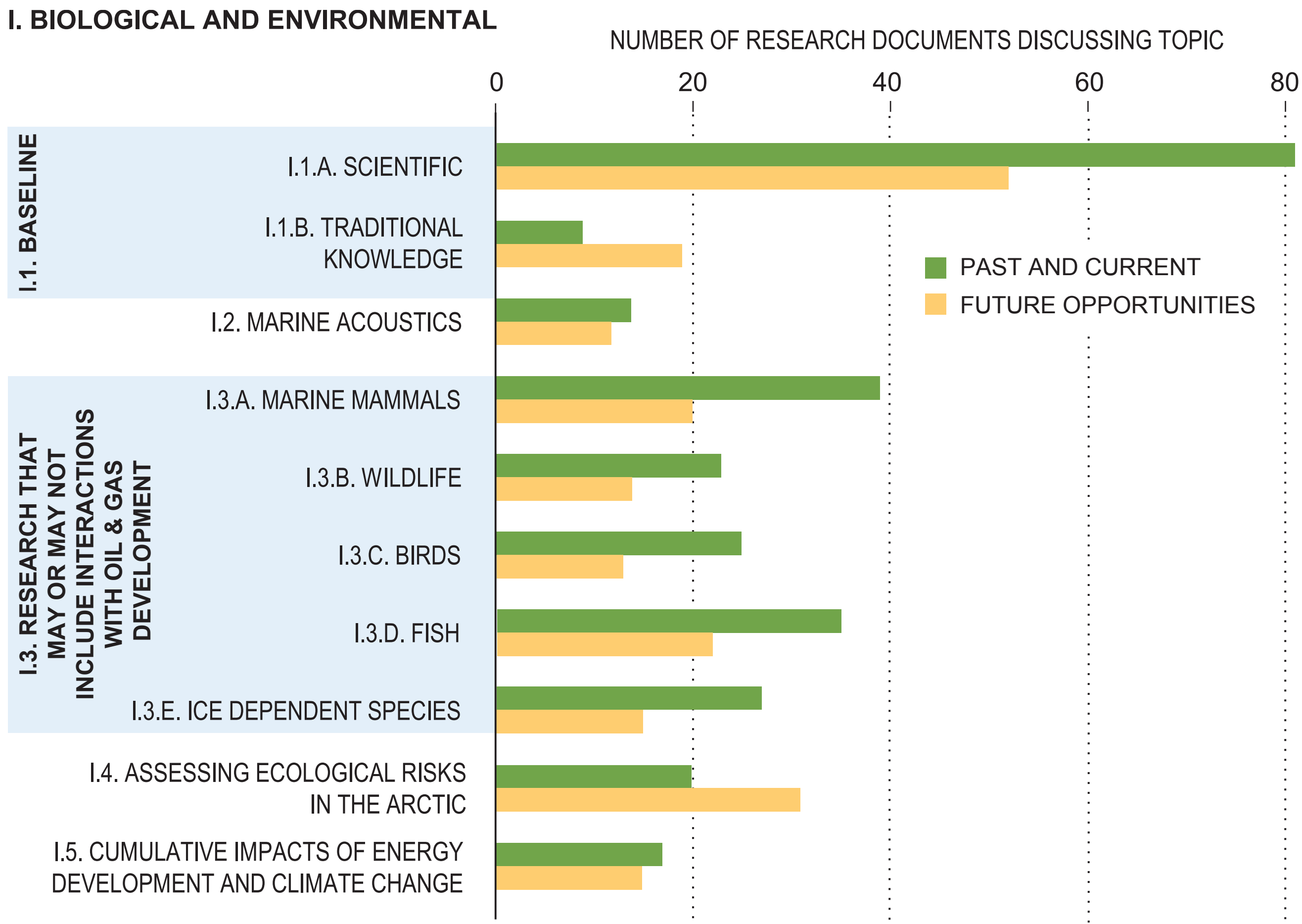
In the Arctic the characterization of existing conditions is necessarily derived from a combination of the knowledge and observations of the people of the North, as well as from established methods of scientific measurement and assessment. Accurate assessment of existing conditions is a critical element in establishing robust regulatory policies that are appropriately protective of resources, and accommodate exploration and development of oil and gas resources. Characterization of the environment is a required element of environmental assessments, as prescribed by NEPA, that support major actions and project proposals as well as permit reviews. This typically includes a broad array of information about the ecosystem such as a full accounting of the flora and fauna present within a project area

Agency		# Permits Required	Relevant Research Science Issues	
Federal	ACHP	2	I. Biological and Environmental	I.4. Assessing Ecological Risks in the Arctic
Federal	BLM	4	I. Biological and Environmental I.1.A. Scientific Baseline I.1.B.Traditional Knowledge Baseline I.3.B. Wildlife I.3.C. Birds I.3.D. Fish I.5. Cumulative Impacts of Energy Dev. and Climate Change	III. Oil Spills IV. Support Technology IV.2. Unmanned Aircraft Systems IV.4. Remote Sensing IV.5. Arctic Technology and Infrastructure VI. Mitigation
Federal	BLM, NPS, USFWS	1	I. Biological and Environmental	
Federal	CEQ	1	I. Biological and Environmental II. Climate Change	III. Oil Spills
Federal	CEQ, USACE, FERC, EPA	1	I. Biological and Environmental II. Climate Change III. Oil Spills	IV. Support Technology V. Physical Oceanography VI. Mitigation
Federal	DOS	1	I. Biological and Environmental II. Climate Change	III. Oil Spills IV.5. Arctic Technology and Infrastructure
Federal	EPA	3	I.3. Research that may or may not include interactions with O&G Dev. I.4. Assessing Ecological Risks in the Arctic I.5. Cumulative Impacts of Energy Dev. and Climate Change	III. Oil Spills IV. Support Technology IV.5. Arctic Technology and Infrastructure
Federal	FAA	3	I.3.B. Wildlife I.3.C. Birds I.5. Cumulative Impacts of Energy Dev. and Climate Change	IV.2. Unmanned Aircraft Systems IV.4. Remote Sensing IV.5. Arctic Technology and Infrastructure
Federal	International Boundary Comm.	1	I. Biological and Environmental II. Climate Change	III. Oil Spills IV.5. Arctic Technology and Infrastructure
Federal	NMFS	5	I.3.A. Marine Mammals I.3.B. Wildlife I.3.C. Birds I.3.D. Fish	I.3.E. Ice Dependent Species I.5. Cumulative Impacts of Energy Dev. and Climate Change III. Oil Spills
Federal	USCG	1	III. Oil Spills	
Federal	USCG, EPA	1	III. Oil Spills	
Federal	USACE	1	I.3.A. Marine Mammals I.3.B. Wildlife I.3.C. Birds I.3.D. Fish I.3.E. Ice Dependent Species	I.5. Cumulative Impacts of Energy Dev. and Climate Change III. Oil Spills IV.5. Arctic Technology and Infrastructure V. Physical Oceanography
Federal	USFWS	2	I.3.A. Marine Mammals I.3.C. Birds	III. Oil Spills

Table 9-1. *Regulatory Permits and Authorizations Required for Oil and Gas Exploration and Development in Alaska's Arctic*

Agency		# Permits Required	Relevant Research Science Issues	
State	ADEC	10	I. Biological and Environmental I.1.A. Scientific Baseline I.3. Research that may or may not include interactions with O&G Dev. I.3.B. Wildlife I.3.C. Birds I.4. Assessing Ecological Risks in the Arctic	II. Climate Change I.5. Cumulative Impacts of Energy Dev. and Climate Change III. Oil Spills IV.2. Unmanned Aircraft Systems IV.4. Remote Sensing IV.5. Arctic Technology and Infrastructure
State	ADF&G	4	I.2. Marine Acoustics I.3. Research that may or may not include interactions with O&G Dev. I.3.D. Fish I.4. Assessing Ecological Risks in the Arctic	I.5. Cumulative Impacts of Energy Dev. and Climate Change III.2. Oil Spill Impacts on Species III.3. Oil Spill Impacts to the Environment IV.5. Arctic Technology and Infrastructure VI. Mitigation
State	ADNR	3	I. Biological and Environmental II. Climate Change	III. Oil Spills IV. Support Technology
State	ADNR, DMLW	7	I. Biological and Environmental I.1.A. Scientific Baseline I.1.A. Traditional Knowledge Baseline I.3.B. Wildlife I.3.C. Birds I.3.D. Fish II. Climate Change	I.5. Cumulative Impacts of Energy Dev. and Climate Change III. Oil Spills IV. Support Technology IV.2. Unmanned Aircraft Systems IV.4. Remote Sensing IV.5. Arctic Technology and Infrastructure VI. Mitigation
State	ADNR Div. of Forestry	1	I.3.B. Wildlife I.3.C. Birds	I.3.D. Fish I.5. Cumulative Impacts of Energy Dev. and Climate Change
State	ADNR, SHPO	1	I.1.A. Scientific Baseline	I.5. Cumulative Impacts of Energy Dev. and Climate Change
State	ADOTPF	7	I.1.A. Scientific Baseline I.1.B. Traditional Knowledge Baseline I.3.B. Wildlife I.3.C. Birds I.3.D. Fish I.5. Cumulative Impacts of Energy Dev. and Climate Change	III. Oil Spills IV.2. Unmanned Aircraft Systems IV.4. Remote Sensing IV.5. Arctic Technology and Infrastructure VI. Mitigation
State	AOGCC	6	I. Biological and Environmental I.3.B. Wildlife I.3.C. Birds I.3.D. Fish	I.5. Cumulative Impacts of Energy Dev. and Climate Change III. Oil Spills IV.5. Arctic Technology and Infrastructure
State	Reg. Comm. of Alaska	1	I. Biological and Environmental II. Climate Change	III. Oil Spills IV. Support Technology
Local	NSB	1	I. Biological and Environmental	II. Climate Change
Regional	NSB Permitting and Zoning Div.	2	I.3.B. Wildlife I.3.C. Birds	I.3.D. Fish I.5. Cumulative Impacts of Energy Dev. and Climate Change
Regional	Fairbanks North Star Borough	1	I.3.B. Wildlife I.3.C. Birds	I.5. Cumulative Impacts of Energy Dev. and Climate Change IV.5. Arctic Technology and Infrastructure
Private	Land owners	1	I. Biological and Environmental II. Climate Change	III. Oil Spills IV.5. Arctic Technology and Infrastructure

Table 9-1. *Regulatory Permits and Authorizations Required for Oil and Gas Exploration and Development in Alaska's Arctic (Continued)*



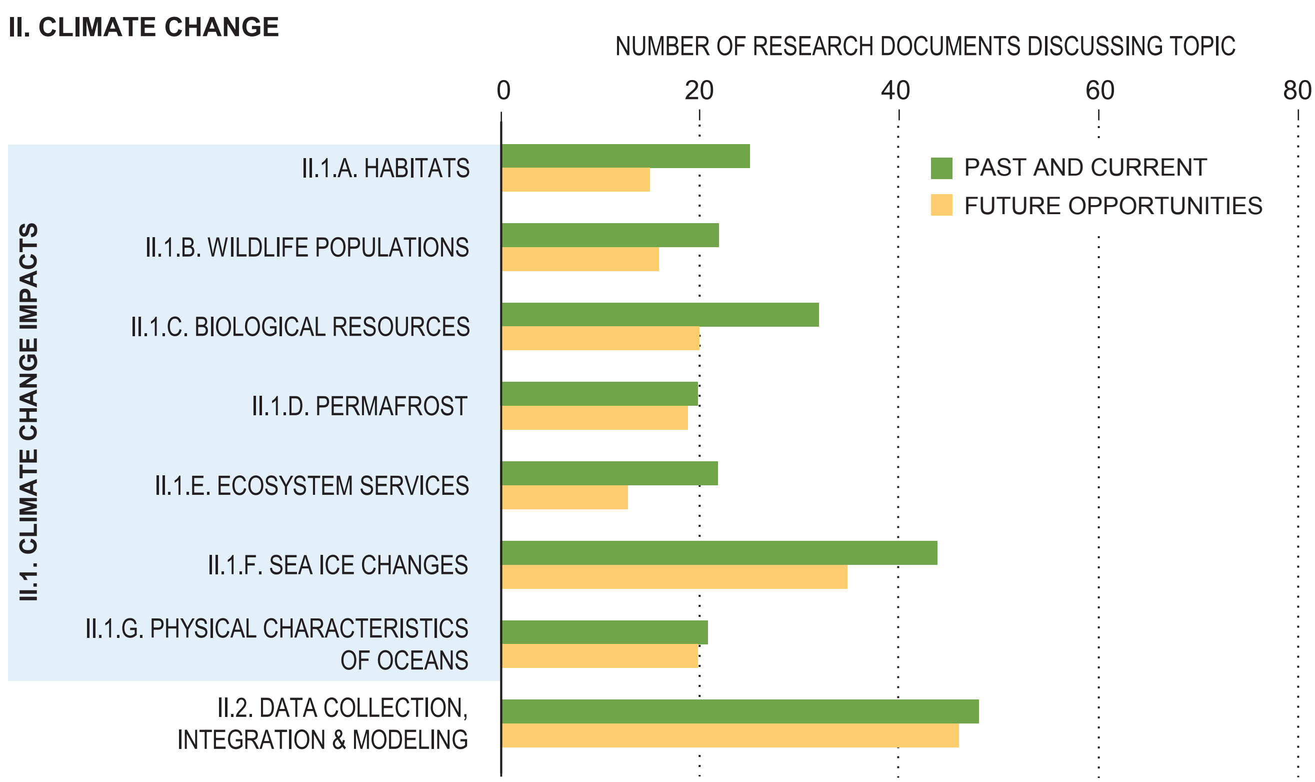


Figure 9-13. *Past, Current, and Future Opportunities for Arctic Research on Biological and Environmental Parameters and Climate Change*

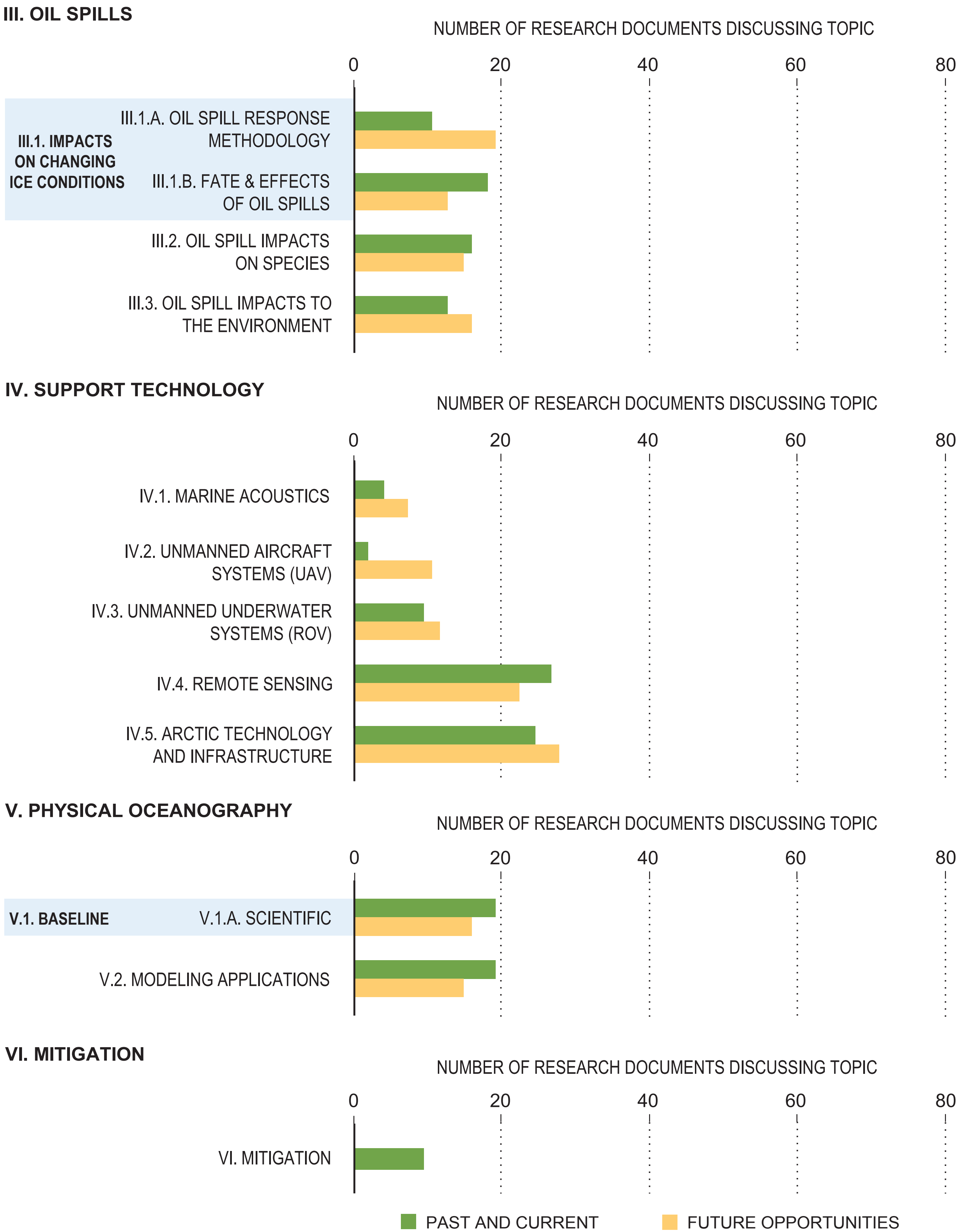


Figure 9-14. *Past and Current Research and Future Research Opportunities in the Arctic on Oil Spills, Support Technology, Physical Oceanography, and Mitigation*

or area of influence, evaluation of population levels and trends, and identification of species sensitivity to perturbation. In general, the more robust the basis of information, the less uncertainty there is about resource-project interactions, and the more accurate the assessment of potential impacts, allowing for appropriate mitigations.

Relevance to Exploration and Development in the Arctic

Data documenting existing conditions are a critical element in the establishment of regulatory policies—e.g., determination of species candidacy for protected status and the determination of critical habitat under the Endangered Species Act or the Marine Mammal Protection Act. The requirement for impact avoidance and mitigation measures may be based upon information about resource presence, abundance or relative abundance, and potential response to actions.

Applying the large body of knowledge from various studies in the Arctic to site-specific conditions requires investigation and comparison at the site level. Information discussed in the earlier section on review of existing ecological understanding is particularly relevant to this application and assessment.

The monitoring of ecological change that may result from project actions can be successful only if it is based on a sound assessment of conditions that exist prior to the proposed activities. If there is too much uncertainty about preexisting conditions, the ability of a monitoring program to detect and explain the reason(s) for change may be extremely limited. Though it is not monitoring in the traditional sense, the ability to detect changes in resource status is a critical requirement for the assessment of resource damages in the case of an accidental release.

Current Knowledge on the Theme

Information about existing conditions within the Arctic is available from the many studies that have been conducted in the past. There is generally good understanding of the species present and their life histories and broad patterns of distribution, movement, population status, and sensitivity.[309,310,311] Recent studies programs, including CSESP (Chukchi Sea Environmental Studies Program),[312] COMIDA-CAB,[313] AKMAP (Alaska Monitoring and Assessment Program),[314] ASAMM (Aerial Survey of Arctic Marine Mammals),[315] AEIS (Arctic Ecosystem Integrated Survey),[316] Transboundary,[317] and CHAOZ (Chukchi Acoustic, Oceanographic, and Zooplankton Study)[318] have significantly advanced the understanding of existing conditions within the OCS and nearshore areas of interest for oil and gas exploration and development. Key areas of uncertainty do, however, exist. While population estimates for bowhead whales are very good, other species of marine mammals are less well understood. Existing stock assessments[319] for many species include broad ranges for population estimates. In some cases (e.g., fin, humpback, killer and minke whales), it is not even clear which stocks or populations are occurring in the Chukchi Sea. For example, the abundance and distribution and community composition of some fishes, especially nearshore fishes in the Beaufort Sea, are reasonably well known; others, especially those in deeper offshore waters, are not well understood.

Planned Research or Investigation

Of the current condition programs listed above, the CSESP, ASAMM, and CHAOZ programs are continuing during 2015. Industry programs in the Prudhoe Bay and Kuparuk oil fields areas continue to build on data collected over the past four decades, with some individual studies (for example, the nearshore fisheries study associated with the Endicott development) continuing to apply the same methods annually for three decades. One of the main industry-funded programs in the Chukchi Sea through the CSESP, is in its eighth year of operation. Among the many components of this study, CSESP continues to deploy and operate extensive arrays of acoustic recorders in both the Chukchi and Beaufort Seas that provide valuable information on the distribution and movement of vocalizing marine mammals and on the levels of ambient and anthropogenic sound in these environments. The BOEM Environmental Studies Program is funding a number of ongoing and new habitat and ecology projects[320] that include studies focused on fishes, birds, marine mammals, ecosystems, physical oceanography, and marine chemistry. A number of these studies are being carried out in collaboration with other state and federal agencies including USGS, NOAA, USFWS, and ADF&G.

The North Slope Borough (NSB) Department of Wildlife continues to conduct a variety of baseline studies including bowhead whale censuses and caribou and bird studies. Collaborations between Shell and the NSB and Northwest Arctic Borough are funding community-based programs in both areas, including a variety of assessments of existing conditions such as ice-seal tagging, ice and open water drifter buoys, and assessments of the anatomy, physiology, and contaminant levels associated with bowhead and beluga whales.

Theme 2: Marine Sound and Biological Resources

Description of the Theme

Humans use sound in the oceans for a variety of reasons such as navigation, defense (sonar), scientific research, and exploration for resources. Underwater sounds are also generated from oil and gas exploration, development, and production activities, and by marine animals themselves. Over the past three decades, sounds generated by offshore oil and gas exploration and production, particularly seismic acquisition, have been of increasing concern for marine life.[321] Sounds can be intermittent, or pulsed, from seismic or other geophysical surveying activities, or they can also be continuous, or non-pulsed, from drilling operations, ships, or managing and breaking ice. Low frequency sounds can travel hundreds of kilometers through water (though not as far in shallow water)[322] while higher frequency sounds generally travel much shorter distances.[323] Anthropogenic sound levels can affect marine life either through direct injury or from disturbance of behavioral patterns.[324,325,326]

The Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA) prohibit, with certain exceptions, the killing, injuring, or disturbing of marine mammals in U.S. waters and by U.S. citizens on the high seas. The exceptions are for Alaska Native subsistence hunting, authorized scientific research, for authorized disturbances incidental to other activities, and in some cases for authorized intentional disturbances. NOAA and USFWS are responsible for administering the MMPA and the ESA.

Arctic oil and gas resources can play a substantial role in meeting global energy needs over the coming years, given their significant potential. As oil and gas exploration increases in the Arctic offshore along with other activities (e.g., shipping, commercial fishing, tourism, etc.), levels of anthropogenic sound introduced into the environment will also increase, potentially affecting marine mammals, fish, and invertebrates.[327,328,329] The oil and gas industry has recognized this challenge, and initiated the IOGP Sound and Marine Life JIP in 2005 (see text box titled "International Oil & Gas Producers' Joint Industry Program on Sound and Marine Life").

Relevance to Oil and Gas Exploration and Development in the Arctic

NOAA has established regulatory thresholds for pulsed and non-pulsed sounds, although the regulations do not include clear definitions separating these two types of sound.[330] To minimize impacts, mitigations are applied that usually include protected species observers to watch for the presence of marine mammals, and advise on shut down requirements if marine mammals approach within a set distance of some activities, or time-area restrictions for conducting some activities (see text box titled "Examples of Typical Mitigation and Monitoring Measures"). The requirements are intended to both mitigate the potential impacts to individual animals and assure that impacts do not affect large populations. Monitoring of marine mammal density, abundance, and behavior is also required in order to demonstrate that the mitigations are adequate and effective.

The MMPA also requires that any impact from oil and gas operations in the Arctic OCS be mitigated such that sufficient marine mammals are available for subsistence harvest. In 1994 the Act was amended to impose the requirement for independent peer review of industry monitoring plans when offshore oil and gas activities might affect the availability of marine mammal subsistence resources, thus codifying a cooperative process worked out between subsistence whalers, the oil and gas industry, and the federal government.[331] This requirement, along with additional mitigations under consideration in the National Marine Fisheries Service Supplemental Draft Environmental Impact Statement[332] and the proposed U.S. Environmental Protection Agency (EPA) General Permit for Geotechnical activities,[333] includes several constraints on producing oil and gas in the Arctic OCS. Proposed mitigations include limiting the number of drilling rigs that can operate in a drilling season, drilling during the open water season only, and a time area closure in the Beaufort Sea from August 25 until the end of the fall whale subsistence harvest.

International Oil & Gas Producers' Joint Industry Program on Sound and Marine Life

There are many organizations actively engaged in researching sound in the marine environment; this area of research is of growing interest and studies have already been conducted by the military, academia, regulators, and the oil and gas industry. The joint industry program (JIP) was established in 2005 and is funded by 14 major oil and gas companies, the International Association of Geophysical Contractors, and the U.S. offshore oil and gas regulator, the Bureau of Ocean Energy Management. It has the most extensive industry research program in this field. This involves identifying, addressing, and answering key questions around the impact of exploration and production activity that have not been tackled systemically by the existing body of science. Working together with multinational groups, experts, and NGOs, the JIP has already committed more than $31 million (U.S.) to research.

The research is divided into five categories that are designed to allow the JIP to fully understand the issues and potential effects associated with underwater sound from E&P activities, and develop new or advanced appropriate mitigation strategies to protect marine life. The categories are:

- Sound source characterization and propagation
- Physical and physiological effects and hearing of animals
- Behavioral reactions and biological significant effects
- Mitigation and monitoring
- Research tools.

When the outcomes of these research categories are applied and integrated, they allow for more rigorous assessment of the risks of sound in the marine environment and improvement in management strategies.

Some areas of research that are particularly relevant to the U.S. Arctic include studies on:

- The status of cetacean stocks in areas where oil and gas activities have been undertaken
- Hearing capabilities and effects of repeated seismic sounds on hearing of different species of ice seals
- Passive acoustic monitoring of vocalizing cetaceans
- Animal tagging technology
- Unmanned aerial survey technology assessment.

IOGP JIP website: http://www.soundandmarinelife.org/.

Current Knowledge and State of the Science

In the oceans, sound is generated by a variety of natural and anthropogenic sources. Examples of natural sources include vocalization by marine life, wind and wave action, ice movements, and meteorological and oceanographic conditions. Oceanographic variables such as the geologic characteristics of the seafloor, the water depth, temperature, salinity and density stratifications can influence the propagation and transmission of sound as it travels through water. Marine mammals use sound to navigate, interact socially, communicate, locate food, and sense the presence of predators. The frequencies at which marine mammals hear sounds are dependent on the species. For example, large baleen whales hear and vocalize primarily in the low frequency range (5-22 Hz), whereas some toothed whales and dolphins utilize higher frequencies (150-160 kHz) to communicate and to echolocate food sources and their surroundings.[334]

Sounds from oil and gas activities may have the potential to affect marine mammals in several ways. If an animal is close enough to a sound source, auditory injury may occur. There are, however, no known instances where auditory injury has been documented that was due to oil and gas activities.[335] Lower-level sounds can cause marine mammals to alter their behavior, ranging from reducing their calling frequency, to altering migration patterns, to disrupting feeding. Sounds from oil and gas activities

Examples of Typical Mitigation and Monitoring Measures Required to Conduct Oil and Gas Activities in the Arctic Ocean

Geophysical Survey Activities

- Protected Species Observers to monitor or shut down exclusion zones
- 30 minute observation of exclusion zone prior to startup
- Negotiated mitigations to protect subsistence harvest
- Protected Species Observers on support vessels
- Slow start or ramp-up of seismic survey sources

Oil and Gas Exploration, Production

- Avoidance of grouping of whales: approach distance minimums of 900 feet
- Helicopter and aircraft minimum elevations 1,000-1,500 feet
- Protected Species Observers on drill rigs, production platforms, and support vessel
- Shutdown requirements if marine mammal in exclusion zones
- Aerial survey monitoring
- Acoustic monitoring

can also raise the background level of sound in the water, making it more difficult for marine mammals to communicate with each other.[336,337]

For example, bowhead whales are known to alter their migration routes and deflect around oil and gas drilling platforms in the Beaufort Sea (see Figure 9-15).[338,339] It has also been observed that bowheads may alter the rate at which they call when exposed to sound levels from oil and gas activity.[340,341] However, evidence to date does not suggest that these changes in behavior cause harm to individual whales or the bowhead population. The bowhead stock has continued to increase in size concurrent with exploration and production activities in the Beaufort and Chukchi Seas. This has also been documented through the IOGP Sound and Marine Life JIP studies on cetacean stock assessments (see earlier text box on the IOGP's Joint Industry Program on Sound and Marine Life).

Fish and invertebrate species may also be affected by increases in sound in the water, though potential effects and impacts are less well understood. Some studies suggest that sounds generated from seismic surveys can decrease catch yields of nearby commercial fishermen,[342] while other studies show no effect. Injuries to swim bladders in fish have been observed in studies where explosives were used.[343] Again, the IOGP Sound and Marine Life JIP has identified these questions and is currently seeking study proposals to further address these questions.

Planned Research or Investigations

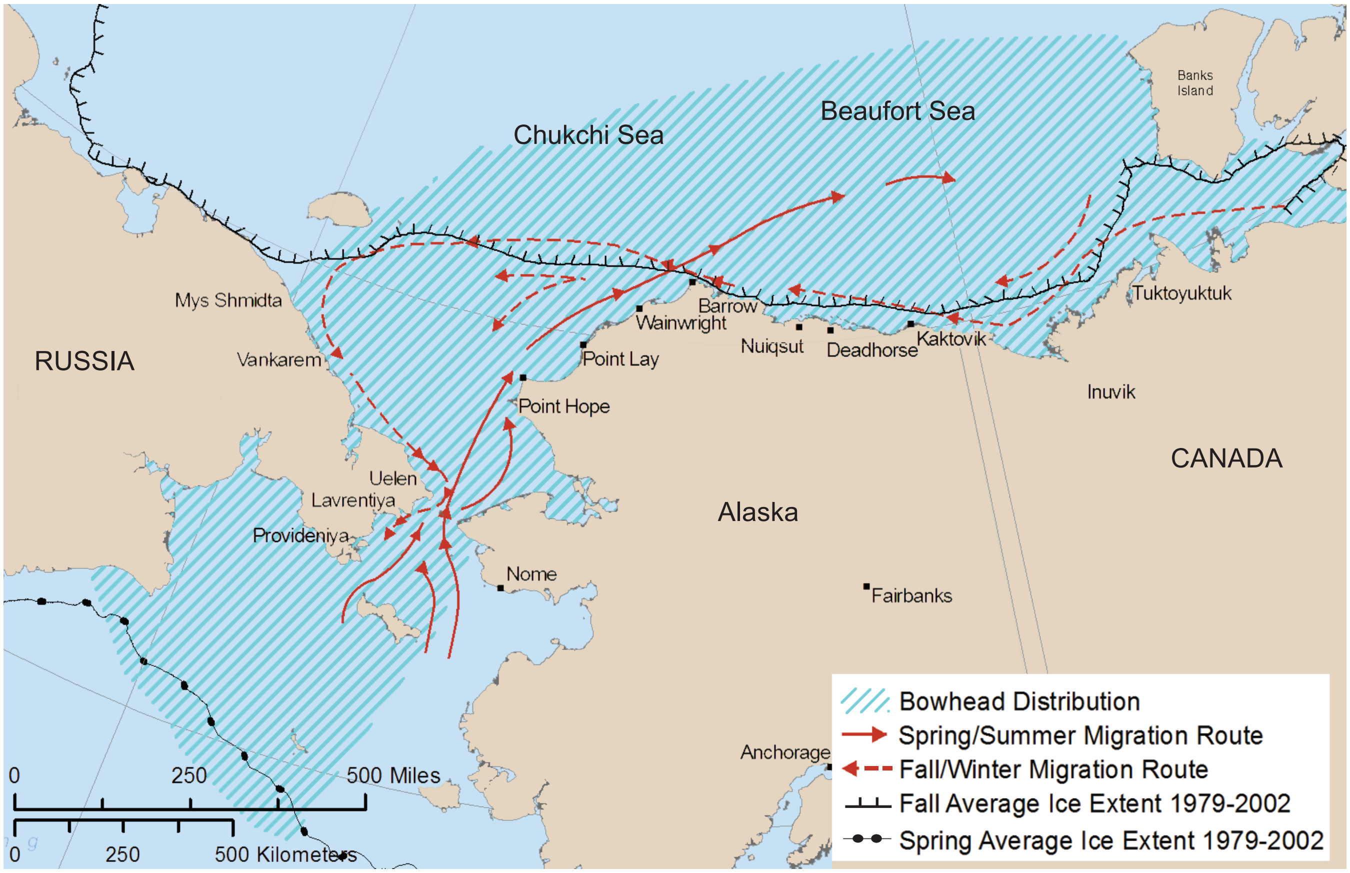
Marine sound research or investigations most relevant to prudent development of oil and gas resources in the Arctic OCS fall into three broad categories:

1. Understanding and assessing risk to marine life from anthropogenic sound
2. Technological developments to reduce sound generated from oil and gas activities
3. Improvements in ways to monitor marine mammals to study effects on fish, birds, and invertebrates.

Additional studies of marine sound research are provided by the Office of Naval Research Marine Mammal and Biology Program,[344] the BOEM Environmental Studies Program,[345] and oil and gas industry through development-specific studies.

Assessing the risk to marine life from oil and gas activities involves many program elements. Some fundamental information is thought to be lacking, for example, in understanding the hearing capabilities of ice seals.[346] However, research is underway on three species of ice seals to determine their hearing in air and water, and to assess how oil and gas industry sounds (particularly seismic survey sounds) may affect their hearing.

It has been known for some time[347] that bowhead whales deflect around some oil and gas operations, but it is not yet clear whether these deflections have a biological significance or interfere with subsistence



Source: Alaska Department of Fish and Game, 2012.

Figure 9-15. *Bering-Chukchi-Beaufort Seas Bowhead Whale Range Map*

harvest. Finally, integrating this knowledge into an analytical framework that takes into account cumulative effects and can then be used by regulators to address level of activity, and authorizations for incidental harassment has been initiated using simulation models, but requires further development.

The oil and gas industry is required to measure the underwater sounds generated from some activities. These sound source verification studies have provided valuable information on the sound levels and frequencies from various types of activities that take place during oil and gas operations. For example, setting anchors for drilling platforms has been shown to be one of the loudest sound producing activities of a particular drilling operation.[348] If levels of anthropogenic sound are determined to negatively affect marine life, quieter technologies may need to be developed. The oil and gas industry continues to assess a number of quieting options for some types of operations. Two examples are (1) bubble curtains, a technology known to reduce sound levels propagating from operations such as pile driving that may have applications to drilling operations, and (2) developing or advancing the technology of marine vibroseis, a technology that may eventually be used as a sound source for seismic surveying instead of air guns in some situations (see text box titled "Sound Quieting Technologies").

Aerial observations of marine mammals in the Arctic OCS have occurred annually since 1979, providing a large data set on historical trends of marine mammal distribution and abundance during the open water seasons. Today this program is titled the Aerial Survey of Arctic Marine Mammals (ASAMM), conducted by NOAA and funded by the BOEM. This program relies on piloted fixed-wing aircraft and Protected Species Observers. Aerial surveys are also a requirement of NOAA and USFWS authorizations for conducting oil and gas activities. As activity levels increase, the need for expanded coverage further from shore will be necessary to assess effects of oil and gas activities on marine mammals. Additionally, relatively little is known about ice seal distribution

Sound Quieting Technologies

Bubble Curtains

Bubbles either continuously generated, or encapsulated and arranged in specific configurations, capture and attenuate sound from various sound sources. This technology may be useful in the Arctic around drilling and production platforms where water depths are relatively shallow and currents weak.

Marine Vibroseis

Marine vibroseis is a technology that can be used to introduce sound energy into the water for purposes of seismic imaging. While not currently commercially available, prototype technologies are under development by the oil and gas industry. Overall peak energy is lower, and systems can be tuned to generate only sound frequencies useful for seismic imaging, possibly reducing effects on marine life.

during the winter season although some satellite tagging of bearded seals has been undertaken (e.g., NOAA, BOEM, ADF&G). Unmanned aerial systems (UAS) are now commercially available and approaching reliability performance that allows for operations in the Arctic environment. Outfitting these systems with high-speed, high-resolution digital camera technology and flying them over the survey area of interest eventually may be a viable alternative to manned flights in some circumstances (Koski et al.,[349] a study funded by the IOGP Sound and Marine Life JIP). Some work has also been done with the camera technology on fixed wing aircraft[350] to improve data collection. Barriers still to be overcome include automated processing of the digital images and Federal Aviation Administration (FAA) approval to fly beyond line of sight distances. Other needed improvements include improved coordination between manned and unmanned aircraft and improved capacities for UAS to operate under Arctic conditions (e.g., to deploy sensors to detect icing conditions). Data transmission technologies and rates are also challenging in this environment, where more broadly available technologies (satellites and GSM cellphones) are limited in the Arctic.

In order to operate safely in the Arctic, ice will need to be managed to avoid damage to drilling and production platforms or facilities. Scouting for ice and managing ice in low visibility conditions risks unexpected encounters with walrus hauled out on ice floes. Technologies such as thermal imaging are needed in order to be able to detect animals on ice when visibility is low. Some systems are commercially available currently;[351] however, the inability to detect animals in fog and mist conditions must be overcome in order for these systems to be useful in the broader Arctic OCS.

Theme 3: Ecological Fate and Effects of Energy-Related Discharges in the Arctic

Description of the Theme

The nature of oil and gas exploration and appraisal (E&A) activities is different from development and production (D&P) operations in the Arctic when potential discharges to the environment are considered. E&A discharges are predominantly intermittent, from drilling platforms and their associated support vessels. This compares with fixed floating or anchored facilities for D&P operations where discharges in temperate regions may be more or less continuous as water is produced from the reservoir formation along with hydrocarbons. To date, however, produced waters are not discharged in Arctic D&P operations. The chemical and physical characterization of all discharges and their environmental fate is well understood from past studies globally and also for Arctic operations.[352] Current discharges and discharge practices cause little or no disturbance to the marine environment if performed in compliance with regulatory requirements.

Discharges from oil and gas exploration facilities in the Arctic OCS are regulated by the U.S. EPA under the National Pollution Discharge Elimination System program (NPDES).[353,354] Thirteen waste streams are authorized for discharge including water-based drilling fluids and drill cuttings, once through cooling water, and discharge of muds, cuttings, and cement at the seafloor. Any component that would cause acute toxicity is prohibited, including diesel oil, free oil, or chromates. Oil-based drilling muds are prohibited from discharge as are discharges onto stable ice.

Assessment of the fate and effects of drilling discharges has shown that water column impacts are transient and limited in spatial extent. Any longer-term fate or effects will be at the seafloor, where the cuttings and any associated drilling muds settle around the drill site. The spatial extent of any such settled cuttings and muds is dependent on the oceanographic conditions in the area. Typically though, these effects are limited to within hundreds of meters of the well site, and depending on the drilling mud type, usually the duration of measurable effect on the environment is measured in years, not decades.[355]

Geotechnical assessments of the seafloor prior to selecting a drill site also can identify environmentally sensitive habitats. Assessment and planning using this information can lead to alternative well sites being identified, which may have a lessened impact on the general ecology of the area.

Relevance to Exploration and Development in the Arctic

More than 50 exploratory wells were drilled in the state and federal waters of the Beaufort and Chukchi Seas between 1981 and 2002. There have been many reviews of existing information on the ecological effects of discharges of drilling muds and cuttings[356,357,358] and tools and data exist to evaluate the potential effects on the receiving environment. Evaluation of the effects on the environment for historical discharge sites in the Arctic OCS has been studied with data available to assess the impacts and recovery of areas.[359] Nonetheless, stakeholder concerns regarding the fate and effects of drilling muds and drill cuttings has led to voluntary zero discharge commitments in the Beaufort Sea and requirements by the federal government for continued study and evaluations.

As part of the NPDES authorization to discharge, the permit holder must develop and implement an environmental monitoring program plan of study (see text box detailing NPDES requirements for an environmental monitoring program) for each well drilled, to demonstrate that offshore exploration drilling discharges will not result in an unreasonable impact on the marine environment. Current permit requirements consist of design and implementation of a four-phase study intended to characterize predrilling site conditions, effects of discharge plumes on physical and chemical composition of the receiving water, initial disturbance of the seafloor sediments, and finally, assessment of recovery from disturbance conditions. These requirements present to the permit applicant a technically complex and logistically challenging study program that must be performed for each well drilled. To achieve the minimum objectives of the study, a drilling program will need to include at least one additional vessel dedicated to implementing the field program.

Currently there is no authorization for development and production discharges, and authorization for discharges related to geotechnical investigation activities is currently under consideration in a proposed permit.[360] It is important to consider the overall life cycle analysis of potential discharges to the environment when planning for E&A activities is being undertaken. In many locations and environments, suitable waste management facilities onshore are not available, and consideration must be given for all waste disposition alternatives. Key stakeholder engagement in assessing this issue and alternative waste management strategies is essential to ensure that the best environmental alternative is identified.

Current Knowledge and State of the Science

Of the 13 waste streams authorized for discharge in the U.S. Arctic OCS, the greatest quantities of discharges relate to drilling muds and drill-cuttings. Drilling muds can vary from water-based gel sweeps, to water-based muds, to synthetic-based drilling muds. They are used at various stages in the drilling process, depending on the geological conditions, the risks to the environment, and the drilling equipment capabilities. Well control is the key driver for drilling mud composition, and is discussed in Chapter 4. Drilling muds are used to remove the rock chips from the wellbore while drilling and keep an overbalanced pressure on the geological structure. These rock chips are predominantly non-hydrocarbon bearing rock, and when separated from the drilling mud on the drilling platform, they have some remaining drilling mud adhered to them. These rock chips and remaining adhered mud are then typically discharged to the sea during the exploration and appraisal phase due to their non-hazardous nature.

Various simulation models and tools are available to assess these discharges. Simulation of the processes

NPDES Requirements for an Environmental Monitoring Program at Each Drill Site for the U.S. Beaufort and Chukchi Seas

Prior to Drilling-Site Characterization

- Physical characteristics: surface wind speed and direction, current speed and direction, water temperature, salinity, depth, and turbidity
- Receiving water chemistry and characteristics: dissolved metals, pH, turbidity, total suspended solids, total aqueous hydrocarbons, and total aromatic hydrocarbons
- Benthic community structure: infaunal and epifaunal invertebrates, bivalves, and crustaceans

During Drilling Activity

- Effluent toxicity characterization of discharges
- Metals analysis of water-based drilling fluids and drill-cuttings
- Plume monitoring and observations for potential marine mammal deflection during periods of discharge
- Plume monitoring and sampling for metals, hydrocarbons, turbidity, and total suspended solids

Upon Completion of Drilling Activity

- Physical sea bottom survey: areal extent and depth or thickness of solids deposition of muds and cuttings discharges
- Sediment characteristics and discharge effects: chemistry, grain size, pollutant concentrations
- Benthic community bioaccumulation monitoring

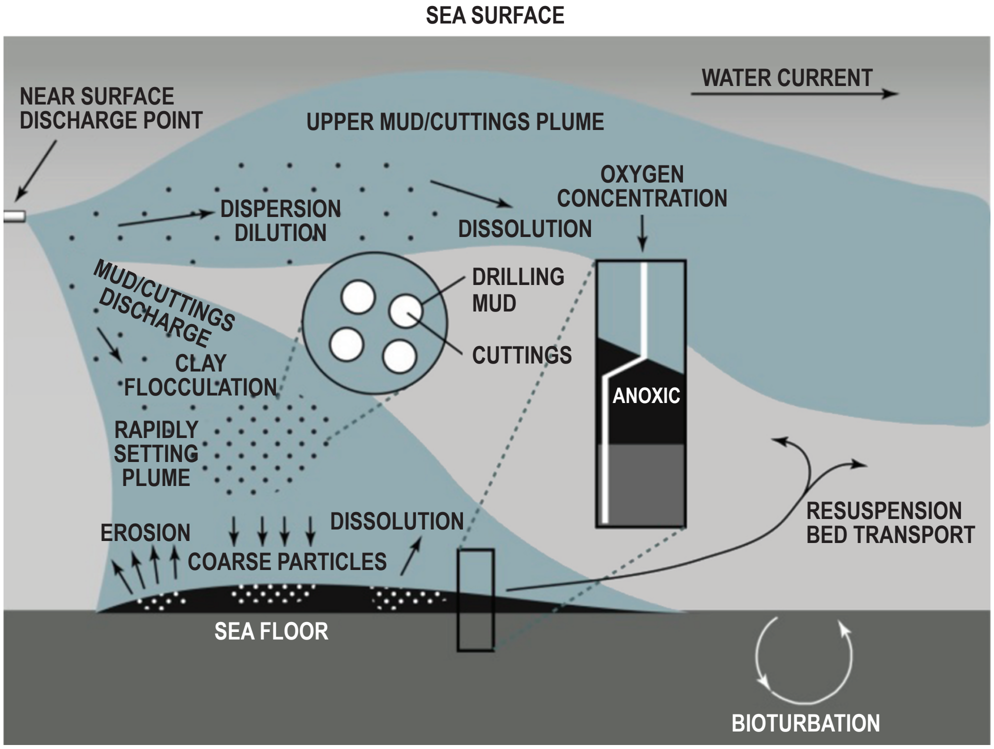
No Later than 15 Months after Completion of Drilling Activity

- Physical sea bottom survey: areal extent and depth or thickness of solids deposition of muds and cuttings discharges
- Sediment characteristics and discharge effects: chemistry, grain size, pollutant concentrations
- Benthic community bioaccumulation monitoring
- Benthic community structure assessment

of discharge patterns and volumes of drill cuttings and muds and their fate in the environment can be made.[361] These models are used to provide the assessment basis for environmental impacts, along with the chemical and physical characterization of the discharge materials. Assessment of seafloor sediments for impacts can be evaluated by remotely operated vehicles (ROVs), sediment profile imaging equipment, and standardized benthic, physical-chemical, and biological sampling, with subsequent laboratory analyses.

When discharged to the ocean, water-based drilling muds and drill cuttings, which are slurries of particles of different sizes and densities containing dissolved inorganic salts and low levels of organic chemicals, form a plume that dilutes rapidly as it drifts away from the discharge point with the prevailing water currents. The water-based drilling fluids and drill cuttings undergo dispersion, dilution, dissolution, flocculation and settling through the water column. Most dissolved components, such as sodium chloride, continue to dilute rapidly by turbulent mixing (eddy diffusion) in the receiving waters. The water-based drilling fluids and drill-cuttings plumes will partition into two phases: (1) a dense, rapidly-settling particulate solids phase and (2) an upper-water-column, slowly-settling phase containing fine-grained (clay-size) particles and dissolved materials (see Figure 9-16).[362] Water-based drilling fluid and drill-cuttings particles may accumulate at a water depth where the density of the water and particles are equivalent.

Ecological effects of drilling muds and cuttings, when detected, are caused predominantly by physical disturbance of the water column and the seafloor benthic communities. High suspended particle concentrations may locally clog gills or digestive tracts of zooplankton or benthic filter feeders. Accumulation of discharged muds and cuttings on the seafloor may bury immobile benthic organisms. Changes to sediment grain size and texture can render the sediment more or less suitable for certain benthic species. Rate of recovery of the benthic communities depends on the thickness of the cuttings layer and the nature



Note: The water-based drilling fluid often forms two plumes, an upper plume containing fine-grained unflocculated (unclumped) solids and dissolved components of the fluid, and a lower, rapidly settling plume containing dense, larger-grained particles, including cuttings and flocculated clay/barite particles. The enlarged circle in the figure demonstrates that drilling fluids (termed "mud" in the figure) coat the cuttings particles. The enlarged rectangle in the figure depicts the reduction in oxygen concentration if sediments become anoxic as a result of discharge deposition.

Source: After Neff 2010.[352]

Figure 9-16. *Dispersion and Fates of Water-Based Drilling Fluids and Drill Cuttings following Discharge to the Ocean*

of the affected communities, but is generally rapid (i.e., within 1 to 2 years).[363,364]

One area of research focus for the oceans more broadly is the potential for ocean acidification and the consequences for further water quality change. This is an element that should be considered in the planning and assessment of the potential discharges to the marine environment from oil and gas development.

Planned Research or Investigation

Integrated and spatially extensive sampling and analysis of the Chukchi Sea, and to a lesser extent the Beaufort Sea, is available to understand site characterization and long-term ecological trends and to assess what potential impacts, if any, discharges from oil and gas exploration activities will have on the Arctic marine ecosystem.

Data in the past 5 years for the northeastern Chukchi Sea have been collected by two large, multi-year baseline studies. The Chukchi Sea Offshore Monitoring in Drilling Area (COMIDA)[365] program is a comprehensive program funded by the BOEM that is designed to establish an integrated knowledge of the Arctic marine ecosystem within the northeastern Chukchi Sea, and specifically within the planning area designated for oil and gas exploration and development. The sampling cruise reports, principal investigators' presentations, seafloor video footage, data models, links to data archive sites, and the May 2012 Final Report are all included on the program's website at http://arcticstudies.org/comidacab.

The Chukchi Sea Environmental Studies Program (CSESP), begun in 2008, is a multi-year, multidiscipline marine science research program in the northeastern Chukchi Sea. The overall purpose of the program is to provide the oil and gas industry partners with the necessary baseline site characterization data that can be used to conduct evaluations on the potential impacts of oil and gas activities. Importantly, it also contributes to the overall knowledge of the northeastern Chukchi Sea marine ecosystem. The studies program has included various scientific disciplines over time, including physical oceanography, chemical oceanography, plankton ecology, benthic ecology (infaunal and epibenthic communities), seabird ecology, marine mammal ecology, pelagic and demersal fisheries, and bioacoustics. Details about the studies and the investigators as well as maps, presentations, and final reports are available through the program website at www.chukchiscience.com.

Three additional study programs are in the planning stage. The Marine Arctic Ecosystem Study (MARES)[366] is an integrated ecosystem research initiative managed by the BOEM with support from nine other federal and private partners. The purpose of MARES is to investigate the integration of physical, biological, chemical and social science aspects of the Beaufort Sea ecosystem from Barrow, Alaska, to the Mackenzie River delta in Canadian waters. NOAA is in the process of establishing biodiversity observation networks[367] for ocean, coastal and Great Lakes ecosystems, including the Arctic Ocean. The North Pacific Research Board has formalized its intention to commit funding toward the development of an integrated Arctic research program.[368]

Enhanced collaboration between the oil and gas industry with pan-Arctic, regional- and site-specific environmental studies being planned or undertaken, as discussed above, by the broad range of stakeholders and agencies is essential. Research plans reviewed for this NPC study have identified a broad range of potential collaborations, as well as key data being collected, all of which can be utilized to assess the fate and effects of discharges to the Arctic environment. Specific opportunities for collaboration and integration are identified in the recommendations at the end of this chapter.

Reduced lag time between data collection and delivery of data products and analyses to end users is important for responding to changes via improved mitigations if required. More automated, digital techniques would expedite assessments. Access to broader spatial scale data for existing or past conditions in the area will assist in improving impact assessment and mitigations. Improved ecological characterization through broader scale techniques (remote sensing, digital mapping, and ecosystem modeling) may identify alternative strategies for environmental management (e.g., waste discharge) if warranted.

Theme 4: Interactions Between Ice-Dependent Species and Oil and Gas Exploration and Development Activities

Description of the Theme

Among the unique fauna of the Arctic, there are several species that regularly interact with, and in some cases depend on, sea ice during all or part of their life histories. The spatial and temporal variability in sea ice cover and other aspects of the environment drive large-scale movements of many of the marine mammal species that inhabit the Arctic. These movements lead to wide seasonal variation in habitat use and marine mammal abundance in particular areas, and to a large degree determine the timing and success of subsistence hunts of these resources by Alaska Natives in the area.[369] For example, the location of the bowhead whale fall migration corridor has been shown to be influenced by the amount of ice that is present in the Beaufort Sea,[370] which in turn can affect the subsistence hunt. Associations with ice include the use of ice by pinnipeds (finned semi-aquatic creatures such as walrus, sea lions, and seals) and polar bears for denning, pupping, and rearing of young; use of ice as a platform for resting between foraging forays or during molt; use of ice as a refuge from competition and predation; and use of ice as a platform for hunting. In some cases, such as the polar bear, ice is a common habitat component for all phases of life history. For other species, obligate ice dependence (i.e., reliance on sea ice platforms) is seasonal.

The patterns of character, abundance, and temporal and spatial availability of ice are changing in the Arctic. Many of these changing patterns are most pronounced in areas where the ice sheets occur seasonally over highly productive areas of continental shelf and in nearshore areas. Although ice still covers, and is projected to cover, these areas for much of the year in the Arctic, variability around the norm is projected to increase as is the annual duration of open water. These factors have the potential to reduce habitat availability or suitability, and to increase concentration of species in decreasing areas of suitability during critical life history periods. Recent data indicate that abundance of ice seals and walruses increases as proximity to ice increases in at least some areas.[371]

Given that ice habitat could become more limited during key parts of the year when exploration and development activities may be focused, it is important to understand the interactions between these ice-dependent species and industry operations. Based upon this understanding, appropriate mitigation measures are established and can be enhanced, such that resources are appropriately protected and exploration and development activities are accommodated.

Relevance to Exploration and Development in the Arctic

Exploration and development in the Arctic occur in the vicinity of ice and, in some cases, require operations within ice habitats. It has been demonstrated through a combination of science and traditional knowledge that some species, namely walruses and bowhead and beluga whales, demonstrate avoidance behavior, changing their distribution and area use patterns in the presence of industry activities.

Ice-associated marine mammals are protected resources under the MMPA and may be protected under the ESA. Within the past 5 years the polar bear and ringed seal have been listed as threatened, the bearded seal was listed as threatened (pending resolution in the courts), and the Pacific walrus was designated as a candidate for listing as threatened or endangered. All of these listing proposals were based in large part upon the decline of ice habitat.

The permitting of exploration and development activities requires evaluation of the potential impacts on these species. In some cases, permits and authorizations may require monitoring programs and prescribed mitigation measures, which may include time-area closures that constrain industry operations, thereby affecting the feasibility of exploration or development.

The subsistence hunting communities of the U.S. Arctic are key stakeholders in the exploration and development of energy resources. In the case of marine mammals, the integrity of subsistence hunting is protected under the MMPA. Some of these hunts occur on ice or in close proximity to ice. As such, the potential for behavioral reactions of these species may influence hunting success.

Current Knowledge on the Theme

Some Arctic marine mammals are known to avoid seismic activities under some circumstances,[372,373,374] while there may be less avoidance of such sounds by some pinniped species.[375,376] Individual marine mammals appear to respond differently to sound stimuli depending on their activities.[377] With respect to ice interactions, the majority of demonstrated impacts have been related to the processes of icebreaking, or ice management during transit and support of exploratory drilling. Walruses have been shown to alter distribution patterns and behavior in the presence of aircraft and vessels around a drilling operation. Disturbed walruses hauled out on ice abandon the ice when an icebreaking ship is within ½ to 1 kilometer.[378] LGL documented similar responses by walruses to vessels operating in ice at a distance of ½ to 1 kilometer in the Chukchi Sea.[379] Beluga whales and narwhals have also been shown to react to the sound of icebreakers.[380] Interactions between ice dependent species and production infrastructure and operations are less well investigated due to the limited offshore presence of the infrastructure. Studies of seal distribution and behavior during ice covered periods indicate that seals are tolerant of many activities.[381]

The USGS has conducted extensive investigation of walrus habitat use in the Chukchi Sea.[382] As ice melts during the open water season, walrus distribution becomes increasingly focused on the shallow area of Hanna Shoal where topography and oceanographic conditions result in high benthic biomass and persistent ice that are favorable to walruses. On the basis of this knowledge the USFWS designated the Hanna Shoal Walrus Use Area[383] and works closely with project proponents to establish mitigation measures for operations in this area.

Planned Research or Investigation

Several studies are examining habitat use patterns and life histories of ice-dependent species. USGS and USFWS operate extensive research programs on polar bears and Pacific walruses as a part of their Changing Arctic Ecosystems program.[384] The ASAMM, ARCWEST (Arctic Whale Ecology Study), and CHAOZ programs that are conducted by NOAA and funded by BOEM examine the distribution and abundance, habitat use, and feeding ecology of cetaceans in the Beaufort and Chukchi Seas. NOAA also conducts research on the abundance and ecology of ice-associated seals in the Chukchi and Beaufort Seas. Quakenbush et al. have been tracking bowhead whales since 2006 and evaluating their movement patterns in relation to areas of industry interest and activity.[385] Projects operated by the North Slope Borough Department of Wildlife and Northwest Arctic Borough are tracking ice seals in the Chukchi and Beaufort Seas.

Theme 5: Population and Habitat Changes of Biological Resources

Description of the Theme

The physical changes that are occurring in the Arctic are well documented[386] and are expected to result in a range of related changes for the different populations and their habitats.[387,388,389]

Relevance to Exploration and Development in the Arctic

Data about existing populations and habitat conditions are critical elements in the establishment of regulatory policies—e.g., determination of species candidacy for protected status and the determination of critical habitat under ESA or MMPA. The requirement for impact avoidance and mitigation measures may be based on information about resource presence and potential response to actions.

The monitoring of ecological change that may result from project actions can only be successful if it is based upon a rigorous assessment of conditions that exist prior to activities. If there is too much uncertainty about pre-existing conditions, the ability of a monitoring program to detect and identify the reasons for change may be extremely limited. Though it is not monitoring in the traditional sense, the ability to detect changes in resource status is a critical requirement for the assessment of resource damages in the case of an accidental release.

Current Knowledge on the Theme

Information about existing conditions within the Arctic is available from the many studies that have been conducted in the past. There is generally good understanding of the species present and their life histories and broad patterns of distribution, movement, population status, and sensitivity.[390,391,392] Recent studies programs, including CSESP,[393] COMIDA-CAB,[394] AKMAP,[395] ASAMM,[396] AEIS,[397] Transboundary,[398] and CHAOZ,[399] have significantly advanced the understanding of existing conditions within the OCS and nearshore areas of energy prospectivity. Key areas of uncertainty do, however, exist. While population estimates for bowhead whales are very good, other species of marine mammals are less well understood. Existing stock assessments[400] for many species include broad ranges for population estimates. These estimates contain considerable uncertainty, however, and many are outdated. In some cases where there are accurate abundance estimates, it is not clear which stocks or populations are utilizing the Arctic. This is the case for the sub-Arctic marine mammal species (e.g., fin, humpback, killer, and minke whales) that are occurring more regularly in the Northern Chukchi Sea. It is also true of the Eastern Chukchi Sea and Beaufort stocks of beluga whales in certain areas at certain times of the year. For fishes, the abundance, distribution, and community composition of some fishes, especially nearshore fishes in the Beaufort Sea, are reasonably well known, while others, especially those in deeper offshore waters, are not well understood.

Planned Research or Investigation

Of the baseline studies programs listed previously, the CSESP, ASAMM, and CHAOZ programs are continuing during 2015. One of the main industry funded programs, CSESP, is operating for the eighth year in the Chukchi Sea. Among the many components of this study, CSESP continues to deploy and operate extensive arrays of acoustic recorders in both the Chukchi and Beaufort Seas that provide valuable information on the distribution and movement of marine mammals and on the levels of ambient and anthropogenic sound in these environments. The BOEM Environmental Studies Program is funding a number of ongoing and new habitat and ecology projects[401] that include studies focused on fishes, birds, marine mammals, ecosystems, physical oceanography, and marine chemistry. A number of these studies are being carried out in collaboration with other state and federal agencies including USGS, NOAA, USFWS, and ADF&G. Oil companies, including BP and ConocoPhillips, that have been operating in the onshore and nearshore environments have invested significantly in long-term monitoring programs.

The NSB Department of Wildlife continues to conduct a variety of baseline studies including bowhead whale censuses, caribou, and bird studies. Collaborations between Shell and the NSB and Northwest

Arctic Borough are funding community-based baseline studies program in both areas, including a variety of assessments of existing conditions such as ice seal tagging, ice and open water drifter buoys, and assessments of the anatomy, physiology, and contaminant levels in bowhead and beluga whales.

Theme 6: Range and Efficacy of Mitigation Measures

Description of the Theme

Environmentally sound oil and gas exploration and development requires understanding the range and efficacy of various mitigation measures that might be required during operations. Well-designed mitigation prevents unnecessary harm to organisms, and limits habitat disturbance in areas where operations are occurring. Some mitigation efforts are expensive for operators to implement because they require work stoppage or significant delays (seasons or years) that affect project schedules, besides the monitoring required to assess whether impact mitigation was successful.

Avoidance of organisms in time and space is probably the most effective mitigation, and has been a key part of the strategies employed during exploration and development of oil and gas operations on the North Slope of Alaska. Shifting noisy or otherwise disruptive activities like construction to periods of the year when the fewest organisms will be affected makes practical sense for many operations. For example, operating during the winter when most animals have migrated from the area or are in hibernation or torpor has been effective for many operations. Similarly, siting of pipeline and travel routes to avoid sensitive areas has been generally effective in limiting or eliminating impacts. Since many of these mitigations can be determined ahead of time, they also generally do not result in work stoppage.

Many operations, however, occur during periods or in places where mitigation other than avoidance is needed. These types of mitigation often limit impacts by reducing exposure levels. For example, it may be possible to decrease sound entering the water from ships, drill rigs, or seismic air guns using sound-insulating materials placed around noise-generating equipment. Similarly, air gun array geometry can be tuned to focus sound downward and into the earth, thus reducing lateral propagation of broadband sounds spreading away from the source. Similarly, discharges from drill rigs limit impacts by cooling water to near ambient conditions, using environmentally acceptable muds, and maintaining levels of discharge that will reach background concentrations over relatively short distances from the point of release. The most drastic form of this type of mitigation is a shut down of operations to avoid exposure of organisms or the environment to levels of sound or contaminants greater than regulatory thresholds. An example is the shutdown of air guns during seismic operations if animals subject to MMPA permitting enter exclusion zones around an air gun array, to avoid exposing them to potentially harmful sound levels.

Lastly, adaptive management strategies are important in allowing operators to work with regulators to implement mitigation when it is needed on a case-by-case basis. Adaptive strategies can be used to replace rigid restrictions that may not be relevant to all scenarios or are likely to result in a decrease in impacts on organisms or the environment. Examples of adaptive management include moving ships to a new location, away from areas where animals may be concentrated, prior to conducting personnel transfer operations by helicopter. Also, use of an adaptive management plan for managing ice floes that have the potential to have walruses present has been effective in limiting the take of walruses in the Chukchi Sea. Additionally, Conflict Avoidance Agreements (CAAs) have been an effective adaptive management tool. Negotiations with the Alaska Eskimo Whaling Commission have allowed industry to conduct a full range of exploration activities before and after the fall bowhead whale hunt while limiting some operations during the hunt to avoid interfering with the animals (subsistence hunts). There have been no known conflicts between industry and bowhead subsistence users in the Alaskan Arctic since the adoption of CAA measures in 2010.

Relevance to Exploration and Development in the Arctic

The efficacy of mitigation affects both oil and gas operations as well as regulators in a number of ways. In particular, the evaluation of potential impacts is important in understanding the level of mitigation that is required. Most mitigation measures err on the side of caution and provide greater protection for organisms and the environment than typically has been demonstrated as necessary to avoid impacts at a specific level. For instance, in most cases, received sound levels where mitigation is required for marine mammals are at distances that are deemed safe for all species and are not implemented with regard to species-specific criteria.

Permit requirements need to be robust yet straightforward for the greatest efficacy in implementing them. Elaborate regulatory criteria require equally elaborate training for people implementing the mitigation, may limit the number of people qualified to implement such actions, and could result in erroneous implementation in some cases. Requirements should be written to allow applicability in the greatest number of situations possible, yet must still have enough flexibility to recognize the unique nature of each operation and not subject any to unnecessary or ineffective requirements or implementation.

Permit requirements and mitigation often require engineering, design, and planning with long lead times. It is important that ample time is available between receiving a permit and the start of operations to allow for compliance with or adjustments to these requirements. This is particularly critical in the Arctic when operating windows may be short because of weather and darkness. To the extent possible, the design of mitigation measures and their implementation via permit regulations should seek to minimize shut down of operations, which is costly and in most cases prolongs the potential for impacts from such operations.

Current Knowledge on the Theme

Mitigation measures for anthropogenic sound, as prescribed by National Marine Fisheries Service (NMFS), are based on sound criteria for cetaceans and pinnipeds that were established in a precautionary manner to ensure protection of all species until more specific data were available to support refinement of these measures.[402,403] Under current NMFS guidelines, "exclusion zones" designed to prevent auditory injury to marine mammals around air gun arrays and other sound sources are customarily defined as the distances within which received sound levels are ≥180 decibels (dB) re 1 µPa (rms) for cetaceans and ≥190 dB re 1 µPa (rms) for pinnipeds. Disturbance to marine mammals could occur at distances beyond exclusion zones if the mammals were exposed to moderately strong pulsed sounds generated by the air guns, or perhaps by vessel or other continuous sounds.[404] NMFS currently assumes that marine mammals exposed to pulsed air gun sounds with received levels ≥160 dB re 1 µPa (rms) or continuous sounds with received levels ≥120 dB re 1 µPa (rms) are likely to be disturbed.

The current NMFS sound criteria have a wide margin of safety and are believed to be well below the sound levels where exposure would have even temporary effects on hearing, let alone cause any permanent damage. As more species-specific data have become available, NMFS has begun to refine the allowable exposure thresholds, which could actually reduce the burden on industry, but as they currently stand, the established criteria provide a margin of safety for all marine mammal species.

Lastly, it should be emphasized that industry often has taken a very conservative approach to mitigating potential effects of anthropogenic noise on marine mammals. One example of this occurred during Shell's 2008 seismic acquisition program in Camden Bay, Beaufort Sea, when aerial surveys revealed small groups of feeding bowhead whales within the 160 dB re 1 µPa (rms) disturbance zone. Although there were fewer whales than specified in the Incidental Harassment Authorization requirement to implement mitigation, Shell relocated operations to an adjacent area with fewer feeding whales. Operations did not resume in the preferred seismic survey location until a subsequent aerial survey confirmed that the main concentration of feeding whales had departed the localized area and the 160 dB re 1 µPa (rms) disturbance zone.

Planned Research or Investigation

Concern for potential impacts on marine mammals from anthropogenic sound has resulted in a significant body of scientific knowledge (reviewed in Richardson et al.;[405] Southall et al.;[406] NMFS;[407] and reported by the IOGP Sound and Marine Life JIP, see earlier text box on the IOGP Sound and Marine Life JIP). Information presented in these reviews demonstrates how much attention this topic has had and continues to receive. As a result, substantial progress has been made to characterize the properties of underwater anthropogenic sound, design and implement appropriate mitigation measures that are protective, and identify further opportunities for ongoing research. Industry is working extensively along with government to identify response thresholds that would be valuable for refining sound and mitigation criteria and to answer other questions of importance to understanding the effects of sound on marine life. These efforts include industry sponsored monitoring and mitigation programs (IOGP Sound and Marine Life JIP) as well as workshops planned by NOAA/NMFS to establish consensus on what constitutes successful monitoring and mitigation, and how it can be achieved.

Theme 7: Methods for Assessing and Forecasting Cumulative Impacts and Risks

Description of the Theme

Potential effects of anthropogenic activities in the offshore environment typically have been assessed on the basis of the individual stressors. NEPA requires that the cumulative impact of a range of potential activities be considered in the environmental assessment. Oil and gas exploration and appraisal activities will be undertaken in the offshore Arctic in areas allocated as license blocks. There are often adjacent blocks for different operators, and exploration activities are undertaken at different time frames for different areas.

Initial environmental and socioeconomic impact assessment of a region of the offshore U.S. Arctic is undertaken by the appropriate regulatory authority prior to a lease sale of the acreage for exploration. This typically is done by considering various exploration and development scenarios based on the regulatory agencies' forecasts or predictions.

Exploration typically comprises geophysical and geotechnical data collection, followed by exploration and appraisal drilling once prospective leads have been identified. The timescales for these activities are discussed in the prudent development sections.

In addition to the potential oil and gas exploration and development activities, there are many other anthropogenic and natural processes going on in the environment. Subsistence hunting by native communities, coastal settlement and development activities, tourism, other natural resource assessment and exploitation, coastal protection activities, defense infrastructure and activities, coastal and trans-Arctic shipping, icebreaking for scientific and operational needs (community resupply), along with climate change, species migrations and invasions/range extension, landform changes, etc., can all be occurring in the same spatial and temporal scales.

Interaction of any or all of the above activities or changes can lead to broader scale changes or synergistic or antagonistic effects. Assessment of such arrays of activities can be very complex, with little in the way of empirical methods available to aid such analysis. Modeling to allow assessment of the cumulative impacts or risks is critical in order to assess the level of the impacts and to determine appropriate mitigation and management strategies for the risks.

Chronic, acute, sublethal, and stress impacts can all be induced or triggered by changes (natural or anthropogenic) in the environment. Anthropogenic underwater sounds have also been suggested as having potential cumulative impacts on marine mammals and are usually assessed on the basis of exposure to one sound source. However, marine mammals receive sounds from multiple dynamic sources that may interact.

How these relate to development assessment and planning is critical to maintaining an environment that is sustainable for future use and resource needs of the communities, state, and the nation. All stakeholders must play an important role in managing the various interests in this activity.

Relevance to Exploration and Development in the Arctic

Exploration and development of oil and gas opportunities requires assessment of environmental risk and impact, and with potential for multiple exploration and development activities in a region, cumulative impact and risk assessment is required in advancing the permitting of such activities. It can be expected that sequential and coincident activities will provide multiple stressors to a changing Arctic environment, and will require mitigation and management strategies commensurate with the assessed risks and potential impacts. Oil and gas proponents will need to apply methodologies that allow for such cumulative impact assessments. Currently, there are few methodologies that allow rigorous or quantitative assessments.

Developing cumulative effects assessments will improve our understanding of which anthropogenic activities should be monitored and managed in the Arctic. This will allow for more effective monitoring in a changing environment.

Planned Research or Investigation

The North Slope Science Initiative (NSSI) is currently undertaking a study using a "development scenario basis" to assess potential needs for future research. This approach is looking at a broad range of anthropogenic activities that are being executed or planned by various Arctic stakeholders. The interaction of these scenarios will be complex and will require new methodologies to allow for a full assessment and to identify appropriate management strategies to support sustainable development in the broader U.S. Arctic.

Oil and gas industry exploration and development proponents have an opportunity to draw on this work and contribute to the broader management regime for the Alaskan Arctic, both onshore and offshore, as prudent development of oil and gas progresses.

Theme 8: Ecosystem Characteristics During Winter Periods

Description of the Theme

The period of winter conditions—i.e., subfreezing temperatures, snow, and ice cover of terrestrial and marine ecosystems, and extended periods of darkness—represents a large portion of the Arctic year. Although this was long thought to be a dormant period for the ecological systems present, recent studies indicate that there are a number of physical and biological processes that occur during this time that maintain productivity and strongly influence ecosystem function throughout the year. Though these periods of strong cold influence are likely to remain the norm in the Arctic, shortening of these periods has the potential to dampen the influence of winter conditions on the system. While some processes slow during the Arctic winter, biota in both terrestrial and marine systems maintain productivity and activity, and some processes even accelerate in winter.[408,409,410]

While the Arctic has generally been less well studied than some more temperate areas, because of the difficulty of access and harsh conditions, the winter is the least well investigated period. In the marine setting, traditional vessel-based oceanographic observing methods require special icebreaking capabilities, vessel freeze-in, or operation in remote areas from the ice surface. All these barriers present their own challenges for safety, health, and the environment.

Relevance to Exploration and Development in the Arctic

Although most Chukchi Sea exploration activity is currently conducted during the relatively short periods of open water, there is still a significant amount of activity in the other seasons, including winter. For example, cost considerations often drive exploration activity into the shoulder seasons that overlap with winter ecological conditions. Furthermore, some exploration in the shallow water of the Beaufort Sea and on land occurs in the winter. When oil or gas are discovered, development and production activities function year-round with operating infrastructure, and supporting operations such as re-supply and construction also occur throughout the year. Understanding the implications of year-round activity, especially in the marine environment, is important to an overall understanding of the potential impacts of exploration and development and accurate development of assessment and permitting documents.

In addition to the general impacts of exploration and development activities, questions about the potential impacts of an oil spill that could occur during winter seasons and the effects on the flora and fauna of the winter ecosystem are a subject of conjecture. Assessing the potential impacts of a winter oil spill is a necessary component of impact assessments related to permitting of both exploration and development activities.

Current Knowledge on the Theme

Primary production occurs during the Arctic winter in both terrestrial and marine ecosystems.[411,412,413] In some cases, epontic algal communities (growing on the underside of the ice) are responsible for 74% of pelagic productivity sustaining populations of benthos and pelagic zooplankton, which in turn support fishes and higher tropic organisms.[414,415,416] Resident populations of ice seals occur in the Arctic throughout the winter and spring and utilize under-ice habitat for foraging and ice habitat for denning, pupping, and rearing young. Polar bears forage on ice and, in the case of pregnant females, den on ice as well as onshore during the winter and spring.

Recent investigations utilizing satellite telemetry[417] and acoustic deployments[418] indicate that bowhead whales use areas that are ice dominated through much of the winter. Polynyas (open water areas surrounded by pack ice) are particularly important areas of upwelling and productivity during winter and spring.[419]

Planned Research or Investigation

The development and expanded application of remote sensing technologies and instrumentation to be deployed on under-ice oceanographic moorings have greatly enhanced capacities to investigate both marine and terrestrial conditions and biological activity in ice and snow dominated environments. Through the CSESP, industry continues to fund acoustic and oceanographic studies in the subnivian environment (i.e., under the snow pack). The NSF maintains an Arctic Long Term Ecological Research site at Toolik Lake where long-term trends and ecological processes are investigated.

Theme 9: Habitat Restoration and Rehabilitation

Description of the Theme

Oil and gas lease stipulations as well as federal regulations (Section 404 of the Clean Water Act) require rehabilitation or restoration when infrastructure is decommissioned. The Natural Resource Damage Assessment (NRDA) process as well as other regulations can also require restoration following events that damage natural ecosystems, such as oil spills and ship groundings.

Return of a damaged or affected site to a functional habitat for plants and animals without restoring the original species and processes is usually considered to be "rehabilitation," while re-establishment of habitat features, species, and processes that were present prior to disturbance is usually considered to be "restoration." In practical terms, the lines between rehabilitation and restoration are often blurred, but in general Arctic projects should be thought of in terms of rehabilitation, reflecting conditions that render a return to the originally occurring species and processes difficult or impossible in meaningful time frames. While most North Slope projects are focused on rehabilitation over time spans of 10 years and longer, many may eventually evolve into restoration projects (over many decades) as plant communities, ground ice conditions, and other site characteristics mature.

Relevance to Exploration and Development in the Arctic

Although various legal mechanisms require eventual rehabilitation, infrastructure intended for decades of service is often designed without serious consideration of decommissioning. In recent years, however, there has been increased interest in "cradle-to-grave" designs. Also, as rehabilitation projects become more common and more visible in the existing North Slope oil fields, recognition of the need to plan for eventual large-scale rehabilitation grows. Two federal government reports pointed out the need for improved rehabilitation planning, noting that the costs of rehabilitation upon decommissioning may not be captured in current practices and that practical means of large-scale rehabilitation are poorly understood.[420,421] North Slope oil spill response guidelines include recommendations that consider impacts of response on potential rehabilitation of vegetation communities.[422] Also, permits for Arctic projects place increasing emphasis on rehabilitation, including off-site rehabilitation as a form of mitigation, and eventual on-site rehabilitation upon decommissioning.

Current Knowledge on the Theme

More than 150 rehabilitation sites are currently managed and monitored in the existing North Slope oil fields, and hundreds of site-specific plans and monitoring reports have been submitted to agencies (see, for example, BP Rehabilitation Site database, available from BP Alaska in DVD format). These sites range in size from a fraction of a hectare to more than 20 hectares. Sites include abandoned exploration drilling pads, abandoned airstrips, oil spill sites, pipeline and cable trenches, sites damaged by vehicle travel, gravel mines, and abandoned artificial islands (see Figure 9-17).

Photo: BP.

Figure 9-17. *An Excavator Removes Gravel from an Abandoned Airstrip on Alaska's North Slope in 2002 (The site is now well-vegetated, and only species typically found in the surrounding tundra occur on the site.)*

Over the past 30 years, numerous peer-reviewed papers have described aspects of Arctic rehabilitation, including work on seeding and fertilizing, other methods of plant establishment, and rehabilitation site performance standards.[423,424,425,426] In the past 5 years, new methods have been tested, including, for example, application of tundra sod capable of establishing natural plant communities within 2 to 3 years and application of tundra mats grown in greenhouses to quickly establish dense stands of the sedge *Carex aquatilis*.

The *North Slope Plant Establishment Guidelines Table*[427] and the *North Slope Gravel Pit Performance Guidelines*[428] summarize basic rehabilitation methods. Annual in-field and in-office meetings bring together agency, academic, and private sector representatives, facilitating knowledge sharing among researchers, practitioners, and regulators involved with rehabilitation.

Planned Research or Investigation

Most planned research is integrated with trials on active rehabilitation sites. For example, improvements in sodding methods are under investigation at several North Slope sites. In addition, limited investigations of wildlife use of rehabilitation sites, especially by nesting birds, have been initiated on existing sites, as have initial pilot-level efforts to understand grazing impacts (especially goose grazing) on development of vegetation communities.

In some cases, research projects unrelated to individual sites could provide needed information. Examples include research on locating viable native species seed sources, optimal timing of seed collection, and seed harvesting techniques, all of which would benefit many future rehabilitation projects even though they cannot be justified as site-specific studies. Similarly, a clear understanding of typical plant and animal community trajectories during the first two to three decades following initialization of rehabilitation is needed, but is beyond the scope of work associated with individual sites. In almost all cases, research related to site rehabilitation in the North Slope oil fields requires 10 years or more, the minimum time typically needed for plant community development in the area. Needs such as these underscore the potential value of a programmatic rather than a site-specific approach to rehabilitation research, a reality recognized by the broader community of North Slope ecological researchers and regulators but not captured by current initiatives.[429]

Methods have progressed substantially over the past 10 years, and the need for a summary review accessible to researchers, regulators, and practitioners grows with each year of additional experience. Future needs also include efforts to scale up current methods for use on larger areas and on more sites, perhaps in part through dedicated research programs or projects, along with development of overall rehabilitation strategies for aging infrastructure and cradle-to-grave planning for new infrastructure.

Theme 10: Air Quality

Description of the Theme

Potential impacts to air quality in existing and proposed oil fields come from (1) air pollutants carried into the area from other regions, including black carbon; (2) combustion emissions primarily associated with natural gas-fired equipment used for heating and electrical power generation in the oil fields; and (3) dust from roads and gravel pads in the oil fields.

Relevance to Exploration and Development in the Arctic

The Clean Air Act requires application of "best available control technology" to limit emissions from all major stationary sources in the United States. In practical terms, permits allowing air pollutant emissions have dramatic impacts on the design of facilities. In some cases, changes to existing facilities trigger requirements for upgrades to emission control technologies.

Both onshore and offshore, regulations intended to control combustion emissions can mandate construction and operating permits that typically require significant time to obtain and that can cause project delays. In addition, compliance with regulations can present challenges, as can stakeholder concerns about air quality. In some cases compliance with air permits may place offshore vessels in areas where they have a greater potential to negatively affect marine mammals or may impede our ability to effectively respond to oil spills. A significant issue facing operators are EPA dispersion models that may overestimate the potential impacts of combustion emissions while also requiring significant data collection and lengthy negotiations with regulators. Onshore or nearshore developments using gravel pad or island construction may limit the footprint of the development to conserve use of wetlands or to lower costs while reducing the distance to the "fenceline" for dispersion modeling purposes. This leads to excessive estimates of impacts and generates what is sometimes called a "perverse incentive"—that is, an incentive generated by an environmental requirement that increases, rather than decreases, environmental impacts.

Although this assessment is focused on offshore oil and gas exploration and development, support and logistics for the offshore activity will require some onshore activities. Construction and use of such facilities will require roads, laydown yards, etc., as identified in Chapter 7 (Logistics), and community interaction on such facilities may also generate road dust. Road dust is not regulated, but its ability to affect and change plant communities close to gravel roads must be considered, especially in heavily trafficked areas such as the roads in Deadhorse, Alaska. Dust from roads can coat vegetation and change the thermal characteristics of soils (mainly by changing soil albedo, or reflectivity), triggering thaw of shallow permafrost and subsequent collapse, or thermokarst, of surface soils. Localized dust-triggered thermokarst is sometimes evident along the western edges of roads, reflecting the prevalence of summer easterly wind. Dust-triggered thermokarst can alter local hydrology, increasing ponding near roads and increasing surface flows through channels that form between previously stable tundra polygons. Impacts have led to occasional calls for improved methods of dust control.

Stakeholder concerns about greenhouse gas emissions, coupled with ongoing discussions about possible changes in greenhouse gas regulations, leads to substantial uncertainty with the potential to affect business decisions.

Current Knowledge on the Theme

Air pollutants carried into the area from other regions result in what is often called "Arctic haze." Military reconnaissance flights as early as 1949 observed reduced visibility at altitudes generally above 1,000 meters. Later research showed that Arctic haze originated as soot and sulphur dioxide emissions from industrial coal furnaces in northern Eurasia and Siberia. This is referred to as black carbon deposition in the Arctic. The U.S. EPA has summarized the current literature on black carbon and states, "Overall black carbon emissions are likely to decrease globally in the next several decades, but this trend will be dominated by emissions reductions in developed countries and may be overshadowed by emissions growth in key sectors (transportation, residential) in developing countries, depending on growth patterns. Black carbon emissions in the United States are projected to decline substantially by 2030, largely due to controls on new mobile diesel emissions." Black carbon management and control has also been identified as a priority under the upcoming U.S. chairmanship of the Arctic Council.

Nitrogen oxides (NO_X) make up the majority of combustion emissions released in the existing oil fields, followed by carbon monoxide, particulate matter, and sulphur dioxide. With exposure time and transport, most nitrogen oxides become nitrogen dioxides (NO_2) and, eventually, nitrate aerosols. Aerosols can, under the right conditions, decrease visibility. Although fallout of combustion emissions has been associated with changes in plant communities in some regions, air pollutant levels in existing and proposed Alaskan Arctic oil fields remain below levels required to affect vegetation. Studies undertaken by Cornell University's Boyce Thompson Institute for Plant Research failed to show measurable impacts to vascular and nonvascular plants, including lichens, at Prudhoe Bay locations specifically chosen because of the relatively high levels of air pollutants.[430] The same researchers exposed vegetation in the laboratory to pollutant levels far exceeding those in the field but did not report chronic or acute effects.

Dust from roads can cause early snowmelt to a distance of 100 meters, allowing early season use by returning waterfowl. During summer, road dust can decrease cover by *Sphagnum* species and other acidophilous mosses (which thrive in more acidic rain- or snow-water), can increase cover by minerotrophic moss species (which thrive in more basic, or alkaline, stream or spring water), and can eliminate soil lichens such as *Cladina* spp., *Peltigera* spp., and *Stereocaulon* spp.[431]

The amount of greenhouse gas (GHG) emissions due to combustion is low compared to other industrialized areas because most power is generated using natural gas-fired combustion turbines. GHG emissions are expected to decrease in the future as even more efficient stationary combustion turbines are installed to meet power requirements.

Planned Research or Investigation

Within the existing North Slope oil fields, operators have implemented comprehensive air quality ambient monitoring programs (see Figure 9-18) to establish baseline conditions, characterize emissions and impacts, and demonstrate Clean Air Act compliance. Support of ongoing work may be jeopardized by changes in oil field management. Efforts are underway to encourage a consortium approach to ongoing support of and possible expansion of existing monitoring programs.

A well-funded multi-year study of dust impacts on vegetation and shallow permafrost began in 2014. Early results suggest that the study, led by Professor Donald (Skip) Walker of the University of Alaska, Fairbanks, will document increased thermokarst near roads over the past 20 years.

Greenhouse gas research, including research on methods to reduce these emissions, is being actively pursued by many of the companies working in the Alaskan Arctic. While most of this research occurs outside the Arctic, results relevant to Arctic operations can be applied in some circumstances.

Theme 11: Integrating Traditional and Local Knowledge

Description of the Theme

There are a variety of definitions for traditional knowledge across the literature and field. The most common definition encompasses the historical knowledge of an area or region and the methods

Photo: BP.

Figure 9-18. *Ambient Air Monitoring Station on the North Slope (As the Arctic oil fields continue to mature, stations like this one could be maintained by a research and monitoring consortium.)*

and customs traditionally deployed to thrive within that area. This information is handed down from generation to generation. Knowledge may pertain to an indigenous group, as it is most often used, or to any long-term peoples within an area. Traditional knowledge can also include those historical adaptations made necessary by changes in physical area characteristics, or as new methods are deployed. Local knowledge, in contrast, need not have the historical depth of traditional knowledge, but is a more current set of knowledge that may be localized to an individual's lifetime.

Complementary to the scientific process, which is subdivided by specialty and may be focused on a specific timeframe, traditional knowledge is taught in a holistic and linked manner. As geographic exploration and scientific studies in the Alaskan Arctic began as early as the 18th century, learning from traditional and local knowledge has been long deemed critical for basic survival. As in other parts of the world, early Arctic expeditions would bring along local guides with this multigenerational knowledge. When initially establishing a field laboratory for Arctic science studies in the 1940s, traditional and local knowledge was applied to existing scientific techniques to optimize processes of construction, technology development and scientific data collection (Figure 9-19).

Relevance to Exploration and Development in the Arctic

The history of peoples of the Arctic and their ability to both pass down traditional knowledge from the earliest years of life and to deploy that knowledge to survive the historically harsh and extreme Arctic environment is acknowledged and discussed by the oil and gas industry and agencies alike (Figure 9-20). In the permitting processes, stakeholder consultation or engagement effort is certainly encouraged, recognizing the potential value to decision-making during development.

Specific areas of relevance for traditional knowledge include insight into the potential need for mitigation of either ecological or human impacts due to development. In addition to traditional knowledge that goes back multiple generations, there is the local

Photo: Linda Brewer, ERM.

Figure 9-19. *The Original Field Laboratory on the North Slope Integrated Traditional Knowledge into Its Scientific Studies*

Photo: Linda Brewer, ERM.

Figure 9-20. *Traditional Knowledge of Whales and Their Migratory Patterns (for Both Subsistence and Preservation of Culture) Has Helped Inform Development*

knowledge that retains experience of those earlier days of oil and gas development, along with experience of construction on permafrost or near species habitats and the effects thereof. Seismic survey activity in the 1960s and its effects on whale migration is an example of this more recently acquired local knowledge.

Traditional knowledge often informs project design and results in operational advantages and environmental benefits, and the permitting process can be disrupted or delayed when traditional knowledge is not visibly incorporated into exploration and development. Concerns reflected in the literature by the traditional knowledge holders include assurance of the oil and gas industries' appreciation of the relationship between subsistence lifestyle patterns and species habitats, the impacts of subsistence lifestyle on health, the preservation of culture, and concerns about cultural impacts due to climate changes.

Current Knowledge on the Theme

Many recent scientific studies have looked at the potential for integrating traditional knowledge and science with some options for co-management of a given process. New roles have been created to further obtain knowledge of local species by those who have the deepest experiences in the environment, and to apply that knowledge to resource development. Those with traditional and local knowledge have been employed within the oil and gas industry as subsistence advisors, village liaisons, and wildlife observers; however, the literature suggests there is more opportunity to integrate and leverage traditional knowledge with science and new industry technologies. An often-mentioned recommendation suggests that this is, and will continue to be, an important contribution in the development of the Arctic.

Planned Research or Investigation

While studies have been done for some time on traditional and local knowledge, researchers frequently miss the opportunity to integrate that knowledge completely into science. Participatory methodologies that incorporate both scientific and traditional and local knowledge are beginning to emerge, and there is interest in identifying an appropriate method of integration. Nevertheless, much of the research appears to be focused on methodology for simply gathering and documenting traditional and local knowledge instead of viewing them as an additional source of data. Emerging efforts to integrate traditional knowledge into science are leveraging existing local knowledge—and the current colleges of the Arctic appear poised to move this into reality, leveraging the local knowledge and experience of working with the industry during the past 50 years to continue the development of the Arctic into the future.

Theme 12: Emerging Technologies for Monitoring Ecological Change

The process of addressing aspects of the research themes identified in the preceding sections can be facilitated by the development and advancement of a number of technical investigative tools. Historically, collection of ecological data has been challenged by limitations of access that are presented by the barriers of the physical environment (ice and temperature extremes) and the remoteness of Arctic locations. Cost, benefit, and risk are also factors that go into the determination of such studies. The creation of research facilities like the Naval Arctic Research Laboratory, Barrow Arctic Science Consortium, the Toolik Creek Long Term Ecological Research site, and oil field infrastructure have provided shore bases from which both marine and terrestrial research can be conducted. Many of the technologies discussed in this section are advantageous, in part because of their ability to collect data during periods of limited access over longer periods of time and to collect, manage, and report large volumes of data.

An increasing number of oceanographic sensors and measurement systems are available for ecological characterization of the Arctic marine system. Many of these systems have been recently reviewed in two NRC studies.[432,433] They are briefly described in this section; the reader is directed to the NRC reports for a more complete discussion and set of references.

These technologies are evolving at a rapid pace, yielding an ever-expanding selection of measurements and options for sampling designs. Nevertheless, there are opportunities to improve the existing suite of available sensors, with improvements largely needed in autonomous sensor packages that are deployed for long time frames (months to a year) from drifting buoys, underwater vehicles, or moorings. These are precisely the platforms required, along with longer-term power supplies and greater data transmission capabilities, to make year-round measurements in remote portions of the Arctic marine environment. For example, the most mature sensors available are those that measure physical parameters of the system (light, ice thickness, currents, temperature, salinity, sediment load, bottom pressure). Substantial improvements continue to be made in nutrient, pH, oxygen, methane, and pCO_2 sensors. Perhaps the most pressing need is for the development of sensors capable of detecting the genomic or molecular signatures of organisms that are or have been present in the area.

Autonomous Underwater Vehicles

Autonomous underwater vehicles (AUVs), include buoyancy-driven ocean "gliders," propeller-driven AUVs, and wave gliders. All have potential for environmental monitoring, ocean process studies, and inspection of industrial facilities in the Arctic. Each vehicle can collect high-resolution data and transmit it nearly in real time. Mission protocols can be preprogrammed or adjusted "at sea" to permit adaptive sampling. The vehicles operate differently from one another to allow independent or collaborative application. Gliders and AUVs have been applied extensively in open water settings including the ice-free waters of the Arctic. Previous under-ice AUV operations include under-ice and bathymetric mapping,[434,435] seafloor exploration,[436] and coastal hydrography.[437] Under-ice glider operations are a more recent development and are still being vetted. Wave gliders have been recently applied to the open water areas of the Arctic Ocean's shelves. These devices come in a range of sizes, payload capacity, navigation options, and endurance limits. Deployment and recovery of the smaller vehicles can be done by hand from small vessels (including skiffs) or through the ice or both, while larger vehicles require mechanical aids (and therefore large vessels or ice camps).

Although these vehicles can incorporate a variety of sensors, sensor configuration and mission design may be limited by vehicle size, power requirements of the sensors, and data storage or transmission capabilities. Gliders and AUVs support standard oceanographic sensors (e.g., conductivity, temperature, depth profilers [CTDs], optics, passive acoustic recorders), while the AUVs can also incorporate acoustic Doppler current profilers (ADCPs), side-scan, and/or ice profiling sonars. Sensor packages for the wave gliders are more limited (5 to 10 meters depth in ice-free conditions) given their size and that their propulsion mechanism limits the depth to which sensors can be deployed. All vehicles are quite flexible in design so that as new sensors evolve, many could be incorporated easily into one or more of these vehicles. While each vehicle type is mature, there are several hurdles to overcome in order to expand their use in the Arctic. Gliders have difficulties navigating under ice, and while new navigational approaches appear promising, through-ice glider deployments and recoveries have yet to be explored. Required glider improvements include incorporating inertial and acoustic navigation systems and a glider propulsion mechanism that would be used intermittently to enable gliders to navigate precisely to an ice hole for recovery. There have been a variety of short-duration, attended AUV deployments under the ice, but extended, unattended operations under the ice will require substantial new developments for navigation, power, and communications. These include an autonomous on-ice power and communication system that drifts with the ice and includes a through-ice docking port by which the AUV can recharge its batteries, transfer data to the surface, and receive new mission protocols. It will also require the distribution of an acoustic transponder network (drifting with the ice or fixed on moorings or on the ocean floor) and acoustic modems for passing the position of drifting beacons to the vehicle. AUVs will also require improved decision-making software for docking and for choosing the appropriate set of transponders by which to navigate. An alternative docking scenario may be feasible in the event that offshore hydrocarbon development occurs and subsea pipelines extend onshore. It may be possible to incorporate fixed AUV docking ports that include communication and power cables associated with the pipeline.

Drifting Buoys

In addition to autonomous vehicles, there is a variety of drifting sensor platforms (buoys) developed for the Arctic Ocean. These buoys are either installed into and drift with the ice, drift in the ocean below the ice, or drift in open water. They can carry a diversity of sensor packages that transmit their position (determined by GPS) and sensor data in real time via Iridium. There are also polar profiling floats that drift for extended periods at a fixed depth beneath the ice and periodically rise to the surface, sampling the water column during ascent. Once at the surface they transmit the data via Iridium, acquire a GPS fix, and then descend again. These profilers do not break through the ice, but will surface if open water is present and then communicate. For periods of extended under-ice operations, the profilers use fixed sound sources for geo-positioning but store their data until they reach open water. To date most of the profilers have been developed to study ice and ocean physics, but it seems feasible that many other sensors can be adapted to these devices as well.

High Frequency Radars

Surface ocean currents (uppermost 1 to 2 meters) can be determined in real time in the absence of heavy ice concentrations from shore-based high frequency radars (HFR). The HFR systems work in pairs and are distributed at 70 to 100 kilometer intervals along the coast. Surface currents are mapped at hourly intervals at a nominal spatial resolution of 6 kilometers, up to 150 to 200 kilometers offshore. (Note, however, that at these high latitudes, the offshore extent varies with diurnal excursions of the ionosphere, or ionospheric disturbances throughout the day, so that range is diminished at night and expanded during the day.) HFR are becoming prevalent along the coastlines of the continental United States, where grid power is easily accessible. Limited access to grid power has prevented their application in the Arctic, but reliable autonomous power and satellite communication systems have been developed recently[438] that allow HFR to operate in some remote locations. HFRs are likely to become more usable in the Arctic for use as real-time response tools for oil spills, search and rescue, and vessel tracking. In addition, HFR data could be incorporated into data assimilation ocean circulation models that may improve short-term predictions of field conditions for use as an oil spill response tool.

Oceanographic Moorings

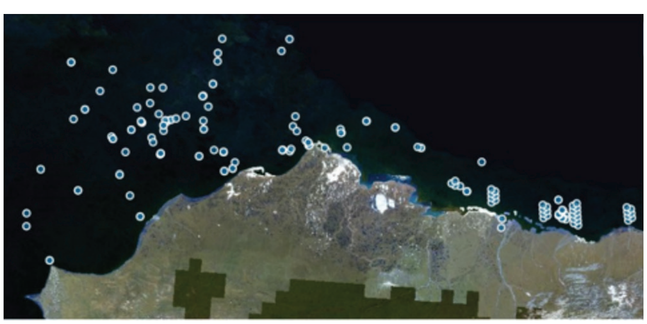
Oceanographic moorings are typically deployed for extended periods (several months to a year) and contain a variety of sensor packages that sample at fixed time intervals. These sensors may include devices for measuring ocean currents, temperatures, salinity, nutrients, bio-optical properties, or sediment loads, and may also include passive acoustic recorders, active acoustic recorders (for zooplankton and fish), ice keel depths, etc. A chief difficulty for Arctic oceanographic moorings is that deep ice keels can capture the moorings and destroy or displace them from their positions so that they are effectively lost. There are, however, a growing number of technologies that allow moorings to operate in the Arctic without loss of instrumentation or data. Hence, the mooring data could be ideal for environmental assessments of how ocean properties vary in time throughout the year in regions and seasons when access by vessels is not feasible. Oceanographic moorings can be modified so that data are transmitted to a surface buoy package, which then relays the data to shore in real time. This approach is feasible during the open water season, but not when drifting pack ice is present. Surface buoy packages can, however, be installed in the landfast ice zone where the ice is immobile. In such an application, under-ice ocean sensors can be connected to the surface package so that real-time data transmission can be implemented.

Acoustic Detection, Recording, and Analysis

Acoustic detection and recording devices have been valuable tools for collecting ecological information about vocalizing marine mammal abundance, distribution, and behavior and about industry sound levels, since the 1980s.[439,440] The capabilities of these systems have greatly increased over the last three decades, and include the ability to identify and locate some animal calls in time and space[441] and to collect data year-round in both open and ice-covered water.[442]

Based on methods developed in support of a single offshore production island (BP's Northstar) beginning in 2001, an acoustic monitoring program in support of offshore exploration activities was established in the Alaskan Chukchi and Beaufort Seas in 2006 (Figure 9-21). The acoustic monitoring program was designed to serve three primary functions: (1) record and characterize industry sound levels and sound propagation; (2) observe call distributions of marine mammals over a large area; and (3) investigate the possible effects of anthropogenic sounds on measurable aspects of bowhead whale behavior, such as call detection rates and locations in the Beaufort Sea. Custom-designed autonomous recorders have been deployed to record industrial sounds produced by anthropogenic activities, and also the vocalizations of marine mammals around these activities. In addition to large-scale acoustic monitoring programs in each sea, focused sound source characterization and sound source verification studies specific to particular industry activities have also been conducted for more than 20 years.

Several other acoustic programs are operated in the Arctic, including aspects of the CHAOZ program that is funded by BOEM and operated by NOAA. BP's work at Northstar used acoustic monitoring to assess potential environmental effects of industrial sounds on migrating bowhead whales beginning in 2001. Recently the ability to record, identify, and communicate data about vocalizing marine mammals has been established on an AUV glider.[443]



Source: Alaska Ocean Observing System.

Figure 9-21. *Deployment Locations of Acoustic Monitoring Devices*

Ice-Capable Research Vessels

Research vessels will always be required for ecosystem assessment, instrument deployment and recovery, and experimental studies in the Arctic. Numerous reports have discussed the need for ice-capable research vessels.[444,445] The NSF's R/V *Sikuliaq*, operated by the University of Alaska, is an ice-capable research vessel designed for operations in ice thicknesses of 1 meter or less, and will be available in 2015. The USCGC *Healy*, a medium-duty icebreaker, has science as its primary mission and is at mid-life, with another 15 to 20 years of service before decommissioning. The USCGC *Polar Star*, a heavy icebreaker, has recently undergone extensive refitting and will serve national security interests in the Arctic and Antarctic. The Arctic Icebreaker Coordinating Committee was established by the USCG, NSF, and University National Oceanographic Laboratory System for the purpose of facilitating and coordinating Arctic research aboard ice-capable research vessels.

Theme 13: Oil Spill Prevention and Response—Ecological Fate and Effects of Oil and Response Measures

Understanding the many aspects and implications of an oil spill in Arctic waters is one of the most significant questions that is raised in relation to prudent exploration and development of this region. For the purpose of convenience to the reader the entire discussion of oil spill prevention, response, and the fate and effects of oil in the environment has been addressed in Chapter 8, and the reader is referred to this chapter. The theme is included within this chapter, however, in recognition that the investigation of the ecological processes and ramifications of oil in the Arctic ecosystem is a widely recognized area of priority research.

When oil enters the ecosystem, either through inadvertent release or through natural seeps,[446] it undergoes a number of processes that ultimately determine the short- and long-term fate of the molecular components of the oil. These processes, in combination with the characteristics of the specific oil released and the presence and relative susceptibility of ecological resources present, influence the ecological effects of that oil. Physical characteristics of the environment, such as temperature and ice, also influence the processes of both fate and effects of oil in an ecosystem. Response measures such as the use of dispersants or in-situ burning may have their own aspects of ecological fate and effects.

There is a large and expanding body of science and literature related to the fate and effects of oil and response measures in a variety of ecological settings. Questions remain, however, about whether the Arctic represents a special case of behavior, persistence, or sensitivity of organisms. It is important to recognize that there is a body of research that has been done on these topics and that the results of these studies to date indicate a general consistency with the fate and effects of oil in more temperate locations. As exploration continues to develop in the Arctic, it can be expected that this science will expand and will continue to inform decision-making and research planning in this field.

CURRENT RESEARCH GROUPS WITH PROGRAMS, INITIATIVES, AND ACTIVITIES ON ARCTIC ECOLOGY

This section provides a summary of current research groups that state they have programs, initiatives, and activities specifically on Arctic ecology. Summaries are organized by entity responsible for the program or initiative such as international, U.S. agencies and organizations, private industry, and public (i.e., nongovernmental) organizations. This is not meant to be an exhaustive list of all Arctic research programs but is focused on ecological programs that currently exist with the purpose of supplementing data requirements necessary for oil and gas exploration and development.

International Organizations

Arctic Council

The Arctic Council was conceived in 1996 as a high-level intergovernmental panel of Arctic nations for the purpose of promoting cooperation and interaction between the Arctic states, with the involvement of indigenous communities and other Arctic inhabitants in common Arctic issues, in particular issues of sustainable development and environmental protection in the Arctic. The Arctic Council member states are Canada, Denmark, Finland, Iceland, Norway, Russian Federation, Sweden, and the United States. There is also a Permanent Participant member category that includes indigenous groups based in the member states. Within the Arctic Council are six working groups:

- Protection of the Arctic Marine Environment
- Conservation of Arctic Flora and Fauna
- Arctic Monitoring and Assessment Program
- Arctic Contaminants Action Program
- Emergency Prevention, Preparedness and Response
- Sustainable Development Working Group.

International Arctic Science Committee

The International Arctic Science Committee (IASC) is a nongovernmental, international scientific organization whose mission is to encourage and facilitate cooperation in Arctic research in all countries engaged in Arctic research and in all areas of the Arctic region. IASC promotes and supports interdisciplinary research in order to foster a greater scientific understanding of the Arctic region and its role in the Earth system.[447]

Pacific Arctic Group

Pacific Arctic Group (PAG) is a group of institutes and individuals with a Pacific perspective on Arctic science. Organized under IASC, the PAG's mission is to serve as a Pacific Arctic regional partnership to plan, coordinate, and collaborate on science activities of mutual interest. The four PAG principal science themes are climate, contaminants, human dimensions, and structure and function of Arctic ecosystems.[448]

International Association of Oil & Gas Producers

International Association of Oil & Gas Producers (IOGP) is an upstream oil and gas producer association with a focus on industry research and advocacy that started in 1974. It works on behalf of the world's oil and gas exploration and production companies to promote safe, environmentally responsible, and sustainable operations. It has published materials that are relevant to the interface of Arctic ecology and the oil and gas industry such as the *Environmental Management in Arctic Oil and Gas Operations–*

Good Practice Guide. This global industry group of 82 member companies is organized into various committees that produce publications, fact sheets, and position papers, and issue industry-focused press releases. IOGP focuses on industry safety and security and promotes social responsibility and sustainability. The IOGP has an Arctic Committee as one of its eight permanent standing committees to be the technical and advocacy focal point for the industry on issues related to upstream activities in the Arctic.

The Arctic Committee and the Environment Sub-Committee are currently addressing several key issues: Arctic science, Arctic oil spill response, climate change, sound and marine life, technology and standards, natural resources management and development, and indigenous peoples. IOGP is currently the leader in Arctic oil spill prevention research and is conducting research in: environmental impacts from Arctic oil spills and Arctic oil spill response technologies, fate of dispersed oil under ice, mechanical recovery of oil in ice, oil spill detection and mapping in low visibility and ice, dispersant testing under realistic conditions, and in-situ burning of oil in ice-affected waters.[449]

The IOGP is also the body that is managing the Sound and Marine Life JIP, which is focused on researching the propagation and transmission of sound, its effects on marine life, mitigation and monitoring methodologies and advanced research tools.

Alfred Wegner Institute, Helmholtz Centre for Polar and Marine Research

The Alfred Wegener Institute (AWI) conducts research in the Arctic and Antarctic, as well as in temperate latitudes. The AWI coordinates polar research in Germany and provides the necessary equipment and key infrastructure for polar expeditions.[450] Scientists from various disciplines and nations use technology for cooperative and interdisciplinary investigations of the global climatic, biological, and geological systems of the earth. Currently, the framework for ongoing scientific projects at the AWI is provided by the research program Polar Regions and Coasts in a Changing Earth System, following the program Marine, Coastal and Polar Systems (2004-2008).

Research Council of Norway

The Research Council of Norway is a national strategic and funding agency for research activities. Svalbard provides a location for Norwegian Arctic research and has come to serve as a venue for an increasing number of foreign research institutions as well. The Research Council seeks to:

- Enhance the knowledge infrastructure of the North
- Obtain the best possible knowledge for public administrators, communities, and trade and industry
- Strengthen international research cooperation.

The Research Council invites researchers, companies, and investors to take part in Norway's northern areas initiative. They state that processes affecting the Arctic region are important in the context of global problems, and encourage the international research community to work together to deal with these important issues.[451]

Natural Environment Research Council, Arctic Research Programme, UK

The Arctic represents a critical region for global environmental change: a region where the UK has significant strategic interests. It is their stance that understanding the drivers and feedbacks of this change, and predicting its scale and rate on time scales from months to decades, represents a major and urgent global scientific challenge of great societal importance. To address these scientific uncertainties, Natural Environment Research Council (NERC) is investing in a 5-year Arctic Research Programme, over the period 2010 to 2015.[452] The Arctic program focuses on four linked scientific objectives:

- Understanding and attributing the current rapid changes in the Arctic
- Quantifying processes leading to Arctic methane and carbon dioxide release
- Reducing uncertainty in Arctic climate and associated regional biogeochemistry prediction
- Assessing the likely risks of submarine hazards associated with rapid Arctic climate change.

Other Countries That Conduct Research Focused on Arctic Ecology

In addition to programs listed above, Sweden, Finland, Denmark, Iceland, Greenland, Russian Federation, South Korea, China, and Canada also conduct Arctic research programs focused on ecology. While not an exhaustive list, the Arctic Research Institute Database provides a list of research institutions by country or by topic and can be accessed to get a list of research programs underway that may be related to Arctic ecology.[453]

United States Agencies and Organizations

Academic Research

University of Alaska Fairbanks, Center for Global Change and Arctic System Research

The Center for Global Change and Arctic System Research (CGC) was established in March 1990 to serve as the focal point at the University of Alaska Fairbanks (UAF) for developing, coordinating, and implementing interdisciplinary research and education related to the role of the Arctic and sub-Arctic in the Earth system, and to stimulate and facilitate global change research in this region. CGC also administers the Cooperative Institute for Alaska Research, a joint venture between NOAA and the University of Alaska that focuses on ecosystem and environmental research related to Alaska and its associated Arctic regions, including the Gulf of Alaska, Bering Sea, Chukchi/Beaufort Seas, and Arctic Ocean. CGC is organized under the International Arctic Research Center,[454] but involves scientists from numerous UAF departments and institutes.

University of the Arctic

The University of the Arctic (UArctic) is a cooperative network of universities, colleges, research institutes, and other organizations concerned with education and research in and about the North. UArctic works to build and strengthen collective resources and collaborative infrastructure that enables member institutions to better serve their constituents and their regions. Through cooperation in education, research, and outreach they work to enhance human capacity in the North, promote viable communities and sustainable economies, and forge global partnerships. Among the goals of UArctic's research area focused on the North are: to increase research cooperation between UArctic member universities and research organizations, to improve opportunities and conditions for research funding, and to promote cooperation with international science organizations and the use of traditional knowledge.[455]

Purdue Climate Change Research Center

The Purdue Climate Change Research Center (PCCRC) was established in April 2004 and is focused on interdisciplinary research on climate change and its ecological, social, economic, and political impacts. The overarching goals of PCCRC research are to understand the causes and consequences of climate change; improve predictive models to project future climate conditions; and inform ongoing state, national, and international policy discussions on climate change, including mitigation and adaptation strategies.[456]

Federal Agency Research

Bureau of Ocean Energy Management, Environmental Studies Program, North Slope

The Division of Environmental Sciences manages the Environmental Studies Program (ESP) for the BOEM. ESP develops, conducts and oversees world-class scientific research specifically to inform policy decisions regarding development of Outer Continental Shelf energy and mineral resources. Research covers physical oceanography, atmospheric sciences, biology, protected species, social sciences, economics, submerged cultural resources, and environmental fates and effects. BOEM is a contributor to the growing body of scientific knowledge about the nation's marine and coastal environment including in the Arctic. BOEM's Alaska Region Office is responsible for managing the development of oil, natural gas, renewable energy, and mineral resources on Alaska's Outer Continental Shelf in an environmentally and economically responsible way. To that end, it manages programs relating to lease management, exploration plans, environmental science, environmental analysis, and resource evaluation. It oversees more than 1 billion acres on the Outer Continental Shelf and more than 6,000 miles of coastline—more coastline than in the rest of the United States combined.[457]

North Slope Science Initiative

The North Slope Science Initiative (NSSI) is an intergovernmental effort to increase collaboration at the local, state, and federal levels to address research, inventory, and monitoring needs as they relate to development activities on the North Slope of Alaska. The vision of the NSSI is to identify those data and information sources that management agencies and governments will need in the future to responsibly manage development and natural resources. The NSSI is made up of the following partners: Bureau of Land Management, USFWS, National Park Service, NOAA, BOEM, Alaska Department of Natural Resources, ADF&G, Alaska Slope Regional Corporation, North Slope Borough, and the Bureau of Safety Environmental Enforcement (BSEE). In addition, the NSSI has an Oversight Group that includes the above organizations with the following additions: USGS, U.S. Arctic Research Commission, Department of Energy (DOE), National Weather Service, and the Coast Guard (USCG). The Science Technology Advisory Panel (STAP) provides advice to the Oversight Group. Members of the STAP are required to receive Federal Advisory Committee Act approval and come from state and federal agencies, industry groups, and other private organizations.

Currently the NSSI has cataloged a total of 123 long-term monitoring studies. The NSSI Oversight Group is undertaking a project called the "Scenarios for North Slope Development and Related Science Needs" to identify future research and monitoring needs. Collaborators on this project include NSSI, the University of Alaska Fairbanks, and GeoAdaptive, LLC. The process will contribute toward strategies to help develop the plausible outlook of future U.S. Arctic development as they pertain to environmental research and monitoring needs. Based on this effort, NSSI will assess the science needed to understand the implications of each scenario, so that NSSI member agencies will be prepared with strategies to collect the appropriate information to make effective decisions.[458]

National Research Council, Polar Research Board

The Polar Research Board (PRB) has a long history of distinguished service to the polar community. PRB exists to promote excellence in polar science and to provide independent scientific guidance to federal agencies and the nation on science issues in the Arctic.[459] The PRB strives to:

- Make research in the polar regions more productive and responsive to the needs of the United States
- Maintain U.S. awareness of and representation in international science programs
- Enhance understanding of issues in polar regions.

The PRB program has two elements: a core element and a study element. Under its core element, the PRB serves as a source of information and assistance to federal agencies, Congress, and others in the polar community, and attempts to foster improved coordination of research activities at both poles. The PRB also serves as the U.S. National Committee for the IASC. Arctic-focused reports include:

- *The Arctic in the Anthropocene: Emerging Research Questions*[460]
- *Responding to Oil Spills in the U.S. Arctic Marine Environment*[461]
- *Seasonal-to-Decadal Predictions of Arctic Sea Ice: Challenges and Strategies*[462]
- *Scientific Value of Arctic Sea Ice Imagery Derived Products*[463]
- *Toward an Integrated Arctic Observing Network*.[464]

Arctic Research Commission

The U.S. Arctic Research Commission (USARC) contributes to the effort of Arctic research by identifying research goals and objectives for the nation, and then working with a broad variety of entities in federal, state, local, and tribal governments, nongovernmental organizations, industry, and in other countries to advance Arctic research. USARC states that it listens to and consults with communities of scientists, researchers, decision-makers, and Arctic residents. Under the Arctic Research and Policy Act, USARC recommends key goals and objectives biennially for the U.S. Arctic Research Program Plan. For this report, USARC gets input from scientific researchers, policymakers, the public in Alaska and the United States, and nations with Arctic interests. In defining its research goals and objectives, USARC cosponsors scientific meetings and workshops on oil spill response; the impacts of an ice-diminishing

Arctic on naval and maritime operations, on the provision of safe supplies of water and sanitary facilities in rural Alaska, on Arctic civil infrastructure, and on "Operating in the Arctic: Supporting U.S. Coast Guard Challenges Through Research."

Interagency Arctic Research Policy Committee

The U.S. Interagency Arctic Research Policy Committee (IARPC) consists of 15-plus agencies, departments, and offices across the federal government. Established by Congress through the Arctic Research and Policy Act, IARPC is chaired by the National Science Foundation.[465] The IARPC states that it:

- Helps set priorities for future Arctic research
- Works with USARC to develop and establish an integrated national Arctic research policy to guide federal agencies in developing and implementing their research programs in the Arctic
- Consults with the USARC on matters related to Arctic research policy, programs, and funding support
- Develops a 5-year plan to implement the national policy, and updates the plan biennially
- Coordinates preparation of multiagency budget documents for Arctic research
- Facilitates cooperation between the federal government and state and local governments in Arctic research
- Coordinates and promotes cooperative Arctic scientific research programs with other nations
- Promotes federal interagency coordination of Arctic research activities, including logistical planning and data sharing
- Submits a biennial report to the Congress through the President containing a statement of the activities and accomplishments of the IARPC since its last report.

National Oceanic and Atmospheric Administration

The NOAA works in Arctic science, service, and stewardship, ranging from biological, physical, and chemical research; to weather and climate services; to nautical charting, spill response, fisheries management, and marine mammal protection. NOAA's six Arctic strategic goals are to: forecast sea ice; improve weather and water forecasts and warnings; strengthen foundational science to understand and detect Arctic climate and ecosystem changes; improve the stewardship and management of ocean and coastal resources in the Arctic; advance resilient and healthy Arctic communities and economies; and enhance international and national partnerships. Other key areas for NOAA are improving Arctic mapping and charting and improving Arctic environmental incidence prevention and response. The geographic scope of NOAA's Arctic Action Plan includes all of the areas defined by the Arctic Research and Policy Act of 1984 including West Bering Sea, East Bering Sea, Chukchi Sea, and Beaufort Sea. NOAA currently has active programs in all of these Arctic geographic subareas.[466]

North Pacific Research Board, Arctic Program

The North Pacific Research Board (NPRB) works on peer-reviewed scientific research in the Chukchi and Beaufort Seas that informs effective management and sustainable use of marine resources. NPRB's Arctic Program involves a synthesis of existing scientific and traditional knowledge of the Arctic marine ecosystem and an identification of research needs to help plan a potential upcoming research program that will likely be undertaken in cooperation with other organizations. Early stages of this program include the Pacific Marine Arctic Regional Synthesis a synthesis of existing information on the marine ecosystem in the Bering Strait and Chukchi and Beaufort Seas. Funding for this effort comes from Shell Exploration and Production and ConocoPhillips. In later stages the Arctic Research Program plans to develop a coordinated, collaborative program to fund science that will improve the understanding of the Arctic marine ecosystem.[467]

Department of Energy

The mission of the DOE is to ensure U.S. security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions. In the Arctic, DOE is currently involved in the "Using Artificial Barriers to Augment Fresh Water Supplies in Shallow Arctic Lakes" project with the UAF. The goal of this project is to implement a snow control practice to enhance snowdrift formation as a local water source that recharges a depleted lake despite possible unfavorable climate and hydrology.[468]

Department of Defense

The U.S. Department of Defense's strategic approach for the Arctic supports the U.S. National Arctic Strategy[469] and enables the United States to exercise sovereignty and protect the homeland, engage public and private sector partners to improve domain awareness in the Arctic, preserve freedom of the seas in the Arctic, evolve Arctic infrastructure and capabilities consistent with changing conditions, support existing agreements with allies and partners while pursuing new ones to build confidence with key regional partners, provide support to civil authorities as directed, partner with other departments and agencies and nations to support human and environmental safety, and support the development of the Arctic Council and other international institutions that promote regional cooperation and the rule of law.[470]

U.S. Coast Guard

The USCG's strategic objectives are to improve awareness of maritime activity, modernize governance of the region, and broaden partnerships. The USCG Arctic strategy document discusses the current status of sea ice including shore-fast ice and multi-year ice. USCG leads efforts to plan for and respond to environmental threats under the National Oil and Hazardous Substances Pollution Contingency Plan. Opportunities for expanded USGC capabilities include the need for more icebreaking ships and long-range patrol vessels, additional aviation assets, improvements to domain awareness, and better charting and communication systems.[471]

Bureau of Land Management

The Bureau of Land Management (BLM) Alaska Energy Program is responsible for the administration of leasable federal minerals, including oil and gas, phosphates, coal, coal bed natural gas, oil shale, and geothermal resources. The BLM reviews and approves permits and licenses from companies to explore for leasable minerals on federal lands. A federal lease must be obtained before development and production of these resources can take place. The primary responsibilities of BLM Alaska's Energy Program include: conducting pre-lease assessments and post-lease sale bid evaluations for the tracts in the National Petroleum Reserve in Alaska; permitting oil and gas exploration and development activities; protecting federal lands from drainage of oil and gas from wells drilled on nonfederal lands; administering federal oil and gas units; inspecting industry operations for compliance with regulations, lease terms, and permit conditions; and conducting mineral evaluations and development scenarios for land exchanges (sales or disposals, resource management plans, environmental impact statements) and land use plans developed by other federal agencies.[472]

U.S. Fish and Wildlife Service

The USFWS functions to enforce federal wildlife laws, protect endangered species, manage migratory birds, restore nationally significant fisheries, and conserve and restore wildlife habitat such as wetlands. In Alaska, the USFWS manages 16 National Wildlife Refuges totaling 76,774,229 acres, dedicated specifically for wildlife conservation, including the Arctic National Wildlife Refuge. USFWS also contributes to research studies to follow up on a 1987 Coastal Plain Resource Assessment and Legislative Environmental Impact Statement to assess the potential impacts of development on the Refuge coastal plain. The USFWS worked with the USGS to produce an update of such research titled *Arctic Refuge Coastal Plain Terrestrial Wildlife Research Summaries* in 2002. USFWS also coordinates and leads the Arctic Landscape Conservation Cooperative.[473]

Arctic Landscape Conservation Cooperative

The Arctic Landscape Conservation Cooperative (ALCC) supports conservation in the Arctic by providing applied science and tools to land managers and policymakers. ALCC is committed to studying topics such as the effects of a warming climate on subsistence food safety, fish and bird distribution, and the preservation of extant data sets that will become increasingly difficult to find and recover with time. Within Alaska, the Arctic LCC encompasses three eco-regions; the Brooks Mountain Range, the Arctic Foothills, and the broad Arctic Coastal Plain.[474]

National Science Foundation

The NSF Arctic Research Opportunities program invites investigators to submit proposals to conduct research about the Arctic. Arctic research includes field and modeling studies, data analysis, and synthesis about the Arctic region. The goal of the NSF Section for Arctic Sciences, Division of Polar Programs, is to gain a better understanding of the Arctic's physical, biological, geological, chemical, social, and cultural processes; the interactions of oceanic, terrestrial, atmospheric, biological, social, cultural, and economic systems; and the connections that define the Arctic. The NSF sponsors the following Arctic research programs: Arctic Natural Sciences Program, Arctic System Science Program, Arctic Social Sciences Program, Arctic Observing Network, and the Polar Cyber Infrastructure.[475]

U.S. Geological Survey

In 2010, the U.S. Secretary of the Interior asked the USGS to conduct an initial, independent evaluation of the science needs that would inform the administration's consideration of the right places and the right ways in which to develop oil and gas resources in the Arctic Outer Continental Shelf, particularly focused on the Beaufort and Chukchi Seas. In 2011, USGS developed more than 50 findings and recommendations in the course of its examination of these topics, including detailed scientific information, key knowledge gaps, and recommendations.[476]

National Center for Atmospheric Research

The National Center for Atmospheric Research (NCAR) is a federally funded research and development center devoted to service, research, and education in the atmospheric and related sciences. NCAR's mission is to understand the behavior of the atmosphere and related physical, biological, and social systems; to support, enhance, and extend the capabilities of the university community and the broader scientific community, nationally and internationally; and to foster transfer of knowledge and technology for the betterment of life on Earth. The NSF is NCAR's primary sponsor, with significant additional support provided by other U.S. government agencies, other national governments, and the private sector.[477]

State Agency Research

Alaska Department of Fish and Game

The ADF&G conducts research in support of its regulatory authority over lands and waters to protect fish and wildlife populations and their habitats. ADF&G land and water use permits, required for development in Alaska's Arctic, are issued through the Division of Habitat and can be divided into two major categories: fish habitat permits and special area permits. The department also reviews land plans and land use actions of other agencies with jurisdiction in the Arctic.

Alaska Department of Environmental Conservation

The Alaska Department of Environmental Conservation (ADEC) is made up of five divisions: Air Quality, Environmental Health, Administrative Services, Spill Prevention and Response, and Water. The Spill Prevention and Response Division is also tasked with the Industry Preparedness Program, which protects public safety, public health, and the environment by ensuring that producers, transporters, and distributors of crude oil and refined oil products prevent oil spills and are prepared materially and financially to clean up spills. ADEC is part of an interagency collaboration with U.S. EPA, NOAA, USFWS, and USGS called National Aquatic Resource Surveys (NARS) – Alaska Monitoring and Assessment Program. The focus of NARS in Alaska for the next 5 years is the Arctic Coastal Plain.[478]

Alaska Department of Natural Resources

The mission of the Alaska Department of Natural Resources (ADNR) is to develop Alaska's resources responsibly by making them available for maximum use and benefit consistent with the public interest. ADNR conducts and contributes to Arctic research in support of this mission. ADNR manages all state-owned land, water and natural resources, except for fish and game, on behalf of the people of Alaska. In 2013, ADNR published *The Oil and Gas Resource Evaluation & Exploration Proposal for the Arctic National Wildlife Refuge 1002 Area* to "foster a cooperative effort between the State, local, and federal governments and private parties to responsibly assess and explore the 1002 Area."[479,480]

Tribal Research

Inuit Circumpolar Council

The Inuit Circumpolar Council's (ICC's) Executive Council made considerable efforts and significant gains in advancing the interests of Inuit with respect to climate change between 2002 and 2006 and undertook many climate change activities. These include communicating its Arctic manifestations to the world, working with those who hope to mitigate the current and future impacts of climate change, and supporting initiatives to hold those responsible for climate change accountable to Inuit and other affected parties. ICC participated in the preparation of the Arctic Climate Impact Assessment by the Arctic Council (2002-2004). ICC also drafted climate change policy recommendations in cooperation with all six permanent participants to the Arctic Council in 2004.

Native Village of Kotzebue

The Native Village of Kotzebue Environmental Program director was hired to develop a program to address environmental issues that identify environmental priorities for the community. In 2011, Whiting et al. produced *Combining Iñupiaq and Scientific Knowledge: Ecology in Northern Kotzebue Sound, Alaska*. The Native Village of Kotzebue continues to work in the area of environmental education, informing Kotzebue's citizens so they can participate more effectively in influencing public policy that will affect their Arctic environment.[481]

Alaska Eskimo Whaling Commission and Environmental Law Institute's Ocean Program

In partnership with the Alaska Eskimo Whaling Commission, the Environmental Law Institute has worked to increase understanding of how communication occurs between researchers and coastal communities during research focused on the Alaskan marine environment. They focus especially on research related to the management of marine subsistence resources, including questions about climate change and its impacts. Their goal is to understand what processes should be used to guide research project design, implementation, and information dissemination so that it incorporates the knowledge and input of coastal communities and benefits them over the long term.[482]

Alaska Beluga Whale Committee

The Alaska Beluga Whale Committee (ABWC) conducts research to understand the biology of the whales to ensure that the populations remain large enough for sustainable harvests. A primary goal of the ABWC is to maintain a healthy beluga whale resource for subsistence use and public enjoyment by future generations. Co-managed research by the ABWC and researchers contributes to collection of whale samples by hunters that scientists cannot get, information sharing with ABWC about safe harvest levels and other scientific baseline data, and sharing of traditional knowledge about the whales that can better inform decision-makers.[483]

Eskimo Walrus Commission

The Eskimo Walrus Commission (EWC) works cooperatively with USFWS to monitor subsistence hunts, collect detailed walrus harvest data and biological samples, and record harvest data through the federally mandated marking, tagging, and reporting program. Gathering culturally based traditional knowledge is an important aspect of co-management. The EWC also works with USFWS to address challenges associated with climate change and the impacts to the walrus population.[484]

Alaska Nanuuq Commission

The Alaska Nanuuq Commission (ANC) is the federal co-management body for the conservation and management of Alaska's polar bears. Along with partners at USFWS, ANC is working together to protect polar bears and the Alaskan Native subsistence way of life by development of a shared harvest management plan under an international agreement between the United States and the Russian Federation.[485]

Ice Seal Committee

The purpose of the Ice Seal Committee (ISC) is "to preserve and enhance the marine resources of ice seals including the habitat; to protect and enhance Alaska Native culture, traditions, and especially activities associated with subsistence uses of ice seals; to undertake education and research related to ice seals." Collection of harvest information is a top priority and is an important contribution to management of seals. In collaboration with ADF&G, ISC has worked to compile available ice seal harvest information into one document that is updated annually.[486]

Regional Research

North Slope Borough, Department of Wildlife Management

The North Slope Borough (NSB) Department of Wildlife Management manages resources encompassing 89,000 square miles in northern Alaska. It contains the following eight Iñupiat villages: Anaktuvuk Pass, Atqasuk, Barrow, Kaktovik, Nuiqsut, Point

Hope, Point Lay, and Wainwright. The Department of Wildlife Management conducts research to support sustainable harvests and fish and wildlife population monitoring from local to international levels.[487] In 2010, NSB entered into a Collaborative Research Agreement with Shell Exploration & Production to guide research based on needs and priorities to help fill data gaps in Arctic research. The NSB and Shell recognized that better scientific information was needed to make good decisions regarding development in the Arctic Ocean, specifically in the Chukchi and Beaufort Seas.[488]

Northwest Arctic Borough, Research Steering Committee

The Northwest Arctic Borough (NWAB) covers approximately 36,000 square miles in Northwest Alaska. The NWAB Planning Department contributes to research and knowledge sharing related to climate change, coastal management and flood protection, land coordination and mapping, and to land management associated with rights-of-way, easements, and historical protection. In April 2013, Co-Principal Investigators Noah Naylor of NWAB and Pauline Harvey of Chukchi College coordinated a Workshop on Improving Local Participation in Research in Northwest Alaska.

Private and Nongovernmental Research

The following summaries provide an overview of industry and nongovernmental organization (NGO) sponsored research as well as collaborations between these entities and with government agencies.

BP Exploration Alaska Inc.

BP Exploration Alaska Inc. (BPXA) has been conducting research in support of oil and gas exploration and development beginning before the beginning of the Endicott Development Project in 1974. Ecological research has supported several BPXA developments including but not limited to Northstar and Liberty Developments and the Trans-Alaska Pipeline. More recently, BPXA initiated annual summaries of monitoring of North Slope ecosystems (2002 to present).[489] The program's goal was to summarize "scientifically sound information on the current status and long-term trends in the composition, structure, and function of North Slope ecosystems, and to determine how well current management practices are sustaining those ecosystems." Some examples of their studies include vegetation and active layer thickness monitoring; tundra nesting birds; snow geese, brant, and ravens; nearshore fishes; the Boulder Patch; ringed seal counts at Northstar Island; underwater sound; and whale calls.

ConocoPhillips Alaska Inc.

ConocoPhillips Alaska Inc. (CPAI) has a history of ecological research in Alaska's Arctic to support development projects dating back to Prudhoe Bay Waterflood (formerly ARCO) and the more recent Alpine Development. CPAI routinely conducts environmental studies to support exploration, development, and operations activities. CPAI has collaborated with stakeholders for their onshore program and has extended that model to the offshore in the Chukchi and Beaufort Seas. These studies have resulted in the accumulation of years of key data that enables CPAI to plan the routing and placement of gravel roads, pipelines, drilling pads, and general operations in a way that minimizes effects to the environment, including effects on migratory birds and other wildlife. Working with federal, state, and local regulators, as well as local communities, CPAI conducts multi-year baseline environmental studies programs, including hydrological surveys, lake surveys for water quality and fish species, archaeological surveys, wildlife surveys (birds and caribou), and vegetation mapping. ConocoPhillips is also a contributor to the Chukchi Sea Environmental Studies Program described in more detail below.

Pioneer Natural Resources (now Caelus Energy)

In 2003, Pioneer Natural Resources (now Caelus Energy) began work on the Oooguruk Development Project and was responsible for studies in and around the Colville River Delta related to caribou, fish, and acoustics monitoring and aerial surveys for marine mammals. Pioneer also conducted forward-looking infrared surveys for polar bear dens. This baseline research contributed to completing the National Environmental Policy Act (NEPA) process to evaluate potential impacts, and ultimately permits for development, in 2006.

Shell Oil Exploration and Production

Shell's Arctic Science program builds on their long experience of exploration and operations in the Arctic and sub-Arctic. Shell works with local people to study historical trends and consider how oil and gas activity can coexist with the subsistence culture and Arctic communities. Shell also learns from indigenous people, whose traditional ecological knowledge can contribute essential information and provide an early warning system for potential environmental problems. Their Subsistence Advisor Program is an example of how the company is drawing on local traditional knowledge to inform environmental studies programs in Alaska's Arctic. Shell carries out integrated research that includes zoology (caribou calving, ecology of forage fishes, ringed seal behavior, etc.), sediment sampling, deepwater studies, and looking at the food web systems that support marine mammals. The Chukchi Sea Environmental Studies Program is a collaborative effort between Shell, ConocoPhillips, and Statoil to collect baseline data about the marine environment for oil and gas permit applications, NEPA compliance, and to help manage these resources. Also as described above, in 2010 Shell entered into a long-term agreement with Alaska's NSB to collaborate on further research into significant environmental challenges connected with developing energy resources in the region.

Statoil-ARCTOS Arctic Research Program

Statoil, an energy company based in Norway, believes in sustainability to help meet the world's growing energy needs in an economically, environmentally, and socially responsible manner. Statoil's values guide them in how they conduct business and in how they work together and with external stakeholders. Statoil conducts integrated ecological research and local stakeholder activities as part of its longstanding interests and operations in the Arctic.

The Statoil-ARCTOS Arctic Research Program was started in 2006. The 6-year research program studied Arctic marine ecosystems. The purpose of the program was to generate additional fundamental knowledge that would lead to improvements in environmental monitoring and management routines for the Arctic. To address these objectives, 62 senior scientists, early career scientists, and students connected to the ARCTOS research network performed research in and on the Arctic, with specific emphasis on the environment and ecosystems of seasonally ice-covered waters.

Examples in offshore Alaska include the Chukchi Sea Environmental Studies Program, which is a collaborative effort between Shell, ConocoPhillips, and Statoil collecting baseline data on the marine environment and ecosystem; the Dynamic Risk Assessment Model for Acoustic Disturbance, which dynamically models the movement patterns and distribution of individual mammals (whales and seals) before, during, and after noise exposure in the Chukchi Sea; and the Traditional Ecological Knowledge of Acoustic Disturbance to Marine Mammals project, part of Statoil's stakeholder engagement activities in the Chukchi Sea, where Statoil partnered with three coastal Alaska Native subsistence communities to understand and document the wealth of information contained within their local and traditional knowledge.

ExxonMobil Arctic Research Program

In the Canadian Northwest Territories, some of the first applications of man-made ice islands for winter exploration drilling (1979) and the first application of gravel islands for production (1985) were employed at Norman Wells. Extended-reach drilling technology for horizontal wells to test reservoir quality underneath the Mackenzie River was also applied here in the late 1970s. In Alaska, ExxonMobil and its co-venture partners continue to assess opportunities for additional recovery improvements at Prudhoe Bay, and application of ExxonMobil's enhanced oil recovery technologies and expertise have markedly increased recoverable reserves. In 1990, ExxonMobil's heat pipe work for the Trans-Alaska Pipeline System (TAPS) was recognized by the United States Space Foundation with an Outstanding Achievement Award for civilian applications of NASA technology. Today, TAPS remains a first-of-its-kind design that has operated successfully within an Arctic environment for more than 30 years. At Point Thomson a number of innovative approaches are being applied to address environmental conservation and protection, including the experimental use of tundra sod for rehabilitation of tundra wetlands and a pilot study using ground surveillance radar to detect polar bears and other wildlife. ExxonMobil also worked closely with the local villages of the North Slope on an engineered ice cellar solution to melting permafrost, and supports the use of marine tracking technology for enhanced vessel safety and emergency response. Furthermore, ExxonMobil has a dedicated internal oil spill response research and technology development program with application to the Arctic ecosystem, which has been maintained for more than 40 years.

Olgoonik Fairweather LLC Chukchi Sea Environmental Studies Program

Olgoonik Fairweather LLC operates the Chukchi Sea Environmental Studies Program funded by ConocoPhillips, Shell, and Statoil. The studies program includes various disciplines of the marine ecosystem, including physical oceanography, chemical oceanography (new in 2010), plankton ecology, benthic ecology (infaunal and epibenthic communities), seabird ecology, marine mammal ecology, pelagic and demersal fisheries, and the hydroacoustic environment.[490]

The Arctic Institute of North America

The Arctic Institute of North America (AINA) is developing a broad research program in the context of a new strategic plan that identifies three focal areas that allow AINA to fulfill their mandate to conduct research on and disseminate information about the physical, biological, social, and cultural aspects of the North, and provide data and information of relevance and interest to northerners and all Canadians. AINA's research goals align with those identified by northern peoples, by Canada's northern research community, and internationally.[491]

Polar Bears International

Polar Bears International's research, education, and action programs address a broad range of issues including those that are endangering polar bears (e.g., climate change, environmental impact of industry, sea ice loss, global warming) and also aspects of population sustainability and endangered species management. Leading scientists from around the world serve on the Advisory Council. Working with their chief scientist, Dr. Steven Amstrup, Polar Bears International addresses what they believe to be the most urgent projects in a warming Arctic. Polar Bear International's projects include: Polar Bear Population Studies, Maternal Den Studies, Sensory Studies, Citizen Science Project, Western Hudson Bay Coastal Surveys, Cortisol Study, and an Arctic Documentary Project.[492]

World Wildlife Fund

World Wildlife Fund (WWF) brings U.S. and Russian counterparts together to support scientific research, community engagement in resource management, and conservation efforts for Arctic species such as Pacific walrus and polar bears. In the Bering Strait, WWF works with partners to identify the most effective measures possible to ensure safe maritime shipping to coexist with community and wildlife needs.[493]

Toolik Field Station, Institute of Arctic Biology, University of Alaska Fairbanks

The Toolik Field Station (TFS) is operated and managed by the Institute of Arctic Biology at the UAF with cooperative agreement support from the Division of Polar Programs, Directorate for Geosciences at the NSF. TFS provides laboratories and support services for Arctic research and education to scientists and students from universities, institutions, and agencies from throughout the United States and the world. Much of what is known about terrestrial and aquatic ecosystems of the Arctic has emerged from long-term research projects at the Toolik Field Station. Projects address the effects of environmental change on Arctic ecology, ecosystem structure, and the function of Arctic tundra, streams, and lakes. Current projects focus on the role of disturbance, especially fire and thermokarst, and interactions with climate change. Projects on animal adaptation to the Arctic include long-term studies of the behavior, ecology, physiology, endocrinology, and genetics of hibernating mammals, migrating songbirds, and overwintering insects.[494]

Oil Spill Recovery Institute

The purpose of the Prince William Sound Oil Spill Recovery Institute (OSRI) is to support research, education, and demonstration projects designed to respond to and understand the effects of oil spills in the Arctic and sub-Arctic marine environments. Working with a wide variety of industry and agency organizations to sponsor technological improvements for oil spill response, OSRI contributes to the testing of new skimmer technologies, sensitivity index maps, and sponsoring workshops to identify best practices and research needs.[495]

Barrow Arctic Science Consortium

The Barrow Arctic Science Consortium (BASC) is a not-for-profit organization based in Barrow, Alaska, that is dedicated to the encouragement of research and educational activities pertaining to Alaska's North Slope and the adjacent portions of the Arctic Ocean. As part of BASC's mission to support science they work with every federal agency that has a presence or wants to have a presence in the U.S. Arctic. BASC works with its sister organization in Russia, the Chukotka Science Support Group, and with numerous international schools and research institutes. With local connections, experience, and knowledge, BASC provides logistical support in the field, assistance with permitting issues, and helps facilitate outreach efforts for researchers.[496]

Other Organizations

There are many other international, state, local, industry, and native organizations who contribute to the identification of scientific questions, funding of research studies, facilitation of research initiatives, and communication of scientific outcomes, and it is not possible to reflect all these in this review. Their contributions are certainly recognized with the scientific and the Arctic communities.

KEY RECOMMENDATIONS FROM THIS ASSESSMENT

Research has been conducted by industry, government, and academia for decades, and much is known about the Arctic ecology and native peoples. Obtaining higher confidence in ecological and human environment conditions and interactions would support improved science-based decision-making. Key study areas include enhancing the ability to determine impacts, better defining special status species listings and critical habitats, and improving ecological resource management. This research would promote prudent development.

- Trustee agencies, such as U.S. Fish and Wildlife and U.S. National Marine Fisheries, could execute multi-year population assessment and monitoring of key Arctic species, including the Pacific walrus, ice seals, polar bears, and bowhead and beluga whales.
- Under its legislative mandate to coordinate scientific data that will provide a better understanding of the ecosystems of the North Slope of Alaska, the NSSI should work with trustee agencies, industry members, and other stakeholders to define, develop, and maintain an ecological monitoring program to detect and interpret change in the Arctic ecosystem.
- DOE, other governmental entities, the National Laboratories, and industry should execute additional studies of fate and effects of oil under Arctic conditions and upon Arctic species: toxicity of oil, oil residue, and dispersants to key Arctic species, including Arctic cod and plankton; the rate and extent of biodegradation of oil in Arctic environments; and the interactions of oil with under-ice communities.
- The federal government (National Marine Fisheries Service) should work collaboratively with industry and other stakeholders to develop a coordinated strategy for industry and government research on interactions between energy development and key species.
  - Specifically, the improved understanding of the response of ice dependent species to specific industry activities (ice management, seismic, drilling, etc.) will inform operational planning and permitting as well as designations and management of critical habitats.
  - NMFS should join BOEM as an observer in the Sound and Marine Life Joint Industry Program.
- The U.S. National Security Strategy for the Arctic Region states that it is vital to "increase understanding of the Arctic through scientific research and traditional knowledge" while at the same time "pursu[ing] innovative arrangements" to ensure "faster progress through a well-coordinated and transparent national and international exploration and research agenda."
  - An important tool to enhance this understanding as well as to implement integrated Arctic management is the enhanced use of the NSSI. It is recommended that NSSI establish appropriate protocols and gather best practices for the effective collection and integration of traditional knowledge, existing science, community engagement, and resource management. NSSI will engage all key stakeholders to develop appropriate methodologies and improvements in this integrated management model.

- An updated Social Impacts Assessment protocol is needed, to improve consistency and the ability to integrate baseline data across agencies, industry, and communities, and to be consistent with other Arctic nations.
  - The Department of State, via the Senior Arctic Official and the Arctic Council Sustainable Development Working Group, should update the Social Impacts Assessment protocol, leveraging the state of Alaska's coordinated framework for a Health Impact Assessment, recently developed by the Alaska Department of Natural Resources and Department of Health in partnership with federal agencies, the Alaska Native Tribal Health Consortium, and local boroughs.
  - The Council for Environmental Quality should include this updated protocol in the existing Environmental Impact Assessment protocol under NEPA.
- The NSSI provides scientific information on both environmental and social science to its 14 federal, state, and local government members and to the public. Enhancement of NSSI capabilities in social science would help provide crucial information for both industry and governments, and provide improved coordination on human environment research activities.
- Industry, government, and academia should work to establish data sharing agreements and promote use of platforms such as Alaska Ocean Observing System and UAF/NSSI catalog.

Along with the above key recommendations, this assessment of research on characterizing and assessing the ecological environment has identified a range of secondary recommendations, and these were discussed in earlier sections of this chapter. The following are key common elements for these recommendations:

- Establish an annual forum or mechanism for routine sharing of information among industry, agencies, and researchers. New opportunities exist to work collaboratively, share resources, and plan strategically to facilitate maximum outcomes from the resources invested. Such a forum should also strive to create and enhance mechanisms for providing financial and logistic resources to support scientific research of mutual interest.
- While recognizing the value and extent of existing relevant scientific knowledge, strengthen and support scientific research efforts to improve the quantity and quality of information upon which permit decisions are based. To ensure that research activities are adequately focused on the information needed for science-based permitting and regulatory actions, regulators should clearly identify, prioritize, and communicate specific information needs to all stakeholders.
- Develop a multi-stakeholder private-public partnership, or a cooperative approach, to fund and oversee applied environmental research and monitoring relevant to economically and ecologically sustainable oil and gas development in the Alaskan Arctic. A cooperative approach will promote and support strategic research rather than research linked to individual development projects and permits. Broad integration of the accumulating data is essential, to provide a strong management basis for the Arctic.
- DOE should facilitate a workshop aimed to identify priority research topics focused on the winter or dark periods so as to facilitate data collection from these periods. This will assist stakeholders and government increase the understanding of ecological processes in this less studied period.
- Industry, government, and academia should work to improve the understanding of the response of ice dependent species to specific industry activities (ice management, seismic surveys, drilling, etc.); and this will inform operational planning and permitting as well as designations and management of critical habitats.
- DOE, BOEM, and NMFS should follow the studies and outcomes of the IOGP Sound and Marine Life Joint Industry Program.

One overarching focus of the recommendations above on the characterization of the ecology of the Arctic, and the application of this science to the management of Arctic resources, is that there needs to be a continuing focus on improving modes of delivery and sharing of scientific information through collaboration. It is through such efforts of all interested and engaged parties that the maximum benefits for the ecology and the communities that depend on these resources will be realized in a sustainable manner.

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Chapter 10

The Human Environment

A framework for prudent Arctic resource development requires an understanding of the human environment if it is to minimize adverse effects on communities and the natural environment and optimize economic benefits. This chapter gives an overview of the people who live in the Arctic and explains how their communities are organized and how they are affected by oil and gas activity. The chapter begins with a review of existing studies, including those funded by governments, NGOs, and industry. It then covers common themes in research, with an evaluation of how each relates to both the people of the Arctic and the impacts of oil and gas activity. Finally, it gives an overview of existing Arctic research and programs.

The term "human environment," as used in this assessment, means understanding the physical, social, economic, and cultural aspects of local communities and how these aspects may be directly or indirectly impacted (positively or negatively) by oil and gas exploration and development and other activities. The chapter begins with a comprehensive review of existing research studies on the U.S. Arctic and the groups that conduct them. In addition, future priority research areas from an oil and gas industry perspective are suggested to support sustainable and responsible resource development.

Indigenous cultures, such as the Inuit (Iñupiat), Yup'ik, Chukotka, and Sami, inhabit the circumpolar Arctic and have survived many episodes of environmental change[1] (Figure 10-1). Climate models predict that sea ice loss and thawing permafrost are accelerating and may cause disruptions to traditional subsistence practices and food security.[2,3,4] Yet, the changing environment may also provide an opportunity for economic and social development, including increased opportunities associated with the opening of trans-Arctic summer shipping routes from the North Atlantic to the Bering Strait.[5]

Oil and gas activities are not new to the circumpolar Arctic or to Alaska's Outer Continental Shelf (OCS). In the 1980s and early 1990s, 32 exploration wells were drilled in Alaska's OCS in the Beaufort and Chukchi Seas. Most of the wells were drilled in the 1980s, with 11 drilled in the 1990s and one in 2002. Oil and gas development in Arctic regions is an important component of the economic activity of all Arctic states. Advances in technology will support ongoing future exploration and production activities. Therefore, ensuring the continued protection of the environment and the communities, while providing employment opportunities via responsible oil and gas development, is a key responsibility for all Arctic stakeholders.

Three key areas of the human environment provide the context of the request by the Secretary of Energy to review U.S. oil and gas activities in the Arctic. These areas are:

- **Social and human health.** This section includes discussion on the demographics, community wellness, local infrastructure and social service needs, and food security considerations.
- **Economic development.** This section provides context for evaluating research needs to understand employment and training needs of indigenous communities and the role that business can play in helping to transfer these skills while expanding business and development opportunities.
- **Cultural.** This section discusses the important issues and background on subsistence harvesting, traditional knowledge gathering and use, heritage resources, and land use.

Source: Arctic Slope Regional Corporation – Energy Services.

Figure 10-1. *Indigenous Cultures of the Arctic*

These key areas encompass the discussions and recommendations that follow in this chapter.

The chapter is organized in four sections. The first section, "Review of Existing Human Environment Understanding," establishes the context for subsequent sections. It reviews the current understanding of the human environment and discusses the historical and current research on the human environment as it relates to oil and gas development in the Arctic. It then provides a brief description of the human environment setting.

The second section identifies the common research themes associated with Arctic decision-making. The five themes are as follows:

1. Sociocultural demographic and wellness patterns
2. Subsistence use patterns
3. Traditional knowledge
4. Protection of food security through evaluation of contaminants in subsistence foods
5. Fate and effect of oil spills.

The third section provides an overview of the organizations currently engaged in Arctic human environment research and the programs in which they are involved. The section emphasizes research work in the U.S. Arctic and programs based in Alaska. However, some notable circumpolar Arctic and international research is described.

Finally, the fourth section, "Key Recommendations from This Assessment," prioritizes research activities and gives recommendations.

Multidisciplinary and collaborative approaches to Arctic research are important, and this importance is demonstrated in this chapter. Multiple stakeholders are responsible for the research required to ensure protective stewardship of the Arctic human environment of the United States. These stakeholders include industry, regulators, academia, and local communities. Individual oil and gas operators have made significant investments in research, data collection, and analysis over recent decades. These investments ensure that impacts to the human environment from their activities are understood and appropriate mitigations are in place. Regulators and academic organizations have an established U.S. Arctic research history that informs decision-making, which balances social and environmental protection with economic opportunity. Local communities have collected knowledge for thousands of years while living in the Arctic. Over generations, they have gathered and shared knowledge gained from and applied to subsistence activities, resources, the physical environment, and other environmental factors. We will refer to this traditional knowledge frequently throughout this analysis.

This collaboration leads to a comprehensive understanding of the U.S. Arctic human environment—a knowledge baseline. Continued collaboration—working collectively, identifying synergies, and common research interests—is critical to the research themes discussed in this chapter and will ensure that informed decision-making supports responsible oil and gas development of the Arctic.

> "I want to emphasize that putting people together and putting industry and local corporations together have proven to be a successful path where all parties work together to achieve a balance that residents can live with." – Gordon Brower, Iñupiaq, North Slope Borough Planning Department.[6]

REVIEW OF EXISTING HUMAN ENVIRONMENT UNDERSTANDING

Previous and Existing Research and Studies

Historical Research in the U.S. Arctic

Waves of Arctic activity such as whaling in the 1800s, military activities in the 1900s, and oil and gas exploration in the late 1900s and early 2000s have driven research on the human environment in the Arctic. While living in the Arctic, indigenous peoples have formed a strong base of local and traditional ecological knowledge.

Early documentation of the Arctic human environment came from the early "outside" travelers who wrote down and shared their experiences of indigenous people. In Alaska, the first non-indigenous visitors who wrote about Native Alaskans were the Russian fur hunters and traders and explorers who accessed Alaska through the Aleutian Islands, exploiting furs as early as the mid-1700s.[7] The Russian fur trade initially focused on the southern Alaska coastal areas—the Aleutian Islands, Cook Inlet, and Kodiak Island. When the Russian American Company was established in 1799, fur trade expanded inland.[8] The Russian Orthodox Church missionaries soon followed the fur traders. The missionaries worked closely with Native Alaska communities, documenting information about them and sending it to Russia. In the 1830s, the missionaries put many Native Alaska languages into written form.[9] These missionaries were among the first ethnographers or researchers of the human environment in Alaska.

Other early knowledge of the human environment comes from explorers, cartographers, miners, and anthropologists. Explorers Frederick Schwatka and Charles Willard Hayes are two such examples. In 1891, these two men traveled then-unmapped areas of the White River, Skolai Pass, and the upper Chitina River drainage, all areas in Alaska. Their diaries of these travels provide a wealth of information on the Native Alaskan populations, geography, and environment.[10] U.S. Geological Survey's Alfred Hulse Brooks was also a pioneer in the history of Alaska human environment studies. Brooks was a scientist of both the natural and human environments. He explored much of Alaska, mapping the state and documenting the Native populations, history, mining, fauna and flora, geology, fisheries, climate, agriculture, and government.[11] Early anthropological/archaeological expeditions and studies include those of Aleš Hrdlička from 1926 to 1938. Hrdlička studied many Alaskan communities and people, including the North Slope and Northwest Arctic communities of Barrow, Kotzebue, Point Hope, Shishmaref, and Wainwright.[12]

The Arctic Research Laboratory, originally called the Naval Arctic Research Laboratory (NARL), was established in 1947 in Barrow, Alaska. Originally operating under the Office of Naval Research in Washington, D.C., the laboratory came under the

National Science Foundation's (NSF) jurisdiction in 1969 when the NSF was named lead agency for Arctic research. In 1980, the Navy relinquished its involvement in NARL.[13,14] In 1989, the Ukpeagvik Iñupiat Corporation, the Barrow Alaska Native Corporation, formally took over managing NARL, which continues to be involved in collaborative research related to the Arctic physical and human environment.

Perhaps the most significant outcome of work at NARL is the established history of collaboration between Iñupiat and non-Iñupiat scientists.[15] From its beginning, NARL has brought global attention to the Iñupiat, providing a detailed history of the area and important Arctic scientific findings.[16] Combining natural science, social science, and traditional knowledge methods, researchers at NARL have conducted a multitude of studies on the physical and human environment. Through NARL, Iñupiat and non-Iñupiat scientists pioneered collaborative research efforts that integrated traditional knowledge and science.[17]

Many of the U.S. Arctic human environment studies have been related to resource development. Often these studies were launched as the result of federal mandates: the National Environmental Policy Act (1969), Outer Continental Shelf Lands Act (1978), and other mandated responsibilities of the Department of Interior (DOI) such as the Bureau of Ocean Energy Management (BOEM) (CFR 30.256.82). For example, Norman Chance's ethnographic studies of the Iñupiat focused on effects of oil and gas discovery and development on the North Slope. His studies provide more than 30 years of observations and analysis that document "baseline" conditions during the beginning of the North Slope oil rush, the changes resulting from oil and gas activity, and the resilience of the Native people and their ability to sustain their culture through times of change.[18]

Both BOEM and the Bureau of Land Management (BLM) continue to contribute substantially to Arctic human environment studies. BOEM was mandated to collect data on the baseline conditions needed to assess and manage the impact on human, marine, and coastal environments by OCS oil and gas activities. BOEM used these baseline core studies to serve as starting points to document subsistence patterns and for subsequent environmental impact statements.

In 2006, BOEM implemented a Study Plan for the Social and Economic Impact Assessment of Alaska OCS Petroleum Development that was funded through the Alaska Sea Grant Program. The major BOEM drivers of the social component of their Environmental Studies Program are: (1) assessing potential socioeconomic effects of OCS activities and (2) the effects of these activities on subsistence as an economic sector in rural communities. The BLM Environmental Studies Program taps scientific knowledge of regional and local experts to collect and disseminate environmental information about resource issues. The program shares and coordinates this research with the international Arctic Council monitoring and assessment programs such as the Arctic Monitoring and Assessment Program (AMAP), the Arctic Council's working group on Conservation of Arctic Flora and Fauna (CAFF), and Arctic Climate Impact Assessments.

The Environmental Studies Program contains a social research component to gather and analyze environmental, social, and economic information for federal lands onshore. BLM assists BOEM with preparing environmental impact statements and facilitating sound decision-making related to the offshore oil and gas program.

As part of its Social and Economic Studies Program, DOI commissioned a study on the North Slope Economy from 1965 to 2005.[19] This report assessed the structure of the North Slope economy, the role of local government, the role of for-profit Alaska Native corporations, the role of other government and nonprofit organizations, and the impact on household economics. In 2009, the Minerals Management Service published a compilation of studies conducted on the human environment as related to offshore oil and gas development, entitled *Synthesis: Three Decades of Research on Socioeconomic Effects Related to Offshore Petroleum Development in Coastal Alaska*.[20] Stephen Braund conducted a comprehensive series of harvest assessments in Barrow and Wainwright from 1987 to 1989, which provided quantitative information on subsistence harvests across all species.[21,22] Braund and colleagues conducted systematic household interviews at regular intervals, collaborating with the North Slope Borough. BOEM's synthesis of three decades of research on socioeconomic effects related to offshore energy development provided an exceptional series of subsistence harvest assessments providing baseline conditions for use in environmental impact statements addressing the prediction and monitoring of potential effects of activities in the Outer Continental Shelf.

State of Alaska Department of Fish and Game Village Subsistence Studies

Since the 1970s, the state of Alaska, through the Alaska Department of Fish and Game (ADF&G), has sustained a program of village subsistence research complementing the sociocultural studies produced by DOI. There have been more than 300 studies focusing on subsistence uses within particular communities and specific topics relating to "customary and traditional use findings" for fish stocks and game populations.

Initially, subsistence harvest data for the OCS development area was largely absent. ADF&G did produce harvest data for Point Lay, which was reported for the first time in a BOEM technical report. Subsequently, there have been additional research studies sponsored by BOEM and the North Slope Borough. With funding from the revenue generated by oil and gas development, the North Slope Borough established a Department of Wildlife Management and a regional Fish and Game Management Committee. These entities are mandated to help protect subsistence activity on the North Slope.

A major finding of ADF&G's subsistence harvest surveys was that contemporary subsistence uses take place within a "mixed economy." This mixed economy includes subsistence hunting and fishing, combined with a cash economy component. These components are intertwined, as cash is necessary to purchase equipment, supplies, and fuel in order to harvest subsistence resources. Multiple ways of living have developed within these communities of users that include the traditional harvest and use of wild resources, adapted to local ecological and economic circumstances.[23]

ADF&G's subsistence harvest research is coordinated with BOEM's Environmental Studies Program subsistence studies and is conducted in partnership with local communities to determine how much local communities depend on food acquired through subsistence hunting and fishing.[24,25,26,27] Recently, ADF&G has communicated with other countries to study sustainable development and impact assessment methods for evaluating traditional cultures in the Arctic regions where industrial development occurs.

Institute of Social and Economic Research, University of Alaska Anchorage

In the 1970s, the NSF awarded a multi-year grant to the Institute of Social and Economic Research (ISER) at the University of Alaska Anchorage to study the social and economic effects of energy development in Alaska. With the discovery of oil on the North Slope in the 1970s and construction of the Trans-Alaska Pipeline System (TAPS) in 1974, research was directed toward the effects of oil development on the local rural Alaskan people. The Institute has a public policy focus on the theme of Arctic social systems, and often works collaboratively with federal agencies such as BLM and BOEM, along with others, to identify information needs and implement research initiatives.

ISER's research has included studies on the human environment and the role that oil plays in Alaska's economy: Prudhoe Bay lease sale in 1969, construction of TAPS, production in the field in 1977, and assessments of statewide impacts of OCS petroleum facilities development in Alaska in the late 1980s. Their research also facilitated the discussion about sustainability in Arctic communities,[28] including studies of Alaska Native regional corporations to help understand local for-profit and nonprofit organizations and their role in establishing financial stability for their shareholders.[29]

ISER's research on the sustainability of the human environment included household surveys of Iñupiat in the Arctic Slope to better understand the relative importance of jobs, wild food harvesting, and social ties for life satisfaction. The results emphasize the importance of nonmaterial measures for life satisfaction, and agrees with other research showing the importance of harvesting wild food and the persistence of a mixed economy—one that combines cash income and wild food harvests.[30]

National Research Council Polar Research Board

The National Research Council (NRC) established the Polar Research Board in 1958. By the end of the

1980s, the Council considered the need to expand social science research in the Arctic and generated *Arctic Social Sciences: An Agenda for Action*. More than 500 studies have been funded since 1991, which have contributed to understanding change in Alaska. NRC funded $25 million worth of Arctic social science research in the period 1995 to 2004, which included the *Cumulative Effects of Oil and Gas Activities on Alaska's North Slope*.[31]

The NRC recently published *The Arctic in the Anthropocene: Emerging Research Questions*,[32] which provides a synthesis of the scientific community's input on emerging research topics concerning the Arctic. This report considers topics that are underrepresented in current Arctic research. The audience for the report is the Interagency Arctic Research Policy Committee (IARPC), which encompasses 15 federal agencies and organizations with Arctic responsibilities. Opportunities for collaboration at local, regional, and international levels are presented.

National Science Foundation Man in the Arctic Program

Funded by the NSF in the early 1970s, the Man in the Arctic Program developed models of Alaska's population and economy to assess alternative policies that are still used today.[33,34] The research theme of the program produced regional-scale surveys to better understand the social, economic, and subsistence effects of oil development.[35,36] Objectives were to:

- Measure and analyze basic changes in the economy and population of Alaska
- Determine significant interactions between outside economic and social forces and Alaska conditions and institutions
- Identify and project policy-relevant consequences of these interactions
- Apply these research findings in analyses of specific public problems and policy alternatives.

Initially, the Man in the Arctic Program assessed the impacts of future petroleum development in Alaska from both the development of the OCS and the construction of TAPS. University of Alaska researchers collaborated with research scientists from other institutions on a broad, long-range program of social, economic, and environmental policy studies in an effort to project changes over the next quarter century in U.S. Arctic and sub-Arctic environments; national energy demand; Alaska oil and gas development; environmental conservation pressures; and the reallocation of more than 200 million acres of U.S. public land among federal, state, and private interests spurred University of Alaska researchers to collaborate with research scientists from other institutions on a broad, long-range program of social, economic, and environmental policy studies. As a joint collaborator with the ISER of the University of Alaska, Man in the Arctic has continued to study the economic, demographic, and sociocultural effects of oil and gas development in Alaska, in collaboration with the University of Alaska. This partnership has provided a unique opportunity to organize historical information to establish a baseline to help researchers understand environmental changes in the Arctic, allowing stakeholders to respond to ongoing and projected changes accompanying oil and gas development.

North Slope Science Initiative

The North Slope Science Initiative (NSSI) was formally authorized in Section 348, Energy Policy Act of 2005 (Public Law 109-58) to identify information for inventory, monitoring, and research activities and to develop an understanding of such information for agencies, local governments, and the public. For more than 20 years, the initiative has published *Emerging Issue Summaries*[37] to inform management decisions. The purpose of these summaries is to validate many of the scientific findings already being addressed by member agencies, share human and monetary resources, and adopt a systematic, collective approach to address future scientific needs.

The North Slope Scientific Initiative maintains an extensive "Data Catalog and Project Tracking" and "North Slope Long-Term Monitoring Summary."[38] The group recommends broad subject areas for study by identifying management information needs. These include the following findings:

- The North Slope is a social-ecological system; consequently, adaptive co-management is critical.
- Land and maritime use decision-making should focus on ecosystem services, food security, and sustainable local livelihood.

- Research, monitoring, and decision-making need to integrate traditional knowledge, social and natural sciences.
- Better data management is needed.
- Two-way community involvement is necessary.
- Coordinated data collection is necessary to prevent informant burnout.

Arctic Council Working Groups

Arctic Monitoring and Assessment Program. Established in 1991, AMAP is one of six working groups of the Arctic Council. The program's role is to monitor pollution and climate change and to document essential relationships among ecosystems and humans within the Arctic region.

A series of assessments that began in the late 1990s and continued into the 2000s addressed six pollution issues: persistent organic pollutants, heavy metals, radioactivity, acidification, petroleum hydrocarbon pollution, and the biological effects of stratospheric ozone depletion.

More recently, in 2007, the Arctic Council charged AMAP to assess human health effects of contaminant exposure by establishing a baseline on the spatial distribution and temporal trends of contaminants in various media across the Arctic. The subsequent investigations led to recommendations including (1) specific international agreements to reduce contaminant levels and effects, (2) mitigation of potential sources of radioactivity, and (3) steps to reduce gaps in knowledge concerning human health.

Sustainable Development Working Group. In the Arctic Council's Sustainable Development Working Group, there is emphasis on study reports such as *Arctic Human Development Report*[39] and *Adaptation Actions for a Changing Arctic*[40] in order to understand the cumulative effects of climate change and resource development activities on the people of the region. The *Arctic Social Indicators* report[41] is the basis of BOEM's social indicators research study currently underway. The survey is based on best practices among social scientists, including Dr. Gary Kofinas's project "The Study of Sharing Networks to Assess the Vulnerabilities of Local Communities to Oil & Gas Development in Arctic Alaska."[42] The results of the social indicators study will be used to monitor effects as part of the social impacts assessment in the Environmental Impact Assessment process.

Industry-Led or -Funded Studies

The oil and gas industry has conducted numerous studies in the Arctic or provided funding for studies on the human environment. Some Alaskan examples are included below.

Industry Economic Analysis of Future Offshore Oil and Gas Development: Beaufort Sea, Chukchi Sea, and North Aleutian Basin

In 2009, Northern Economics and the University of Alaska Anchorage prepared an economic analysis of future offshore oil and gas development in the Arctic for Shell Exploration and Production. The study provides a qualitative and quantitative analysis of the potential economic benefits to the state of Alaska and local communities from developing oil and gas resources in the OCS. This study concluded Alaska OCS development could generate an average of 35,000 jobs per year over the next 50 years—a 6% increase compared to total statewide employment without OCS development. The findings are a catalyst for thinking about actions that state and local governments, industry, and other stakeholders might undertake to address potential effects from OCS development. If OCS development were to occur, the 2009 economic analysis asserts, it could be a significant driver of the next generation of economic activity by extending the duration of the petroleum industry in the state.

Shell Collaborative Science Agreements

Recent separate collaborative science agreements between Shell and the North Slope Borough (2010) and Northwest Arctic Borough[43] are providing communities a stronger voice in directing research and encouraging use of traditional knowledge and consideration of subsistence issues in research programs. The agreements also serve to build capacity within the communities with participation from coastal villages and independent scientists. One project that has come out of the collaborative science agreement with the North Slope Borough is the "Experts Workshops to Comparatively Evaluate Coastal Currents and Ice Movement in the Northeastern Chukchi Sea"[44] with contributions on Iñupiaq knowledge of currents and ice from several traditional knowledge experts from Barrow, Point Lay, Nuiqsut, and Wainwright, Alaska, and scientists from the University of Alaska Fairbanks, National Snow and Ice Data Center

& University Corporation for Atmospheric Research, and the Arctic Slope Regional Corporation (ASRC).

Statoil Traditional Ecological Knowledge of Acoustic Disturbance to Marine Mammals: Partnership Between Statoil and Three Alaska Native Communities

As part of Statoil's stakeholder engagement activities regarding their leases in the Chukchi Sea, feedback given to Statoil's team has centered on concerns that offshore drilling may disrupt marine mammals and has included consistent requests to incorporate traditional knowledge in studies. Alaskan communities have intense concern about the noise and sight of exploration and production activities disturbing marine mammals that are important for subsistence. Behavioral reactions of marine mammals to sound disturbance are complex and have been the focus of extensive investigation over the past decade. This is identified as a research theme in the chapter on the ecological environment (Chapter 9) and is also the subject of a Joint Industry Program on Sound and Marine Life that is funded by a number of oil and gas operators currently active in the Arctic. Through thousands of years of subsistence on marine mammals, Native Alaskans have developed extensive traditional knowledge of marine mammal behavior in a variety of contexts.

Statoil understands the value of traditional knowledge for the risk assessment and development process, specifically that this body of knowledge allows for a better evaluation and subsequent avoidance and mitigation of potential impacts to marine mammals and subsistence. In recognition that the best available information about marine mammals requires an integration of scientific and traditional knowledge, Statoil partnered with three coastal Alaskan communities—the Native governments of Kotzebue, Wainwright, and Point Hope—to document traditional knowledge of how marine mammals respond to sound disturbance.

ExxonMobil Kaktovik Programs

ExxonMobil is involved in a number of ongoing initiatives to communicate with local residents about the Point Thomson development, focusing primarily on the Kaktovik community when developing collaborative programs. Ongoing consultation involves an open dialogue between ExxonMobil and residents of the North Slope Borough on how suggestions and recommendations are addressed and incorporated into design, location, construction, and operations. One example of a successful recent collaboration included partnering with residents of Kaktovik to assess cultural resources on Barter Island. With the help of local experts and a high school intern, and in cooperation with local agencies, the Point Thomson archaeology team employed sophisticated technologies to record artifacts and investigate heritage sites. Some of these technologies and excavating techniques were later taught to students in the Harold Kaveolook School through ExxonMobil's Science Ambassador Program.

Another Point Thomson initiative involves developing an ice cellar for the local community. Following the fall bowhead whale subsistence hunt, community members receive their shares of the whale meat but often lack adequate measures to store it. Traditionally, this meat has been stored in ice cellars that are dug beneath the permafrost to ensure the meat does not spoil. Some of the effects of climate change—encroaching coastlines, melting permafrost, and changing surface water hydrology—have challenged the viability of this storage mechanism. After helping to establish the Kaktovik Community Foundation, ExxonMobil contributed funding to support the subsequent design, and construction of an ice cellar to meet community needs.

BP Restoration of Tundra in Oilfields Using Traditional Knowledge

BP is working on a way to reclaim small patches of disturbed land using indigenous plants, using a concept based on Iñupiat traditional knowledge. Several years ago, a local resident showed BP scientists how to use tundra sod blocks as a revegetation technique, a traditional way of protecting and insulating ice cellars for subsistence food storage. This method was adopted by BP to treat tundra scars caused by excavation during oil spill response. Now the idea has been taken a step further with an adaptation for small patches of disturbed tundra. After revegetation was completed, researchers returned in 2014 and found the sedge mats intact and the plants growing well.

ConocoPhillips Nuiqsut Subsistence Studies

ConocoPhillips works closely with the community of Nuiqsut, located 7 miles from the Alpine Field, on two long-term monitoring studies to understand the impact of oil field operations on caribou hunting and the Colville River fall fishery. The intent of the Caribou Subsistence Use Monitoring Project is to assemble multi-year data on impacts on caribou subsistence uses in order to come to a common understanding of these impacts by the community of Nuiqsut, industry, and government oversight agencies. With the assistance of the Kuukpik Subsistence Oversight Panel, Inc., Braund Associates formed a Nuiqsut panel of caribou experts to assist with developing the monitoring plan and identifying active caribou harvesters to interview.

The fall fishery monitoring in the Colville River is focused on the fall harvest of Arctic cisco (*Coregonus autumnalis*; *qaaktaq*, in Iñupiaq), which is a staple in the diet of Nuiqsut residents and traded widely with other northern Alaska communities. The goals of the monitoring program, ongoing for more than 28 years, have been to obtain estimates of total catch data for subsistence fishers and to predict future harvests. Furthermore, the monitoring program serves as an early warning system if predicted recruitment or other indicators suggest long-term threats to Arctic Cisco populations.

Brief Description of the Human Environment Setting in Alaska

Social and Human Health

Demographics

Alaska's population at statehood in 1959 was approximately 224,000, and surpassed 736,000 in 2013.[45] The discovery of oil, combined with other major events such as Alaska statehood in 1959, the enactment of the Alaska Native Claims Settlement Act (ANCSA), the establishment of the North Slope Borough in 1972, passage of the Alaska National Interest Lands Conservation Act in 1980, and the opening of the National Petroleum Reserve-Alaska (NPR-A) for oil and gas development, brought significant changes to Alaska's population, especially in the North Slope Borough. Large population booms occurred in the state following the discovery of oil in Prudhoe Bay in 1968 and the subsequent construction of TAPS, although many workers left after construction was complete. Oil development had significant effects, positive and negative, on the economic, institutional, environmental, and social aspects of the North Slope region.[46]

Statewide data on population, employment, taxes, and census are available online for economic regions, boroughs, census areas, and communities on the Alaska Department of Labor website.[47] The Alaska Oil and Gas Association publishes reports assessing the specific role of the oil and gas industry in Alaska's private and public sector economy.[48] For a local viewpoint, the North Slope Borough has published its fourth volume of the *North Slope Borough Economic Profiles and Census Reports*. The North Slope Borough census provides a detailed look at changes occurring in the eight borough villages by comparing aspects of life among the villages. The report focuses on the villages as separate communities as opposed to focusing on the borough as a whole. This methodology is employed in the belief that understanding the dynamics of change within each community provides a broader analysis of the socioeconomic and cultural changes occurring in the North Slope.[49]

North Slope Borough and Northwest Arctic Borough. There are 16 communities in the North Slope Borough and Northwest Arctic Borough; local governments exercise legal government power, including taxation, education, and planning and zoning services. The North Slope Borough was created in 1972 as a result of oil and gas activity on the North Slope and the Northwest Arctic Borough was created in 1986 when the Red Dog Mine was developed. Both governments provide employment, education, and other services to all of their communities. Subsistence is an important year-round aspect of the socioeconomic makeup of the mixed subsistence-wage economies of many communities in both these regions.

The 2010 census report revealed how important subsistence resources are for the total population. The census shows that just over 76% of the total population of the North Slope was Iñupiat, while 80% of the total population of the Northwest Arctic identified as Iñupiat. Of the reporting households in the North Slope Borough census, 99% used subsistence foods and 53% reported receiving most of their diet from subsistence foods.[50]

Although some researchers previously had predicted a decline in subsistence participation in northern Alaska due to pressures from modern technological advances, most Arctic social science researchers today conclude that the mixed economy is vital to the survival of the Iñupiat.[51] In fact, because the relationship between wage employment and subsistence depends on subsistence users having some flexibility in their work schedules,[52] many employers within the North Slope allow their employees special time off for subsistence activities.

Health and Wellness

In spite of the harsh environment and the extreme remoteness of many Arctic communities, basic standards of health are in place, with sanitation available for 60% of the Arctic population and water available for 82%. Increasingly, rural Alaskan communities are gaining access to piped water and sewage treatment and moving away from "honey bucket" and trucked water systems. The Alaska Native Tribal Health Consortium established its Scattered Sites program to provide water and sewage service statewide to Alaska Native homes.[53] Other water and sewer installation projects occur through borough projects.[54,55]

Life expectancy rates have also improved significantly over the past few decades. In 1950, the life expectancy at birth for an Alaska Native was 47 years while the U.S. national average was 66. By 2000, life expectancy had increased to 69.5 years, a growth of over 20 years. Much of the improvement in life expectancy rates can be attributed to disease prevention activities that have significantly reduced morbidity and mortality rates from infectious diseases. For instance, in 1950 infections accounted for 47% of deaths among Alaska Natives, but by 1990 that rate had dropped to 1.2%.[56] The development and expansion of infrastructure, such as sewage disposal and safe water supplies, have also accounted for the significant improvement in Arctic health.

Changes in living conditions in the Arctic reflect the economic shift away from solely subsistence hunting and gathering to a cash-based economy. These changes have had a positive effect on the physical health of Arctic communities by providing a more stable food supply, improving housing conditions, and reducing morbidity and mortality from infectious diseases.

In 2012, the North Slope Borough published a *Baseline Community Health Analysis Report* that found that since the early 1970s many aspects of health have improved for its residents. These likely reflect substantial investments made in health and social services, education and employment opportunities, community infrastructure, public safety, and the local legislation restricting access to alcohol.[57] The overall improvement speaks to the resilience of the people and an ability to adapt not only to the harsh and changing climate but also to the social, cultural, and economic transformation they have experienced.

The analysis also found that despite the many community health improvements, significant health inequalities persist in rural communities, including the North Slope and Northwest Arctic. Chronic diseases such as cancer, heart disease, and lung disease have emerged as leading causes of illness and death in Alaska Natives. Injuries remain a major health disparity, especially among youth, and the related problems of alcoholism, family violence, and sexual assault continue to plague many communities. During the later decades of the twentieth century a pattern emerged in Alaska, characterized by epidemic levels of suicide among young Alaska Native men, particularly in northern regions of the state.[58] This pattern has been observed also in other Arctic nations and is a priority within the Arctic Council's Sustainable Development Working Group and the Inuit Circumpolar Council.

The impact of the changing Arctic on the overall health of Arctic indigenous people has increased concerns about food security. While more produced food is reaching remote Alaska communities, quality foods do not necessarily reach them. Food that most often survives the travel to communities is processed, packaged, and preserved; it is not fresh. Fresh foods that travel these distances are at risk of chemical contamination, damage, and loss of flavor and nutrition.[59] Obesity in Arctic populations is on the rise. This is attributed in part to increased consumption of processed foods with high amounts of sugar and fat, and decreased consumption of traditional foods.[60,61,62,63,64]

Although the people now are more dependent on a cash economy, subsistence remains a vital component in the overall health of many Arctic indigenous communities. Wage income also provides the opportunity to purchase food when harvests are low, pay for medical care, and other lifestyle improvements. Adoption of an employment-based cash economy can result in development of practices that are less culturally sustainable. Those with jobs have less time to hunt, fish, and gather subsistence resources; less time to spend with extended family; and in whaling communities, less time to help whaling crews prepare and harvest.[65]

As part of its Social and Economic Studies Program, DOI commissioned a study on the North Slope Economy from 1965 to 2005.[66] This report assessed the structure of the North Slope economy, the role of local government, the role of for-profit Alaska Native corporations, the role of other government and nonprofit organizations, and household economic impacts. The North Slope Borough employs the highest number of working individuals on the North Slope. A large portion of the borough income comes from taxes, permit fees, and royalties on oil and gas. In a 2007 assessment, Baffrey and Huntington reported that economic assets in Nuiqsut were encouraging: Kuupik's (Nuiqsut Village Corporation) revenues were over $10 million per year; from 1994 and 2004, personal income had increased 40%; Nuiqsut community infrastructure had increased; and middle-class amenities and goods were available in the village.[67] These positive changes resulted largely from the Alpine development. These enhancements have a downside, however, as people become more reliant on the cash economy and may not be able to sustain themselves without it.

Another risk to cultural sustainability is the effect of out-migration. Arctic indigenous people are moving from rural communities to larger urban areas, leaving smaller populations in their communities.[68,69,70,71] As people move from communities, employees and subsistence hunters may be leaving, affecting local economic assets. The local people are closely linked with social and cultural assets, such as cultural values, identity, social networks, and traditions.[72]

Protection of Food Security Through Evaluation of Contaminants in Subsistence Foods

Since the 1980s, the North Slope Borough Wildlife Management Department has had a comprehensive health assessment program to sample bowhead whales for contamination levels, and other scientists have collected tissues of various subsistence species as part of an intensive study of contaminants. Many locally caught marine and terrestrial mammals, seabirds, and marine and freshwater fish have been tested for contaminants including organochlorines (PCB and DDT), polyaromatic hydrocarbons, heavy metals, and radionuclides. Studies' results indicated that contamination of northern Alaska animals is low compared to other areas of the Arctic. The levels of contaminants are below levels of concern. Local documentation demonstrated that traditional foods are of low risk of exposure to contaminants at concentrations that represent potential health impacts.

Starting in 2011, an unusual mortality event impacting ice seals and walrus in the Bering and Chukchi Seas occurred. Animals with abnormal hair loss and skin sores led to concerns about radiation contamination from the Fukushima incident reaching Arctic waters. Whether the illnesses affecting the seals and walrus were related, remains unconfirmed. Both animals remain undiagnosed despite extensive testing for toxic algae, viruses, bacteria, and industrial contaminants including radiation. While no connection to Fukushima or industrial activities was found, these types of events increase the fears related to food security and potential impacts of industrial activities.

While a release of chemical constituents that are not common in the natural marine environment to that environment may occur from energy exploration and development activities, presence of a chemical does not immediately mean there will be health effects.[73] The U.S. Environmental Protection Agency issues individual and general National Pollutant Discharge Elimination System (NPDES) permits for water discharges and to maintain water standards. These permits authorize and control the discharge of pollutants into waters of the United States, and general permits authorize one or more discharges from multiple facilities within a specific industrial category such as oil and gas exploration. These regulations and associated permits assist in protecting human health and the environment for residents of the North Slope.

The state of Alaska Department of Environmental Conservation considered the concept of "environmental risk" during the development of the regulations guiding the cleanup of contaminated sites throughout the state. The issue presented during regulatory development was on the level of acceptable risk. Communities dependent on fish and wildlife resources where industrial activity was located were very concerned with contaminant pathways that could affect subsistence foods and use areas.[74]

Co-management of subsistence species by resource trust agencies such as the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS); and organizations such as the Alaska Eskimo Whaling Commission (AEWC) and Alaska Eskimo Walrus Commission (EWC) enhance food security by providing subsistence hunters with a voice in the decision-making. Through consultation requirements, industry engages with these co-management groups to identify food security concerns and to develop Plans of Cooperation. Specifically, the AEWC has developed an effective Conflict Avoidance Agreement process to work collaboratively with industry on ways to avoid impacts to subsistence users.[75] These methods include communication tools to share locations between hunters and industry, avoiding certain times and areas until completion of whaling activities, and minimizing discharges that may contain contaminates of concern. Through this collaborative process, specific concerns can be raised, discussed, and potential mitigation measures identified.

Economic Impact

Almost 4 million people live in the eight Arctic states, including many distinct indigenous groups found only in the Arctic, where they continue traditional activities while they adapt to the modern world. This adaptation has produced an expansion of a cash-based economy existing in combination with a traditional subsistence-based economy that relies on systems of harvest, sharing, and barter. In this integrated economy, monetary needs include financial resources sufficient to support healthy communities and traditional subsistence activities. With rising energy costs and the decline in current oil and gas activities, the sustainability of Arctic communities is at risk. In recognition of this risk, the overarching theme for the Canadian Chairmanship of the Arctic Council (2013-2015) was "Development for the People of the North," with a focus on responsible Arctic resource development, safe Arctic shipping, and sustainable circumpolar communities. Seeking new sources of oil and gas revenues and diversifying economic opportunities is essential for the future of Arctic communities.

Government/Land Owner Revenues

Oil and gas development accounts for a significant proportion of economic productivity in Arctic regions across the globe. Alaska's Arctic, both onshore and in the OCS, has long been recognized for its significant resource potential, which has resulted in decades of exploration and development activities. Through the development of Prudhoe Bay, Kuparuk, and other North Slope oil fields, over 17 billion barrels of oil have flowed through TAPS to markets in the United States and abroad. Through royalty and taxes, this economic pipeline fuels more than a third of all economic activity in Alaska including a significant portion of the government jobs, schools, roads, and community services.

Today, oil and gas development is a third of the state of Alaska's economic activity providing roughly 90% of the state's general fund revenue, with minerals, timber, seafood, and tourism contributing to the balance. In 1976, the state of Alaska created the Alaska Permanent Fund (APF) to save some of the oil royalties for future generations. The APF is now valued over $52 billion (as of January 2015) providing annual dividend payments to qualified Alaskans with a portion of the fund's earnings.[76] From 1982 through 2008, the dividend program paid out about $16.7 billion to Alaskans. This program has a stimulative effect on the state's economy and represents an important source of income for Alaskans, particularly those in rural Alaska with limited income sources.[77]

In 1972, the seven villages on the North Slope formed the North Slope Borough, a home rule form of local government. With an area of 94,743 acres, the North Slope Borough is larger than the state of Rhode Island. The tax base in the borough consists mainly of high-value property owned or leased by the oil industry in the Prudhoe Bay area. The Alaska Department of Commerce Community and Economic Development reported that the North Slope Borough oil and gas property tax revenues had exceeded $180 million annually between 2000 and 2013.[78] In 2014, the North Slope Borough's budget was over $377 million, with over 85% of revenues coming from oil and gas property taxes.[79]

While development activities continue onshore, the offshore potential holds the key to the long-term future of U.S. Arctic oil and gas activities and to economic stability in the region. Alaska's OCS is estimated to hold approximately 27 billion barrels of oil and 132 trillion cubic feet of natural gas, and its development is vital to stemming the decline of throughput through TAPS, which drives the economic engine for the North Slope Borough and the state and contributes to the overall economy of the United States. In the most recent draft supplemental Environmental Impact Statement for Chukchi Sea Lease Sale 193, BOEM estimates that the total royalties to the federal government will be $89 billion with an additional $4 billion accruing to the North Slope Borough and the state in taxes and $2.8 billion in royalty from state production owing to a reduction in the TAPS tariff.[80]

While oil and gas production from Alaska's OCS or federal land has been limited to date, the federal government has received benefits through lease sales and annual lease rental fees from lease sales in the Chukchi Sea, Beaufort Sea, and in the NPR-A. While 50% of the revenue received from oil and gas activities in the NPR-A is shared with the state and local governments, government revenue from Alaska's OCS is not. This is in stark contrast to the OCS revenue sharing provisions in the 2006 Gulf of Mexico Energy Security Act, which created provisions of sharing 37.5% of all quality OCS revenues from the Gulf of Mexico with four states and their coastal subdivisions. Enacting revenue sharing provisions in the Alaska OCS is a high priority for Alaskan communities and lawmakers, who believe this dichotomy in lease terms should be rectified in Alaska's favor.

While a majority of Alaska's Arctic oil and gas activities occur on state or federal lands, the Alpine Field is the first to produce resources from Native-owned lands. ASRC, the North Slope Iñupiat Native Corporation, owns a portion of the subsurface in the Colville River Unit (Alpine Field) as well as the Greater Mooses Tooth Unit in NPR-A. Royalties from these areas not only increase ASRC shareholder dividends but also benefit ANCSA Corporations across the state through ANCSA 7i and 7j sharing provisions.

ASRC has six major business segments, including petroleum refining and marketing, energy support services, construction, government services, resource development, and industrial services. It is the largest gross revenue producing regional corporation and reported $2.5 billion in revenues in 2013.[81] According to ASRC Vice President of Lands and Resource Development Richard Glenn, "Fifty years of exploration and thirty years of operation by the oil industry in a region that has no other significant local economy have left us with many positive cumulative effects. These include benefits to our government, local and regional corporations, community organizations, and North Slope residents."[82]

Plans for future development concurrent with declining production of existing oil fields suggest the need for understanding sustainability in this new environment and diversifying opportunities. Toward this challenge and forging new partnerships for economic development, in July 2014 ASRC and six North Slope village corporations joined together to create a new company, the Arctic Iñupiat Offshore, LLC (AIO). AIO and Shell Gulf of Mexico, Inc., entered into a binding agreement that allows AIO an option to acquire an interest in Shell's acreage and activities on its Chukchi Sea leases.

The AIO partnership and other new initiatives such as the North Slope Port Authority,[83] which was formed in 2014 to facilitate the development of infrastructure that could spur shipping and tourism activities, are indicative of the discussion and concern about the economic dependence on Prudhoe Bay production and its eventual decline.

Employment and Training

As of 2011, the oil and natural gas industry supported 9.8 million full-time and part-time U.S. jobs and 8% of the U.S. economy.[84] In Alaska, the oil and gas industry accounts for approximately 10% of employment and 13% of all resident earnings.[85] Industry job investment in Alaska has increased; in 2013, it accounted for 33% of all wage and salary employment and 38% of all wages.[86] This is through direct, indirect, and induced jobs created by investment activity primarily in Alaska's Arctic. The Alaska Department of Labor notes that seven out of ten oil and gas workers (71%) were Alaska residents.

Rural areas of Alaska typically have a higher percentage of unemployment rates than more urban areas of the state. As shown by the 2010 census conducted by the North Slope Borough,[87] the unemployment rates may be even higher than what is reported by the state of Alaska and the U.S. Census Bureau because of inaccurate reporting and an underreporting of underemployment. Many rural residents could be identified as discouraged workers and have removed themselves from the employment scene because of prolonged difficulty in finding employment. Future research may be able to provide a better understanding of this scenario and provide recommendations on ways to utilize this potentially underrepresented segment of the workforce. On the North Slope, the North Slope Borough—including the North Slope Borough School District—is the largest employer of permanent residents. According to the Alaska Department of Labor, unemployment in the North Slope Borough has ranged from 3.5% in 1975 to a peak of 10.1% in 2007.[88] The current unemployment rate is 4.2%.[89] Note that this is in contrast to the unemployment rate in the neighboring Northwest Borough of 13.2%, because so many North Slope residents benefit from direct employment by the North Slope Borough. While direct employment of North Slope Borough residents in the oil and gas industry is limited, the tax revenue described in the previous section fuels local jobs in the villages through the borough services and school district. Increasing local employment opportunities is a priority for the industry as well as the ANCSA corporations in the region, and they collaborate frequently on training, education, and workforce development initiatives.

Subsistence and wage-based employment exist as the primary interdependent aspects of the overall economy. Residents often pursue wage employment opportunities in order to further participate in subsistence activities, which require cash in order to pay for fuel and other essential equipment such as snow machines, boats, fuel, ammunition, and rifles.[90] Residents often seek to balance their subsistence pursuits with wage employment opportunities through seasonal employment opportunities and other mechanisms.

Developing this workforce has been a priority for the state of Alaska as well as industry for many years. In May 2014, the Department of Labor issued the Alaska Oil and Gas Workforce Development Plan, which lists over 270 occupations and basic job descriptions in the oil and gas industry. Of these jobs, 60% require more than a high school diploma, and one in five require a bachelor's or advanced degree. As listed in the report, a significant amount of training and education resources in Alaska are available. However, it is often difficult, especially in rural Alaska, to effectively connect high school education to job training.

Continued collaboration and research are needed to employ more young rural residents in the industry and this is an area that may yield significant benefits for Arctic communities.

Local Content

To support activities in the Alaska OCS, the oil and gas industry often looks to utilize local business ventures to provide goods and services to operations. The Alaska Support Industry Alliance, a nonprofit, represents over 500 businesses providing services to the Alaska resource industries. These businesses reflect an experienced and vast contractor base supported by the industry. In the Alaska OCS, this presents a unique opportunity to build the capacity of local corporations, which can be leveraged into successful lines of business.

Oil and gas activities in the Alaska OCS also have offered an opportunity for regional and village ANCSA corporations to develop new service lines. This in turn creates jobs and training opportunities for their shareholders. For example, to help members benefit from potential exploration activities, the Olgoonik Corporation in Wainwright, Alaska, teamed up with a local logistics and research firm to form Olgoonik Fairweather, LLC., which organized and managed the extensive Chukchi Sea Environmental Studies Program on behalf of ConocoPhillips, Shell, and Statoil from 2010 to 2014. Through contracts, joint ventures, and other business opportunities, ANCSA corporations provide oil field support, drilling, oil spill response, environmental consulting, stakeholder engagement, corrosion inspection, construction resources, and logistics management to the oil and gas industry.

More opportunity still exists for research on how to increase training and business development in rural Alaska, which can lead to more employment opportunities in villages and in all remote Arctic communities. Investment in telecommunications, energy solutions, and infrastructure such as ports and airstrips driven by the opening of the Arctic Ocean would present economic development opportunities in general, including but not limited to oil and gas.

Social Investment

Having healthy and sustainable communities is a goal for many Arctic leaders including those at the

North Slope Borough and the Arctic Council. In Alaska, the oil and gas industry places an emphasis on social investment, because the industry plays such a critical role in the economy. Because of this investment, the nonprofit industry in Alaska is thriving. There are more nonprofit groups per person in Alaska than in any other U.S. state, at an estimate of more than one nonprofit per 100 people. In 2007, Alaska nonprofits had revenue over $3.1 billion, with 43% coming from federal grants, 12% from private donations including the oil industry, and the rest from government fees such as Medicaid. With the downturn in federal spending after 2008, the nonprofits' reliance on private donations has increased.[91]

In 2012, ConocoPhillips Alaska, Inc., and BP Alaska together contributed over $11.5 million to Alaskan nonprofit and educational organizations. This group and other companies operating in the state contribute sizable endowments to the University of Alaska system through programs such as the Alaska Native Science and Engineering. Ilisagvik College in Barrow, the only tribal college in Alaska, also receives significant contributions from companies on the North Slope such as Shell and ConocoPhillips to fund scholarships and workforce development programs.[92,93]

Investments in rural community infrastructure such as the Northwest Arctic Borough's (NWAB's) Star of the North Magnet school; playgrounds in Nuiqsut, Wainwright, and Point Hope; and a recreation center in Barrow were also made by industry after those projects were identified as priorities by these communities. In Nuiqsut, the community closest to Conoco-Phillips's Alpine Field, natural gas is provided free of charge to the Nuiqsut Gas Co-Op and residents pay a small fee to cover distribution/conditioning costs, allowing for the lowest energy costs anywhere in the nation.

By working cooperatively with the industry toward the potential of Alaska OCS development, community priorities rise to the surface of social investment for operators. Good projects designed to support healthy and sustainable communities need to be identified and developed in order to maximize the social investment in the future.

Cultural Aspects

Subsistence Harvesting

Subsistence use patterns vary seasonally; subsistence species migrate across the landscape and growth cycles transition throughout the year. Similarly, these patterns may change over long periods of time. Many researchers have collected data on subsistence activities over the past few decades, and some have synthesized these data (for example, Braund and Kruse 2009).[94] However, more long-term monitoring and data synthesis would be useful to fully understand subsistence use patterns over the long term: how Arctic or global change affects those patterns and how subsistence users may be affected by these aspects of subsistence patterns are not thoroughly understood.

Much is known about current and past subsistence practices based on numerous studies that have been conducted on baseline subsistence conditions and to evaluate interactions with oil and gas activities. To date researchers from federal, state, and local governments; oil and gas industry; and academia have examined the following issues:

- What communities harvest[95,96,97,98,99,100,101,102,103,104,105,106,107]
- How communities harvest resources[108,109,110,111,112,113,114,115,116,117,118,119,120]
- Subsistence use areas through detailed mapping efforts[121,122,123,124,125,126,127]
- Effects from oil and gas exploration and development.[128,129,130,131,132,133,134,135,136,137,138,139]

On the North Slope, studies on subsistence and impacts on subsistence living patterns have been conducted since the late 1970s.[140,141,142,143,144,145,146,147,148] Some of these are stand-alone studies, while others comprise components of multidisciplinary studies.

There are reports that subsistence use areas and practices are changing as a result of climate change. In the AMAP Oil and Gas Assessment 2007, Michael Baffrey and Henry Huntington synthesized 30 years of data analyzing the social and economic effects of oil and gas on Arctic populations.[149] This and other comprehensive synthesis and long-term studies, such as the recently completed Cross Island Whaling Monitoring program,[150] provide data from which subsistence use patterns and changes in patterns over time can be interpreted and evaluated.

Traditional Knowledge

Because U.S. federal and Alaska state regulations require that local populations be consulted and traditional knowledge used to mitigate adverse impacts on the environment (for example, EO 13175: Tribal Consultation, EO 12868: Environmental Justice, and Alaska National Interest Lands Conservation Act), an extensive body of work exists on traditional knowledge collected from Arctic communities.[151,152,153,154,155,156,157,158,159,160,161] Traditional knowledge has been used in research on the human and biophysical environments, through sociocultural studies, subsistence mapping studies, and biological resource studies.[162,163,164,165,166,167,168,169,170,171,172,173,174,175,176,177,178]

A pivotal example of traditional knowledge assisting scientists and its use in politics resulted from the International Whaling Commission's (IWC's) 1977 decision to ban whaling because the IWC was concerned the bowhead population was too low to sustain a subsistence harvest.[179,180,181,182,183] In response, whalers formed the AEWC—consisting of one representative from each Alaska bowhead whale hunting community. AEWC collaboration between Iñupiaq traditional knowledge and science led to more accurate population estimates for the bowhead whale, which in turn led to defensible subsistence hunting quotas. The whalers knew the bowhead migration was not confined to the nearshore leads where the IWC information was based, but that their migration path was much broader. Iñupiat and scientists worked together to obtain a census that was representative of the Arctic bowhead whale population. They increased the census area and used different counting techniques, a large part of which were based on traditional knowledge of the area. Additionally, they included acoustic and aerial survey techniques in their study.[184] The result: noticeably more bowhead whales were observed than in the IWC's original estimates. Subsistence whalers could continue the bowhead hunts, and hunting quotas were set for subsistence villages. By consulting traditional knowledge and incorporating it into western scientific applications, the AEWC regained their hunt.[185,186]

Learning from the Whaling Commission and IWC interaction, Alaska Native beluga whale hunters and government biologists established the Alaska Beluga Whale Committee (ABWC) as a proactive measure. They knew that detailed information on beluga populations, stock, and harvest numbers were needed for adequate planning. Today the ABWC uses traditional knowledge and science to manage beluga stocks and beluga subsistence activities.[187] Following suit, marine mammal co-management groups have also been formed for the walrus (Alaska Eskimo Walrus Commission), ice seals (Ice Seal Committee), and polar bears (Alaska Nanuuq Commission).

Climate Change Impacts on the Human Environment

The Arctic climate has seen a significant change since the 1980s because of the combined effects of several factors that include: changes in wind patterns and loss of multi-year ice cover due to a unprecedented positive shift of the Arctic Oscillation in 1989; a self-reinforcing, coupled ice melt and heat adsorption mechanism related to loss of reflective ice cover; and melting caused by gradual global atmospheric warming and by the influx of warmer oceanic waters from lower latitudes.[188] The risks associated with these recent dramatic climatic changes in the Arctic are recognized as a serious issue by all Arctic stakeholders including industry, regulators, and the indigenous communities.

The changes are occurring at the same time that there is increased interest in offshore oil and gas industry exploration, shipping, and tourism in the Arctic. The climate has changed in the past and people have adapted; however, current trends indicate climatic variables such as loss of sea ice cover are changing faster than anticipated based on atmospheric warming alone and in an unprecedented way.[189] Surface temperatures are warming faster in the Arctic than at lower latitudes, which has resulted in thawing of previously stable permafrost.[190,191] As a consequence, climactic changes need to be, and are, considered when evaluating the susceptibility of environmental resources to industry activities.

The sustainability of Arctic communities may be at risk because of changes in the natural environment in which they exist. Coastal erosion along Alaska's northwestern coast threatens the physical nature and the viability of many communities.[192] Some Alaska communities have relocated or are in the process of relocating, because entire village sites are eroding.[193]

Seasonal changes in ice conditions and changing weather increases hazards for people dependent on winter on-ice travel.[194,195] The steepened warming trend observed since the late 1980s has shortened periods during which hunters can safely travel on frozen surfaces and limits the time they can hunt for the subsistence resources on which they depend. In the 2010-2011 winter, freeze-up in Iqaluit, Canada was 59 days later than usual. The Nunavut in the region could not subsistence hunt during that time and relied on food banks to survive the winter.[196] In 2013 and 2014, unsafe sea ice conditions near Barrow severely limited the traditional spring bowhead whale hunt.

Changes in the climate can impact the way humans interact with the environment as seen in the widespread coastal erosion and river flooding affecting many remote Alaskan communities. Coastal erosion along Alaska's northwestern coast threatens the physical nature and the viability of many communities.[197] Alaska's coastline makes its communities more vulnerable to coastal erosion than other circumpolar coastal communities,[198] because it is very dynamic, and this results in short-term changes in the location and character of tidal inlets and other coastal features. More than 200 Native Alaskan communities are located along the coast and riverbanks, to capitalize on the locations' subsistence hunting and fishing resources. Coastal locations and riverbanks are susceptible to periodic and severe erosion caused by storms. Coastal villages have become more susceptible to erosion and flooding as a result of rising temperatures that cause protective shore ice to form later in the year, leaving the villages' coastline vulnerable to fall storms. Coastal erosion and annual flooding have caused significant property damage to homes, public buildings, airstrips, and other facilities and infrastructure.[199]

In 2003, the U.S. Government Accountability Office (GAO) noted that four Alaska villages were in imminent danger and were planning to relocate.[200] Village relocation is a costly, complex, and time-consuming process. Relocation is not as easy as moving residents to another village or town. Each community has its own identity closely linked to its location, environment, and resources, and relocation is not necessarily a preferred solution, such as is the case with Shaktoolik.[201] Those villages that accept relocation often find that they prefer establishment of a new village.[202,203]

Changing climate is also influencing wildlife habits and migration patterns of subsistence resources, affecting human spatial and temporal subsistence patterns. A widespread concern is that with the loss of multi-year ice, conditions will become increasingly unfamiliar and the hunting season will shorten.[204] In northern Alaska, spring sea-ice patterns are changing, affecting the reliability of Chukchi communities' spring bowhead whale hunt. Spring whale migration is 2 weeks earlier than it was in 1987.[205]

Terrestrial vegetation is also changing; according to traditional knowledge the tundra has more grass than it did historically.[206] Climate change models used by the BLM for the NPR-A predict the overall effect on vegetation from long-term climate change will be a significant shift in vegetation type. Growing seasons are expected to be longer, soils warmer, and drier, resulting in "significant acreages of boreal cordillera [ecological zone], with vegetative cover ranging from open to closed forest canopies; western tundra, which is similar but with a moist, subpolar climate, patches of stunted trees, and a greater presence of tall shrub communities; and boreal transition with boreal forests in valleys and lowlands, and scattered pockets of permafrost."[207] These changes are already observed in some areas of the North Slope.[208] Changes in vegetation on which subsistence species depend have the potential to affect the abundance and distribution of subsistence species and thus communities' subsistence use areas and activities.

From the local remote Arctic communities' perspective, the greatest risks associated with the recent changes in climate are those to subsistence food sources. These communities depend on the interaction between the environment and biological resources. If the environment changes, and subsistence species become less abundant or extinct, there may not be reserve food sources.[209] Additionally, subsistence plays an important role in cultural identity and sustainability, such that changes to wildlife population and wildlife migration patterns can disrupt people's cultural way of life. Warming of permafrost layers is also affecting traditional ice cellars, causing subsistence foods to spoil and hunters to seek new forms of storage.

Long-term monitoring of subsistence resources and activities provides an opportunity to evaluate changes and potential impacts due to climate change and other factors at play in the Arctic. Monitoring studies that identify and evaluate changes in local communities benefit the development of mitigation or response measures. There are a number of ongoing and planned research studies in Arctic Alaska:

- *North Pacific Research Board (NPRB) Human Dimensions.* Within the 2015 request of research proposals, the NPRB added a new research subcategory—Human Dimensions. With this, the NPRB encourages research that integrates social science approaches to gain a broader understanding of socio-ecological systems.[210]

- *NWAB Subsistence Mapping.* This 4-year (2011-2014) collaborative effort produced maps showing the region's subsistence areas that can be used to help protect subsistence resources during decision-making for zoning, land use, and proposed development.[211,212,213]
- *North Slope Borough Economic Profile and Census.* This census monitors the economic, demographic, and health status of the North Slope communities. Among the various aspects it addresses is subsistence—harvests, use, sharing, and resources.[214,215,216]
- *BOEM's 2012-2014 Dispersal Patterns and Summer Ocean Distribution of Adult Dolly Varden from the Wulik River, Alaska, Evaluated Using Satellite Telemetry.* This project studies the distribution of this important subsistence fish so that regulators can make informed decisions during National Environmental Policy Act (NEPA) analyses.[217]
- *Subsistence Mapping of Wainwright, Point Lay, and Point Hope Communities (2014-2017).* This project will provide baseline mapping data to be used to monitor impacts to the communities in the vicinity of the Chukchi Sea Lease Sale Area.[218]
- *Traditional Knowledge Implementation: Establishing Arctic Community Panels of Subject Matter Experts.* This project seeks to identify local and traditional knowledge experts from Arctic communities and to organize them into consultant panels that will engage in incorporating traditional knowledge into BOEM-funded scientific research (2015-2020). Research would include oceanography, biology, and social systems, including subsistence.[219]

The NEPA process requires cumulative effects to be considered when impacts from an undertaking are assessed. Federal regulators will evaluate how impacts from oil and gas activities may interact with impacts associated with a changing climate. This has implications for the management of Arctic resources[220] that may result in additional or modified regulations on permitted activities, such as oil and gas exploration and development.

The stability of permafrost on the North Slope is a growing issue. In 2002, the U.S. Arctic Research Commission formed a task force on climate change, permafrost, and infrastructure impacts. The task force concluded that widespread evidence of permafrost warming and thawing exists. The changing permafrost conditions were reported to have substantial implications for Alaska's transportation system, TAPS, and the approximate 100,000 Alaskans living in permafrost areas. For example, warming and melting permafrost results in ground subsidence and erosion, which in turn threatens the stability of infrastructure and buildings.[221]

The oil and gas industry maintains a consistent focus on safety and risk assessment in the Arctic, as it does globally. Major investments in technology and research spanning many decades have resulted in ice and weather forecasting capabilities and real-time reporting focused on the Arctic. Oceanographic and environmental data collected by Shell, ConocoPhillips, and Statoil between 2008 and 2014 are available through the Alaska Ocean Observing System.[222] These studies and monitoring efforts will allow industry to prepare for changing conditions.

COMMON RESEARCH THEMES RELATED TO DECISION-MAKING

Through the processes of review of recommendations derived from more than 100 research review and planning documents and analysis of regulatory drivers for sociocultural data needs, the Human Environment study team has identified a number of recurrent investigative themes that can enhance our understanding of the potential interplay between oil and gas development and the people of the Arctic. The results of these review processes reflect the cumulative and common recommendations of a number of preexisting initiatives, including the National Academy of Sciences, the NSF, and the U.S. Arctic Research Commission, which had been established to answer the question of what research is needed on Arctic sociocultural resources. The study team applied an additional filter to the broad range of potential research opportunities that can be undertaken on the Arctic human environment by identifying key areas that are particularly important for supporting prudent development of Arctic oil and gas resources. Specific themes have been used to categorize the potential studies and to assess research priorities. The resulting five research themes have been vetted with key stakeholders and participants, including representatives of tribal organizations and Native corporations of the North Slope in workshops both in Washington and Fairbanks.

The following subsections cover the following five themes:

1. Sociocultural demographic and wellness patterns
2. Subsistence use patterns
3. Traditional knowledge
4. Protection of food security through evaluation of contaminants in subsistence foods
5. Fate and effect of oil spills.

In these subsections, themes are addressed according to the following outline:

- Description of the theme
- Relevance to exploration and development in the Arctic
- Planned research or investigation.

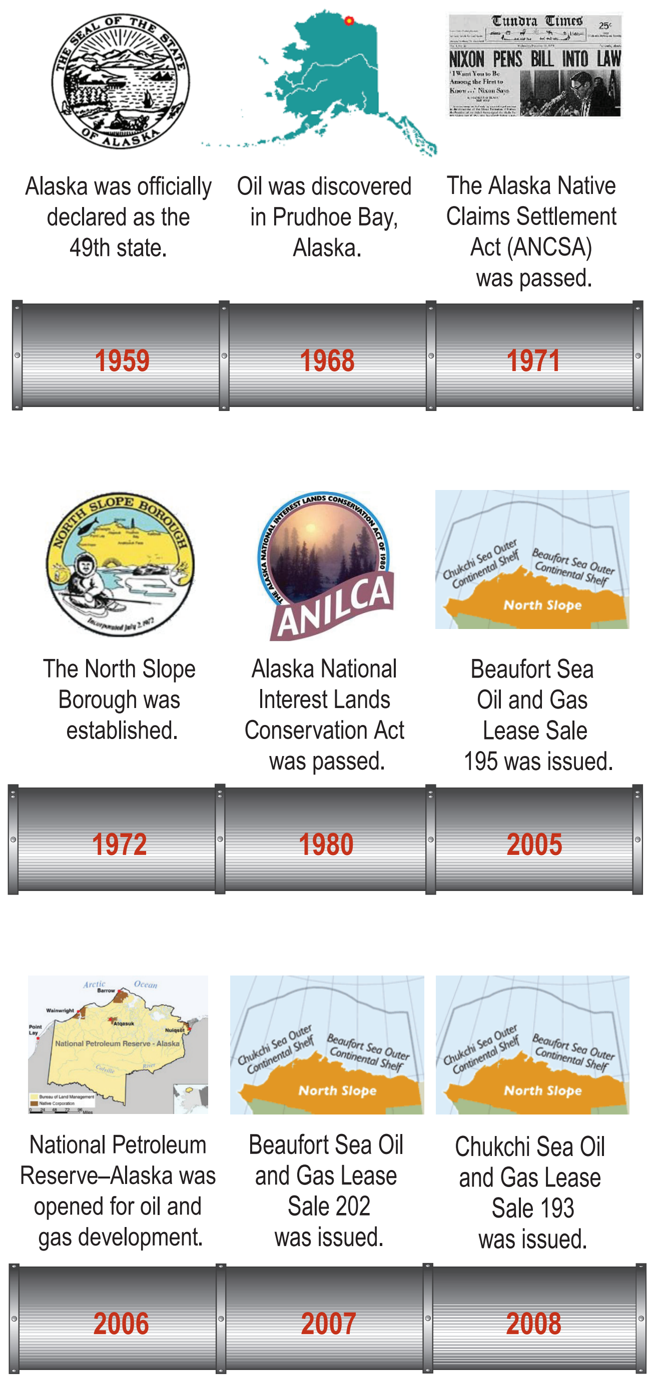
Theme 1: Sociocultural Demographic and Wellness Patterns

Description of the Theme

Understanding demographic and population characteristics and potential changes in the U.S. Arctic will continue to be critical. This includes understanding population attributes such as population estimates, employment by industry, and unemployment rates. Issues to consider also include how small populations, isolated locations, and reliance on subsistence resources affect demographic patterns. This theme also includes continued insight into effective community wellness monitoring to ensure that meaningful changes in community well-being—both positive and negative—from oil and gas activities can be observed. An understanding of the demographics and sociocultural makeup of the region's population and its wellness is needed to assess the impacts of Arctic development on local communities.

Relevance to Exploration and Development in the Arctic

Recent research by the state of Alaska estimates that Alaska's population will grow from 714,142 in 2010 to 915,211 in 2035.[223] It is forecast that new jobs generated by OCS development could increase the statewide population by 5% over the next 50 years.[224] Figure 10-2 shows the major oil and gas activities in Alaska's development since statehood. Increased activity in oil and gas will continue to have significant impacts on the local populations of this region.



Source: Arctic Slope Regional Corporation – Energy Services.

***Figure 10-2.** Major Oil and Gas Development Activities in Alaska Since Statehood*

Prior to the discovery of oil in Prudhoe Bay in 1968, employment in the North Slope was limited mostly to federal and state activities. By the time the North Slope Borough was formed in 1972, employment opportunities were available in construction, oil and gas extraction, and support services such as transportation, communications, and utilities. In addition, the expansion of public facilities and services on the North Slope has improved the quality of life by providing improvements in safety, transportation, and communication and increasing household incomes.[225] While North Slope residents generally agree that oil and gas development and associated activities have improved their quality of life in many respects, the social effects of rapid economic development is a common concern.[226] These concerns include how increased economic development will impact residents' reliance on subsistence lifestyles, changes in the cultural and demographic makeup of villages, and increased reliance on outside resources.

Because of these concerns, it is important that we understand the impact that economic development due to offshore oil and gas activities has on subsistence hunting and fishing, as well as how it can cause changes in the cultural and demographic makeup of villages and increased community reliance on outside resources.

Planned Research or Investigation

BOEM's Alaska office publishes a yearly assessment of information needs and study profiles. In 2014, BOEM focused on upcoming lease sales, as well as planned and proposed exploration activities in the Beaufort and Chukchi Seas. The profiles assessed what changes might occur over time in socioeconomic and subsistence lifestyles in coastal Alaska communities. Following its completion, BOEM will use the study *Social Indicators in Coastal Alaska: Arctic Communities*, to update key sociocultural and economic baseline data to analyze the local and regional impacts from offshore exploration and development activities for select communities, including Point Lay, Wainwright, Barrow, Nuiqsut, and Kaktovik.[227]

The North Slope Borough (NSB) Department of Planning and Community Services is conducting a review of all eight borough village comprehensive plans in preparation for updating the NSB Area Wide Comprehensive Plan. The comprehensive planning process encompasses economic and demographic analysis, land use analysis, and stakeholder engagement on issues and priority projects. Community participation provides a forum where residents can share perspectives on the impacts of oil and gas development onshore and offshore. Participants can also discuss the results of recent scientific, social, and economic studies and impact assessments.[228]

Residents express concern about the potential cumulative impacts of offshore and onshore development on subsistence lifestyles.[229] In preparing NEPA documents, BOEM increasingly recognizes the need to assess cumulative or aggregate impacts on the local population over time. Aggregate-effects research includes a broader set of sociocultural issues: the changing relationship between a cash economy and household subsistence activities, changing sources of anxiety and stress at various levels of organization, changes in sharing subsistence resources, and potential changes in recruiting youth into subsistence activities. Establishing and maintaining a set of social indicators will be important for estimating long-term aggregate impacts.

Theme 2: Subsistence Use Patterns

Description of the Theme

Subsistence is vital to the way of life for indigenous peoples,[230,231,232,233] and their concerns about how oil and gas exploration and development may affect subsistence activities are understandable. U.S. regulatory agencies have imposed, and oil and gas industry operators have adopted (both mandatorily and voluntarily), mitigation measures to prevent and reduce their impact on subsistence resources.

Understanding the potential interactions of oil and gas activities with subsistence activities, and patterns that may be changing as a result of other causes, will continue to be critical. Concern also has been expressed by local communities that climate change is resulting in variations on subsistence species distribution and access to hunting opportunities, which in turn affect subsistence communities.

Therefore, this research theme focuses on understanding and documenting subsistence activity patterns to ensure responsible development of oil and gas operations and reduce any potential conflicts with subsistence activities.

Relevance to Exploration and Development in the Arctic

Addressing real and perceived risks to subsistence practices is important to the success of all oil and gas exploration and development activities in the Arctic.

BOEM sponsored several years of subsistence mapping studies that provide data for evaluating the effects of oil and gas activities, determining where oil and gas leases should and should not be offered or sold, the appropriate timing of activities to reduce conflict with subsistence needs, and other mitigation measures.[107,234,235,236,237,238,239,240] This is especially important since in certain areas and times, subsistence activities and resources may be vulnerable to oil and gas activities.

Sounds generated by oil and gas activities can deflect migrating whales and may disrupt the bowhead whale hunt by deflecting the whales away from the hunters.[241,242] However, industry has established procedures to work with whalers to minimize or avoid the impact on subsistence hunting by staging operations, if possible, when whales are not in the area and by ceasing operations when the whaling is occurring in the area.

One tool that is available to resolve the potential for impacts is the Whaling Commission Conflict Avoidance Agreement, which in recent forms specifies times for area closures for both the Beaufort and Chukchi Seas that correspond to open water season activities occurring during subsistence whaling. Through the agreement, oil and gas exploration and seismic activities have been able to operate outside specific areas and times and avoid affecting subsistence.[243,244,245]

Where there are overlaps in space and time between subsistence use of the environment and industrial activities, there is the potential for negative impacts but also for cooperation. Subsistence advisor programs have helped instill cooperation. Hired as industry employees or contactors, subsistence advisors can play an important role in coordinating with residents in the villages before, during, and after project activities, identifying potential conflicts prior to and during project activity. Subsistence advisors accompanying oil and gas activities can identify potential conflicts with subsistence users and resources at the time of the activity, and act as liaisons between industry and subsistence users.

Industry operators conducting offshore activities hire Iñupiat and biology-trained protected species observers (PSOs) as part of marine mammal monitoring and mitigation programs. These programs use traditional knowledge of the region and biological science to monitor marine mammals potentially affected by sounds and activities conducted by the operators. The programs also contribute to federal agency reporting requirements and to data collection on marine mammals. PSOs spend time aboard offshore vessels monitoring occurrence and behavior of marine mammals. They record numbers of mammals observed, their distance from vessels and activities, reactions to activities, and "takes by harassment" as defined by NMFS. These PSOs also act as real time advisors and communicators to recommend and call for mitigation measures to avoid potential impacts on the marine mammal resources and the subsistence hunting of those resources.

Onshore, subsistence users are concerned with helicopters deflecting caribou migration and habitat use and interfering with subsistence hunter activities. Both the North Slope Borough and the BLM monitor helicopter travel and landings through permitting processes. For example, the BLM requires holders of the NPR-A Access Authorization to maintain and submit an aircraft-landing log.

In the United States, multiple agencies require industry to consult or offer to consult with subsistence communities and subsistence management groups and submit plans to mitigate impacts. When activity is planned in or near traditional Arctic subsistence hunting areas, the NMFS requires operators to submit a formal permit request that includes a plan of cooperation. Yearly, NOAA/NMFS conducts a peer review where activities and marine mammal monitoring and mitigation and subsistence conflict avoidance are discussed. Similarly, the BLM NPR-A Subsistence Advisory Panel advises the BLM on how best to minimize impacts on subsistence hunters from oil and gas activities through multiple co-management meetings per year.

Data syntheses of studies like this and the ongoing studies noted below will provide comprehensive integrated understanding of trends that can be used to reduce any potential conflicts with subsistence activity that may vary or be intensified owing to climate change.

Planned Research or Investigation

There are many projects that provide indispensable insight into the importance of subsistence in modern Arctic cultures and its relevance to Arctic oil and gas planning, permitting, and operation. Within Northwest Alaska and on Alaska's North Slope, public and private entities coordinate in extensive ongoing studies. Studies and data collection take a variety of forms. Ongoing and planned studies monitoring impacts on subsistence activities include subsistence mapping efforts, harvest studies, and socioeconomic analyses. Examples are:

- *NWAB Subsistence Mapping*. This 4-year (2011-2014) collaborative effort to produced maps showing the region's subsistence areas that can be used to help protect subsistence resources during decision making for zoning, land use, and proposed development.[246,247,248]
- *North Slope Borough Economic Profile and Census*. The census monitors the economic, demographic, and health status of the North Slope communities. Among the various issues it addresses are subsistence—harvests, use, sharing, and resources.[249,250,251]
- *BOEM's 2012-2014 Dispersal Patterns and Summer Ocean Distribution of Adult Dolly Varden from the Wulik River, Alaska, Evaluated Using Satellite Telemetry*. This project studies the distribution of this important subsistence fish so that regulators can make informed decisions during NEPA analyses.[252]
- *Subsistence Mapping of Wainwright, Point Lay, and Point Hope (2014-2017)*. This project provides baseline subsistence mapping data to be used to monitor impacts in the communities in the vicinity of the Chukchi Sea Lease Sale Area.[253] This study has not yet commenced.
- *Traditional Knowledge Implementation: Establishing Arctic Community Panels of Subject Matter Experts*. This project seeks to identify local and traditional knowledge experts from Arctic communities and organizes them into consultant panels that will engage in incorporating traditional knowledge into BOEM-funded scientific research (2015-2020). Research would include oceanography, biology, and social systems, including subsistence.[254]

Data syntheses of studies will provide comprehensive integrated understanding of subsistence trends that can be used to understand the effects of climate change. To understand changes in long-term subsistence use over time and space, comprehensive synthesis of the collected data is needed; in conjunction with long-term monitoring and documentation of subsistence use, this can provide valuable insights. Data sharing, data access, and transparent analysis will help identify any changes to the long-term patterns.

Theme 3: Traditional Knowledge

Description of the Theme

Traditional knowledge "has an empirical basis and is used to understand and predict environmental events."[255] It informs and teaches local populations how to conduct themselves in culturally appropriate ways, how to survive in, sustain in, and connect with their environments.[256] Traditional knowledge has long served Arctic indigenous cultures for daily activities and during times of adversity, and can be beneficial to the oil and gas industry when incorporated into its planning and operations. Industry and Alaska Native residents have made important collaborative steps in incorporating traditional knowledge and science.

Traditional knowledge incorporated with science has improved operating practices, safety procedures, and emergency and environmental response practices. For example, local experts with traditional knowledge have described a number of places where consistent wind patterns and currents result in accumulation of surface debris on the ocean and on the shoreline. NOAA began incorporating this traditional knowledge about into their Arctic Environmental Response Management Application (ERMA) following a series of workshops on coastal currents and ice movement. This information is on the ERMA website and can be used by environmental engineers, spill responders, planners, and decision-makers.[257]

Industry participants have conducted a number of interviews and other traditional knowledge gathering projects to understand how Iñupiat use Alaska's northwest coast, what resources and areas need protecting, how resources may be affected by industry activities, and how to protect them from industrial activities.[258,259]

Traditional knowledge has demonstrated its value time and again, yet incorporating it into scientific research, resource management, and mitigation can be challenging.[260,261,262,263,264,265] Longstanding conflicts between Western and traditional ways to manage resources endure.[266] Natural resource managers and scientists are often unfamiliar with the social science methods and techniques necessary for cross-cultural dialogues and traditional knowledge integration[267] and traditional knowledge has spiritual aspects that are difficult to fit into scientific constructs.[268] Identifying the proper knowledge keepers also can be a challenge: not everyone in a community is an expert on all topics, and community power structures can make it difficult for an outsider to elucidate who the experts are.[269] With concerns about intellectual ownership and control, sometimes people are hesitant to share this knowledge.[270,271]

Even when focused on a common goal, scientists and traditional knowledge experts' approaches may vary. The *Experts Workshops to Comparatively Evaluate Coastal Currents and Ice Movement in the Northeastern Chukchi Sea*[272] is a good demonstration of the issue. Geophysical scientists tend to focus on characterizing the mean ice and current conditions before looking at the variability, whereas hunters using traditional knowledge focus on short-term variability and anomalies in the ice and current that may affect navigation and safety while working on the ice.[273] The collaboration between science and traditional knowledge is not merely the sharing of ideas, methods, and information; it is communication between different worldviews. Translation of content must occur even when those involved speak the same language in order to assure mutual understanding.[274] Yet, this interaction between worldviews has led to many successful management decisions, strategies to avoid impacts, and development of mitigation measures relevant to Arctic resources, people, and exploration and development activities.

Relevance to Exploration and Development in the Arctic

Traditional knowledge has relevance to exploration and development in both activity implementation and regulation. U.S. federal and Alaska state regulations require that local populations be consulted and traditional knowledge used to mitigate impacts on the environment (for example Executive Order [EO] 13175: Tribal Consultation, EO 12868: Environmental Justice, and ANILCA).

Traditional knowledge has become increasingly important to industry when conducting risk assessments of potential activities as a matter of safety, law, and social responsibility.[275] When industry actively solicits community and traditional knowledge experts' participation at multiple steps of a risk assessment—planning, developing methods, implementation, and review of findings—it instills a collaborative atmosphere among communities, biologists, co-management groups, and industry. This body of knowledge allows for a better evaluation, and subsequent avoidance and mitigation of potential impacts to marine mammals and subsistence. For example, industry participants have gained understanding of how small-scale disturbances such as sound, vision, and smells affect marine mammals.[276]

Traditional knowledge informs what resources may be affected, how they may be affected, and how impacts may be mitigated.[277,278,279,280] BOEM oil and gas lease stipulations use traditional knowledge. For example, BOEM requires exploration and development programs to include orientation programs that help educate personnel about social, cultural, and environmental concerns in the area. Lease stipulations require the use of traditional knowledge about subsistence use areas and patterns, when requiring lessees to implement marine subsistence mammal monitoring and subsistence harvest conflict avoidance programs.[281]

Another impact mitigation measure employed by offshore industry operators is the communications centers or communications and call centers (Com Centers). Com Centers are operated annually during bowhead subsistence whale hunts.[282] Com Centers facilitate communication between open-water subsistence hunters and industry vessels to minimize and avoid conflicts between subsistence hunters and industry activities. The centers involve individuals from the Native villages located on the North Slope, who speak and understand Iñupiaq. The Com Center operators track the locations and progress of industry activities, whalers, and other subsistence hunters as reported to them and relay information between vessels and industry operators.

Traditional knowledge can benefit exploration and development operational and safety procedures.

Several workshops held in March 2013 brought Iñupiat from Barrow, Wainwright, Point Lay, and Nuiqsut; private sector scientists; and agency scientists together to discuss Chukchi and Beaufort Sea ice conditions and ocean circulation and how these factors may affect response to oil and hazardous substance spills. They found traditional knowledge complements large scale remote sensing and ice-ocean models. It provides guidance on coastal currents, local weather, and bathymetry controlling ice and currents that disperse marine life in the northeastern Chukchi Sea and Beaufort Sea. This workshop is an example of effective collaborative analysis using traditional knowledge and science, and through it, several types of studies were recommended to continue collaborative work and provide better data to inform marine navigation.[283]

Information gained through interviews with traditional knowledge experts provides valuable information to industry during oil spill contingency planning. For example, food in ice cellars along the coastline and near communities could be at risk in an event of oil stranding during periods of above normal water levels.[284] By learning the value of these cellars and where they are located, industry prioritizes coastline areas for protection in the event of an oil spill. Furthermore, engagement with community members and traditional knowledge experts can inform industry on ways to avoid inadvertent damage to ice cellars during oil spill response activities.

Incorporated with regulation, project planning, social science, and natural science, traditional knowledge plays a successful role in mitigating impacts that may result from oil and gas activities. A number of conflict avoidance measures based on traditional knowledge of local animal habitat, behavior, migration, and seasonality are directed to limit negative impacts from oil and gas activities. Annual Conflict Avoidance Agreements between offshore operators and the Whaling Commission, cooperative mitigation efforts, and monitoring efforts like that implemented for ConocoPhillips' Meltwater Project are examples.[285,286,287] Both the Conflict Avoidance Agreements and the Meltwater Project in the Kuparuk River Unit are considered traditional knowledge success stories.[288,289] The Conflict Avoidance Agreement uses traditional knowledge to inform mitigation measures including industry shutdown periods and communication strategies to facilitate real-time decision-making.

Impact mitigation informed by traditional knowledge affects how some oil and gas activities are conducted. For example, traditional knowledge states that aircraft pose one of the greatest potential negative impacts on successful hunting and long-term caribou migration patterns.[290] As a result, in their land use and field study administrative approvals, the North Slope Borough puts altitude restrictions on aircraft. The BLM puts restrictions on where, when, and how such helicopter-supported activities occur in the NPR-A. These permit stipulations can affect the timing and amount of research studies conducted for the oil and gas industry, supply transport to remote locations, and other aerial support for oil and gas.

Planned Research or Investigation

Ongoing and planned research will further the incorporation of traditional knowledge into scientific studies, regulation, and mitigation measures, thus strengthening its role in oil and gas and other development activities. Within Alaska, multiple entities are pursuing efforts to utilize traditional knowledge in a number of areas. These include:

- *NWAB Subsistence Mapping*. This 4-year collaborative effort will produce maps showing the region's subsistence areas. The maps will help protect subsistence areas during decision-making for zoning, land use, and proposed development.[291,292,293]
- *Traditional Knowledge Implementation: Establishing Arctic Community Panels of Subject Matter Experts*. This 5-year project will establish subject matter expert panels in multiple U.S. Arctic communities so that traditional knowledge is incorporated into "a meaningful management process."[294] Scientists engaging in BOEM-funded projects will consult this panel on topics such as ocean currents, ice movement and behavior, marine mammal subsistence hunting, seabird and waterfowl harvest, subsistence sea-run fish, and subsistence terrestrial and nearshore species use.[295]
- *WALRUS (Walrus Adaptability and Long-Term Responses)*. This 5-year project is using traditional knowledge and scientific findings to project walrus sustainability.[296]

- *Cumulative Effects of Arctic Oil Development: Planning and Designing for Sustainability.* This ongoing 4-year project is studying the effects from oil and gas development and infrastructure.[297]
- *Camden Bay Collaboration – Shell – Whaling Commission.* Experts from both the traditional whaling community and a combination of bowhead whale survey specialists and acousticians are evaluating available information to inform joint application of mitigation measures related to protection of subsistence harvest of bowhead whales, while accommodating exploration drilling in the Camden Bay area of the eastern Beaufort Sea.
- *Statoil.* In 2013, Statoil partnered with three coastal Alaskan communities—the Native governments of Kotzebue, Wainwright, and Point Hope—to document traditional knowledge of how marine mammals respond to sound disturbance. This research project is called Traditional Ecological Knowledge of Acoustic Disturbance.[298]

Agencies, industry, and scientists are incorporating traditional knowledge in research activities. Once it is incorporated, industry and scientists need traditional knowledge keepers to:

- Inform local residents that traditional knowledge has been considered
- Evaluate whether or not the implementation methods have worked
- Assess how those methods can be improved.

These efforts help build collaborative strategies and mutual trust among the various participants.[299]

Additional research would be fruitful both in terms of continued collection of traditional knowledge within the indigenous communities of the Arctic and in terms of sharing best practices for collection and quality assurance. While standard practices exist for acquisition of traditional knowledge, innovation within the field of survey techniques and data synthesis and improvement of the intersection between traditional knowledge and western science would benefit both communities.

Where there are different operator, contractor, agency, and other stakeholders pursuing simultaneous research studies in the same area, care must be taken to see that communities are not inundated with multiple meeting and monitoring efforts. Leadership is over-committed and cannot address all issues and interests of all such parties.[300]

Theme 4: Protection of Food Security Through Evaluation of Contaminants in Subsistence Foods

Description of the Theme

While food security is defined in varying ways, from purchasing power and nutrient intake to the sustainability of agricultural production, for the Alaskan Iñupiat, food security is synonymous with environmental health. The Iñupiat possess a unique understanding of food security encompassing both cultural and environmental systems: systems that interlink and support each other.[301] With the many changes in the Arctic, from a changing climate to industrialization (increased oil and gas activities, increased shipping), protection of food security is emerging as a key theme in Arctic communities.

Food security can be characterized as secure and reliable access to subsistence use areas and subsistence resources, and the assurance that subsistence foods contain no environmental or industrial pollutants that could threaten human health (Figure 10-3). Changes in climate, human activities involving noise or discharges, and the presence of infrastructure each may have the potential to affect the habitat, population size, and movements of subsistence species.[302]

Photo: Shell.

Figure 10-3. *Cutting Up Whale Meat*

Changes in ice conditions and weather patterns are having an impact on traditional hunting methods, creating safety concerns for subsistence hunters. The levels of contaminants currently in the Alaskan Arctic do not at this time seem to have any effects on public health and food safety.[303] However, there is the perception and concern of risk of contamination from low probability, high-impact events such as an oil spill, which could threaten food security.

According to the North Slope Borough 2010 survey of population and economic conditions, a significant percentage of respondents reported experiencing food insecurity. Households finding it difficult to get the traditional foods they needed for healthy meals ranged from 33% in Barrow to 62% in Anaktuvuk Pass.[304] Although sharing traditional foods is an integral value of subsistence culture, those households reporting difficulty in obtaining the traditional foods, therefore experiencing food insecurity, are somewhat less likely to share traditional foods.[305]

Relevance to Exploration and Development in the Arctic

Alaska Native populations are aware that oil and gas development brings the potential of additional environmental contamination.[306,307] While historical onshore development is seen as limited in its impact, in the unlikely event of an oil spill in the Alaska OCS, the area that may be potentially impacted is much greater, causing heightened concerns related to food security. Marine mammals, especially the bowhead whale, provide a critical connection to culture and nourishment of the Inuit. This relationship with oil and gas activities and traditional practices has created an awareness of the "importance of a healthy marine environment in sustaining traditional diets for Inuit and aboriginal peoples." "Conserving the environment is one way to address food security," according to Henry Huntington, the Pew Charitable Trust's Arctic science director, at a recent meeting of the Arctic Council.

Planned Research or Investigation

The Inuit Circumpolar Council–Alaska has been working on a study to define food security from an Inuit perspective. The information gathered is being aggregated and analyzed to obtain a greater understanding of an Inuit food security definition and to identify overarching drivers of food security and insecurity in order to develop an Inuit definition of food security. The project will contribute to understanding the pressures on traditional food resources and communities that are resulting from climate changes and increased human presence and development. Four objectives will be met by this project: (1) provide an understanding of Arctic food insecurity from an Inuit perspective; (2) identify drivers of food in/security; (3) identify what needs to be monitored in order to create action plans; and (4) create an assessment tool.

Since the 1990s, BOEM has, as part of the Environmental Studies Program, conducted the Arctic Nearshore Impact Monitoring in Development Area (ANIMIDA) and continuation of ANIMIDA in the Beaufort Sea to provide baseline data and monitoring results for possible chemical contamination, turbidity, productivity of sensitive biological areas, and subsistence whaling in the vicinity of oil industry development in the Beaufort OCS. Likewise, in the Chukchi Sea, BOEM conducts the Chukchi Sea Offshore Monitoring in Drilling Area (COMIDA) baseline study. COMIDA is a chemistry and benthos (seabed-dwelling organisms) study that, along with the Hanna Shoal Ecosystem Study, provides baseline data and monitoring results for possible contamination and productivity of sensitive biological areas important to subsistence species. Both ANIMIDA and COMIDA represent the types of long-term monitoring and assessment studies needed to track the levels of possible contaminants in the ambient environment and the persistence of those that potentially could result from oil and gas activities and have an effect on subsistence-based communities.

The Arctic Council's AMAP is a long-term monitoring program for contaminants in the circumpolar Arctic.[308] Continued research into the concentrations of contaminants in fatty tissues of subsistence species is vital to food security for subsistence cultures in the Arctic.

Theme 5: Fate and Effect of Oil Spills

For ease of review, findings and recommendations related to oil spill prevention and response have been consolidated in Chapter 8. The topic of fate and effects of oil spills is one that has specific relevance to the human environment and is included here as one of the five identified research themes, given its importance. Readers interested in this topic are encouraged to refer to Chapter 8 for a fuller understanding of this report's findings and recommendations.

With respect to the influence of oil and gas exploration and development on Alaska's OCS human environment, the potential for a significant petroleum release that could affect indigenous Arctic communities is a prominent concern. Specifically, concern focuses on potential impacts to subsistence lifestyles. The perceived or real contamination of the biophysical environment may have direct social consequences that could challenge ecological security.[309] Understanding the fate and effects of a spill in the Arctic is integral to an informed understanding of potential impacts and the identification of preventative measures of a spill. These measures include development and application of effective response technologies and strategies that are focused on preserving those ecosystem services and access that are most relevant to subsistence use.

Effective spill response is dependent upon knowledge of environmental characteristics, on both a regional basis (e.g., weather patterns and ocean conditions) and on local conditions (e.g., local currents, eddies, and temporal variability). As the holders of traditional knowledge, the incorporation of traditional knowledge into trajectory and other fate modeling and projection of effects can add significantly to the efficacy of oil spill response planning.

OVERVIEW OF EXISTING RESEARCH ACTIVITIES, PROGRAMS, AND INITIATIVES IN THE ARCTIC

This section summarizes current research programs, initiatives, and activities related to social and cultural issues in Arctic ecology. This section complements the earlier section of the chapter on the history of human environment research and studies.

Inuit Organizations

Alaska Eskimo Whaling Commission
http://www.aewc-alaska.com/

The Alaska Eskimo Whaling Commission (AEWC) is a co-management entity that serves the interests of bowhead whalers in ten villages extending from Saint Lawrence Island to Kaktovik. The major objectives of AEWC are to safeguard the bowhead whale and its habitat and to support the whaling activities and culture of its member communities. The commission plays an important role in influencing research priorities for bowhead whales and related ecosystem. The AEWC's individual village commissioners also are significant repositories of traditional knowledge, but the organization does not directly collect or distribute research data.

Alaska Native Tribal Health Consortium Local Environmental Observer Network
http://www.anthc.org/chs/ces/climate/leo/

This Local Environmental Observer program archives community-based observations of new species or new environmental behavior; it includes observations from communities in the Pacific Marine Arctic Research Synthesis (PacMARS) region.

Eskimo Walrus Commission
http://www.kawerak.org/ewc.html

The Eskimo Walrus Commission (EWC) co-manages subsistence walrus harvests and is primarily a stakeholder organization. Chartered in 1978 by Kawerak, Inc., of Nome, the EWC is the organization representing Alaska's coastal walrus hunting communities. Initially formed as a consortium of Native hunters, EWC is a recognized statewide entity working on resource co-management issues, specifically walrus, on behalf of Alaska Natives. The EWC is an essential cultural, natural, and subsistence resource to the Alaskan coastal Yup'ik and Iñupiaq communities. A cooperative agreement between the USFWS and EWC was developed in 1997 to encourage subsistence hunters' participation in conserving and managing walrus stocks in coastal communities. In 1998, a Memorandum of Understanding among the EWC, the ADF&G, and the USFWS was signed, facilitating joint management of the Pacific Walrus Conservation Fund. The majority of the funds for this conservation endowment come from the sale of raw ivory by the EWC during state conferences and events.

Eskimo Walrus Commission Traditional Knowledge Study of Pacific Walrus. The EWC has been conducting a "Traditional Ecological Knowledge About Pacific Walrus Study" since 2014. The result of the project will be a comprehensive report on traditional knowledge about Walrus in six or seven Iñupiaq communities. Through this project, the EWC is conducting research using interviews with elders and active hunters in each community. The project is scheduled to be completed by 2016. This study is funded through grants from Kawerak, ConocoPhillips, and others.

Alaska Beluga Whale Committee

http://www.north-slope.org/departments/wildlife-management/co-management-organizations/alaska-beluga-whale-committee

The Alaska Beluga Whale Committee (ABWC) was formed in 1988 and is composed of hunters, managers, and scientists. Its goals are to:

- Maintain a healthy beluga whale resource for subsistence use and public enjoyment by future generations
- Encourage the safe and efficient harvest, processing, and use of beluga whales; reduce the number of struck and lost whales through regional management plans
- Ensure that belugas are used as fully as possible in a nonwasteful manner
- Obtain accurate harvest information and biological samples from each region
- Educate and promote understanding about beluga issues among users, resource managers, and other interested groups
- Obtain biological information and traditional knowledge necessary for sound management and conservation of beluga whales
- Oversee enforcement of regional management plans and hunting guidelines and promote enforcement of habitat protection laws.

Alaska Ice Seal Committee

http://www.north-slope.org/departments/wildlife-management/co-management-organizations/ice-seal-committee

The Ice Seal Committee (ISC), originally called the Ice Seal Working Group, was formed in December 2004 and consists of five delegates, one from each of the five regions where ice seals occur in Alaska. The purpose of the ISC is "to preserve and enhance the marine resources of ice seals including the habitat; to protect and enhance Alaska Native culture, traditions, and especially activities associated with subsistence uses of ice seals; to undertake education and research related to ice seals." The ISC has identified the collection of harvest information as a priority. Collecting and reporting harvest information demonstrates concern for the resource and is an important contribution to resource management that federal managers have been unable to accomplish. The ISC has collaborated with ADF&G to compile all available ice seal harvest information into one document. The ISC updates and approves the document on an annual basis.

The Alaska Nanuuq Commission

http://thealaskananuuqcommission.org/

The Alaska Nanuuq Commission (ANC) was formed in 1994 and has been appointed as a full partner to the U.S. Fish and Wildlife Service in the management of polar bears. The Alaska Nanuuq Commission represents 15 coastal villages from Kaktovik to the villages of Gambell and Savoonga on St. Lawrence Island. Each village passed a tribal resolution directing that the ANC represent them in all matters concerning polar bears. The ANC is directed by commissioners appointed by each village. The Alaska Nanuuq Commission is active in most polar bear matters both national and international. The ANC has been the primary Native organization to advance the conservation of polar bears through representation of Alaska's polar bear users in all issues of polar bear management. The ANC's mission is to ensure that Alaska Native hunters will continue to have the opportunity to harvest these resources through conservation of the species.

The First Alaskans Institute

http://www.firstalaskans.org/

Among the resources intended to help facilitate broad-range capacity building in Alaska Native communities are the links to ongoing and completed projects, some of which study indigenous perspectives on quality of life and subsistence.

Inuit Circumpolar Council

http://www.inuitcircumpolar.com/

The Inuit Circumpolar Council (ICC) is a nongovernmental stakeholder organization representing indigenous communities on a pan-Arctic basis. Part of the ICC's research program is an ongoing study of food security from the Inuit perspective, and this information was used in development of the social science portion of the Pacific Marine Arctic Research Synthesis. The "DRUM" newsletter, which is archived and can be accessed through a link on the ICC website, is an efficient way to stay informed on the current projects and community involvement on the regional and international levels.

Inuit Circumpolar Council–Alaska, How to Assess Food Security from an Inuit Perspective: Building a Conceptual Framework on How to Assess Food Security in the Alaskan Arctic. Since July 2012 the Inuit Circumpolar Council–Alaska has visited 14 Alaska Inuit villages to collect information and perspectives from traditional knowledge holders on the topic of food security, through semi-directive interviews and community meetings. This project has been funded partially by ConocoPhillips.

Indigenous People's Council for Marine Mammals
http://www.ipcommalaska.org/about.html

The Indigenous People's Council for Marine Mammals (IPCoMM) includes many of the recognized co-management entities such as the Eskimo Walrus Commission discussed elsewhere. Project documentation available at the referenced website includes policy documents, workshop summaries, etc. This resource is intended to inform the Indigenous People's Council for Marine Mammals and to assist members of indigenous communities seeking to form partnerships with government agencies and other organizations.

Kawerak
http://www.kawerak.org/

Kawerak, Inc., is a nonprofit community development corporation based in Nome. It provides local information on each of the villages in the Bering Strait region. Kawerak also houses the Eskimo Walrus Commission, which is discussed in a separate entry. Kawerak's goal is to assist Alaska Native people and their governing bodies to take control of their future. With programs ranging from education to transportation, and natural resource management to economic development, Kawerak seeks to improve the region's social, economic, educational, cultural, and political conditions.

Native Village of Kotzebue
http://www.kotzebueira.org/

The referenced website includes a "Projects" tab that leads to the descriptions and mapping products connected with a series of seal tagging projects in Kotzebue Sound. These projects were carried out as community-agency partnerships and engaged local experts, who were able to combine subsistence opportunities with participation in the research.

Academic

Institute of Social and Economic Research, University of Alaska Anchorage (ISER)
http://www.iser.uaa.alaska.edu/research/arcticsocial/

ISER studies look at public policy issues across the Arctic—issues that not only affect Alaska but are common across the region. ISER's work centers on:

- Compiling data on changing social and economic conditions around the Arctic
- Analyzing migration as an adaptation to change in Arctic communities
- Potential ways of strengthening institutions for Arctic governance.

Pacific Marine Arctic Research Synthesis
http://pacmars.cbl.umces.edu/

The 2014 Pacific Marine Arctic Research Synthesis (PacMARS) (in press) provides "...a comprehensive list of studies, datasets and key multidisciplinary projects in the Chukchi and Beaufort Sea region."

Alaska Native Knowledge Network
http://ankn.uaf.edu/index.html

The Alaska Native Knowledge Network provides resources for teachers, advises on the ethics of conducting research in local communities, and provides summaries of workshops and conferences relevant for Alaska Native Studies.

Regional

North Slope Science Initiative – Emerging Issue Summary
http://quickr.mtri.org/LotusQuickr/nssi/PageLibrary852570A00051053F.nsf/50A1CAB4146896648525786B005EAD56/33A03D1BC5BAAED785257998004ED286/?OpenDocument

Highlights of the findings of the Emerging Issue Summary for Social and Economic Dimensions of North Slope Communities are as follows:

- Increasing oil and gas activities and climate change are critical issues facing people living on the North Slope.

- There is a growing need to integrate knowledge of social and natural sciences with local and traditional knowledge when monitoring, researching, and making decisions about land use, natural resources management, and industrial development on the North Slope.
- The evaluation of decisions for land and maritime use should be reoriented to include a focus on systems-based concepts such as ecosystem services, food security, and sustainable local livelihoods.
- There currently is an increase in social science research activities on the North Slope, but limited coordination, review, and endorsement of studies. This limited coordination may lower the quality of social data by creating problems such as informant burnout.
- Traditional knowledge is recognized by many as valuable, yet there remains a need to develop methods that facilitate community engagement in studies and resource management. Such efforts should be linked with regional, statewide, national, and international scale programs.
- The practice of "adaptive co-management" in a changing North Slope social-ecological system is critical in times of rapid change, and could inform the design and implementation of resource management policies on the North Slope.
- Changes in the infusion of cash to villages from past North Slope oil and gas development have affected life dramatically for the Iñupiat. Plans for future development concurrent with declining production from existing oil fields suggest the need to identify strategies that ensure the long-term sustainability of North Slope villages and local and regional government and nongovernment organizations.

North Slope Borough
http://www.north-slope.org/

The NSB is committed to having economically, spiritually, and culturally healthy communities. The borough works with the tribes, cities, corporations, schools, and businesses to support a strong culture, encourage families and employees to choose a healthy lifestyle, and sustain a vibrant economy.

NSB's Department of Health and Social Services produced a *Baseline Community Health Report* in 2012.

The Iñupiat Heritage Center is a dynamic repository and conveyor of traditional cultural knowledge, values, and skills of the North Slope region. This is accomplished by:

- Collecting, recording, preserving, documenting, displaying, and interpreting artifacts and other associated materials relating to the history, culture, and traditions of the Iñupiat people
- Drawing upon the reservoir of traditional cultural knowledge, supporting local and borough-wide cultural awareness
- Researching and developing educational, historical and cultural materials in close cooperation with community leaders, village elders, the IHLC (Iñupiat History, Language, and Culture) Commission, the North Slope Borough School District and Ilisaġvik College.

Northwest Arctic Borough
http://www.nwabor.org/forms/subsistencemapconfreport.pdf

The NWAB conducted a Subsistence Mapping Project that was funded by the Oak Foundations and the Coastal Impact Assistance Program (CIAP). The project met the goals of the comprehensive plan. These goals were to promote and maintain the subsistence way of life, maintain the Iñupiaq culture, self-determination, to foster appropriate economic development, and to raise the standard of living.

Beaufort Regional Environmental Assessment
http://www.beaufortrea.ca/

The ongoing Beaufort Regional Environmental Assessment (BREA) is a multi-stakeholder initiative to sponsor regional environmental and socioeconomic research that will make historical information available and gather new information vital to the future management of oil and gas in the Beaufort Sea. Research components cover biology, from lower trophic levels (lower positions on the food chain) to mammals and birds; sea ice; meteorology; and more. Field campaigns for biological surveys were conducted during the summers of 2012 and 2013. Data are not yet publicly available, but presentations from a February 2013 workshop are available at http://www.beaufortrea.ca/results-forum-2012-2013/.

Bering Sea Sub-Network
http://eloka-arctic.org/projects/bssn.html

The Bering Sea Sub-Network (BSSN) is a current NSF project involving a number of local residents of Bering Sea communities in providing community-based observations, particularly through surveys. This project is positioned to communicate concerns from Russian villages that are participating in the project. The project coverage currently extends only as far north as St. Lawrence Island and the Gulf of Anadyr, so some lessons learned from the southern Bering Sea may not be immediately transferable to the PacMARS study area.

Northwest Arctic Borough
http://www.nwabor.org/

The NWAB is the regional government entity based in Kotzebue and extends over much of northwest Alaska. The borough website includes information on the communities in the borough, and also provides information on the borough's Subsistence Mapping Program. A 2011 conference report[310] summarizes the subsistence mapping project, which engages participation of subsistence experts from the NWAB communities and aims to provide cultural resources for education, as well as for planning associated with development.

State

Alaska Department of Natural Resources, Office of History and Archaeology
http://dnr.alaska.gov/parks/oha/index.htm

The Alaska Office of History and Archaeology (OHA) and State Historic Preservation Office (SHPO) provide historic preservation programs to encourage the preservation and protection of the historic, prehistoric, and archaeological resources of Alaska. It is the policy of the state to preserve the historic, prehistoric, and archaeological resources of Alaska from loss, desecration, and destruction so that the scientific, historic, and cultural heritage embodied in these resources may pass undiminished to future generations (A.S. 41.35.010).

State of Alaska Community Database Online
http://commerce.alaska.gov/cra/DCRAExternal

This website provides a brief and basic introduction to the history, culture, and contemporary living conditions in Alaska, including the communities in the PacMARS region.

Federal

Arctic System Science
http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13426

Arctic System Science (ARCSS) focuses on relationships of global changes with Arctic human systems. The scope of ARCSS includes effects of Arctic oil and gas development and climate change on peoples of the North.

Alaska Annual Studies Plan

The BOEM Study Plan lists five ongoing and one planned study related to subsistence in the Arctic. Their titles and justifications are as follows:

- *Study of Sharing Networks to Assess the Vulnerabilities of Local Communities to Oil and Gas Development Impacts in Arctic Alaska (AK-05-04a).* "This information will be used for NEPA analysis and documentation for Beaufort Sea and Chukchi Sea Lease Sales and DPPs [Development and Production Plans]. This study addresses aspects of USGS Recommendations 3.06, 3.08, and 6.10."
- *Continuation of Impact Assessment for Cross Island Whaling Activities (AK-08-01).* "Long-term study efforts to monitor potential effects of such development activities (Northstar and Liberty) have occurred through the ANIMIDA [Arctic Nearshore Impact Monitoring in Development Area] and cANIMIDA [continuation of ANIMIDA] projects, 1999-2007. There remains a continuing, ongoing need to monitor Cross Island whaling activities for potential impacts over the next 5 years. The information will be used for NEPA analysis and documentation for Beaufort Sea Lease Sales and DPPs. This study addresses aspects of the USGS recommendations 3.06, 3.07, 3.08, and 6.10."
- *COMIDA: Impact Monitoring for Offshore Subsistence Hunting (AK-08-04).* "This study will constitute a key component of Chukchi Sea environmental studies pertinent to Chukchi Sea Lease Sale 193 scheduled for 2007. Industry has expressed strong interest in leasing in this area,

likely followed by exploration and possibly development. The COMIDA workshop conducted November 1-3, 2006 recommended the monitoring of offshore subsistence hunting. The BOEM needs to establish an early baseline in the area and to monitor on an annual basis any significant changes in subsistence activities over time. In particular monitoring efforts should be directed toward the hunt for marine mammals, including bowhead and beluga whales, walrus, polar bears, and seals. The BOEM analysts and decision-makers will use the information in NEPA analysis and documentation for Lease Sales, EPs [exploration plans] and DPPs [development and production plans], and in post-sale and post exploration decision-making in the Chukchi Sea. This study addresses aspects of USGS recommendations 3.06, 3.07, 3.08, and 6.10."

- *Social Indicators in Coastal Alaska: Arctic Communities (AK-11-09).* "This study will update key sociocultural and economic baseline data for analysis of potential local and regional impacts from offshore exploration and development activities that may occur in federal waters off the North Slope of Alaska. Information from this study will be used for Outer Continental Shelf Lands Act and NEPA analyses, for documentation, and may serve as the basis for long-term monitoring for Chukchi and Beaufort oil and gas exploration in the region."
- *Subsistence Use and Knowledge of Beaufort Salmon Populations (08-12-04).* "This study will … be used to meet EFH [essential fish habitats] and NEPA requirements for Beaufort Sea lease sales. This research will inform local communities, local and state resource managers, and BOEM of ecosystem health, which is so important to subsistence lifestyle. This study addresses aspects of USGS recommendation 3.06."
- *Baseline Nutritional Survey: Inventory and Content Analysis of Subsistence and Market Foods as Consumed by North Slope Communities (proposed for 2013).* "This study will facilitate scientific understanding and analysis of potential health impacts that could derive from oil and gas industrial activities. It will also address longstanding concerns about potential cumulative effects of oil and gas activities on the North Slope."[311]

National Science Foundation,
Arctic Social Sciences Program
http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13425

The NSF is currently soliciting projects in their Arctic Social Sciences Program. Some currently funded projects include:

- Collaborative Research: Glacial Retreat and the Cultural Landscape of Ice Floe Sealing at Yakutat Bay, Alaska
- A Comparative Study of the Medical Ethnobotany of the Chukchi and Naukan Yup'ik of Siberia and the Central Alaskan Yup'ik
- Assessing Knowledge, Resilience, and Adaptation and Policy Needs in Northern Russian Villages Experiencing Unprecedented Climate Change
- The Archaeology of Herring: Reconstructing the Past to Redeem the Future.

Bureau of Land Management,
Alaska's Cultural Heritage Program
http://www.blm.gov/ak/st/en/prog/cultural.html

The public lands entrusted to BLM-Alaska are a gateway to knowledge of the past. From fossil discoveries of ancient dinosaurs that lived above the Arctic Circle to traces spanning over 14,000 years of the human past and cultures. How people and animals lived in Alaska over time and the forces that shaped their changing environments can be studied.

U.S. Geological Survey
http://www.usgs.gov/newsroom/article_pf.asp?ID=2931

In "Observations of Climate Change from Indigenous Alaskans," the U.S. Geological Survey (USGS) conducts interviews with Yup'ik hunters and elders in the villages of St. Mary's and Pitka's Point, Alaska, to document their observations regarding climate change. The elders expressed concerns ranging from safety, such as unpredictable weather patterns and dangerous ice conditions, to changes in plants and animals as well as decreased availability of firewood.

Smithsonian National Museum of Natural History, Arctic Social Sciences
http://www.mnh.si.edu/arctic/html/overview.html

Arctic research is supported by the NSF's Office of Polar Programs (OPP). The OPP Arctic Social Sciences program has been supporting multidisciplinary and interdisciplinary research since 1990. Projects encompass the disciplines of anthropology, archaeology, sociology, political science, psychology, linguistics, geography, law, and related fields.

Arctic Research Consortium of the United States
http://www.arcus.org/assp

The NSF Arctic Social Sciences Program is a multidisciplinary and interdisciplinary program encompassing all social sciences research supported by NSF. The Arctic Social Sciences Program supports research that documents and analyzes the dynamic cultures, economies, and technologies of northern populations.

Arctic Research Consortium of the United States (ARCUS) provides support to the Arctic Social Sciences Program by organizing workshops to bring together social scientists and researchers from other fields to promote cross-disciplinary collaboration and to identify important research themes and how to deal with them.

Arctic Human Health Initiative
http://arctichealth.nlm.nih.gov/

The Arctic Human Health Initiative (AHHI) website is a U.S. government data portal that provides search functions for original research publications relating to human health at high latitudes. Bibliographical information on more than 100,000 publications, both peer-reviewed and nonpublished literature, is included. Other features of the website are links to other web portals and websites that provide information on a wide variety of Arctic topics. References to out of print publications and information from special collections held in the Alaska Medical Library at the University of Alaska Anchorage are included.

Arctic Landscape Conservation Cooperative
http://arcticlcc.org/

Landscape Conservation Cooperatives are an initiative led by DOI, which has responsibilities for national park and wildlife refuge management, as well as other federally owned lands and resources. The Arctic Landscape Conservation Cooperative (ALCC) provides information needed to conserve natural and cultural resources in the face of landscape scale stressors, particularly climate change.[312]

Not all of the projects supported by the ALCC are relevant to PacMARS since the landscape protection components are often located in watersheds and on land, but the Shore Zone mapping program and the Threatened Eider Database[313] are considered to be two of the most significant contributions of the ALCC relevant to PacMARS. Another component of the program is the BIOMAP Alaska project, which is using local residents of Barrow, Kotzebue, and Kaktovik to collect data on local observations, and upload that information via the web.

Arctic Social Indicators Project
http://www.svs.is/en/the-arctic-social-indicators-project-en

The Arctic Social Indicators (ASI) project is a follow-up to the Arctic Human Development Report, described below. The 160-page *Arctic Social Indicators* report was published in 2010.[314] It is a high-level summary of social indicators on a pan-Arctic basis. References to original literature are included.

BIOMap Alaska
http://arcticlcc.org/projects/human-system/biomap/

This is a web-based citizen-science project to collect local observations in Kotzebue, Barrow, and Kaktovik.

Bureau of Land Management (BLM) NPR-A Subsistence Advisory Panel Documents
http://www.blm.gov/ak/st/en/res/npra_sap/npra_sap_docs.html

During the PacMARS social science analysis, the transcripts from the meetings of the Subsistence Advisory Panel for the National Petroleum Reserve of Alaska, organized by BLM, were reviewed.

Although the focus is primarily on land-based resources, a review of concerns related to the marine environment is provided.

U.S. National Park Service Shared Beringian Heritage Program
http://www.nps.gov/akso/beringia/

The U.S. National Park Service funds projects of scientific and community importance in the Beringia Region of western Alaska and Chukotka. The projects are local community-based, and relatively small in scope. A complete list of current projects is available at the program website. The PacMARS analysis considers these projects to be important even at a small scale as they contribute to maintaining neighboring community continuity throughout the Beringia region.

Subsistence Fisheries in Northwest Alaska, Funded by the U.S. Fish and Wildlife Service

This study is documenting local observations of climate change relevant to subsistence fisheries in Noatak, Selawik, and Shungnak.

Subsistence Use and Knowledge of Beaufort Sea Salmon Populations, Funded by the Bureau of Ocean Energy Management

This project incorporate local observations from subsistence fisheries to generate better understanding about salmon use and distributions on the North Slope in response to apparent increases in salmon populations.

Nongovernmental Organizations

Alaska Community Action on Toxics
http://www.akaction.org/Tackling_Toxics/Food/Traditional_Foods.html

Alaska Community Action on Toxics is an organization that advocates for Alaska Native concerns connected with contaminants and the safety of the locally harvested food.

RurAL CAP – Rural Alaska Community Action Program
http://www.ruralcap.com/

RurAL CAP, founded in 1965, is a private, nonprofit organization working to improve the quality of life for low-income Alaskans, specifically in rural areas. While not specifically a research organization, knowledge from this large organization (>1,000 employees in 81 Alaskan communities) was incorporated into the social science evaluation of PacMARS efforts.

Pan-Arctic

Arctic Human Development Report
http://svs.is/images/pdf_files/ahdr/English_version/AHDR_first_12pages.pdf

The Arctic Human Development Report (AHDR) was a high-level social science assessment of the welfare of human communities in the Arctic sponsored by the Arctic Council. The report summarizes knowledge and facilitates comparisons on a circumpolar basis, rather than serving as an original source of data.

References in each chapter provide original data. The report also identifies important bibliographical resources.

Community Adaptation and Vulnerability in Arctic Regions

The Community Adaptation and Vulnerability in Arctic Regions (CAVIAR) report was an International Polar Year project examining community vulnerabilities on a pan-Arctic basis. Two communities in the PacMARS study area, Kaktovik and Wainwright, were included in the initial planning for the project.

Canadian Healthy Oceans Network
http://chone.marinebiodiversity.ca/

The Canadian Healthy Oceans Network (CHONe) is a National Science and Engineering Research Council of Canada strategic network, focused on biodiversity science for the sustainability of Canada's three oceans including the Arctic. The network includes approximately 150 researchers from 14 universities across Canada, the federal Department of Fisheries and Oceans, and seven other government laboratories, to carry out 35 collaborative research projects in three interconnected themes.

Chukotka Native Marine Mammal Hunter Association
www.pacificwalrus.ru

This local Chukotka-based organization is monitoring haul-out locations of walruses in Russia with support from the Chukotka Branch of the Pacific

Research Fisheries Center (ChukotTINRO). As sea ice retreats, it has been more common for walruses to haul out on the Chukchi coast instead of resting on sea ice, and the animals are vulnerable while on shore to human disturbance. The referenced website provides information, links to literature and Russian-language reports on this shift in walrus behavior. Also posted on the website is a final report in English that summarizes traditional knowledge of walruses and hunting, based upon extensive interviews of local walrus hunters in villages of Chukotka.

Center for Ocean Studies Education Excellence
http://www.coseealaska.net/

The Alaska Center for Ocean Studies Education Excellence (COSEE) is an educational outreach effort providing useful resources for integrating Alaska Native knowledge and other topics pertinent to PacMARS.

Exchange for Local Observation and Knowledge of the Arctic
http://eloka-arctic.org/

The Exchange for Local Observation and Knowledge of the Arctic (ELOKA) is a project framework that was initiated during the International Polar Year. It facilitates the collection, preservation, exchange, and use of local observations and knowledge of the Arctic. ELOKA provides data management and user support through the National Snow and Ice Data Center, and it fosters collaboration between resident Arctic experts and nonresident researchers. The Bering Sea SubNetwork project, described elsewhere in this document, is one associated project. Another project under the ELOKA framework is the Seasonal Ice Zone Observing Network.[315,316] SIZONet is an unusual project that has a significant local community observation component documenting locally observed sea ice distributions near Wales and Barrow in the context of satellite-based data

Extractive Industries Working Group, International Arctic Social Sciences Association
http://www.arcticcentre.org/InEnglish/RESEARCH/Extractive_Industries_Working_Group.iw3

This working group of the Extractive Industries Working Group, International Arctic Social Sciences Association (IASSA) is chaired from the Arctic Centre of the University of Lapland. It serves as a clearinghouse of information on extractive industries in the Arctic, including identifying data gaps and needs. Courtney Carothers, University of Alaska Fairbanks, is the key working group member who is undertaking research in the PacMARS study area.[317] This work includes projects on:

- Climate Change and Subsistence Fisheries in Northwest Alaska, funded by the U.S. Fish and Wildlife Service. This study documents local observations of climate change relevant to subsistence fisheries in Noatak, Selawik, and Shungnak.
- Subsistence Use and Knowledge of Beaufort Sea Salmon Populations, funded by the Bureau of Ocean Energy Management. This project incorporates local observations from subsistence fisheries to generate better understanding about salmon use and distributions on the North Slope in response to apparent increases in salmon populations.

Moved by the State: Perspectives on Relocation and Resettlement in the Circumpolar North
http://www.alaska.edu/move

This project was the U.S. portion of a larger international collaboration that was conceived under BOREAS, a EUROCORES Program of the European Science Foundation (ESF). The full ESF project is a collaboration of researchers from five countries, including the U.S., Canada, Russia, Greenland, and Finland. The U.S. components included five individual researchers from the University of Alaska Fairbanks and the University of Maryland.

The Arctic Council Sustainable Development Working Group
http://www.sdwg.org/

The Sustainable Development Working Group (SDWG) is an entity of the Arctic Council. A number of social science and sustainable development project reports and deliverables are available on its website. Some of these documents are discussed elsewhere in this document. Although SDWG is a high-level, pan-Arctic entity, PacMARS used insights from working group documents as part of its analysis.

Sea Ice Knowledge and Use
http://gcrc.carleton.ca/siku

The Sea Ice Knowledge and Use (SIKU) Project was undertaken during the International Polar Year and documented indigenous observations with a focus on sea ice and the use of ice-covered habitats. The project website hosted at Carleton University is a treasure trove of traditional ecological knowledge from Alaska and Chukotka. Other components of the project were undertaken in Greenland and Canada. Sea ice dictionaries and other traditional knowledge that was transferred were used during the PacMARS synthesis.

Sea Ice for Walrus Outlook
http://www.arcus.org/search/siwo

The Sea Ice for Walrus Outlook (SIWO) is an activity that started in 2010, and is primarily a resource for Alaska subsistence hunters in coastal communities in the Bering Strait region. The SIWO provides weekly reports from April through June with information on sea ice conditions in the Northern Bering Sea and southern Chukchi Sea. One of its goals is to improve sea ice forecasting at smaller scales than is usually provided through the National Weather Service by incorporating knowledge and local observations from Bering Strait residents.

Survey of Living Conditions in the Arctic
http://www.arcticlivingconditions.org/

The Survey of Living Conditions in the Arctic (SLiCA) was funded in the United States by the National Science Foundation. The overall pan-Arctic project examined human living conditions of Inuit, Sami and indigenous people of Chukotka. The website includes protocols protecting the raw survey data, and conditions for access, which are evaluated on a case-by-case basis. The survey results allow quantitative comparisons of the consumption of marine resources in the North Slope, Northwest Alaska, and Bering Strait region.

Arctic Council Working Groups

Protection of the Arctic Marine Environment (PAME) Working Group is mandated to address policy and nonemergency pollution prevention and control measures related to the protection of the Arctic marine environment from both land and sea-based activities (Arctic Council 2014). The Conservation of Arctic Flora and Fauna (CAFF) Working Group was formed in 1991 (pre-dating the Arctic Council) and addresses biodiversity issues (through the Circumpolar Biodiversity Monitoring Program or CBMP) and provides the most recent scientific information and data to Arctic policymakers. The Arctic Council now oversees and coordinates CAFF, which has become an important forum for the discussion and development of strategies, assessments, monitoring and recommendations that feed into the Arctic Council process to increase knowledge, address knowledge gaps, and contribute to the knowledge necessary to inform policy.[318] AMAP is another Arctic Council working group tasked with monitoring and assessing the status of the Arctic Region in respect to pollution and climate change issues; documenting levels, trends, pathways, processes, and effects on ecosystems and humans; proposing actions to reduce associated threats for consideration by governments; and producing sound science-based, policy-relevant assessments and public outreach products to inform policy decisions.[319]

Arctic Contaminants Action Program (ACAP) is the working group responsible for reducing emissions of pollutants into the environment in order to reduce the identified pollution risks. ACAP encourages Arctic state governments to take remedial and preventive actions relating to contaminants and other releases of pollutants. It also acts as a strengthening and supporting mechanism to encourage national actions to reduce emissions and other releases of pollutants.

Emergency Prevention Preparedness and Response (EPPR) is the working group responsible to address the various aspects of prevention, preparedness and response to environmental emergencies in the Arctic. Members of EPPR exchange information on best practices; and conduct projects to include development of guidance and risk assessment methodologies, response exercises, and training. The goal is to contribute to the protection of the Arctic environment from the threat or impact that may result from an accidental release of pollutants or radionuclides. In addition, the working group considers questions related to the consequences of natural disasters.[320]

The Sustainable Development Working Group (SDWG) is tasked with proposing and adopting steps to be taken by the Arctic states to advance sustainable development in the Arctic, including opportunities; protecting and enhancing the environment and the economies, culture and health of indigenous peoples and Arctic communities; and improving the environmental.[321]

International Arctic Science Committee

The International Arctic Science Committee (IASC) is a nongovernmental, international scientific organization whose mission is to facilitate cooperation among all countries engaged in pan-Arctic Research. IASC promotes and supports interdisciplinary research in order to foster a greater scientific understanding of the Arctic region and its role in the "Earth System."[322]

IASC is organized into working groups, action groups, and advisory groups. Working groups are at the core of IASC's activities. IASC working groups identify and formulate scientific plans, list research priorities, encourage science-led programs, promote future generations of Arctic scientists and act as scientific advisory boards to the Council. The scientific scope of the Social and Human Sciences Working Group includes all aspects of social sciences and humanities research in the Arctic, as well as its connections with other IASC working groups. The actual work of the Social and Human Sciences Working Group will be determined by a dynamic list of scientific focus areas. The geographic scope of the Social and Human Sciences Working Group is the Arctic as defined in the map accompanying the Arctic Human Development Report issued by IASC. The geographic scope can be extended south where it is appropriate for an understanding of Arctic social and human processes. The scientific foci of the Social and Human Sciences Working Group are: indigenous peoples and change: adaptation and cultural power dynamics; exploitation of natural resources: past, present, future; histories and methodologies of the Arctic sciences and arts; perceptions and representations of the Arctic; human health and well-being; and security, international law and cooperation. Based on the scientific foci, a list of crosscutting issues was adopted, based on working group needs and on opportunities provided by the focus areas of other working groups. The list of crosscutting issues is as dynamic as the list of scientific foci; its development and refinement will depend on actual cross-working group interactions. The issues are: human health, well-being and ecosystem change; collaborative community research on climate change; competing forms of resource use in a changing environment; people and coastal processes; and perception and representation of Arctic science.

Other Arctic Nations

Canada

Canada conducts substantial Arctic research, and consideration for Canada's indigenous Arctic people has strong influence on the government's position with respect to Arctic issues. The country's Arctic strategy is built on four pillars: exercising Canadian sovereignty, promoting economic and social development, protecting the Arctic environment, and improving and devolving governance for Canadian Northerners.

The Canadian Arctic Resources Committee (CARC) is a citizens' organization dedicated to the long-term environmental and social well-being of northern Canada and its peoples. Their premise is the application of sustainable development and the precautionary principle. Their policy and advocacy work is grounded in solid scientific and socioeconomic research and experience.

Canadian Arctic Resources Committee. (http://www.carc.org/index.php?option=com_content&view=article&id=160%3Aarctic-science&catid=57%3Arecommendations-for-canadian-foreign-policy&Itemid=181, Copyrighted material 2010, Accessed September 24, 2014.) A number of research needs have been identified that relate to social characterization: basic knowledge of ecosystem functions, carrying capacity and integrity in the context of climate change, contaminants cycling, and industrial impacts; multiple issues links, e.g., contaminants as environmental and public health research areas; multi-theme research; sustainable development versus economic expansion; mega-resource development project research; damage control, damage prevention, damage remediation; incorporating social science research in all relevant policy areas; and conducting net benefit research for sustainable development.

The growing documentation on traditional or indigenous knowledge adds considerably to the knowledge base upon which policies and practices can be based. Increasingly, Aboriginal communities are seeking scientific information to link to their own understanding of themselves and the environment around them. Some scientists also now are forging relationships with traditional knowledge holders to provide a more detailed foundation on which to develop their own research agendas.

Denmark (Including Greenland and the Faroe Islands)

Denmark developed a new Arctic strategy in 2011 that was put forth in a document titled *Denmark, Greenland and the Faroe Islands: Kingdom of Denmark Strategy for the Arctic 2011-2020*. The document states: "A strategy for the Arctic region is first and foremost a strategy for development that benefits the inhabitants of the Arctic—involving common interests relating to, for example, international agreements, and regional and global issues. Such a development incorporates a fundamental respect for the Arctic peoples' rights to utilize and develop their own resources as well as respect for the indigenous Arctic culture, traditions and lifestyles and the promotion of their rights. Denmark and Greenland's cooperation on Arctic indigenous peoples dates back to 1973 when the Arctic Peoples' Conference at Christiansborg Palace in Copenhagen became a launching point for the international organizing of indigenous peoples."

Iceland

The Stefansson Arctic Institute (SAI) is an independent institute of the Icelandic Ministry for the Environment with a focus on the human dimension of sustainable development in the Arctic region. It is located in Akureyri in Northern Iceland and bears the name of Arctic explorer and anthropologist Vilhjálmur Stefánsson (1879-1962). The staff at the Stefansson Arctic Institute includes researchers with a broad interdisciplinary social science and humanities research background and experience leading and participating in international projects. The role of SAI is to be a forum for cooperation in multidisciplinary research; promote sustainable development in northern areas; strengthen Icelandic participation in international endeavors in this field; facilitate and coordinate Arctic research in Iceland; gather and disseminate information regarding northern issues; advise the government and cooperate with others internationally; and provide facilities for scholars who pursue research relevant to the SAI's agenda.

Norway

In Norway, development in the Arctic has been the government's highest foreign policy priority since 2005. In 2006, Norway issued the document entitled "The Norwegian Government's High North Strategy." The overarching objectives are to gain greater knowledge, create more activity and have an increased presence in the north, and to lay the foundations for sustainable economic and social development in the future. Integrated resource management in the High North includes the protection of the natural resource base for indigenous peoples' economic activity, of their cultural heritage and traditional knowledge, and of reindeer husbandry areas. It also includes protection of the environment along the coast and of traditional seawater and salmon fisheries. The Norwegian government is interested in developing existing and new forms of economic activity as a basis for settlement patterns and to safeguard Sami culture. The government has appointed a committee to review the rights of the Sami and others to fish in the sea off Finnmark. Efforts are also ongoing to safeguard reindeer husbandry areas, for example through the proposed amendments to the Reindeer Husbandry Act. The Sami Rights Commission is currently examining the use and management of land and natural resources in areas used by the Sami people outside Finnmark County.

The Arctic Climate Impact Assessment (ACIA) documents how indigenous peoples have adapted to earlier climate change. The climate change currently taking place may have major impacts on the way of life of indigenous peoples, and priority will be given to knowledge building in this field, in cooperation with other countries in the High North.

In addition, the Research Council of Norway (RCN) issued the document titled "Research Strategy for the Arctic and Northern Areas 2011-2016." One of the six key themes developed in the strategy deals specifically with social research and is called "Social Development in the Arctic and Northern Areas."

Climate change is threatening traditional ways of life and livelihoods. Infrastructure is also strongly affected by the rapid changes in climate. Arctic communities are under pressure from the global society's economic interests and activities, which are steadily advancing northwards. It is critical to learn more about how the changes in the Arctic will create winners and losers.

Sweden

Sweden's Arctic priorities fall into three thematic categories: (1) climate and the environment, (2) economic development, and (3) the human dimension. Swedish Arctic research is world-class and is conducted not only in the fields of engineering and natural science but also in social science and the humanities. In 2012, the Arctic Research Centre at Sweden's Umea University established the Swedish Association for Arctic Research in Humanities and Social Sciences. The purpose of this initiative is to strengthen humanities and social science research within the Arctic and northern fields in Sweden and internationally.

The aim is to improve the opportunities for collaboration, new projects and information distribution by taking the following actions:

- Work to achieve a holistic picture of human-social science polar research in Sweden—the researchers, research projects, and organizations
- Identify research problems that need to be addressed in the present, with an eye toward possible future problems
- Promote social science polar research to funding agencies and decision-makers
- Initiate research projects and applications for research funding
- Strengthen the connection between Swedish social science polar research and international research within this field
- Work to increase access to the logistical resources for polar research managed by the Swedish Polar Research Secretariat
- Increase cooperation between humanities and social science polar research and natural science polar research
- Function as the research committee working together with the Swedish humanities and social science representatives in IASC and SCAR.

Russian Federated States

Excerpted from the website of the Arctic Centre (Arktinen Keskus), University of Lapland. http://www.arcticcentre.org/EN/RESEARCH/Sustainable-Development-Research-Group/Anthropology-research-team/Anthropology-of-northern-Russia

"The Russian North covers half of the circumpolar Arctic Area, hosts more than 50% of the Arctic human population and immense reserves of natural resources. Anthropology as dealing with human cultures and livelihoods, and particular the processes of rapid social change in the Russian North, is important for the Arctic Centre with its circumpolar and interdisciplinary research mandate.

Reindeer pastoralism is the dominant way of life of indigenous people in the north from Norway to the Bering Strait. Its comparative study, particularly in relation to cultural change and continuity in post-Soviet Siberia, can contribute a lot to understanding of theories of pastoralism, human-animal-environment relations, subsistence and commoditization processes. In this respect, research on the Arctic North can become relevant far beyond the borders of this geographic region.

The same is true for the topic of social impact assessment of industry on human communities. Comparative anthropological research has been completed with different colleagues on the relations between reindeer herders and industrial companies and their workers for the last 8 years, currently in two northern Russian regions, the Nenets and Yamal Nenets Okrug. Part of this work is funded by a project of the Academy of Finland, ENSINOR. The topic of impact mitigation and relation between stakeholders active in and affected by industrialization has also been explored jointly with colleagues at the Scott Polar Research Institute (SPRI) of the University of Cambridge. In a seminar series "TransSectoral Partnerships" funded by the Economic and Social Science Research Council of the UK, a dialogue was facilitated to exchange ideas and sustainable development in the Russian oil and gas sector."[323]

Finland

Finland's position as an Arctic country in the Nordic region is very similar to Sweden's. Neither country borders the Arctic Ocean, both are EU member states, and both have indigenous Sami populations. Finland's Arctic Research Programme 2014-2018 will create a knowledge base that further strengthens expertise related to northern conditions in various issues closely linked to the functioning of society. Examples of these include energy efficient and clean technology solutions based on research; continuous monitoring and remote management systems of the Arctic environment and infrastructure; snow management solutions; icebreaking and oil spill response and modeling related to sea ice; electronic social and healthcare services and remote medicine solutions; understanding of the interaction between culture and the environment; functional materials; and management of massive data materials and the development of services based upon these. One of the four thematic areas of the research program is directly linked to social science and is called "good-quality life in the north" and is supported by the following definitions and research directions:

- The nature of changes touching the Arctic region and the historical dimension of the changes: humans as objects adapting to change and active operators
- Survival of society and people in the Arctic region and the changes in work, living conditions, communities, culture, and identity
- Study of the basic situation of indigenous peoples and the development of culture-sensitive services, and the matching of provision and use of wellbeing services in the event of change
- The transcultural and unique nature of the Arctic region: holistic research on the coexistence of ethnic groups
- Research on the human-nature relationship and, for example, the development of assessment methods for long-term environmental and social effects.

KEY RECOMMENDATIONS FROM THIS ASSESSMENT

This study highlights that the oil and gas industry has been operating and working responsibly and collaboratively for decades with our neighbors and other stakeholders in the U.S. Arctic. A significant body of knowledge on the human environment exists partly because of information collected to understand and mitigate potential impacts of oil and gas operations from development. However, continued focus on understanding the human environment is critical to ensure a sustainable future for the U.S. Arctic in balance with ongoing and future oil and gas production. In recent years there have been multiple studies that have identified emerging research areas to continue understanding this complex topic. The National Research Council through its recent study report, *The Arctic in the Anthropocene: Emerging Research Questions,*[324] identified several research issues relevant to the human environment. Issues identified included growing human capacity, community engagement, and stakeholder initiated research. In 2011, the USGS conducted an evaluation of the science needs to inform decisions on Outer Continental Shelf energy development in the Chukchi and Beaufort Seas; issues that were relevant to the human environment included the importance of subsistence harvest research. The U.S. Arctic Research Commission's 2013-2014 program plan identified some focus areas in the area of cultural identity, especially research into education methods of teaching Native languages.

The recommendations from this study fall broadly into the following six categories.

Preservation of Cultural Sustainability. Building on past and current efforts, new studies can help to identify changes in sustainability patterns. Sustainability is a product of the interplay of culture, economy, health, and environment. While numerous studies and programs examine these areas individually, more work is needed to examine the synergies and tradeoffs among them in order to approach sustainability in a systematic way. The federal government should take the lead in developing a framework for connecting these topics so that government, industry, and others can better understand the ways that specific policies and actions affect sustainability. A first step in achieving such a framework should be a study that includes extensive dialogue between representatives of the research communities in each of the identified components of sustainability and representatives of the people of the U.S. Arctic to define culturally appropriate targets and goals by which sustainability can be assessed and metrics by which these components and the outcome of their collective influence can be forecast, monitored, and assessed. Resource agencies should work collaboratively to define the scope of and fund such a study and identify the appropriate entity to implement it.

Ensuring Food Security. Continued research into the concentrations of contaminants in fatty tissues of subsistence species is vital to food security for subsistence cultures in the Arctic. Future work could leverage the Arctic Council's Arctic Monitoring and Assessment Program, a long-term monitoring program for contaminants in the circumpolar Arctic[325] and ensure that ambient chemical levels due to future increased energy exploration and development activities are monitored effectively. Efforts by

U.S.-based researchers to collect and analyze tissues from subsistence species for contaminants of concern should be continued and supported in a long-term programmatic manner. This program should work closely with the subsistence hunting community to obtain tissues through robust collection techniques, to be grounded in the observations of hunters about animal health, and be responsive to the concerns of the subsistence communities of the U.S. Arctic.

Optimized Consultation and Community Engagement. Though there are presently ample opportunities for local communities to participate in a multitude of planning and regulatory processes and development projects through a multitude of meetings, there is room for improvement in this process. The consultation and engagement of Arctic communities needs to be optimized to be as useful and meaningful as possible, while limiting the burden on local communities. This includes combining consultation for projects where possible and targeting times and places where planning and regulatory processes are most flexible.

Traditional Knowledge Studies. There is an opportunity for ongoing research to maximize how traditional knowledge is collected and how best to integrate this critical information with data collected from scientists in physical, biological, and social science disciplines. Research should be conducted on best practices for effective collection and integration of local traditional knowledge with science and effective community engagement in studies and resource management. This research should include the participation of local communities to gain their perspective on different methods and what needs to be improved.

Standardization of the Socioeconomic Impact Assessment Process. A formalized social impacts assessment (SIA) framework does not exist within the U.S. regulatory framework.[326] The Arctic Council Sustainable Development Working Group is considering a recommendation to the Council to institutionalize social impact assessment into Environmental Impact Assessment processes.[327] While SIA methods need to be flexible in order to fit the particular human environment being assessed, institutionalization and standardization of methods will provide quality control and quality assurance in the SIA process. Associated with this research effort is the need to optimize a framework of socioeconomic indicators, to further optimize the monitoring of impacts from oil and gas activity on the human environment. Resource agencies should work with the state of Alaska Department of Natural Resources and Department of Health to follow the processes that have yielded a coordinated framework for Health Impact Assessment. Under this program the state of Alaska is able to partner with federal agencies, the Alaska Native Tribal Health Consortium, local boroughs, and stakeholders.

Collaboration Framework Evaluation. Ensuring the protection of the environment and the community while providing opportunity via responsible oil and gas development is a key stewardship approach for all stakeholders in the U.S. Arctic. Working collaboratively and identifying synergies and common research interests will be critical to continuing to have the information required in the area of the human environment discussed in this chapter, to ensure informed decision-making that supports responsible oil and gas development of the Arctic. The North Slope Science Initiative (NSSI) has a legislatively mandated objective to provide the best scientific information on both environmental and social science to its 14 federal, state, and local governmental members and to the public. Enhancement of NSSI capabilities in the area of social science would help provide critical information needed by both industry and governments.

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