Exhibit 1

U.S. Environmental Protection Agency Region 10, Outer Continental Shelf Prevention of Significant Deterioration Permit to Construct, R10OCS/PSD-AK-2010-01, Shell Offshore Inc. (Sep. 19, 2011)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 900
Seattle, Washington 98101-3140

OUTER CONTINENTAL SHELF PREVENTION OF SIGNIFICANT DETERIORATION PERMIT TO CONSTRUCT

Permit Number: R10OCS/PSD-AK-2010-01 Issuance Date: September 19, 2011

In accordance with the provisions of Clean Air Act (CAA) Section 328 and Code of Federal Regulations (CFR) Title 40, Part 55, and the provisions of Part C to Title I of the CAA and 40 CFR § 52.21,

Shell Offshore Inc.
3601 C Street, Suite 1000
Anchorage, AK 99503

is authorized to construct and operate the Noble Discoverer (Discoverer) drillship and its air emission units and to conduct other air pollutant emitting activities in accordance with the permit conditions listed in this permit, and only at the following lease blocks from the Beaufort Sea lease sales 195 and 202:

<u>BF 195:</u> 6657 6658 6659 6707 6708 6709 6712 6713 6751 6752 6757 6758 6764 6773 6774 6801 6802 6814 6815 6822 6823 6824 6851 6873 6874

<u>BF 202:</u> 6259 6308 6309 6310 6359 6406 6407 6409 6410 6457 6459 6460 6461 6508 6510 6511 6512 6558 6559 6560 6561 6562 6609 6610 6611 6612 6660 6662

Terms not otherwise defined in this permit have the meaning assigned to them in the referenced statutes and regulations. All terms and conditions of the permit are enforceable by the United States Environmental Protection Agency (EPA) and citizens under the CAA.

_____/S/_______________ ___09/19/2011__________
Richard Albright Date
Director, Office of Air, Waste and Toxics

TABLE OF CONTENTS

List of Tables

AUTHORITY

The United States Environmental Protection Agency (EPA) is issuing this outer continental shelf (OCS)/prevention of significant deterioration (PSD) permit pursuant to Section 328 of the CAA, 42 U.S.C. § 7627, and the implementing OCS regulations at 40 CFR Part 55, and pursuant to Part C to Title I of the CAA, 42 U.S.C §§ 7470 to 7492, and the implementing PSD air quality regulations at 40 CFR § 52.21. This action is based upon the application submitted by Shell Offshore Inc. (Shell or permittee) on January 18, 2010, supplemental submittals identified in the administrative record for this permit action, and upon the technical analysis performed by the EPA.

In addition the EPA is issuing this OCS/PSD permit consistent with Article 3 of the State of Alaska Air Quality Control Regulations 18 Alaska Administrative Code (AAC) 50.302 (Construction Permits), and 18 AAC 50.306 (Prevention of Significant Deterioration Permits), the applicable provisions of which have been incorporated into 40 CFR Part 55 Appendix A.

FINDINGS

On the basis of the information in the administrative record, the EPA has determined that:

1. The permittee will meet all of the applicable requirements of the 40 CFR Part 55.
2. The permittee will meet all of the applicable requirements of the 40 CFR § 52.21.
3. The permittee will meet all of the applicable requirements of 18 AAC 50.

APPROVAL CONDITIONS

Shell is authorized to construct and operate the vessels and emission units listed in Tables 1 through 6, at any of the lease blocks identified on Page 1 of this permit, and consistent with the representations in the permit application and subject to the conditions in this permit.

Coast Guard Safety Zone. The permit does not authorize operation unless:

a. The Discoverer is subject to a currently effective safety zone established by the United Sates Coast Guard (USCG) which encompasses an area within at least 500 meters from the center point of the Discoverer and which prohibits members of the public from entering this area except for attending vessels or vessels authorized by the USGC (such area shall be referred to as the "Safety Zone"); and

b. Shell has developed in writing and is implementing a public access control program to:

   - locate, identify, and intercept the general public by radio, physical contact, or other reasonable measures to inform the public that they are prohibited by Coast Guard regulations from entering the Safety Zone; and
   - communicate to the North Slope communities on a periodic basis when exploration activities are expected to begin and end at a drill site, the location of the drill site, and any restrictions on activities in the vicinity of Shell's exploration operations.

1.5. Confirmation that emissions from the source would impact no area where an applicable increment was known to be violated. The confirmation shall include a description of the legal and factual basis for this determination.

2. **Duration of Exploration Operations.** The permittee shall only conduct exploration drilling operations in the Beaufort Sea between July 1 and November 30 each year (referred to hereafter as the "drilling season").

2.1. During any drilling season, the permittee shall not operate the Discoverer as an OCS Source in excess of 120 calendar days. Each partial day the Discoverer is operated as an OCS source shall be counted as a calendar day.

2.2. During any drilling season, the permittee shall not conduct any drilling activity in excess of 1,632 hours. Drilling activity is defined as any time when the top drive is engaged and turning the conventional rotary bit and any time when conducting mud line cellar (MLC) activity as defined in Condition B.2.3.

2.3. During any drilling season, the permittee shall not conduct any MLC activity in excess of 480 hours. MLC activity is defined as any time when any MLC compressor engine (Units FD-9 – 11) or HPU engine (Units FD-12 – 13) is operating.

2.4. For each drill site at which the Discoverer operates, the permittee shall record the following:

2.4.1. The location of each drill site, using a modern global positioning system to determine the location. Location shall be recorded by providing coordinates in the following formats:

2.4.1.1. Latitude and longitude, and

2.4.1.2. Universal Transverse Mercator grid system.

2.4.2. The lease block within the Beaufort Sea lease sales 195 or 202 where the drill site is located.

2.4.3. The date and hour that the Discoverer became an OCS Source at that drill site.

2.4.4. The date and hour that the Discoverer ceased to be an OCS Source at that drill site.

2.4.5. For each period of drilling activity except for periods of MLC activity, the permittee shall record the following:

2.4.5.1. The date and hour at which the top drive is first engaged and turning the conventional rotary bit; and

2.4.5.2. The date and hour at which the top drive is disengaged and no longer turning the conventional rotary bit.

2.4.6. For each period of MLC activity the permittee shall record the following:

2.4.6.1. The earlier of the following two points in time; the date and hour in which the first MLC compressor engine (Units FD-9 – 11) begins operation and the date and hour in which the first HPU engine (Units FD-12 - 13) begins operation; and

2.4.6.2. The later of the following two points in time; the date and hour in which the last MLC compressor engine (Units FD-9 – 11) ceases operation, and the date and hour in which the last HPU engine (Units FD-12 – 13) ceases operation.

2.5. Any time spent drilling a relief well shall be included in the time recorded in Conditions B.2.1.

2.6. By the 10th of each month, the permittee shall calculate and record the following operating parameters for the previous month and a running total for the current drill season or 12-month period, based upon recordkeeping performed pursuant to Conditions B.2.1, B.2.2, and B.2.3:

2.6.1. The number of days the Discoverer operated as an OCS source;

2.6.2. The number of hours of drilling activity; and

2.6.3. The number of hours of MLC activity.

3. **Drilling Season Notification.** Each drilling season, the permittee shall report to the EPA via facsimile the information below, within 3 days of occurrence:

3.1. The date and hour that the Discoverer became an OCS Source at the first drill site of that drilling season; and

3.2. The date and hour that the Discoverer ceased to be an OCS Source at the last drill site of that drilling season.

4. **Global Positioning System.** The permittee shall use a global positioning system on the Discoverer and Associated Fleet (except for the Kvichaks Nos. 1-3 and Rozema Skimmer) as follows:

4.1. Monitor and record the date, time and location of the Discoverer and Associated Fleet when the Discoverer becomes and ceases to be an OCS source.

4.2. Monitor and record the date, time and location when each vessel in the Associated Fleet enters or leaves the 25 mile radius area around the Discoverer.

4.3. Once each hour, monitor and record the date, time, and location of the Discoverer and Associated Fleet.

4.4. Once each hour, monitor and record the date, time, direction the bow of the Discoverer is pointed, and wind direction at the Discoverer.

5. **Best Available Control Technology (BACT) for Sulfur Dioxide (SO_2) Emissions from Discoverer Emission Units.** The permittee shall not combust any liquid fuel with sulfur content greater than 0.0015 percent by weight, as determined by Condition B.5.1, in any emission unit on the Discoverer (except for Unit FD-7).

5.1. Representative fuel samples shall be obtained using one of the methods in 40 CFR § 80.330(b). The sulfur content of the fuel shall be determined using ASTM D 5453-08b.

Exhibit 2

U.S. Environmental Protection Agency Region 10, Outer Continental Shelf Prevention of Significant Deterioration Permit to Construct, R10OCS/PSD-AK-09-01, Shell Gulf of Mexico Inc. (Sep. 19, 2011)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 900
Seattle, Washington 98101-3140

OUTER CONTINENTAL SHELF PREVENTION OF SIGNIFICANT DETERIORATION PERMIT TO CONSTRUCT

Permit Number: R10OCS/PSD-AK-09-01 Issuance Date: September 19, 2011

In accordance with the provisions of Clean Air Act (CAA) Section 328 and Code of Federal Regulations (CFR) Title 40, Part 55, and the provisions of Part C to Title I of the CAA and 40 CFR § 52.21,

Shell Gulf of Mexico Inc.
3601 C Street, Suite 1000
Anchorage, AK 99503

is authorized to construct and operate the Noble Discoverer (Discoverer) drillship and its air emission units and to conduct other air pollutant emitting activities in accordance with the permit conditions listed in this permit, and only at the following lease blocks from the Chukchi Sea lease sale 193:

NR02-02: 6819 6820 6821 6822 6868 6869 6870 6871 6872 6918 6919 6920 6921 6922 6968 6969 6970 6971 6972 7018 7019 7020 7021 7022 7023 7068 7069 7072

NR03-01: 6105 6106 6155 6156 6161 6162 6211 6212 6261 6363 6364 6413 6414 6415 6418 6419 6462 6463 6464 6465 6467 6468 6469 6512 6513 6514 6515 6516 6517 6518 6519 6562 6563 6564 6565 6567 6568 6569 6612 6613 6614 6615 6616 6617 6618 6665 6666 6667 6668 6705 6706 6712 6715 6716 6717 6753 6754 6755 6756 6761 6762 6765 6766 6767 6803 6804 6805 6810 6811 6812 6813 6814 6815 6816 6817 6853 6854 6855 6860 6861 6862 6863 6864 6865 6866 6903 6904 6905 6908 6909 6910 6911 6912 6913 6914 6915 6916 6953 6954 6955 6956 6957 6958 6959 6960 6961 6962 6963 6964 6965 7006 7007 7008 7009 7010 7011 7012 7013 7014 7056 7057 7058 7059 7060 7061 7062 7063 7106 7107 7108 7109 7110 7119

NR03-02: 6114 6115 6161 6163 6164 6165 6213 6214 6215 6220 6259 6261 6263 6264 6265 6270 6271 6321 6322 6359 6360 6371 6372 6409 6410 6422 6423 6459 6508 6558 6608 6658 6671 6672 6708 6713 6714 6715 6721 6722 6757 6761 6762 6763 6764 6765 6766 6771 6807 6811 6812 6813 6814 6815 6816 6817 6856 6862 6863 6864 6865 6866 6905 6912 6913 6914 6915 6916 6962 6963 6964 6965

NR04-01: 6352 6401 6402 6452 6453 6503 6504 6554 6604

NR03-03: 6007 6008 6009 6010 6017 6018 6020 6056 6057 6058 6059 6067 6068 6070 6108 6219 6560 6561 6609 6610 6611 6658 6659 6660 6709 6721 6722 6723 6759 6771 6772 6773 6823

Terms not otherwise defined in this permit have the meaning assigned to them in the referenced statutes and regulations. All terms and conditions of the permit are enforceable by the United States Environmental Protection Agency (EPA) and citizens under the CAA.

____________________ ____________________
Richard Albright Date
Director, Office of Air, Waste and Toxics

TABLE OF CONTENTS

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List of Tables

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FINDINGS

On the basis of the information in the administrative record, the EPA has determined that:

1. The permittee will meet all of the applicable requirements of the 40 CFR Part 55.
2. The permittee will meet all of the applicable requirements of the 40 CFR § 52.21.

APPROVAL CONDITIONS

Shell is authorized to construct and operate the vessels and emission units listed in Tables 1 through 5, at any of the lease blocks identified on Page 1 of this permit, and consistent with the representations in the permit application and subject to the conditions in this permit.

Coast Guard Safety Zone. The permit does not authorize operation unless:

a. The Discoverer is subject to a currently effective safety zone established by the United Sates Coast Guard (USCG) which encompasses an area within at least 500 meters from the center point of the Discoverer and which prohibits members of the public from entering this area except for attending vessels or vessels authorized by the USGC (such area shall be referred to as the “Safety Zone”); and

b. Shell has developed in writing and is implementing a public access control program to:

    - locate, identify, and intercept the general public by radio, physical contact, or other reasonable measures to inform the public that they are prohibited by Coast Guard regulations from entering the Safety Zone; and
    - communicate to the North Slope communities on a periodic basis when exploration activities are expected to begin and end at a drill site, the location of the drill site, and any restrictions on activities in the vicinity of Shell’s exploration operations.

16.3.4 The monitoring result which triggered the additional monitoring.

16.4 The Operating Report must include reports of any required monitoring, including all emission calculations required by the permit.

B. SOURCE WIDE REQUIREMETNS

1. **Drill Site Notification.** At least 6 months prior to the Discoverer becoming an OCS Source, the permittee shall notify the EPA via facsimile of the following information:

1.1. The location of the proposed drill site, using coordinates in the following formats:

1.1.1. Latitude and longitude, and

1.1.2. Universal Transverse Mercator grid system.

1.2. The lease block within the Chukchi Sea lease sale 193 where the drill site is located;

1.3. The proposed date that the Discoverer will become an OCS Source at that drill site;

1.4. Confirmation that emissions from the source would impact no Class I area. The confirmation shall include a description of the legal and factual basis for this determination; and

1.5. Confirmation that emissions from the source would impact no area where an applicable increment was known to be violated. The confirmation shall include a description of the legal and factual basis for this determination.

2. **Duration of Exploration Operations.** The permittee shall only conduct exploration drilling operations in the Chukchi Sea between July 1 and November 30 each year (referred to hereafter as the “drilling season”).

2.1. During any drilling season, the permittee shall not operate the Discoverer as an OCS Source in excess of 120 calendar days. Each partial day the Discoverer is operated as an OCS source shall be counted as a calendar day.

2.2. During any drilling season, the permittee shall not conduct any drilling activity in excess of 1,632 hours. Drilling activity is defined as any time when the top drive is engaged and turning the conventional rotary bit and any time when conducting mud line cellar (MLC) activity as defined in Condition B.2.3.

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2.4. For each drill site at which the Discoverer operates, the permittee shall record the following:

2.4.1. The location of each drill site, using a modern global positioning system to determine the location. Location shall be recorded by providing coordinates in the following formats:

2.4.1.1. Latitude and longitude, and

2.4.1.2. Universal Transverse Mercator grid system.

2.4.2. The lease block within the Chukchi Sea lease sale 193 where the drill site is located.

2.4.3. The date and hour that the Discoverer became an OCS Source at that drill site.

2.4.4. The date and hour that the Discoverer ceased to be an OCS Source at that drill site.

2.4.5. For each period of drilling activity except for periods of MLC activity, the permittee shall record the following:

2.4.5.1. The date and hour at which the top drive is first engaged and turning the conventional rotary bit; and

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2.4.6.2. The later of the following two points in time: the date and hour in which the last MLC compressor engine (Units FD-9 – 11) ceases operation and the date and hour in which the last HPU engine (Units FD-12 – 13) ceases operation.

2.5. Any time spent drilling a relief well shall be included in the time recorded in Condition B.2.1.

2.6. By the 10^{th} of each month, the permittee shall calculate and record the following operating parameters for the previous month and a running total for the current drill season or 12-month period, based upon recordkeeping performed pursuant to Conditions B.2.1, B.2.2, and B.2.3:

2.6.1. The number of days the Discoverer operated as an OCS source;

2.6.2. The number of hours of drilling activity; and

2.6.3. The number of hours of MLC activity.

3. **Drilling Season Notification.** Each drilling season, the permittee shall report to the EPA via facsimile the information below, within 3 days of occurrence:

3.1. The date and hour that the Discoverer became an OCS Source at the first drill site of that drilling season; and

3.2. The date and hour that the Discoverer ceased to be an OCS Source at the last drill site of that drilling season.

Exhibit 3

Holland-Bartels, Leslie, and Pierce, Brenda, eds., 2011, An evaluation of the science needs to inform decisions on Outer Continental Shelf energy development in the Chukchi and Beaufort Seas, Alaska: U.S. Geological Survey Circular 1370

An Evaluation of the Science Needs to Inform Decisions on Outer Continental Shelf Energy Development in the Chukchi and Beaufort Seas, Alaska

Edited by Leslie Holland-Bartels and Brenda Pierce

Circular 1370

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2011

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Suggested citation:

Entire publication:
Holland-Bartels, Leslie, and Pierce, Brenda, eds., 2011, An evaluation of the science needs to inform decisions on Outer Continental Shelf energy development in the Chukchi and Beaufort Seas, Alaska: U.S. Geological Survey Circular 1370, 278 p.

Example for chapter within the publication:
Kolak, J.J., 2011, Chapter 2. Geological context, *in* Holland-Bartels, Leslie, and Pierce, Brenda, eds., 2011, An evaluation of the science needs to inform decisions on Outer Continental Shelf energy development in the Chukchi and Beaufort Seas, Alaska: U.S. Geological Survey Circular 1370, p. 13-40.

Contents

Chapter 1

Framing the Assignment and Process

By Leslie Holland-Bartels and Brenda Pierce

"As a significant owner of Arctic resources, the United States has a responsibility to know what it owns, to understand basic biology, geology, and natural history of its assets, and to understand the population dynamics of the living resources it manages—alone, or in concert with the State of Alaska and other Nations" (U.S. Arctic Research Commission, 2010).

"Among the greatest uncertainties in future energy supply and a subject of considerable environmental concern is the amount of oil and gas yet to be found in the Arctic" (Gautier and others, 2009).

Background

On March 31, 2010, Secretary of the Interior Ken Salazar announced a national strategy for Outer Continental Shelf (OCS) oil and gas development. In that announcement, the Administration outlined a three-pronged approach (U.S. Department of the Interior, 2010a):

> *Development:* "…expand development and production throughout the Gulf of Mexico, including resource-rich areas of the Eastern Gulf of Mexico…"
>
> *Exploration:* "…expand oil and gas exploration in frontier areas, such as the Arctic Ocean and areas in the Atlantic Ocean, to gather the information necessary to develop resources in the right places and the right ways."
>
> *Conservation:* "…calls for the protection of special areas like Bristol Bay in Alaska…national treasure[s] that we must protect for future generations."

In a companion announcement (U.S. Department of the Interior, 2010b), within the Administration's "Exploration" component, the Secretary asked the U.S. Geological Survey (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 OCS, particularly focused on the Beaufort and Chukchi Seas (fig. 1–1). Why the focus on the Arctic OCS? First, oil resource potential is significant. On Alaska's North Slope, the Nation's largest oil field—Prudhoe Bay—has been in production for several decades. Oil has been produced from the Beaufort Sea OCS since the early 2000s and the Arctic OCS potential for production of additional oil and gas resources is very high. Accessing such resources will require development not only in the offshore waters of the Arctic OCS, but also additional infrastructure in the coastal areas of Alaska's North Slope. Beyond energy potential, this area (or region) supports unique fish and wildlife resources and ecosystems; and indigenous peoples who rely on these resources for subsistence. While the potential for and interest in energy resources is clear, there is significant public discourse over the Nation's abilities to develop such resources safely, to understand environmental and social consequences of any development, and to frame effective impact prevention and mitigation strategies. That discourse often revolves around different views on the sufficiency of the scientific information available to consider energy development decision options and to understand environmental sensitivity in this frontier area.

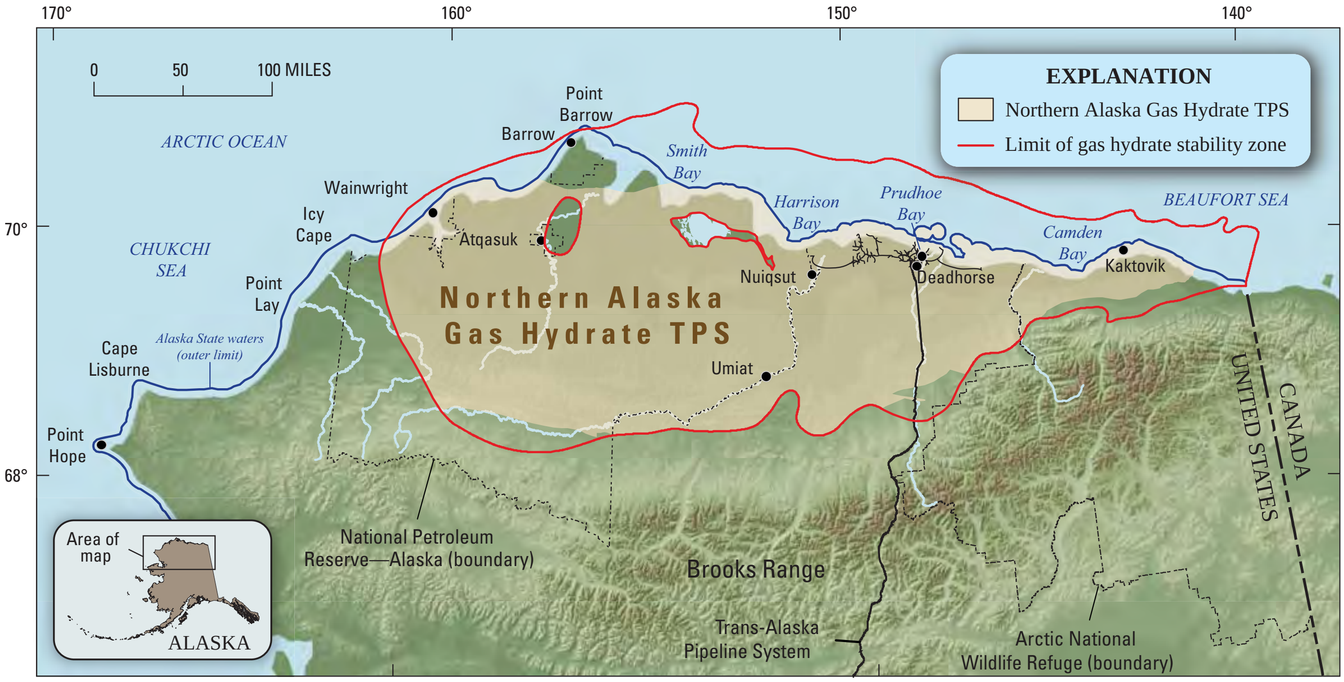


Figure 2–6. Map showing extent of the Northern Alaska Gas Hydrate Total Petroleum System (TPS) (shaded in tan), and the limit of gas hydrate stability zone in northern Alaska (red outline). Collett and others (2008) used this TPS as a basis for the first assessment of undiscovered, technically recoverable gas-hydrate resources beneath the Alaska North Slope and State-owned waters. Modified from Collett and others (2008).

and quantification of the resource. Specific National Research Council (2010) recommendations pertaining to the quantification of the resource include:

> "Pilot seismic surveys using existing geophysical methods optimized to map and quantify in-place methane hydrate accumulations;"
>
> "Improved understanding of *in-situ* properties of sediments containing methane hydrate through comprehensive testing (geophysical, geochemical, microbiological, geomechanical) of undisturbed natural drill cores and synthetic samples;" and
>
> "Consideration of the development of new geophysical imaging, processing, and quantification techniques, particularly with respect to quantifying the in-place resource."

In recognizing some of these knowledge gaps and research needs, the U.S. Arctic Research Commission (2010) recommended gas hydrate research (onshore and offshore) as one of the areas of emphasis for the Department of Energy's Arctic Energy Office. The U.S. Arctic Research Commission (2010) also noted that it may be appropriate to consider the inclusion of Arctic mapping and gas hydrates research activities within other agencies' resource assessment and earth science program plans.

Gas Hydrate Studies—Climate Change Linkages and Geohazards

In addition to the study of gas hydrates from an energy resource perspective, the potential linkages among subsea gas hydrates, climate change, and sea-level changes, particularly on the Beaufort continental slope, have long been recognized (Kayen and Lee, 1991). One of the key research questions regarding these linkages is discerning whether gas hydrate degassing plays a causative role in global warming, or is merely a response to the effects of rapid global warming (Ruppel and Pohlman, 2008). The long-term warming may lead to dissociation of the gas hydrates, during which gas is released. This release of gas can change the physical properties of the surrounding sediments and affect infrastructure through loss of borehole integrity and (or) regional subsidence (Lee and others, 2010). However, most of the scenarios that may suggest gas hydrates as a geohazard to traditional hydrocarbon infrastructure do not manifest themselves at the time the well is being drilled, but rather result as a consequence of the long-term warming of the sediment associated with hydrocarbon production (National Research Council, 2010).

The National Research Council (2010) review recommended that further studies are required to address the processes involved in (1) the transmission of methane from

Chapter 3

Ecological and Subsistence Context

By Anthony R. DeGange and Lyman Thorsteinson

Introduction

This chapter provides a general overview of the physical and biological environments of the Beaufort and Chukchi Seas. We also include information on the human communities and subsistence resources of this area. This chapter, along with Chapter 2, Geological Context, which discusses the current knowledge of oil and gas resources, sets the stage for other chapters in this report that delve into greater detail on important aspects of these marine areas and resources and their relationship to oil and gas leasing, exploration, and development. In this chapter, we present findings and recommendations that speak to the state of the broader science foundation of the Arctic. This information informs specific oil and gas development-related discussions in later chapters. Two broad syntheses have recently captured much of this information, some of which is repeated here (Hopcroft and others, 2008a; Minerals Management Service, 2008). These summaries are authoritative and should be consulted to develop a broader framework of the previous research in the Beaufort and Chukchi Seas.

The Beaufort and Chukchi Seas are marginal seas of the Arctic Ocean (fig. 1–1). They lie north and northwest, respectively, of Alaska. Both seas are linked atmospherically via the Aleutian Low, whose variable position, strength and interactions with Arctic air masses affect meteorological conditions. They are linked oceanographically with the Pacific Ocean primarily via the Bering Strait, through which northward flow transports waters and organisms from the Bering Sea Shelf. The Beaufort Sea extends from Point Barrow in Alaska east to Banks and Victoria Islands of the Canadian Arctic Archipelago and the Amundsen Gulf. The Chukchi Sea extends from Point Barrow, Alaska and the Beaufort Sea in the east to Wrangell Island and the East Siberian Sea in the west. The Bering Strait forms the southern boundary of the Chukchi Sea and connects it with the Bering Sea and Pacific Ocean.

Physical Oceanography

(from Weingartner and others, 2008, and Minerals Management Services, 2008)

The marine topographies of the Beaufort and Chukchi Seas are starkly different (fig. 3–1). The Chukchi Sea is underlain by a broad continental shelf that extends nearly 900 km from the Bering Strait north to the shelf break. In contrast, the Beaufort Sea has a narrow continental shelf. East of Point Barrow, the continental shelf narrows to about 70 km and then widens again farther east near Mackenzie Bay and as it extends eastward into the Amundsen Gulf. The topography of this region includes Wrangel Island, at the approximate western boundary between the Chukchi and East Siberian Seas, and Herald and Hanna shoals in the Chukchi Sea Shelf north of Bering Strait. Submarine canyons include the Herald Valley and Central Channel in the Chukchi Sea, and the Barrow Canyon at the boundary between the Chukchi and Beaufort Seas. In the Beaufort Sea, there is little along-shelf variability in bathymetry, except for Barrow Canyon to the west and Mackenzie Valley near the Alaska-Canada border. There are numerous barrier islands along the Beaufort Sea coast and a number of bays and lagoons on both shorelines that form important wildlife habitats.

The water of the Beaufort Sea reflects three distinct oceanic regimes (Weingartner and others, 2008). The first consists of Pacific Ocean waters that exit the Chukchi Sea Shelf through the Barrow Canyon. The second is the offshore boundary of the continental shelf and slope. The upper layer is a westward flow that is the southern edge of the wind-driven Beaufort Gyre. Below that the flow is eastward over most of the slope. The third regime is formed by discharge from the Mackenzie River that intrudes into the Beaufort Sea through wind-forcing.

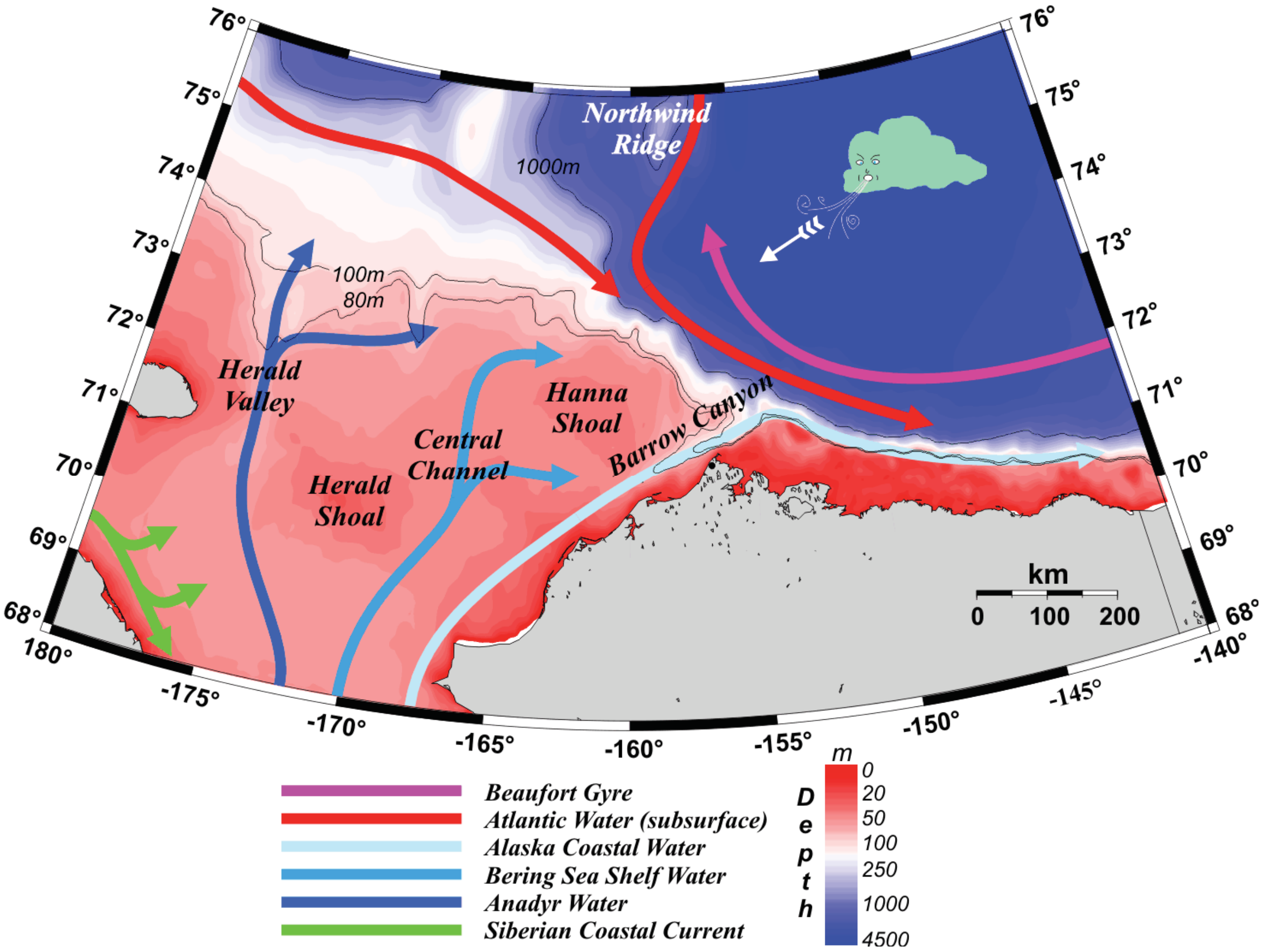


Figure 3–1. Schematic circulation map of the northern Chukchi Sea and western Beaufort Sea. From Weingartner and others (2008).

Surface circulation in the Beaufort Sea is dominated by the southern edge of the perpetual clockwise gyre of the Canadian Basin (fig. 3–1). The subsurface Beaufort Undercurrent flows in the opposite direction, to the east, over the Outer Continental Shelf. Currents in the shallower waters of the inner Beaufort Sea Shelf primarily are wind driven and, thus, can flow either east or west. Because the principal wind direction during the summer ice-free season is from the east, near-shore flow generally is from east to west.

Under persistent east winds, bottom marine water can move onshore, where it is forced to the surface. This upwelling of marine water can cause some otherwise brackish and warm areas along the coast to become colder and more saline.

The Chukchi Sea receives water flowing northward through the Bering Strait, driven by the 0.5 m drop in sea level between the Aleutian Basin of the Bering Sea and the Arctic Ocean. Coachmen and others (1975) provide a good overview of the northward movement of Bering Sea waters into the Chukchi Sea. Three distinct water masses, each of different origin move northward through the Bering Strait. Anadyr Water, cold, high salinity, nutrient-laden oceanic water that originates along the slope of the Bering Sea Shelf, flows northward through Anadyr Strait, west of St. Lawrence Island and into the central Chukchi Sea. As much as 72 percent of the water transported through the Bering Strait in the summer may come through Anadyr Strait. Alaska Coastal Water originates in the Gulf of Alaska. This low salinity, seasonally warm water hugs the Alaska coast as it transits the Bering Sea into the Chukchi Sea. It is influenced by freshwater run-off from major rivers in western Alaska. Bering Shelf Water is the resident water mass of the central shelf region south of St. Lawrence Island. It is intermediate in character between Anadyr and Alaska Coastal Water, is advected northward on both sides of St. Lawrence Island, and then flows through the Bering Strait where it mixes with the other water masses. These waters are an important source of plankton and carbon in the Chukchi and Beaufort Seas, influencing the distribution and abundance of marine biota and seasonal migrations of many species (Piatt and Springer, 2003; Hopcroft and others, 2008a; Weingartner and others, 2008). The deeper waters offshore in the northern Chukchi Sea also are a potentially important source of nutrient-rich waters.

3.01. Findings and Recommendations: Circulation processes along the Chukchi Sea shelfbreak and around Hanna Shoal in the northeast Chukchi Sea are poorly understood. The circulation here is part of a broader circulation field that connects the Chukchi and Beaufort slopes and carries waters draining from the western Chukchi Sea Shelf through Herald Valley to the eastern Beaufort Sea. There is high interest in the Hanna Shoal area for oil and gas exploration and development.

The wind field is poorly understood in the Beaufort Sea and these winds are important in shelf and slope dynamics and would influence the movement of pollutants in this area. Meteorological models and observational studies of the barrier winds and sea breeze effect should be undertaken in conjunction with a review of existing data to determine the scales of the along- and cross-shelf winds.

Circulation processes at the seaward edge of the landfast ice edge are complex insofar as these involve ice dynamics and wind and buoyancy forcing. Ice edge processes are critical in understanding how waters in inshore and offshore areas interact.

The large-scale circulation and thermohaline structure of the Beaufort Sea needs to be better understood with consideration given to the large inter-annual variability in winds and ice conditions.

Measurements and models of wave regimes and storm surges should be conducted for the Beaufort and Chukchi Seas. A preliminary review of the 60-year long Barrow wind record suggests that wind intensities and extremes have increased over the past 15 years. Summer/autumn ice retreat over the last decade also has been unprecedented. These changes will have a major influence on the wind wave and storm surge climate of the Beaufort Sea and should be factored into offshore, nearshore, and onshore development scenarios.

Sea Ice Dynamics

The presence of ice in the Arctic Outer Continental Shelf (OCS) is one of the most important physical conditions to be dealt with in developing OCS oil and gas resources. The seasonal sea ice cycle is a pervasive force in the Arctic, influencing human activities and many aspects of the region's natural history and shows great seasonal and inter-annual variability off the coast of Alaska. Generally speaking, there are two types of sea ice: fast ice that is anchored along the shore and free-floating pack ice which moves with winds and currents. These two types of ice interact to cause an extensive, somewhat predictable, system of flaw leads (swathes of open water in between ice) and polynyas off the coasts of the Chukchi and Beaufort Seas eastward to the Canadian Archipelago. These flaw leads and polynyas become more prevalent in the spring and are important features that dictate the seasonal movements and northward migrations of wildlife species, such as bowhead whales and marine birds.

Maximum sea-ice cover occurs in March or early April, lagging minimum insolation in late December by 3 months because of the heat capacity of the ocean and the cold atmosphere. At this time, essentially all of the Beaufort and Chukchi Seas are ice-covered (fig. 3–2). Winter ice cover extent in the Arctic has declined since the late 1970s (fig. 3–3) along the southern margins of sea-ice extent, but not dramatically so (fig. 3–2). Maximum retreat of the sea ice occurs in September, again lagging maximum insolation by about 3 months. The extent of sea-ice loss in September since the satellite record began has been dramatic (fig. 3–4). By September, in normal years, the ice pulls away from the Arctic coasts of Canada, Alaska, and Siberia, leaving a nearly continuous, relatively ice-free corridor around the permanent ice pack. This corridor varies in width. In recent years, the ice-free corridor has expanded to hundreds of kilometers in the East Siberian Sea and offshore of the northern Alaska coast. The contrasts between 1980, a representative year with extensive ice cover, and 1987, when sea-ice extent in the Arctic was at a record minimum, and the long-term median ice edge are dramatic (fig. 3–4).

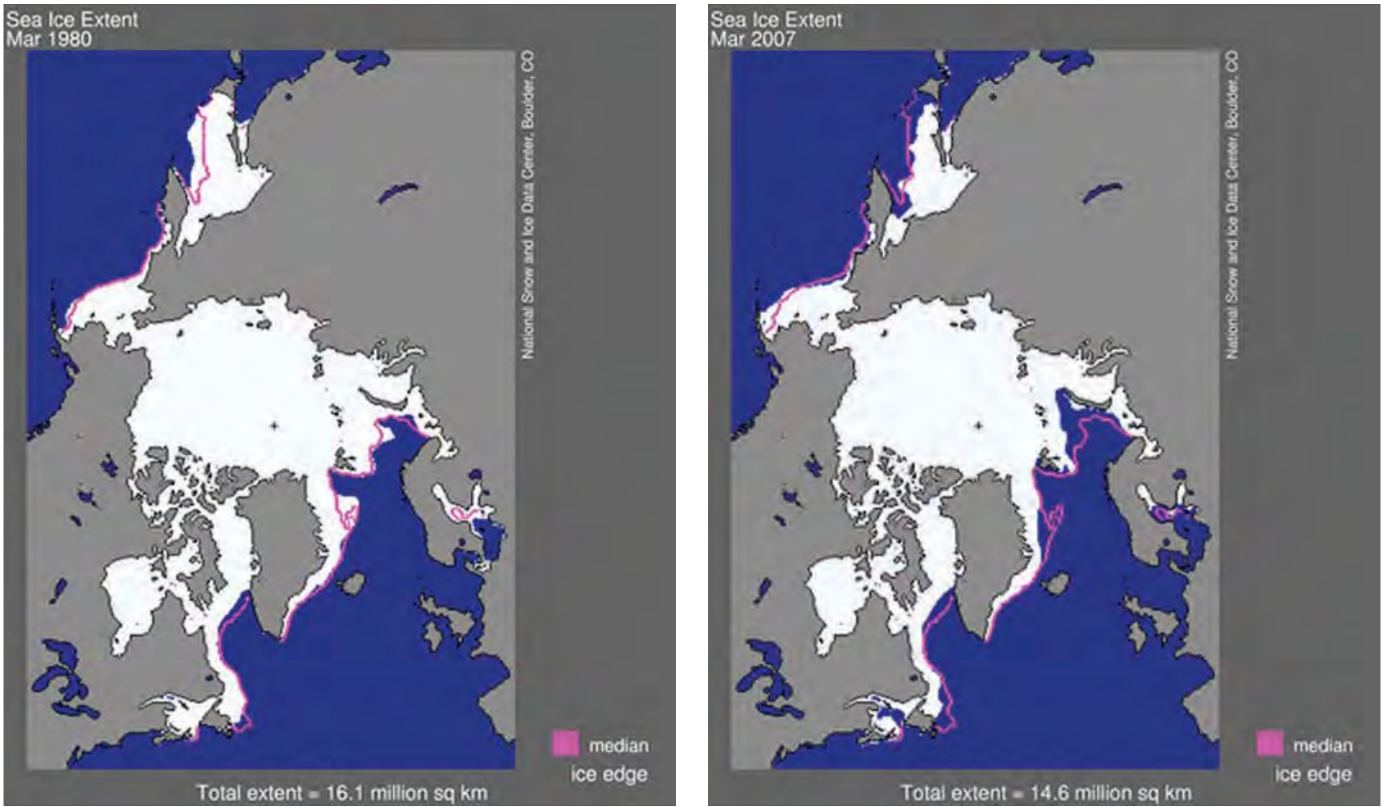


Figure 3–2. Maps showing sea-ice extent for single months and single years, using 1980 as an example of an extensive ice cover year, and 2007 as the record minimum year—maximum winter extent. The magenta line plots the long-term median ice edge based on years 1979–2000. Source: National Snow and Ice Data Center (2007a), accessed April 15, 2011, at http://nsidc.org/cgi-in/bist/bist.pl?annot=1&legend=1&scale=100&tab_cols=2&tab_rows=2&config=seaice_index&submit=Refresh&mo0=03&hemis0=N&img0=extn&mo1=09&hemis1=N&img1=extn&year0=1980&year1=2007.

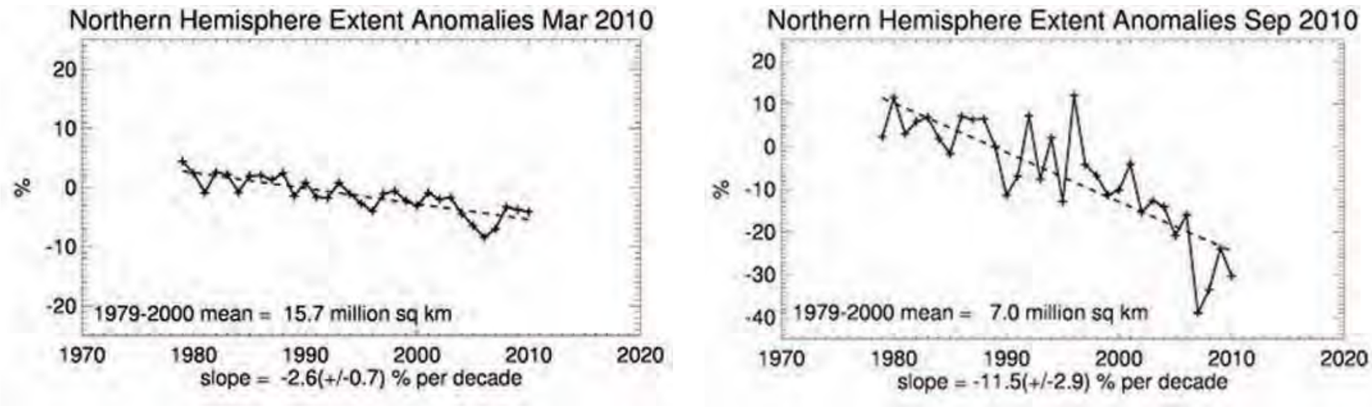


Figure 3–3. Plots of sea-ice extent anomalies for March (maximum sea-ice extent) and September (minimal sea-ice extent) expressed as percent-departure from average (that is, anomalies as compared to the 1979–2000 mean). Source: National Snow and Ice Data Center (2007b), accessed April 15, 2011, at http://nsidc.org/cgi-bin/bist/bist.pl?config=seaice_extent_trends&submit=Go%21.

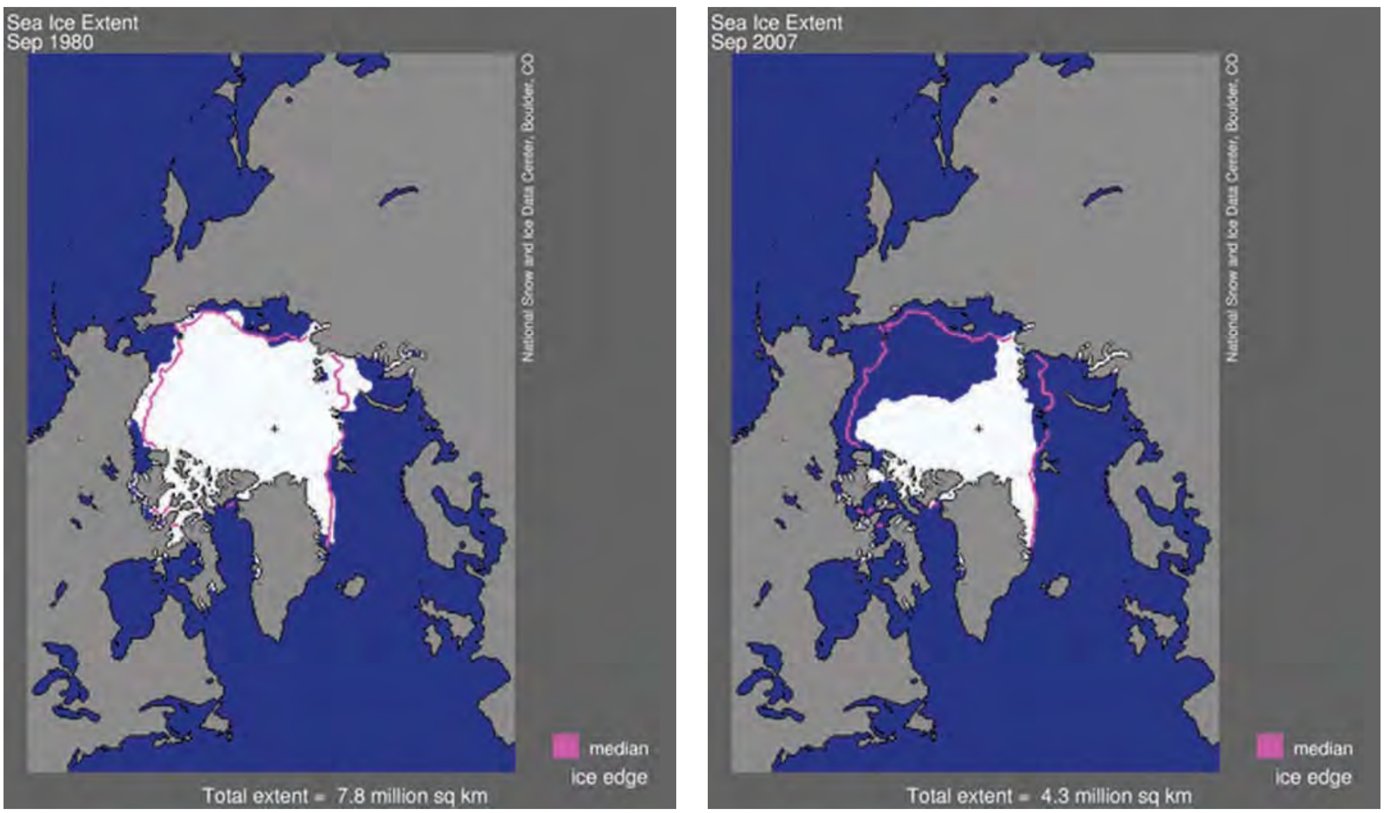


Figure 3–4. Maps showing sea-ice extent for single months and single years, using 1980 as an example of an extensive ice cover year, and 2007 as the record minimum year. The magenta line plots the long-term median ice edge based on years 1979–2000. Source: National Snow and Ice Data Center (2007a), accessed April 15, 2011, at http://nsidc.org/cgi-bin/bist/bist.pl?annot=1&legend=1&scale=100&tab_cols=2&tab_rows=2&config=seaice_index&submit=Refresh&mo0=03&hemis0=N&img0=extn&mo1=09&hemis1=N&img1=extn&year0=1980&year1=2007.

Even in years of extensive sea-ice retreat in the Beaufort and Chukchi Seas, storms and winds can cause changes in ice cover that can profoundly influence sea-ice dependent wildlife movements. For example in 2008, fragments of sea ice that were not visible to satellites persisted over the continental shelf of the eastern Chukchi Sea and were successfully exploited by walrus where they did not need to come ashore to rest. This contrasted with 2007, 2009, and 2010 when walrus did come ashore in northwest Alaska, presumably in response to a lack of sea ice over shallow continental shelf waters in the Chukchi Sea. Similarly in 2010, a large swath of broken ice persisted north of Cross Island in the central Alaska Beaufort and may have contributed to the lack of polar bears found on shore in August (L. Peacock, U.S. Geological Survey, oral commun., 2010).

In addition to dramatic decreases in sea-ice extent during late summer and autumn, the character of sea ice in the Arctic also is changing, tending to be younger and thinner (fig. 3–5). The longer sea ice remains in the Arctic Ocean the thicker it becomes as a result of additional freezing and through deformation. The thinning of Arctic Ocean sea ice has occurred largely because of the export of older, thicker sea ice out of the Arctic through Fram Strait, east of Greenland. This is important because younger, thinner ice is more vulnerable to melting as a result of warmer air and water temperatures, perpetuating a feedback cycle because of the ability of open ocean to absorb solar insolation.

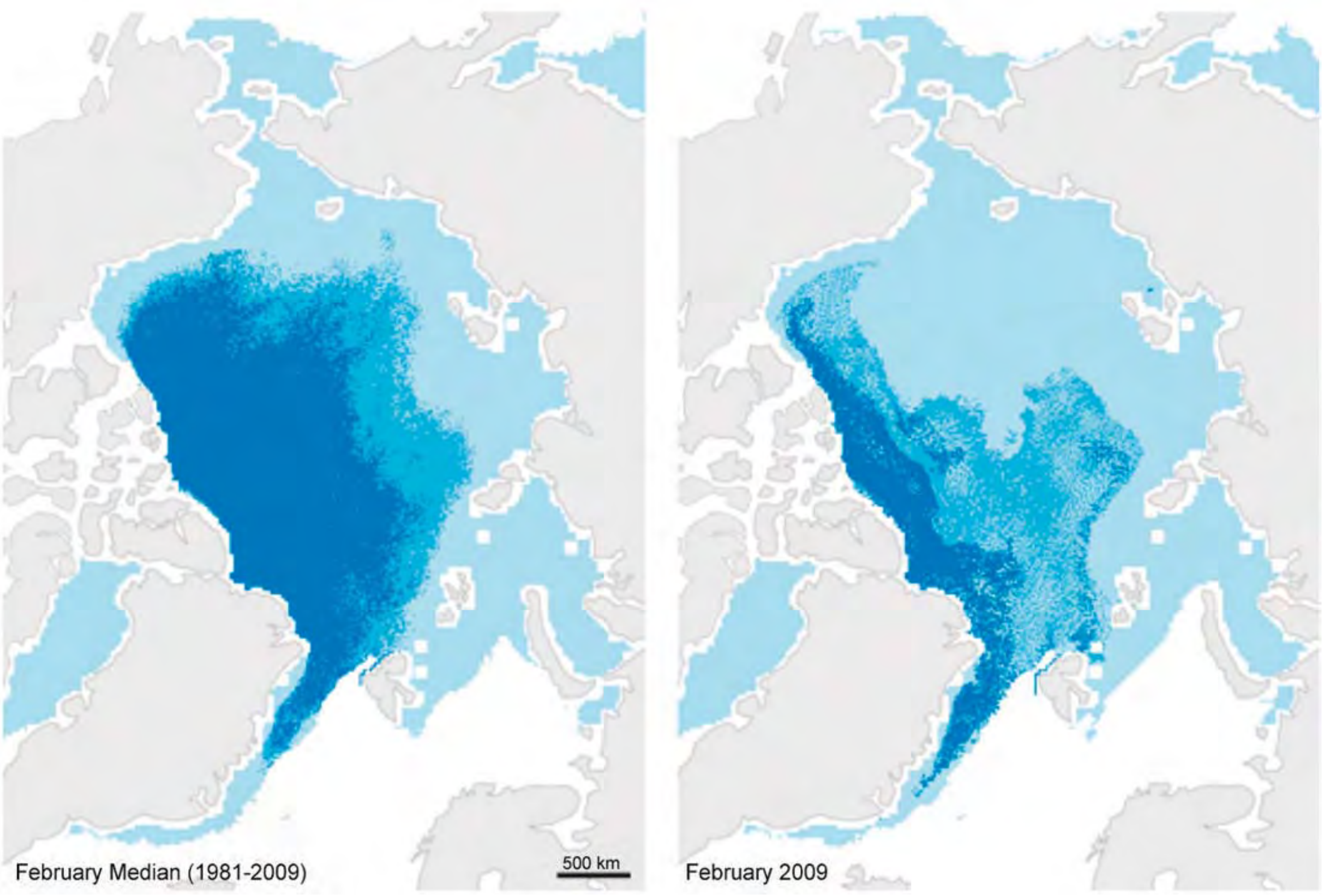


Figure 3–5. Maps showing old versus new ice in the Arctic for February. These maps show the median age of February sea ice from 1981 to 2009 (left) and February 2009 (right). As of February 2009, ice older than 2 years accounted for less than 10 percent of the ice cover. Dark blue equals ice greater than 2 years old; medium blue equals 2 year old ice; pale blue equals annual ice. Source: National Snow and Ice Data Center (2010), accessed April 15, 2011, at http://nsidc.org/sotc/sea_ice.html.

3.02. Findings and Recommendations: Ice seasons of shorter duration and longer open-water seasons will favor longer seasons for resource development and transportation.

The northern Chukchi and Beaufort Seas are undergoing rapid ice retreat that will result in a change in ocean dynamics that might alter upwelling and biological productivity. If so, this could have cascading effects on all aspects of marine and coastal ecosystems.

A reduction in the sea-ice cover and a lengthening of the ice-free season, particularly in autumn when wind speeds are strongest, will result in larger wind waves and storm surges, resulting in more rapid coastal erosion. These changes could influence patterns of abundance of fish and wildlife, subsistence use patterns, and how development occurs along the coast. Research is needed to understand how the wind wave field and storm surges will change in response to changes in sea ice concentration and extent.

Improved understanding is needed of the impact of the changing ice regime on species and on biological hot spots in the Chukchi Sea and southwestern Beaufort Sea ice, which have high levels of biological productivity.

Seafloor Substrates

Soft sediments dominate the seafloors of the continental shelves of the Beaufort and Chukchi Seas. These are largely combinations of muds, sands, and gravels (fig. 3–6). These soft-sediment bottoms support high densities and biomass of benthic invertebrates, particularly in the extensive shallow shelf areas of the Chukchi Sea where productivity is high (see Benthos). Only two areas with hard substrates have been identified in the entire region (Smith, 2010) (fig. 3–6)—one in Peard Bay, southwest of Barrow, and the other in Steffanson Sound near Prudhoe Bay that is known as the “boulder patch” (Dunton and others, 1982). The boulder patch is characterized as sediment with greater than 10 percent boulder cover. It provides attachment habitat for the endemic kelp *Laminaria solidungula* and other macroalgae, which are the primary carbon source for consumers living there.

Primary and Secondary Productivity

(from Hopcroft and others, 2008b; Stockwell and others, 2008; and Yager and others, 2008)

Within the Arctic, the combination of cold temperature, occurrence of sea ice, and extreme seasonal variations in light regimes controls phytoplankton growth and governs its spatial and temporal growth patterns. The stabilizing effect of sea ice allows production to occur near the surface under low light intensities. A large number of planktonic algae thrive in Arctic waters but there seem to be relatively few truly Arctic species. Estimates of phytoplankton biomass vary widely depending on the region, with the highest values found in the Chukchi Sea. Algal production and biomass in the Arctic primarily are controlled by light, stratification, and nutrient fields. On the shelves, advection and turbulent mixing of nutrients through the Bering Strait and local nutrient re-mineralization sustain extremely high primary production values on the Chukchi Sea Shelf (fig. 3–7). Much of that production is not grazed and falls to the seafloor to fuel benthic communities. In addition to phytoplankton, ice algae contribute to the total primary production of the Arctic Ocean with higher production values in first-year ice compared to multi-year ice. The contributions of ice algae to total primary production range from less than 1 percent in coastal regions up to 60 percent in the central Arctic Ocean.

Secondary producers include the microbes, protists, and zooplankton that consume phytoplankton and algae. Compared to phytoplankton and mesozooplankton, much less is known about the composition, distribution, and rates of activity of microbes and protists in the Arctic Ocean, and this confounds the ability to predict the impact of climate change or other disturbances on food webs and basic biogeochemical processes. Biomass of heterotrophic microbes in Arctic surface waters shows a strong response to seasonal changes in phytoplankton stocks. In the Chukchi Sea, concentrations of bacteria start out low in the spring, increase over the course of the bloom, and are highest in late summer. Heterotrophic protists include nanoflagellates, ciliates, and dinoflagella.

Recent work in the Gulf of Alaska, the Bering Sea, and shelf and slope regions of the western Arctic Ocean has confirmed the role of these organisms, known as microzooplankton, as consumers of phytoplankton in sub-Arctic and Arctic food webs. Although it is likely that phytoplankton and sea ice algae still represent a crucial food source for the larger zooplankton, utilization of microzooplankton as food is recognized as being of similar import, particularly during periods when phytoplankton standing stock is low or of poor quality. Because strong local pulses of primary production are a frequent characteristic of high-latitude oceans, including the Chukchi and Beaufort Seas, the response of microbes (including both bacteria and protists) to these pulses determines the rate of re-mineralization and the fraction of total production exported to the benthos. Weak microbial activity in the Arctic contributes to the high degree of bentho-pelagic coupling in many shelf regions of the Arctic and the consequent strength of demersal ecosystems.

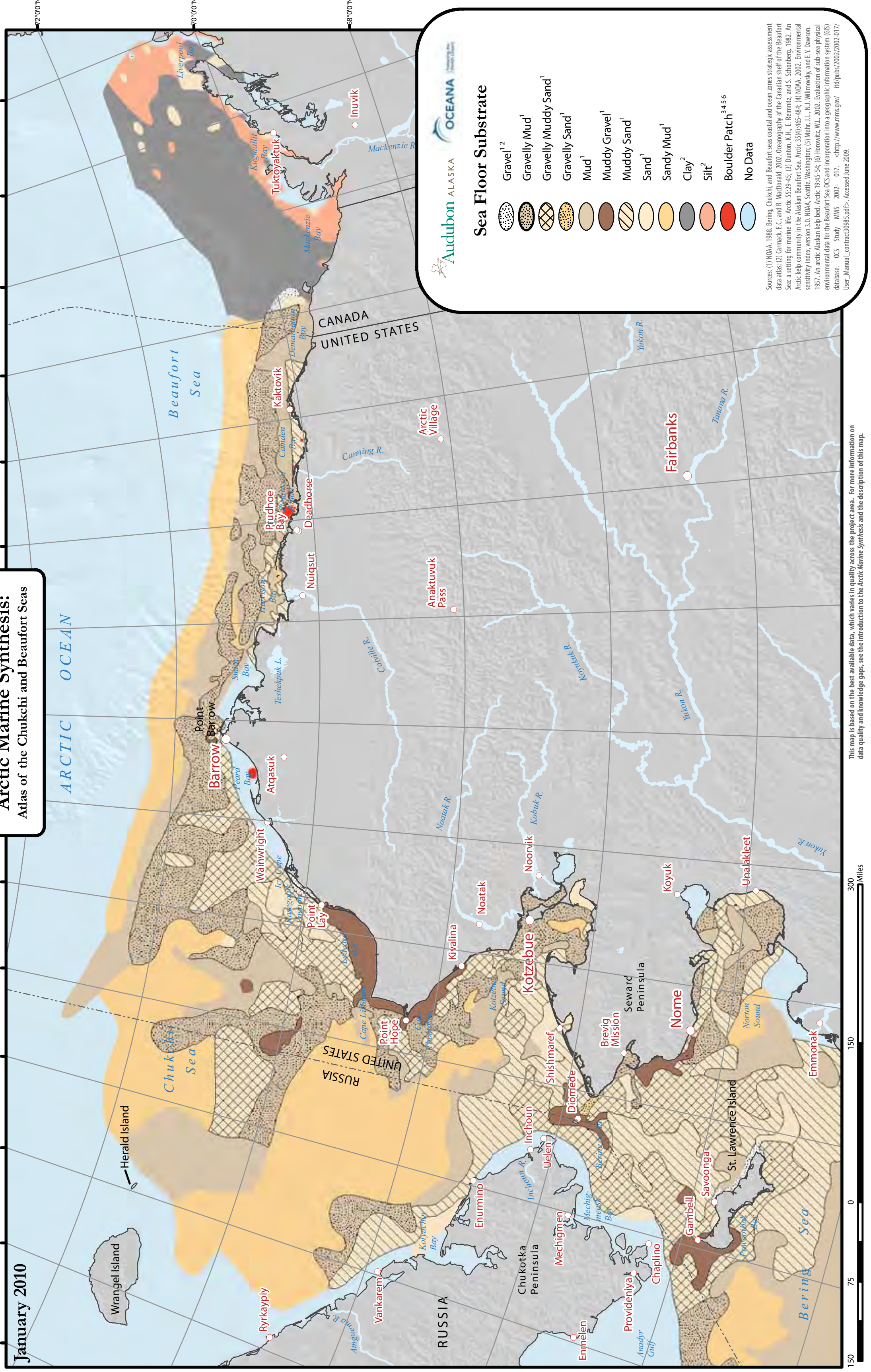


Figure 3–6. Seafloor substrates of the Alaska Beaufort and Chukchi Seas. From Smith (2010).

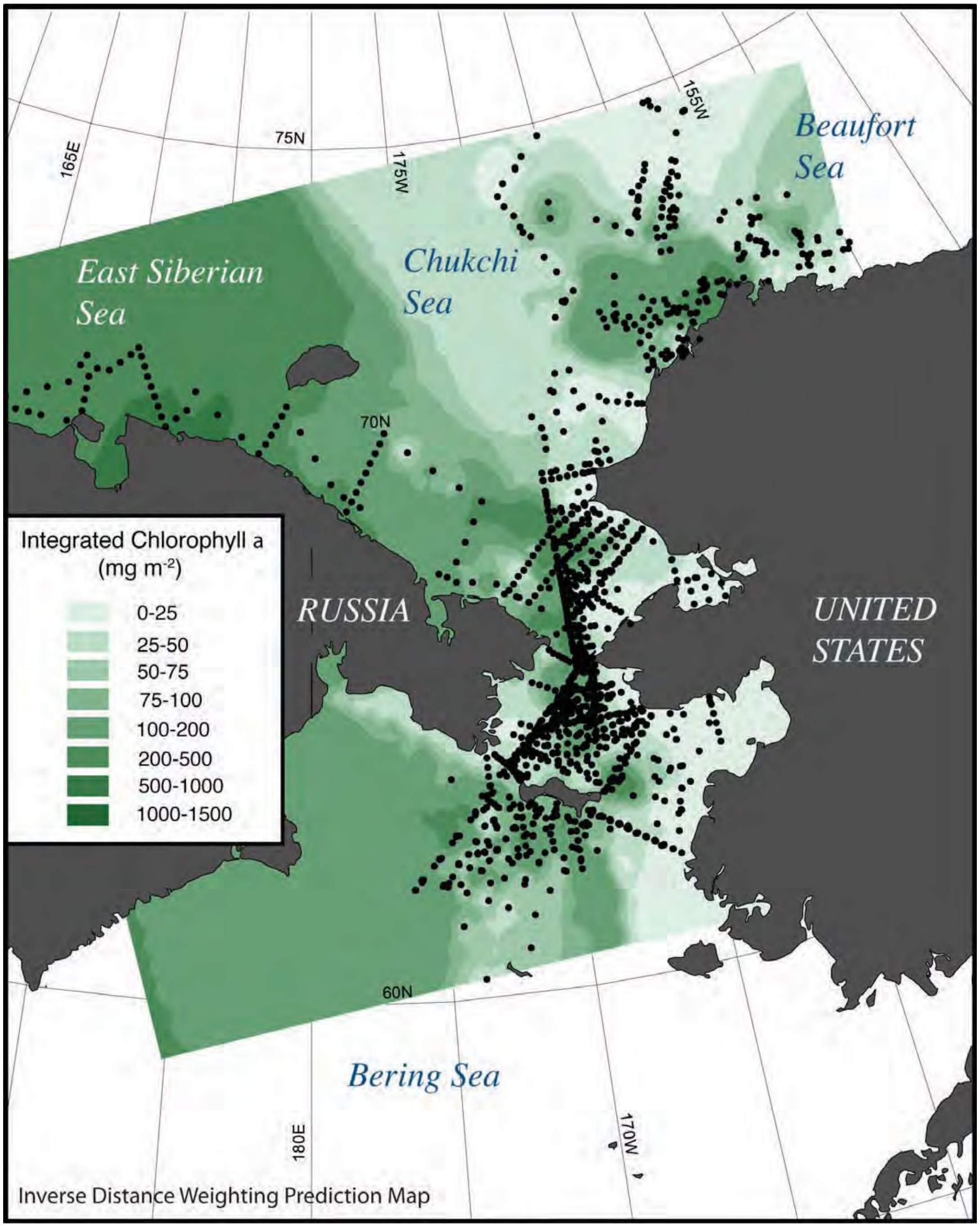


Figure 3–7. Contours of integrated chlorophyll *a* concentrations (mg m^{-2}, milligrams per square meter) based on discrete measurements (black points denote sampling locations), April–September 1976–2004 (Grebmeier and others, 2006).

Zooplankton are the major grazers of the primary production in the Arctic and determine the resources available to many higher trophic levels, such as fish, seabirds, and marine mammals. In the Chukchi Sea, large quantities of Pacific zooplankton enter the region through the Bering Strait, in a complicated mixture of water masses. The influx of the rich Pacific water determines the reproductive success of both the imported and resident zooplankton communities. Both inter-annual and long-term variation in climate will affect the relative transport of these various water masses and hence the composition, distribution, standing stock, and production of zooplankton and their predators in the Chukchi Sea. Zooplankton abundance and community structure also affect the amount and quality of carbon exported to the benthic communities in this region. In contrast, the Beaufort Sea primarily is Arctic in character, with cross-shelf exchange mechanisms more important in determining the relative contribution of "oceanic," "shelf," and estuarine species. In the Eastern Beaufort, the outflow of the McKenzie River has significant impact on both the composition of the zooplankton and its productivity. Thus, the Beaufort Sea is responding to a fundamentally different set of factors than the Chukchi Sea, even if they are both driven by similar climate-related variations and trends.

Although copepods typically predominate throughout the Arctic, there is a broad assemblage of other planktonic groups. Euphausiids are less abundant and diverse in Arctic waters than elsewhere, but can be important prey for higher trophic levels such as bowhead whales, birds, and fishes. Larvaceans (Appendicularians) have been shown to be abundant in Arctic polynyas, and are transported in high numbers through the Bering Strait into the Chukchi Sea. Similarly, important and common predatory groups, such as the chaetognaths, amphipods, ctenophores, and cnidarians have been reported on in detail by only a few surveys. Hyperiid amphipods also can be common in Arctic waters, and like chaetognaths, have a potential to graze a large proportion of the *Calanus* population. Relatively little is known of the abundance, composition, or ecology of the delicate gelatinous zooplankton, such as jellyfish. There are indications that climate change has resulted in increased numbers of jellyfish in the Bering Sea in recent years. Scientists have recorded jellyfish piled up several feet deep along shorelines near Barrow, Alaska. The ecological impact of these predators is substantial and underestimated in polar waters.

The ongoing reduction of the sea-ice cover will have major impacts on the ecosystems and biogeochemical fluxes on the extensive continental shelves of the Arctic Ocean. Many processes involved in the regulation of the vertical and trophic fluxes of particulate organic carbon, and the production of dissolved organic carbon, are controlled by the zooplankton. Knowledge of zooplankton community ecology, especially the temporal and spatial distribution patterns of the different classes of zooplankton, is needed to understand the role of sea-ice variability in dictating fluxes of biogenic carbon on and off the shelves.

3.03. Findings and Recommendations: Now that some recent baselines have been established for phytoplankton, microbes, and zooplankton, it is critical that long-term repeated measurements are established from the Bering Strait northward throughout the Chukchi Sea, and extending into the Beaufort Sea. Continued annual sampling at a series of fixed stations/transects during a consistent seasonal time-window is required to establish long-term and inter-annual trends.

Benthos

(from Bluhm and others, 2008)

Benthic food supply originates in surface waters and is highly seasonal in the Arctic. Densities of sedimenting particles and their nutritional values range vastly from the nutrient rich waters of the northern Bering and Chukchi Seas to the oligotrophic deep waters of the Arctic Basins. In general, however, comparisons of energy fluxes show that the benthic systems receive more energy in the Arctic than temperate and tropical systems.

Much of the broad, shallow shelf of the Chukchi Sea is strongly influenced by northward flowing nutrient-rich Pacific water through the Bering Strait, resulting in very high benthic biomass, which is among the highest worldwide in soft-sediment macrofaunal communities (fig. 3–8). Specifically, the south-central Chukchi Sea has the highest algal and faunal biomass on the combined Bering Sea and Chukchi Sea Shelf. This is the result of high settlement rates of organic production that is not grazed by microbes and zooplankton. These rich benthic communities, tied to high pelagic production and advection, serve as prey for a variety of diving sea birds and marine mammals, a key feature of the productive Chukchi Sea. Close to 1,200 species are known from the Chukchi Sea fauna to date with amphipods, clams, and polychaetes dominating infaunal community. Important macrofauna prey species for higher trophics include bivalves taken by walrus, in particular *Macoma* spp. and *Mya truncata* and benthic amphipods utilized by gray whales and bearded seals. Within the epifauna, ophiuroids dominate abundance and biomass in much of the surveyed Chukchi Sea, and other patchily distributed echinoderms (especially asteroids), gastropods, ascidians, sponges, cnidarians, and bryozoans also are locally abundant.

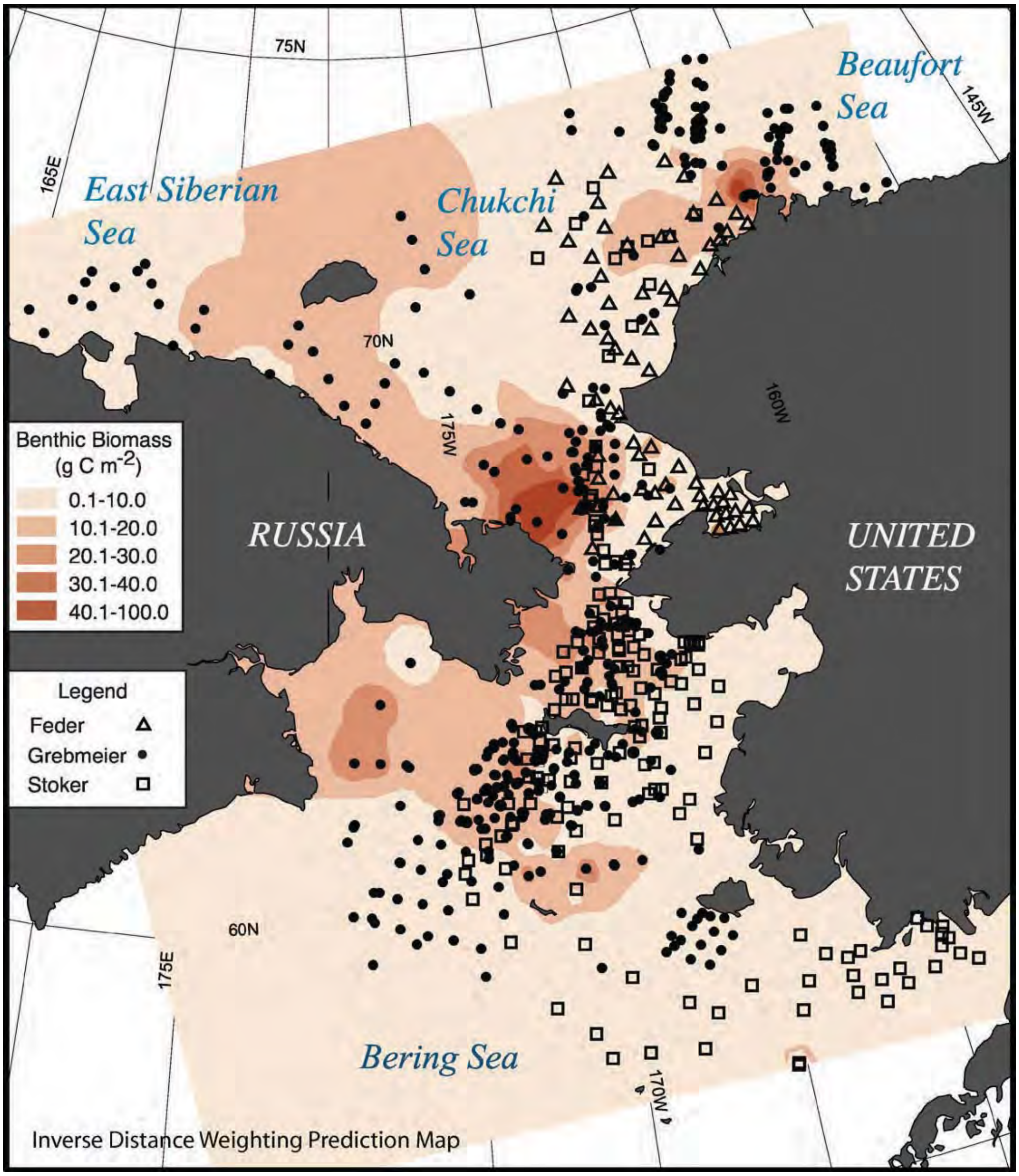


Figure 3–8. Benthic biomass distribution in the Chukchi and northern Bering Seas. (From Grebmeier and others, 2006.) (g C m^{-2}, grams of carbon per square meter.)

The comparatively narrow Beaufort Sea Shelf is influenced by large freshwater inflow from numerous small rivers and streams, the larger Colville and Mackenzie Rivers, and permafrost resulting in estuarine conditions in the nearshore. Because of this freshwater flow, non-marine sources of carbon may play an increasingly important role for the benthic food web in parts of the nearshore Beaufort Sea. The Beaufort Sea seafloor is dominated by soft sediments, but high ice cover and associated scouring, along with glacial erratics, have left coarser sediments (gravel and boulders) in various areas of the Beaufort Sea. The Alaskan part of the Beaufort Sea coast is fringed by sandy barrier islands forming numerous shallow lagoons with average depths less than 5 m and ecological traits different from those in the open water. Compared to the Chukchi Sea, productivity and benthic biomass in the Alaskan Beaufort Sea are dramatically lower. Consequently, benthic-pelagic coupling is not as pronounced as in the Chukchi Sea and food chains are longer.

Much less is known about the slopes of the Chukchi and especially the Beaufort Sea, and the adjacent basins (Bluhm and others, 2008). The existing investigations of the slopes and abyssal infaunal benthos in the western Arctic revealed low abundances and biomass values relative to the shelves, especially with increasing water depth and distance from the shelves. At taxonomic levels of phylum and orders, the soft-bottom deep Arctic macrofauna appear to be similar to the shelf communities: polychaetes, bivalves, and crustaceans are dominant, but on a family, genus, and species level, inventories differ from the shelves.

3.04. Findings and Recommendations: Regional hot spots for regular monitoring should include the southern Chukchi Sea, Barrow Canyon, and the Barter Island area. Secondly, source areas of organic and inorganic carbon should receive special attention, such as the inflow of nutrient-rich Anadyr water through the Bering Strait and river and permafrost run-off along the coastlines. The importance lies in regular sampling of the same areas to establish long-term time series.

Routine and robust monitoring of the benthos in areas of offshore development would be useful to establish trend information and to monitor the impacts of development and pollution.

Marine Mammals

The marine mammal fauna of the Chukchi and Beaufort Seas off the coast of Alaska are among the most diverse in the World and are of high scientific and public interest. Fifteen species and (or) stocks of marine mammal are common to the study area (table 3–1). Many of the species are used for subsistence purposes by Alaska Natives and many have an important symbolic role in cultural identity. Some have a high profile because they are covered by international conservation agreements (polar bear) or because they are classified as threatened or endangered under the Endangered Species Act (ESA). All marine mammals in the United States receive special protection under the Marine Mammal Protection Act (MMPA). The MMPA places a moratorium on the take, including harassment, of all marine mammals with special exemptions for subsistence use by Alaska Natives, for permitted activities such as research and public display, and for restricted permitted take incidental to commercial fishing and industrial activities. Additional protection is afforded to any species that is classified as depleted under the Act. Any species that is classified as threatened or endangered under ESA is automatically classified as depleted under MMPA. The marine mammals found in the Beaufort and Chukchi Seas study area include baleen and toothed whales, ice seals, walruses, and polar bears. For many of these species, their distribution, movements, and life history events are closely tied to the presence or absence of sea ice. Most species are harvested by coastal subsistence hunters, and they can make up a substantial proportion of the annual diet in coastal communities.

Status of Important Marine Mammal Stocks that Inhabit the Beaufort and Chukchi Seas

Information on the status of marine mammals is derived primarily from the most recent stock assessments provided by the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) for whales, pinnipeds, Pacific walrus, and polar bears (Allen and Angliss, 2010). Some life history information on these marine mammal species also is included in the stock assessments, but is widely available elsewhere.

Bowhead Whale (*Balaena mysticetus*)

The western Arctic stock of the bowhead whale is almost exclusively an Arctic species. It summers in the Canadian Beaufort Sea, migrates through the U.S. Beaufort Sea into the Chukchi Sea and winters in the northern Bering Sea. They generally are associated with shelf and slope waters of the Arctic, where they feed primarily on copepods and euphausiids. With the advent of satellite telemetry, detailed information on bowhead whale movements are now available (Quakenbush and others, 2010) (fig. 3–9). Bowhead whales are classified as endangered under the ESA and depleted under the MMPA. The most recent (2001) estimate of the population of western Arctic bowhead whales is 10,545 and the population is increasing. Bowhead whales are an important subsistence species and are hunted in the spring and autumn as they pass coastal Alaska villages in the northern Bering, Chukchi, and Beaufort Seas. Noise, oil pollution, and climate warming are important concerns. Key information needs include: continued assessments of population size; integrative research on oceanography, prey availability, foraging and behavioral ecology; characterization of wintering habitat; and development of models incorporating data on whales, sea ice, and oceanography to predict the effects of climate change and anthropogenic impacts.

Table 3–1. Most common marine mammal stocks found in the Chukchi and Beaufort Seas of Alaska.

[Information primarily from Allen and Angliss (2010). Endangered Species Act (ESA) status: D, de-listed; E, endangered; P, proposed for listing; T, threatened]

Name	Stock	Estimated population	ESA status
Spotted seal (*Phoca largha*)	Alaska	Not available	
Bearded seal (*Erignathus barbatus*)	Alaska	Not available	P
Ringed seal (*Phoca hispida*)	Alaska	Not available	P
Ribbon seal (*Histriophoca fasciata*)	Alaska	Not available	
Beluga whale (*Delphinapterus leucas*)	Beaufort Sea	39,258	
	Eastern Chukchi Sea	3,710	
Harbor porpoise (*Phocoena phocoena*)	Bering Sea	48,215	
Gray whale (*Eschrictius robustus*)	Eastern North Pacific	18,813	D
Humpback whale (*Megaptera novaeangliae*)	Western North Pacific	938	E
Fin whale (*Balaenoptera physalus*)	Northeast Pacific	5,700	E
Minke whale (*Balaenoptera acutorostrata*)	Alaska	Not available	
Bowhead whale (*Balaena mysticetus*)	Western Arctic	10,545	E
Polar bear (*Ursus maritimus*)	Southern Beaufort Sea	1,526	T
	Chukchi/Bering Seas	2,000	T
Pacific walrus (*Odobenus rosmarus*)	Alaska	129,000	P

Gray Whale (*Eschrictius robustus*)

The eastern North Pacific stock of the gray whale winters and calves in lagoons on the Pacific side of Baja California, Mexico, and summers primarily in the shallow northern Bering and Chukchi Seas. It was formerly listed under the ESA, but responded well to protection from overexploitation and was delisted in 1994. Recent population estimates range from 18,178 to 29,758. The population is believed to be at or approaching carrying capacity. It is unclear how climate change will affect this species. Because the gray whale is primarily a benthic feeder, relaxation of the tight pelagic-benthic coupling that currently fuels high rates of benthic productivity in the Chukchi Sea would likely not favor this species.

Beluga Whale (*Delphinapterus leucas*)

Two stocks of beluga whale are found in the study area: the Beaufort Sea stock and the eastern Chukchi Sea stock. Satellite tagging suggests that the range of these two stocks may widely overlap. Whales tagged in Kasegaluk Lagoon in the Chukchi Sea moved north, with males moving into deep waters of the Beaufort Sea with more than 90-percent ice cover, and adult and immature females moving to the shelf break of the Chukchi Sea. The size of the eastern Chukchi Sea stock is not known but it is not believed to be declining. The Beaufort Sea stock numbers about 39,000 animals. It is assumed that most whales from these two stocks winter in the Bering Sea where they are closely associated with pack ice.

Ribbon Seal (*Histriophoca fasciata*)

The Alaska stock of the ribbon seal inhabits the Bering, Chukchi, and western Beaufort Seas and is associated with open water, pack ice, and rarely shorefast ice. They are most abundant in the northern edge of the ice front in the central and western Bering Sea in the winter and recent data suggest that they migrate into the Chukchi Sea in the summer. A reliable population estimate is not available. The NMFS received a petition to list the ribbon seal under the ESA in 2007. In December 2008, NMFS determined that listing the ribbon seal was not warranted (National Marine Fisheries Service, 2008). The NMFS concluded that although a gradual decline in the ribbon seal population is likely with a decrease in frequency of years with suitable sea-ice habitat, ribbon seals are not likely to become an endangered species within the foreseeable future (Boveng and others, 2008).

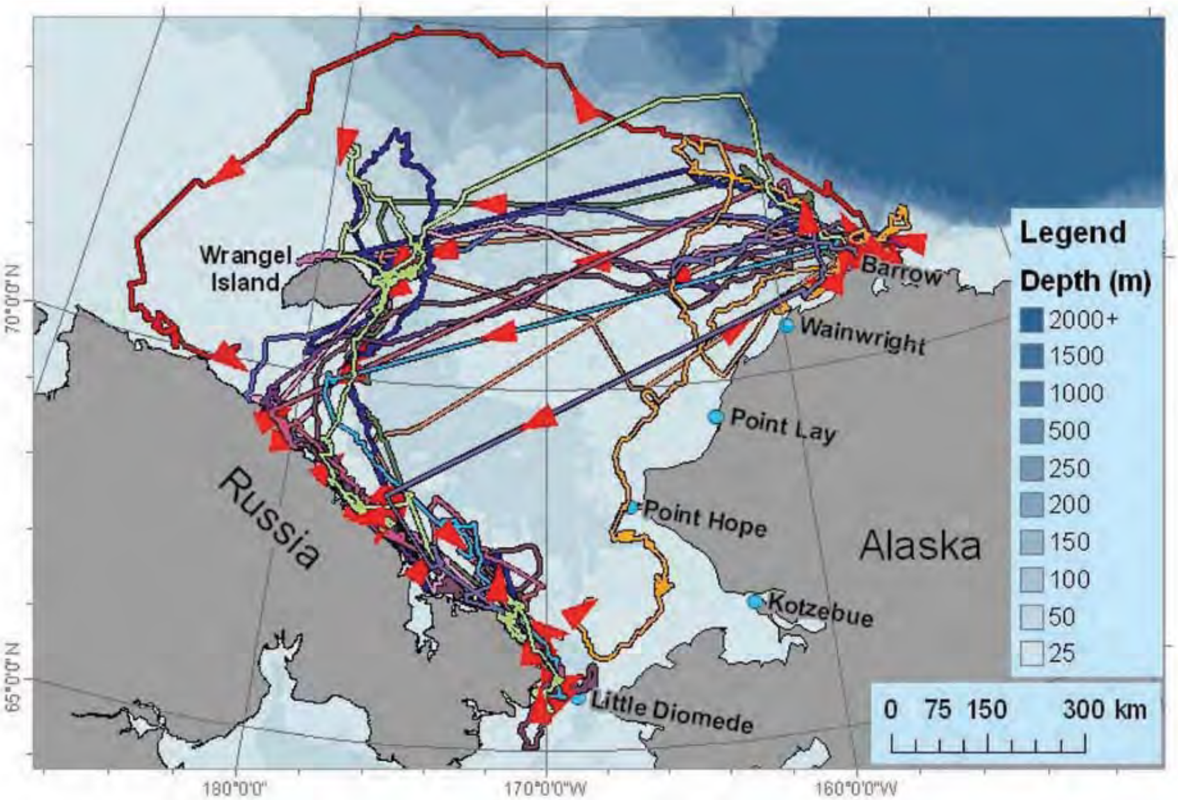
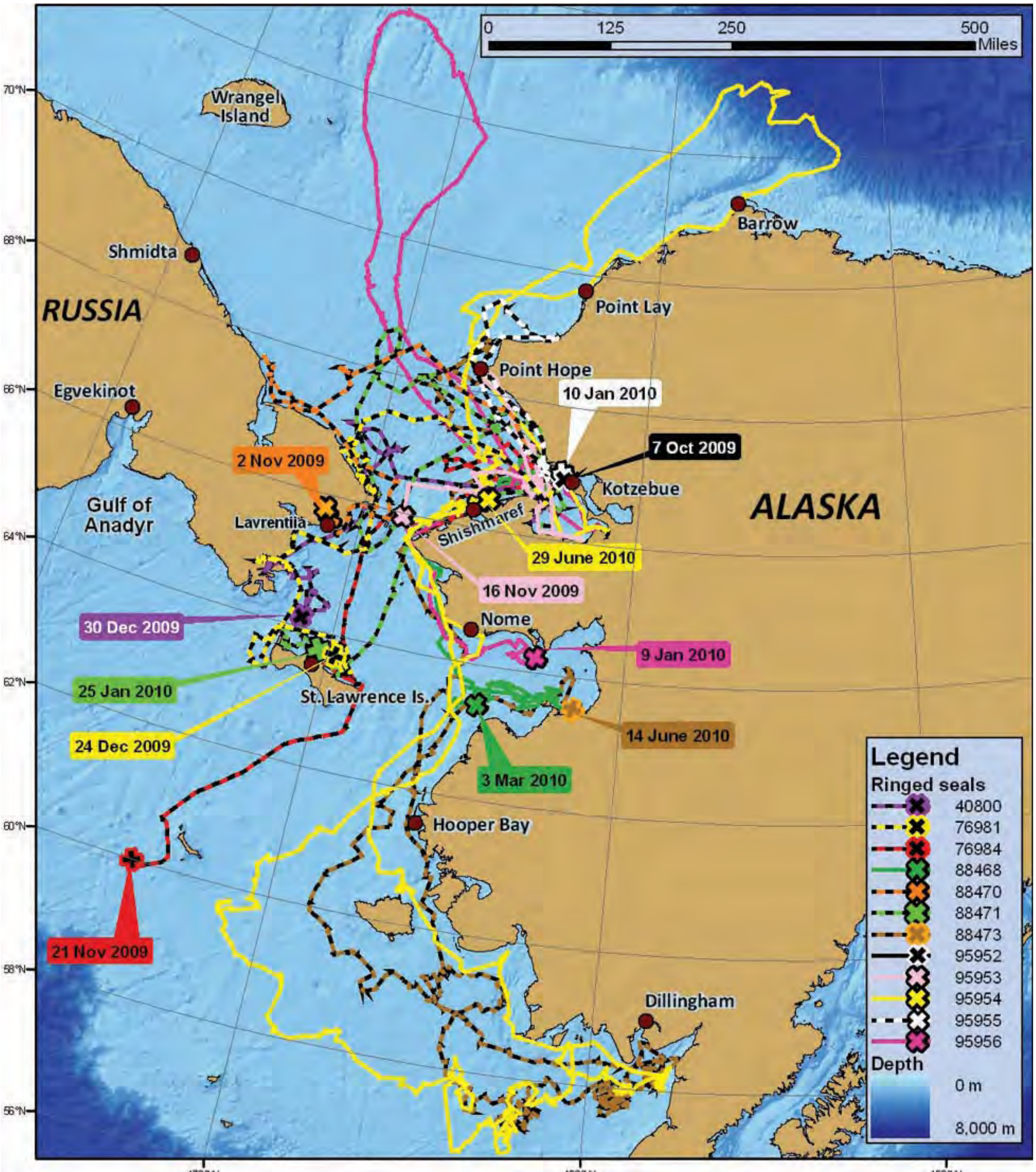


Figure 3–9. Track lines of bowhead whales in the Chukchi Sea in the autumn. Source: Alaska Department of Fish and Game (2009), accessed April 18, 2011, at http://www.adfg.alaska.gov/static/home/about/management/wildlifemanagement/marinemammals/pdfs/bow_move_chukchi_sea.pdf. Also see Quakenbush and others (2010) for detailed analysis of bowhead whale movements in the autumn and winter.

Ringed Seal (*Phoca hispida*)

Ringed seals are the most abundant of the ice seals in Alaska, are tightly associated with sea ice, and are an important subsistence species. Ringed seals are found throughout the Beaufort, Chukchi, and Bering Seas, as far south as Bristol Bay in years of extensive ice coverage. They are found in the study area year round, but some ringed seals obviously migrate south with the ice in the winter. Ringed seals are an ice seal that tend to prefer large floes (that is, greater than 48 m in diameter) and are often found in the interior ice pack where the sea-ice coverage is greater than 90 percent. Recent research suggests that ringed seal densities are higher in nearshore fast and pack ice and lower in offshore pack ice. They remain in contact with ice most of the year and pup on the ice in late winter-early spring in sub-nivean dens on the sea ice. An example of movement data now becoming available on ringed seals because of advances in satellite telemetry is shown in figure 3–10. An animation of these seasonal movements that also shows sea ice is available at Kotzebue IRA (2010; http://www.kotzebueira.org/current_projects.html).

A reliable estimate for the Alaska stock of ringed seals is not available but they probably number at least in the low hundreds of thousands. The NMFS received a petition to list ringed seals under the ESA on May 28, 2008, due to loss of sea-ice habitat caused by climate change in the Arctic. In December 2010, the NMFS published a proposed rule to list the ringed seal as a threatened species. This proposal included the Arctic, Okhotsk Sea, Baltic Sea, and Lake Ladoga subspecies of ringed seal (National Marine Fisheries Service, 2010a). Ringed seals of the Beaufort and Chukchi Seas are part of the Arctic subspecies. A fifth subspecies from Lake Saimaa in Finland was listed as endangered in 1993. Information gaps include: population size; stock structure; foraging ecology in relation to prey distributions and oceanography; relationship of changes in sea ice to distribution, movements, reproduction, and survival; models to predict the effects of climate change and anthropogenic impacts; and improved estimates of harvest.



Movements of 7 male (dashed lines) and 5 female (solid lines) ringed seals between 26 September 2009 and 29 June 2010. Cooperators include the Native Village of Kotzebue and the Alaska Department of Fish and Game with funding from the U.S. Fish and Wildlife Service, Tribal Wildlife Grant. Additional tags were funded by Shell and a grant from the National Fish and Wildlife Federation. The last known locations are labeled with an 'X'.

Figure 3–10. Movements of ringed seals marked with satellite transmitters near Kotzebue, Alaska. Source: Kotzebue IRA (2010), accessed April 18, 2011, at http://www.kotzebueira.org/current_projects2.html.

Bearded Seal (*Erignathus barbatus*)

Bearded seals, an important subsistence species, primarily are a benthic-feeding seal usually associated with shallow water over the continental shelf (less than 200 m) that is at least seasonally ice covered. During winter, they are most common in broken pack ice and also inhabit shorefast ice in some areas. In Alaska waters, bearded seals are distributed over the continental shelf of the Bering, Chukchi, and Beaufort Seas. This species also is found in the study area year round and like ringed seals, some individuals migrate south in the winter with the sea ice. There is no reliable population estimate for the Alaska stock of the bearded seal. Earlier estimates of abundance ranged from 250,000 to 300,000. The NMFS received a petition to list bearded seals under the ESA on May 28, 2008, due to loss of sea-ice habitat caused by climate change in the Arctic. The NMFS published a Federal Register notice in September 2008 indicating that there were sufficient data to warrant a status review of the species. In December 2010, the NMFS published a proposed rule to list the Beringia Sea and the Okhotsk Sea bearded seals as a threatened species (National Marine Fisheries Service, 2010b). Figure 3–11 is an example of the kinds of information on movements and distribution that are becoming available on this species and other ice seals through advances in satellite telemetry. An animation that depicts the southerly movements of bearded seals with advancing sea ice is available at Kotzebue IRA (2010; http://www.kotzebueira.org/current_projects.html). Information gaps include: population size; stock structure; foraging ecology in relation to prey distributions and oceanography; relationship of changes in sea ice to distribution, movements, reproduction, and survival; models to predict the effects of climate change and anthropogenic impacts; and improved estimates of harvest.

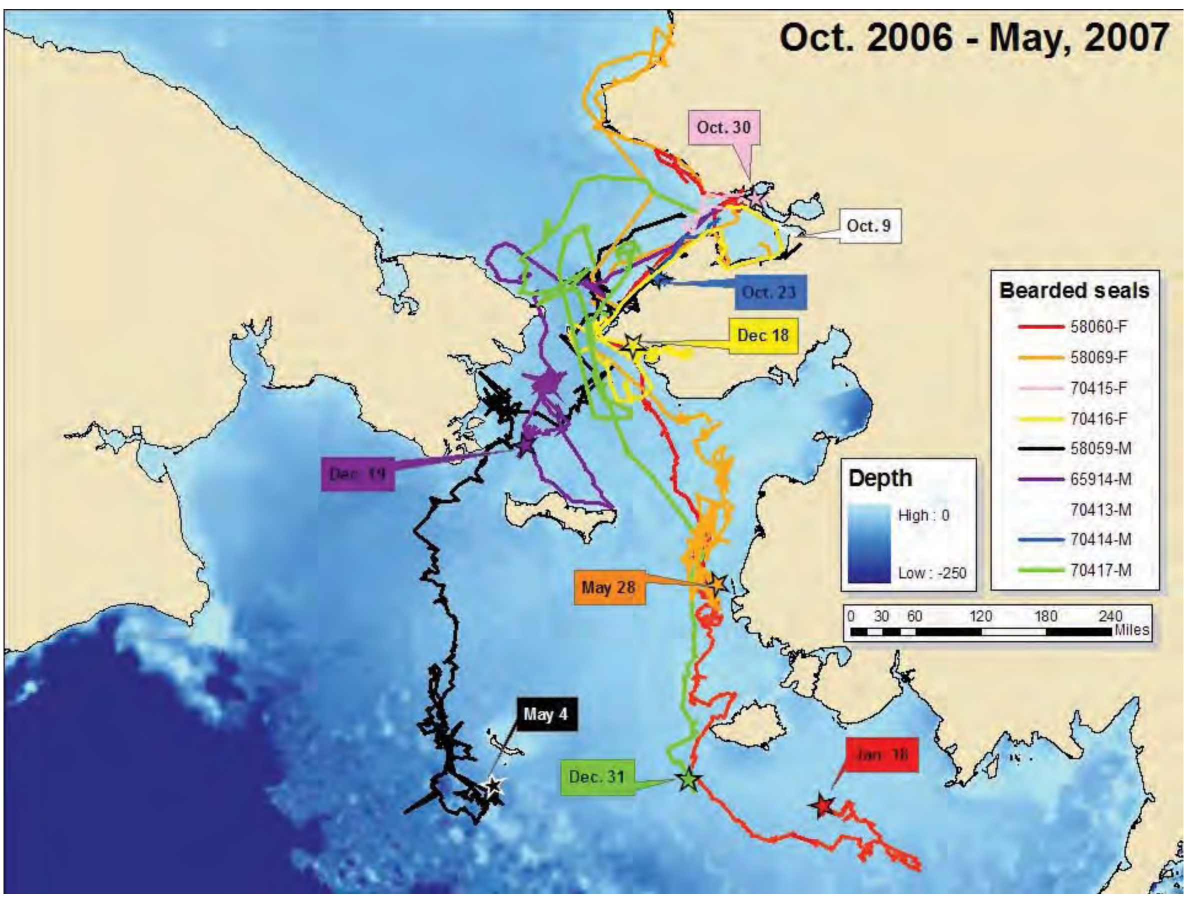


Figure 3–11. Movements of bearded seals tagged with satellite transmitters in the vicinity of Kotzebue. Source: Kotzebue IRA (2010), accessed April 18, 2011, at http://www.kotzebueira.org/current_projects.html.

Spotted Seal (*Phoca largha*)

Spotted seals are distributed along the continental shelf of the Bering, Chukchi, and Beaufort Seas. Satellite tagging studies showed that seals tagged in the northeastern Chukchi Sea moved south in October and passed through the Bering Strait in November. Seals overwintered in the Bering Sea along the ice edge and made east-west movements along the edge. A reliable estimate of spotted seal population abundance is currently not available, although the NMFS's current estimate for the eastern and central Bering Sea is about 101,500 (National Marine Fisheries Service, 2009). The NMFS received a petition on May 28, 2008, to list spotted seals under the ESA due to loss of sea-ice habitat caused by climate change in the Arctic, but concluded there are insufficient data to make reliable predictions of the effects of Arctic climate change on the Alaska spotted seal stock. In their Final Rule, the NMFS concluded that spotted seals in the Pacific exist as three Distinct Population Segments (DPS) and determined that only the southern DPS was threatened under the ESA (National Marine Fisheries Service, 2009). This DPS is located in the Sea of Japan and Yellow Sea, well outside of our geographic area of study. The NMFS published a Final Rule to that effect in October 2010 (National Marine Fisheries Service, 2010c).

Pacific Walrus (*Odobenus rosmarus*)

Pacific walrus range throughout the continental shelf waters of the Bering and Chukchi Seas, occasionally moving into the East Siberian Sea and the Beaufort Sea. They use sea ice over shallow, continental shelf waters as a moving platform for resting from which they dive to the seafloor for benthic invertebrates, such as clams. During the summer months, females and young migrate into the Chukchi Sea with the sea ice; however, thousands of animals, primarily adult males, aggregate near coastal haulouts in the Gulf of Anadyr, Bering Strait region, and in Bristol Bay. While in the Chukchi Sea, walruses are distributed broadly over the continental shelf, especially in the southern Chukchi Sea and along the coastlines of Chukotka and Northwest Alaska as indicated by satellite tags (fig. 3–12). Recent research has improved our understanding of how walruses use sea ice (Udevitz and others, 2009; Jay and others, 2010) and is beginning to shed light on how walruses will respond to diminishing sea ice in the Chukchi Sea (Jay and Fischbach, 2008; Fischbach and others, 2009; Jay and others, 2011). Modeling suggests a trend of worsening conditions for Pacific walrus through the end of this century (Jay and others, 2011). The estimate of the population from a 2006 survey of about 129,000 walruses is biased low because some areas known to be important to walrus were not surveyed due to poor weather conditions (Speckman and others, 2010). In February 2008, the USFWS received a petition to list the Pacific walrus under the ESA. On February 8, 2011, the USFWS announced that listing the Pacific walrus under the ESA was warranted, but precluded due to other higher priority listing actions. Like other ice-associated pinnipeds, walrus are difficult to study. Information gaps include: population size; stock structure; foraging ecology in relation to prey distributions and oceanography; relationship of changes in sea ice to distribution, movements, reproduction, and survival; models to predict the effects of climate change and anthropogenic impacts; and improved estimates of harvest. Impacts to walrus of changes in Arctic and subarctic ice dynamics are not well understood. Harvest and oil and gas development also are potential conservation concerns.

Polar Bear (*Ursus maritimus*)

Polar bears are perhaps the best known of the Arctic marine mammals in Alaska. Two stocks of polar bears are currently recognized in Alaska, the Chukchi Sea stock that is shared with Russia and the southern Beaufort Sea stock that is shared with Canada. The two stocks overlap widely in the vicinity of Point Barrow. Most polar bears remain with the sea ice throughout the year in the Beaufort and Chukchi Seas, but as sea ice retreats farther offshore in the summer and autumn increasing numbers of bears are coming to shore (Schliebe and others, 2008). In both seasonal and non-seasonal sea-ice environments, recent studies suggest that longer ice-free seasons are affecting polar bear size, recruitment and survival, and in some cases population size (Amstrup and others, 2008; Hunter and others, 2010; Regehr and others, 2010; Rode and others, 2010). The southern Beaufort Sea stock is currently estimated at 1,526 based on capture-recapture data. It has been difficult to derive an estimate for the Chukchi Sea stock, but it is estimated at about 2,000 bears based on an extrapolation of aerial den surveys. Both stocks of polar bears are classified as depleted under the MMPA and threatened under the ESA. Both stocks of polar bears are currently under study in Alaska, but comparatively less is known about polar bears in the Chukchi Sea.

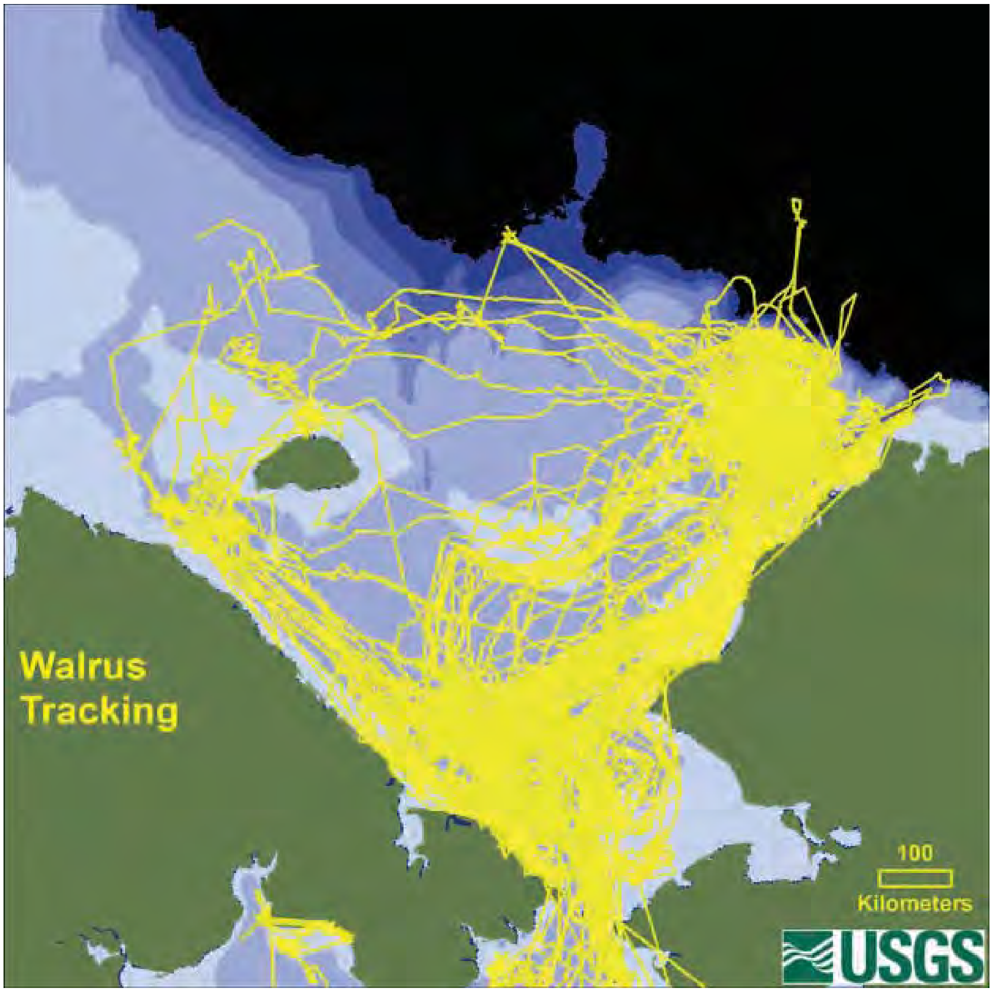


Figure 3–12. Tracks of Pacific walrus tagged with satellite transmitters depicting distribution over the continental shelf (U.S. Geological Survey, unpub. data, 2007–2010).

Overview—Arctic Marine Mammal Information Needs

Because of their high visibility, high public interest, and importance to subsistence harvesting, Arctic marine mammals have received considerable research interest. Yet, many Arctic marine mammals are challenging to study and little is known about basic life history metrics, movements, and populations. Considerable resources are devoted to research and management of Arctic marine mammals by management agencies [NMFS, USFWS, and Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE)], and research organizations [for example, USGS, National Science Foundation (NSF), North Pacific Research Board] and considerable success has been achieved in better understanding some of these species. Polar bears in the southern Beaufort Sea are perhaps the best studied of all Arctic marine mammals in Alaska because they are accessible and visible, spending most of their lives on top of the sea ice, often close to shore. Most other marine mammals spend their lives either in the water or under the ice, sometimes far from shore, and are far more difficult to study. Particularly lacking are data on abundance, distribution, movements, age-specific vital rates, sea-ice habitat relationships, and human-marine mammal interactions, although data gaps are being filled for some species. Rapidly changing sea-ice conditions in the Arctic have exacerbated the difficulty in assessing and predicting the impacts of development on many marine mammal species.

3.05. Findings and Recommendations: Population enumeration is poor, even non-existent, for many species, and relatively good for a few. Without information on stock structure, however, which is poorly known for many species but fundamental to management, data are difficult to interpret even for species where abundance estimates exist.

There is little or no information about wintering distribution and habitats for most species except polar bears and gray whales. Existing data for most species are for non-winter months when researchers can access marine mammal habitat.

New modeling of the impact of oil pollution on marine mammals using updated oil-spill trajectory models, population models, satellite telemetry data, and new information on distribution and abundance would be informative for some species.

Trophic interactions of marine mammals were first studied 30 years ago. Although trophic structure generally is understood for most species (for example, general prey types, where they feed in the food web), seasonal, annual, and geographic variability in diet are poorly quantified and foraging areas are poorly described.

Thirty years ago, as part of Outer Continental Shelf Environmental Assessment Program (OCSEAP), the need for basic biological information about key forage species was highlighted by seabird and marine mammal researchers. Little progress has been made since those recommendations were made. Among the most important forage species are: Arctic cod (*Boreogadis saida*), saffron cod (*Eleginus gracilis*), sandlance (*Ammodytes hexapterus*), capelin (*Mallotus villosus*), copepods (*Calanus* spp.), and euphausiids (*Thysanoessa* spp.).

Threshold levels quantifying the anthropogenic effects (noise, hydrocarbons, contaminants, shipping, displacement, attractants, air pollution, commercial fishing, and so on) from industrial development on marine mammals are needed for select target species. Sensible mitigation measures should be the end-product of these research efforts.

Long-term ecological monitoring and life history analyses are needed for focal marine mammals. Measurements from infrequent studies can be very misleading. Because of great changes that have occurred in the Arctic, especially to sea ice, measures from studies conducted 30 years ago may or may not reflect current population dynamics. These types of studies are expensive, so thought should be given to identify and target "indicator" species although ESA requirements force study at the species level.

Conduct long-term, longitudinal studies of habitat use/foraging areas and trophic complexes at one or more biological hotspots—that is, include marine mammals in long-term and site-specific oceanographic studies such that data on habitat are obtained concurrent with information on marine mammal habitat selection. Long-term monitoring programs on most marine mammal species are lacking because of cost and complex logistics. Exceptions to this do exist (for example, mark-recapture studies in the southern Beaufort Sea for polar bears and annual aerial surveys for bowhead whales), but costs for these programs are high and are increasing.

Studies using advances in satellite telemetry have revolutionized our ability to track wildlife. Continued telemetry studies of a suite of pinnipeds, cetaceans, and polar bears are needed to understand spatial distribution, sea-ice relationships, migration strategies, and migration corridors and can be used to evaluate site-specific impacts of development activities.

Local residents are often the first to notice changes in fish and wildlife populations. Mechanisms should be developed to better solicit and integrate their local traditional knowledge (LTK) as a basic source of information.

Marine and Coastal Birds

Many bird species that reside in marine and coastal habitats (for example, seabirds, sea ducks, and loons) are highly vulnerable to oil pollution. Most marine birds that occur in the Beaufort and Chukchi Seas are there during the open water season; exceptions include eiders and seabirds that winter in polynyas and at the ice edge. Arrival times usually coincide with the formation of leads during spring migration to coastal breeding areas. Many seabirds (such as murres) and sea ducks (such as king and common eiders and long-tailed ducks) will closely follow leads during spring migration. Migration times vary between species, but spring migration for most species takes place between late March and late May. All marine and coastal birds breed outside the OCS lease sale areas, but spend time in the Chukchi and Beaufort Seas after breeding or during their non-breeding seasons. Departure times from the Beaufort and Chukchi Seas for the autumn and winter vary between species and often by sex within the same species, but most marine and coastal birds will have moved out of the Beaufort and Chukchi Seas by late autumn before or during the formation of sea ice. Detailed information on marine use of the Chukchi and Beaufort Seas by marine birds is relatively sparse. Johnson and Herter (1989) in their "Birds of the Beaufort Sea" summarize what was known of all birds from marine and coastal areas of the Beaufort Sea; a similar treatment of the birds of the Chukchi Sea is not available. Coastal and marine habitats of the Beaufort and Chukchi Seas contain a number of areas for birds that are of State, continental, and global importance (fig. 3–13). These Important Bird Areas, or IBAs, are sites that provide essential habitat for one or more species of bird. IBAs include sites for breeding, wintering, and (or) migrating birds and may be a few acres or thousands of acres, but usually they are discrete sites that stand out from the surrounding landscape. IBAs may include public or private lands, or both, and they may be protected or unprotected. To qualify as an IBA, sites must satisfy at least one of the following criteria. The site must support:

- Species of conservation concern (for example, threatened and endangered species);

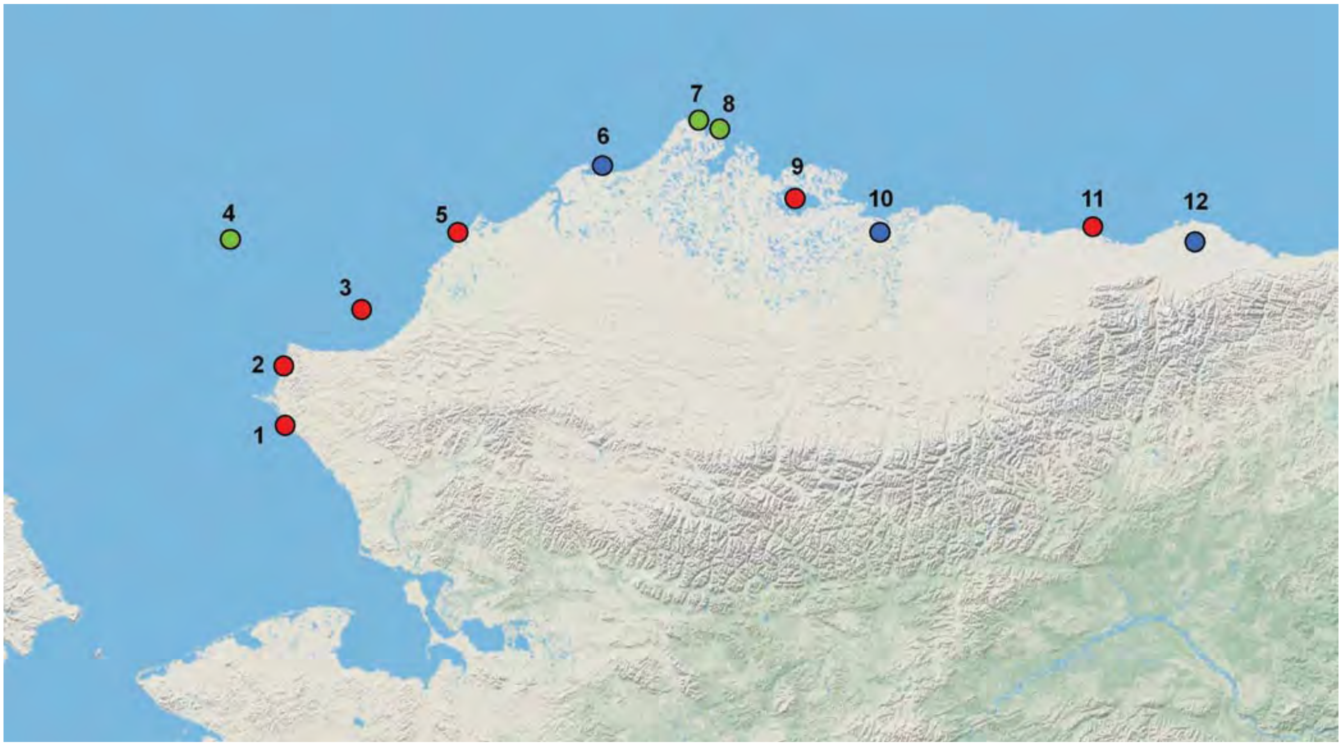


Figure 3–13. Important Bird Areas (IBAs) of the Beaufort and Chukchi Seas. Green dots = IBAs of State significance; Blue dots = IBAs of North American significance; Red dots = IBAs of global significance. Numbers are found in table 3–2. Source: Audubon Alaska (2011), accessed April 18, 2011, at http://ak.audubon.org/birds-science-education/important-bird-areas-0.

Table 3–2. National Audubon Society Important Bird Areas (IBAs) of the Beaufort and Chukchi Seas from the Point Hope area north and east to the United States-Canada border.

[Source: Audubon Alaska (2011), accessed April 18, 2011, at http://ak.audubon.org/birds-science-education/important-bird-areas-0. Map No. is shown in figure 3–13]

Map No.	IBA name	Primary reasons for designation
1	Cape Thompson	One of two major, cliff-nesting seabird colonies in the eastern Chukchi Sea
2	Cape Lisburne	The other major, cliff-nesting seabird colony in the eastern Chukchi Sea
3	Ledyard Bay	Critical Habitat for threatened spectacled eider; important marine habitat for seabirds
4	Southeast Chukchi (marine)	Important marine habitat for fulmars, shearwaters, auklets, and other seabirds
5	Kasegaluk Lagoon	Important feeding and staging area for shorebirds and Pacific black brant
6	Peard Bay	Important habitat for Pacific black brant, shorebirds, long-tailed ducks, and common and spectacled eiders
7	Cooper Island	Largest black guillemot colony and northernmost horned puffin colony in Alaska; site of long-term research project
8	Elson Lagoon	Important staging habitat for shorebirds, especially red phalaropes and a variety of waterfowl species
9	Teshekpuk Lake/Dease Inlet	Internationally recognized as a molting area for Arctic nesting geese
10	Colville River Delta	Major importance as breeding, feeding, and staging area for waterfowl, shorebirds, and raptors
11	Eastern Beaufort Sea Lagoons and Barrier Islands	Post-breeding habitat for waterfowl, especially long-tailed ducks, and red and red-necked phalaropes
12	Northeast Arctic Coastal Plain	Foraging and staging habitat for post-breeding lesser snow geese

- Restricted-ranges species (species vulnerable because they are not widely distributed);
- Species that are vulnerable because their populations are concentrated in one general habitat type or biome; or
- Species, or groups of similar species (such as waterfowl or shorebirds), that are vulnerable because they occur at high densities due to their congregatory behavior.

Colonial and Non-Colonial Seabirds

Nesting habitat for seabirds is limited in the area, so they are aggregated in a few very large colonies. Cliff-nesting seabirds reach their northern extent in the Chukchi Sea at Cape Lisburne and Cape Thompson. These colonies provide most of the cliff-nesting habitat for thick-billed murres (*Uria lomvia*) and black-legged kittiwakes (*Rissa tridactyla*) in the eastern Chukchi and are the largest colonies in the region with more than 200,000 birds present at each location. Horned puffins (*Fratercula corniculata*) breed at Cape Lisburne, as well as at Chamisso Island in Kotzebue Sound in the southern Chukchi Sea, and more recently at Cooper Island, a small barrier island in the western Beaufort Sea. A well-studied colony of black guillemots (*Cepphus grille*) is located at Cooper Island. Small colonies of glaucous gulls (*Larus hyperboreus*) and Arctic terns (*Sterna paradisaea*) are distributed in coastal areas throughout the study area (Sowls and others, 1978; Weiser and Powell, 2010). During the ice-free season, seabirds move into the Chukchi Sea from areas farther south and are distributed widely. These include murres (*Uria* spp.), black-legged kittiwakes (*Rissa tridactyla*), crested (*Aethia cristatella*), least (*Aethia pusilla*), and parakeet (*Cyclorrhynchus psittacula*) auklets, short-tailed shearwaters (*Puffinus tenuirostris*), northern fulmars (*Fulmarus glacialis*), jaegers (*Stercorarius* spp.), and others.

Kittlitz's Murrelets (*Brachyramphus brevirostris*), a small, uncommon, non-colonial seabird that nests primarily in glaciated landscapes in southeast and south-central Alaska, west through the Aleutian Islands, also nest in small numbers on the Seward and Lisburne Peninsulas in northwest Alaska. At-sea records for this species exist in Kotzebue Sound, near Point Hope and in Ledyard Bay, including the Chukchi Sea oil and gas lease area and the Beaufort Sea (R. Day, Alaska Biological Research, Inc., oral commun., 2011). Kittlitz's Murrelets are a species of conservation concern because of recent population declines in more southerly areas of their breeding range. They are considered a candidate species under the Endangered Species Act by the USFWS. Very little is known about their population status, distribution, and abundance in northwest Alaska.

Loons

Three species of loons nest in coastal areas of the Chukchi and Beaufort Seas and use coastal marine habitats for foraging: the red-throated loon (*Gavia stellata*), Pacific loon (*G. pacifica*), and yellow-billed loon (*G. adamsii*). Red-throated loons tend to nest in small tundra ponds close to the coast and feed primarily in saltwater during the breeding season, making trips back and forth to their nesting ponds. Both Pacific loons and yellow-billed loons nest on larger tundra lakes that contain fish. All loons use coastal marine habitats during parts of their annual cycle. Red-throated loons and yellow-billed loons have an interesting migration strategy. Birds from the North Slope migrate and winter in coastal habitats along the western North Pacific wintering as far south as the Korean Peninsula. In contrast, birds nesting on the Seward Peninsula winter in marine waters of western Alaska. Recent telemetry data indicate widespread use of coastal and marine habitats in the Chukchi Sea during breeding and migration (fig. 3–14).

The USFWS was petitioned to list the Alaska breeding population of yellow-billed loons, and after review determined that listing the species was warranted but precluded because of higher priority listing actions. It is a candidate species under the ESA. Relatively little is known about these species in Arctic Alaska, although all three species of loons are currently under study on the North Slope of Alaska. Ongoing concerns include disturbance from development (loons are particularly vulnerable to disturbance), oil pollution, and harvest.

Sea Ducks

Fifteen species of waterfowl make up the sea ducks, which nest in coastal areas or in freshwater habitats and winter primarily in coastal marine habitats. Five species dominate the sea duck avifauna of the Chukchi and Beaufort Seas: the long-tailed duck (*Clangula hyemalis*), and the eiders (common eider *Somateria mollissima*, king eider—*S. spectabilis*, spectacled eider—*S. fischeri*, and Steller's eider—*Polysticta stelleri*). Common eiders, king eiders, and long-tailed ducks are the most abundant of the species. Eiders and long-tailed ducks are the first of the waterfowl to appear in the spring, exploiting leads in the ice as they open in the Chukchi and Beaufort Seas between shorefast and pack ice. Common eiders nest primarily in small colonies on barrier islands and other coastal habitats. Other sea ducks are more dispersed nesters across the North Slope. Sea ducks migrate in large numbers along the coasts of the Chukchi and Beaufort Seas to and from nesting grounds in Alaska and the Canadian Arctic, and are important subsistence species. Coastal lagoons of the Beaufort Sea are particularly important habitats for long-tailed ducks after breeding and before freeze-up.

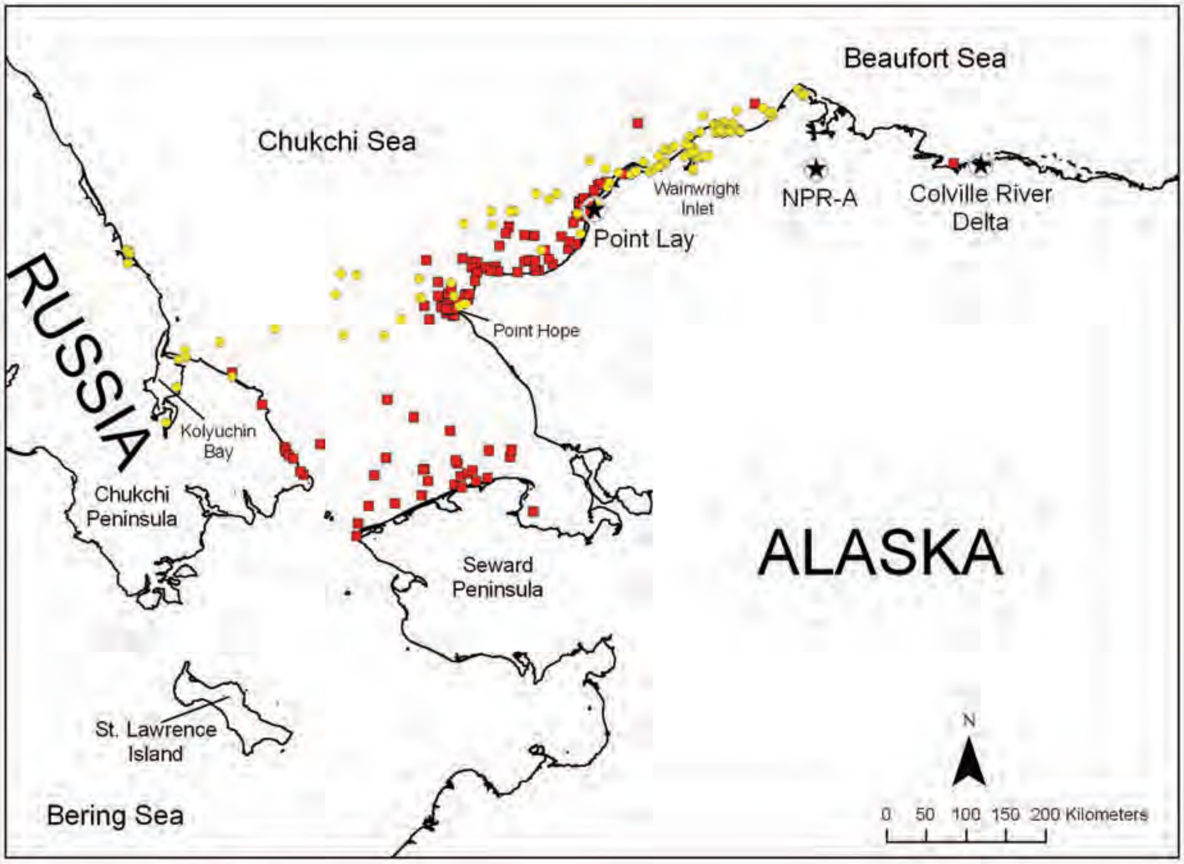


Figure 3–14. Locations of red-throated (red squares) and yellow-billed (yellow circles) loons based on satellite transmitters in 2010. Sites of original marking are indicated by stars (U.S. Geological Survey, unpub. data, 2010). (NPR-A, National Petroleum Reserve Alaska.)

Two species of eiders are of particular conservation concern for the Department of the Interior: spectacled eider and Steller's eider. Both are listed as threatened by the USFWS. Spectacled eiders breed across the North Slope of Alaska, especially west of the Prudhoe Bay area. They use coastal marine habitats during non-breeding in both the Beaufort and Chukchi Seas (fig. 3–15). Ledyard Bay in the Chukchi Sea is an important staging area and formally designated as Critical Habitat for this species. The entire World's population winters in highly dense concentrations within the sea ice of the northern Bering Sea (fig. 3–15) between St. Lawrence and St. Matthew Islands. An ongoing telemetry study will reveal new information about timing of migration, migratory pathways, and residence times in coastal areas of the Beaufort and Chukchi Seas that could be impacted by development activities.

Steller's eiders were formerly an abundant breeding bird on the Yukon Delta and the North Slope. During summer, they are now found primarily between Prudhoe Bay and Point Lay and number in the low thousands. Following breeding, they undergo a long migration to molting and wintering habitats on the Alaska Peninsula and the Aleutian Islands where they mix with the more abundant population of Steller's eiders that breeds in Russia.

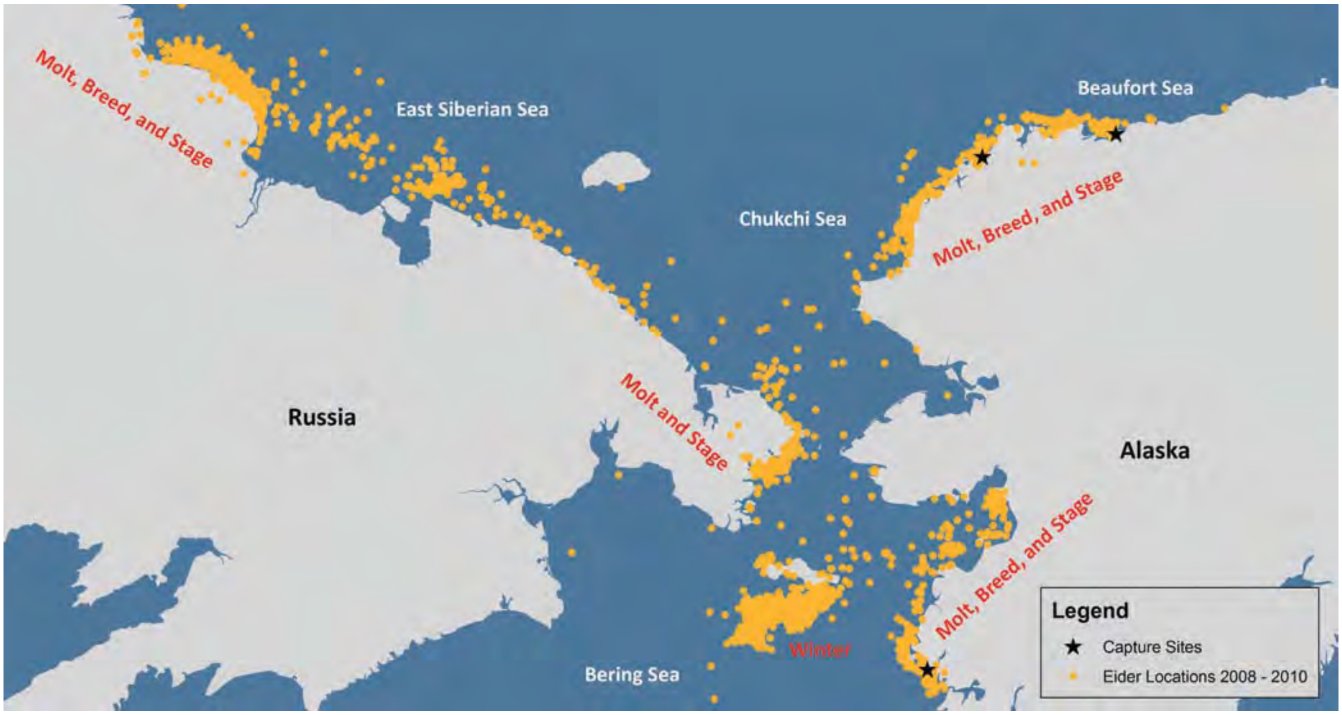


Figure 3–15. Locations (yellow dots) of spectacled eiders instrumented with satellite transmitters. Black stars are sites of original capture. Note use of the Beaufort Sea and Chukchi Sea coasts and extensive mixing of birds in United States and Russian waters (U.S. Geological Survey, unpub. data, 2010).

Geese and Swans

Geese and swans are the largest of the waterfowl that use coastal areas in the Chukchi and Beaufort Seas. The tundra swan (*Cygnus columbianus*) and four species of geese (greater white-fronted goose—*Anser albifrons*, lesser snow goose—*Chen caerulescens*, Pacific brant—*Branta bernicla nigricans*, and Canada goose—*B. canadensis*) exploit these habitats during the summer months. Tundra swans are a common breeding bird on tundra habitats of the coasts of the Beaufort and Chukchi Seas. Virtually the entire population of tundra swans that nest on the Beaufort Sea coast winter in the Atlantic Flyway. Marked swans nesting along the coast of the Chukchi Sea wintered in the Pacific Flyway.

All four species of geese breed in the study area. Greater white-fronted geese are abundant and breed within a 30 km strip along the coasts of the Chukchi and Beaufort Seas (Johnson and Herter, 1989). They winter in the Pacific and Central Flyways. Lesser snow geese nest colonially on Howe Island near Prudhoe Bay and west to the Meade River, Teshekpuk Lake, and the Colville River Delta. They also nest as far west as the Point Lay area on the coast of the Chukchi Sea (Ritchie and others, 2000). Lesser snow geese from Alaska primarily winter in California, New Mexico, and Mexico. Pacific brant nest on the Arctic Coastal Plain from the Sagavanirktok Delta west to the Barrow area and south to the Point Lay area on the coast of the Chukchi Sea (Stickney and Ritchie, 1996; Ritchie and others, 2000). They stage in the autumn at Izembek Lagoon and winter primarily on the Alaska Peninsula and south to Baja California, Mexico. Pacific brant have exhibited a significant and continuous population decline over the period 1965–2009. Suspected limiting factors include loss of wintering and staging habitats and harvest. The most critical habitats for waterfowl species in the Beaufort and Chukchi Seas area include coastal nesting colonies; pre- and post-breeding staging habitats in estuaries such as Kasegaluk Lagoon, Peard Bay, Smith Bay, and Harrison Bay; and molting sites in the large-lake and coastal areas northeast of Teshekpuk Lake. Breeding Canada geese have increased in numbers on the Arctic Coastal Plain over the last 2 decades, although the density of molting birds in the Teshekpuk Lake area has remained relatively stable over the past 30 years.

The Teshekpuk Lake area in the National Petroleum Reserve–Alaska (NPR–A) is an internationally important habitat for molting Arctic-nesting geese, especially white-fronts, brant, and Canada geese. Many failed-nesting and non-nesting brant from the Yukon-Kuskokwim Delta undergo a northward migration to molt in this area. Recent research suggests that brant are shifting molting sites within the NPR–A from freshwater lakes to coastal areas, perhaps in response to ecosystem changes related to saltwater intrusion into freshwater marshes that enhances growth of saltwater tolerant vegetation that brant favor (Flint and others, 2008; Lewis and others, 2010).

Shorebirds

Coastal areas of the Beaufort and Chukchi Seas support large numbers of breeding, staging, and migrating shorebirds. At least 29 species of shorebirds nest in this region, the most abundant being American golden plovers (*Pluvialis dominica*), semipalmated sandpipers (*Calidris pusilla*), pectoral sandpipers (*C. melanotos*), dunlin (*C. alpina*), long-billed dowitchers (*Limnodromus scolopaceus*), and red-necked (*Phalaropus lobatus*) and red (*P. fulicaria*) phalaropes (Alaska Shorebird Group, 2008). The Arctic Coastal Plain of Alaska is considered one of the premier shorebird breeding areas in the World. Distributions of shorebird species vary within the area; in general, the largest numbers and the greatest diversity occur west of the Colville River, although certain sites east of the Colville River (for example, Prudhoe Bay, Canning River Delta) also have high species richness. The Alaska Shorebird Group (2008) identified a number of areas on the coasts of the Chukchi and Beaufort Seas that are important to shorebirds. These include the Colville River Delta, the Canning River Delta, Kasegaluk Lagoon, Peard Bay, Elson Lagoon, and shorelines and barrier islands along the coastal plain of the Arctic National Wildlife Refuge.

All shorebirds are absent from the Arctic Coastal Plain and most also are absent from Alaska during the non-breeding season. Many undertake spectacular migrations to southern hemisphere wintering areas after gorging on invertebrates on western Alaska tideflats (for example, Gill and others, 2008). Because of that, Alaskan-breeding shorebirds are vulnerable to a variety of threats outside of Alaska (Alaska Shorebird Group, 2008).

All Alaska breeding species of shorebirds are considered at-risk. Alaska currently has 20 shorebird populations considered to be of high concern or imperiled and 21 populations of low to moderate concern. The Alaska Shorebird Group (2008) recognized American golden plover, upland sandpiper, whimbrel, bar-tailed godwit, red knot, sanderling, dunlin, and buff-breasted sandpiper as priority conservation species for the Arctic Coastal Plain. Many of these species, as well as pectoral, western, and semipalmated sandpipers, and red and red-necked phalaropes use coastal areas for feeding after breeding and prior to migration and could be vulnerable to development and oil spills. Phalaropes are the only shorebirds that also regularly use offshore areas.

Overview—Arctic Birds Information Needs

The most significant information need for birds using offshore marine and coastal regions of the study area is for recent data on species composition, distribution, and abundance. We know little about the present-day distribution of marine birds in the region; in fact, most of the data on distribution and abundance of birds in coastal and marine areas of the Chukchi and Beaufort Seas were gathered in the 1970s and 1980s (fig. 3–16) (U.S. Geological Survey, unpub. data, 1974–79, 1980–89, 1990–99, 2000–2008). These data show a wide variety of seabirds using this region, including loons and several marine geese and ducks in coastal areas; shearwaters, phalaropes, and auklets concentrated in early autumn in the Chukchi Sea; and Arctic specialists concentrated on the coast or offshore in the Beaufort Sea, for example, Ross's gull (*Rhodostethia rosea*), Sabine's Gull (*Xema sabini*), black guillemot, glaucous gull, jaegers, and Arctic tern. The present day distribution and abundance of these species are largely unknown, although declines are documented or suspected for several species (ivory gull [*Pagophila eburnean*], Ross's gull, some eider, and loon species), and it would require a repeat of historical surveys to assess changes. This is especially critical because of the large changes that have occurred in the Arctic, especially related to the diminished extent of sea ice in the Beaufort and Chukchi Seas in summer and autumn. Data collected in the 1970s and 1980s may no longer be relevant to management needs. This data gap is being addressed to some extent by the BOEMRE and USFWS through BOEMRE's Environmental Studies Program, and through Shell's Chukchi Offshore Monitoring In Drilling Area Program (COMIDA).

In addition to general information on distribution and abundance, integrated studies on seabird dynamics of the central Chukchi Sea in relation to oceanography, sea-ice change, and trophic dynamics are needed. The central Chukchi Sea is highly productive during summer, with extremely high levels of primary production and enormous standing crops of zooplankton. Most of this is due to the conveyor belt of rich waters brought north from the Bering/Anadyr current. In late summer/early autumn, the central Chukchi Sea also supports immigration of vast numbers of shearwaters, auklets, phalaropes, and other planktivorous seabirds. Most of what we know of the seabird movement into the Chukchi Sea is based on limited opportunistic surveys. A more detailed study of the dynamics of this area, including the lease sale area, is warranted given its strategic position north of the Bering Strait, and the pathway through which all vessels (including tankers) must travel to get to and from the Arctic Ocean.

Data needs are not restricted to marine areas. Continued monitoring of reproductive performance of seabirds at colonies at Cape Lisburne and Cooper Island are essential as colony performance provides a window into what is occurring in offshore marine areas. Coastal and inland areas also are changing and along with it the birds that depend on these habitats. Coastal erosion, saltwater intrusion, and thermokarsting are all active processes, resulting in habitat changes that will influence birds. Offshore development will result in onshore development as well, principally to support the offshore activities and to move oil and gas products, likely through pipelines to the Trans-Alaska pipeline. This infrastructure will require careful site planning and mitigation to prevent impacts to wildlife populations.

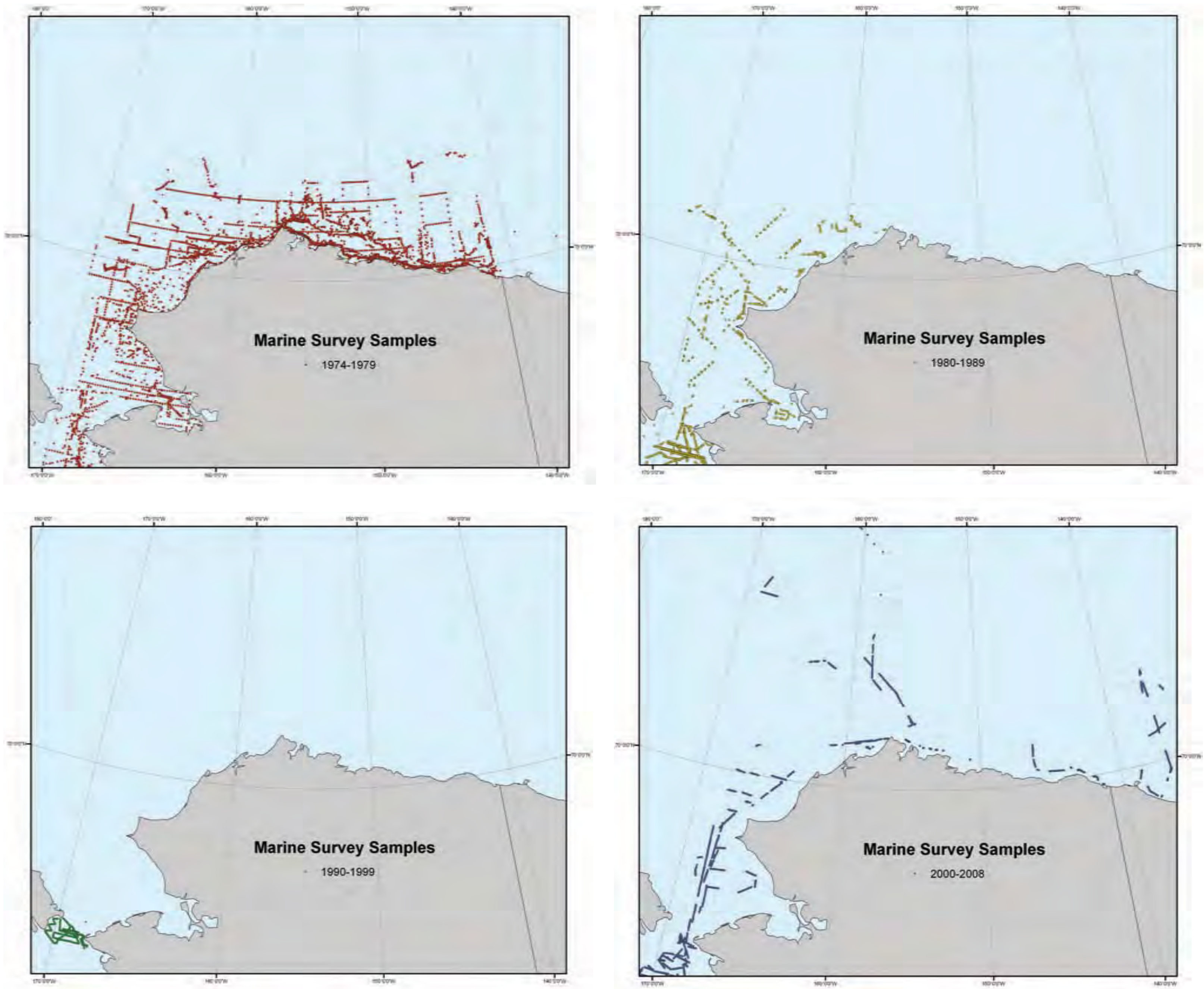


Figure 3–16. Distribution of marine bird surveys in the Beaufort and Chukchi Seas by decade showing disparity of temporal and spatial sampling among decades. Source: U.S. Geological Survey (2011), North Pacific Pelagic Seabird Database, accessed April 18, 2011, at http://alaska.usgs.gov/science/biology/nppsd/index.php

3.06. Findings and Recommendations: Recent at-sea information on marine birds for most of the study area is lacking or unpublished. Similarly, with the exception of information from Cooper Island and Cape Lisburne, much of the seabird colony information is out-of-date. Filling these data gaps would enhance our ability to measure the effects of climate change and assess the impacts of development and transportation.

The Chukchi Sea is a dynamic area for marine birds during the summer. Studies to examine seasonal dynamics of seabirds in the Chukchi Sea related to oceanography, climate, sea-ice dynamics, primary and secondary productivity and movements of birds from breeding colonies (for example, Cape Lisburne) are necessary. Studies in the Chukchi Sea Lease Sale Area have been underway by Shell to address this but are not yet published. Similar studies, but focused on sea ducks and their benthic habitats, also would be helpful to evaluate climate impacts and to assess impacts of oil and gas development.

Data from studies of birds at colonies, for example at Cooper Island and Cape Lisburne, need to be published and continued. Onshore studies of seabirds to measure abundance, productivity, and food habitats provide a unique window and understanding into offshore marine processes.

Modeling the impact of oil pollution on birds using oil-spill trajectory models, population models, satellite telemetry data, and new information on seabird distribution and abundance would be informative for some species.

A better understanding of the timing of migration and habitat use of at-risk species of waterbirds in the Chukchi and Beaufort Seas. New information based on satellite telemetry is available for common, king, and spectacled eiders, and red-throated and yellow-billed loons. Existing data need to be analyzed and published, and additional telemetry studies are necessary to assess timing and pathways of migration and use of coastal areas for foraging and molting for other species including Pacific brant, long-tailed ducks, and Pacific and Arctic (*G. arctica*) loons.

Coastal lagoons of the Chukchi and Beaufort Seas are important stopovers for migrating birds, particularly Pacific brant. Data on distribution, numbers, and periods when birds occur in coastal lagoons are needed to identify sensitive areas and times when disturbance should be minimized.

Further analyses and studies are needed to increase the understanding of seasonal and inter-annual variation in shorebird use (numbers of birds, timing of their use, change in site quality) of key post-breeding areas, especially coastal areas where oil development is likely to occur (for example, the deltas of the Meade, Ikpikpuk, Colville, Sagavanirktok, and Canning Rivers, and coastal sites on NPR–A).

Sea-level rise, increased frequency and severity of storms, and more frequent and severe episodes of coastal erosion and flooding are occurring or are predicted to occur in the study area and could have large impacts on migratory birds. Many northern shorebird and waterfowl species are dependent on these littoral habitats during some phase of their annual cycle. Understanding change in coastal geomorphology—from both physical and trophic standpoints and whether driven by climate change or other factors—is an important data gap.

If an oil spill were to occur in broken sea-ice habitats, or if lead systems were to become contaminated with oil, understanding and being able to predict what wildlife would be affected in these ice habitats and the effectiveness or consequences of hazing Arctic marine animals, including birds, will be important.

Local residents are often the first to notice changes in fish and wildlife populations. Mechanisms should be developed to better solicit and integrate local traditional knowledge as a basic source of information.

Marine and Diadromous Fish

The Alaskan Chukchi and western Beaufort Seas support at least 112 fish species (L. Thorsteinson, U.S. Geological Survey, written commun., 2010; also see Mecklenburg and others, 2002). Dominant families of fishes include lampreys, sleeper sharks, dogfish sharks, herrings, smelts, whitefishes, trouts and salmons, lanternfishes, cods, sticklebacks, greenlings, sculpins, sailfin sculpins, fathead sculpins, poachers, lumpsuckers, snailfishes, eelpouts, pricklebacks, gunnels, wolffishes, sand lances, and righteye flounders. Forty-nine species are known to be common to both the Beaufort and Chukchi Seas. Additional species are likely to be found in the Alaskan Arctic when coastal and offshore waters are more thoroughly surveyed.

Marine Arctic fishes of Alaska can be divided into two primary assemblages: marine fish and diadromous fish.

Marine Fish

Mecklenburg and others (2008) and Minerals Management Service (2008) recently described the state of knowledge of Arctic marine fishes. Marine waters support the most diverse, although least well known, fishes of the area. Studies of marine fishes in the region are very limited; most of the surveys/studies have been performed in coastal waters landward of the 200-m isobath, with few surveys having sampled deeper waters. Studies have been hampered by a lack of commercial fisheries, short ice-free seasons, and logistical difficulties. Marine fishes prefer the colder, more saline coastal water seaward of the nearshore brackish-water zone. As summer wanes, the nearshore zone of the Alaska Beaufort Sea becomes more saline due to decreased freshwater input from rivers and streams and marine intrusions associated with summer storms. During this time, marine fishes often share nearshore brackish waters with diadromous fishes, primarily to feed on the abundant epibenthic fauna or to spawn. In autumn, when diadromous fishes have moved out of the coastal area and into freshwater systems to spawn and overwinter, marine fishes remain in the nearshore area to feed. The USGS, in collaboration with BOEMRE, is currently developing an Arctic Marine Fish Ecology Catalog that will provide a complete set of species accounts and synthesize ecological knowledge about the marine ecology of fishes in the Chukchi and Beaufort Seas (Thorsteinson and others, 2011). This catalog also will include aspects of the human dimensions of fish use in the region by summarizing subsistence catch data to depict regional harvest patterns.

To better understand fish resources, the Minerals Management Service (2008) further refined the scale of primary fish assemblages into secondary, ecological assemblages based on fish behavior and ecology, and general oceanographic/landscape features, such as the continental shelf break or polar ice. These assemblages and their widespread or abundant species include: (1) the neritic-demersal assemblage (at or near the seafloor of the continental shelf) with twohorn and fourhorn sculpin, polar eelpout, and Arctic flounder; (2) the neritic-pelagic assemblage (within the water column of the continental shelf) with Pacific herring, Arctic cod, capelin, and Pacific sand lance; (3) the oceanic-demersal assemblage (living on or close to the bottom off the continental shelf—seaward of the 200-m isobath) with ogac, ribbed sculpin, spatulate sculpin, shorthorn sculpin, spinyhook sculpin, archer eelpout, pale eelpout, and daubed shanny; (4) the oceanic-pelagic assemblage (inhabiting the water column of oceanic waters seaward of the 200-m isobaths) with Pacific herring, Arctic cod, polar cod, pollock, Pacific sand lance, and the glacier lanternfish; and (5) the cryopelagic assemblage (inhabiting neritic or oceanic waters, but during their lifecycle, are associated with sea ice) with Arctic cod and Pacific sand lance.

Because of the influence of sea ice in the Arctic, and in particular the importance of Arctic cod in Arctic marine ecosystems, additional detail is provided here. The term "cryopelagic" is used to describe fishes that actively swim in neritic or oceanic waters but, during their lifecycle, are associated with drifting or fast ice. Both young and adult fishes can be associated with ice or water immediately beneath the ice. These relationships are usually trophic in nature, but in some cases, ice provides fishes with a shelter from predators. Andriyashev (1970) described what may be the first known cryopelagic fish species, the Arctic cod. Arctic cod are most common among broken ice or near the ice edge. Here, as the ice thaws and breaks up, phytoplankton and zooplankton develop and provide food for Arctic cod. It is possible that the fish also feed on organisms of the amphipod-diatom ice community inhabiting the lower ice layer. At the same time, cod apparently use sea ice as shelter from the numerous enemies attacking them from both water and air. Arctic cod play a significant role in relatively short food chains that directly, or indirectly, support subsistence lifestyles of indigenous people. The Arctic cod is a key prey of many marine mammals and seabirds as evidenced by their occurrence in the diets of belugas and ringed and bearded seals, Pacific walruses (occasionally), thick-billed and common murres, black guillemots, black-legged kittiwakes, northern fulmars, Arctic terns, and glaucous, Sabine's, ivory, and Ross's gulls. Arctic cod also are of indirect importance to polar bears and Arctic foxes, because their principal marine food, the ringed seal, also relies on them as food. Considerable research underscores the critical function of Arctic cod in Arctic marine ecosystems, because no alternate food source of equivalent trophic value exists.

Diadromous Fish

Diadromous fishes are those that move between and are able to live in fresh, brackish, and (or) marine waters due to various biological stimuli, such as feeding or reproduction, or ecological factors, such as temperature, oxygen level, or specific spawning-habitat need. Diadromous fishes include all migration types (anadromous, catadromous, and amphidromous) between marine and freshwaters, including single lifetime events, repetitive multiyear events, spawning migrations, feeding migrations, and seasonal movements between environments. Diadromous fishes inhabit many of the lakes, rivers, streams, interconnecting channels, and coastal waters of the North Slope. Common diadromous fishes include Arctic cisco, least cisco, Bering cisco, rainbow smelt (now Arctic smelt), humpback whitefish, broad whitefish, Dolly Varden char, and inconnu. The highest concentration and diversity of diadromous fishes in the area occur in river-delta areas, such as the Colville and the Sagavanirktok Rivers. Lakes that are accessible to diadromous fishes typically are inhabited by them in addition to resident freshwater fishes. The least cisco is the most abundant diadromous fish found in these lakes. With the first signs of spring breakup, adult and juvenile diadromous fishes move out of freshwater rivers and streams and into the brackish coastal waters.

Some diadromous fishes disperse widely from their streams of origin (for example, Arctic cisco and some Dolly Varden char). Others, like broad and humpback whitefish and least cisco, do not; they are seldom found anywhere but near the mainland shore. Most diadromous fishes initiate relatively long and complex annual migrations to and from coastal waters. However, some populations of Dolly Varden char, least cisco, and broad and humpback whitefish never leave freshwater. Arctic cisco in the Colville River area originate from spawning stocks of the Mackenzie River in Canada. The vast majority of the Arctic cisco inhabiting the Alaskan Beaufort Sea were carried there from Canada by westerly currents. During the Alaska phase of their life history, Arctic ciscos reside in the Colville River Delta from autumn to spring, and then forage into food-rich coastal waters during the brief Arctic summer. The Colville River, by virtue of its size, is the major overwintering site for Arctic cisco in Arctic Alaska, although other deltas, such as the Sagavanirktok, may harbor smaller populations. During the 3- to 4-month open-water season that follows spring breakup, diadromous fishes accumulate energy reserves for overwintering, and, if sexually mature, they spawn. Although their prey is concentrated in the nearshore zone, their preference for this area also is believed to be correlated with its warmer temperature.

Overview—Arctic Fish Information Needs

A combination of literature review and expert consultations was used to evaluate existing information and knowledge about Arctic marine and anadromous fishes in light of its adequacy for decision making. Baseline surveys for marine fish and shellfish resources tend to be dated for most of the study area (1960s to 1990s) with most data collections reflecting infrequent sampling with respect to time and geography and objectives for environmental assessment purposes more so than for fisheries management. In the past 5 years, Shell has sponsored surveys in the northeastern Chukchi Sea, National Oceanic and Atmospheric Administration (NOAA)/BOEMRE surveys offshore and to the west of Barrow, and NOAA/Russia expeditions into the northern Chukchi Sea and Arctic Basin. With respect to OCS oil and gas development, fisheries investigations have focused on coastal habitats and their use, primarily during open-water periods, by salmonid species valued in subsistence and small-scale commercial fisheries, and nearshore fishes that might be affected by changes in brackish water habitats by solid-fill causeways in and nearby Prudhoe Bay. The National Science Foundation and others have funded ecological research in the northern Bering and southeastern Chukchi Seas to investigate coupling of regional pelagic and benthic ecosystems.

Resource inventories for freshwater, marine, and anadromous/amphidromous fish are reasonably complete for the Chukchi and Beaufort Seas. Life cycle information is lacking for all species, and with respect to fish species, is most complete for Arctic cisco in the Colville River. Although information about the population dynamics for key species of ecological significance (for example, Arctic cod, sand lance, and capelin) or subsistence use (for example, Dolly Varden, Arctic cisco, and inconnu) is critical for analysis of potential oil-spill impacts or other ecosystem disturbances, this level of resolution does not exist. Potential oil-spill impacts in shallow, coastal waters during open-water periods (June–September) could seriously impact key anadromous/amphidromous fish populations including Dolly Varden (from rivers originating in the Brooks Range), whitefish (from lower energy rivers/lakes to the west of the Brooks Range and northwestern Alaska), and salmon (Kotzebue Sound). Similarly, existing life history and habitat utilization information suggest that certain marine populations that seasonally aggregate in nearshore and intertidal areas for spawning (for example, herring, capelin, and rainbow smelt [now Arctic smelt]) or feeding (for example, Arctic cod) could suffer significant losses from spills or associated onshore industrial developments supporting OCS activities (for example, tankers and service vessels, pipelines, or causeways and artificial islands) or other kinds of resource extraction (for example, gravel mining).

3.07. Findings and Recommendations: Information about status and trends, habitat requirements, relative distribution and abundance, and knowledge of life history stages of marine fish is incomplete and unavailable for large expanses of Arctic nearshore and shelf waters and should be developed for indicator species (that is, species that are broadly distributed, of subsistence or ecological significance, readily available for vulnerability assessments, and deemed sensitive to offshore oil and gas development). Onshore-offshore linkages associated with life history requirements have not been described.

Logistical, technological, and cost considerations have limited the practicality of winter surveys and under ice resource information is limited and inadequate for evaluation of impacts.

Greater reliance on modern scientific technologies and their applications, such as remote sensing, telemetry, genetics and molecular biology, and quantitative ecology (for example, predictive models) is needed to establish species environmental relationships, address existing gaps about relative importance of habitats, understand natural variation in fluctuating stocks, and to more accurately assess effects of proposed offshore oil and gas activities.

Effects of ocean variability on production cycles and the distributional behavior, movement, and abundance of marine and anadromous fishes should be emphasized in future research and monitoring on select resources in strategic locations and undertaken to understand natural trajectories of change and effects of human interactions.

Effects of environmental parameters on physiological processes [feeding, digestion, assimilation, growth, responses to stimuli (that is, orientation and swimming speed), and reproduction] are poorly known for most Arctic fish species. These processes are dependent on key water properties, including temperature, salinity, light penetration, and oxygen concentration. Animal health also is affected by the presence of toxic substances, infectious pathogens, and parasites.

Seismic and noise effects on fishery resources have not been studied and is a research need. Much information could be borrowed from marine mammal research in Alaska and elsewhere regarding natural ambient sound and anthropogenic sound levels to guide experimentation.

Effects of invasive species associated with increased tankering, vessel support, and offshore construction activities on important biological habitats and ecosystems are unknown.

Biological hotspots for long-term research and monitoring of coastal, marine, and human impacts need to be identified. Potential sites include: Bering Strait (marine ecosystem processes); Kasegaluk, Simpson, and Beaufort lagoons (nearshore fish assemblages); Barrow Canyon/Hannah Shoal (benthic productivity); Capes Lisburne and Thompson (seabird colony and fishery oceanography dynamics); Point Barrow (transitional biogeographic zone); Boulder Patch (kelp bottom ecosystem); Stefansson Sound/Camden Bay (Arctic cod ecology); Mackenzie, Colville, and Canning River Deltas (physical and biological onshore-offshore linkages); ice edge and polynyas (biological significance to fish, birds, and marine mammals).

Local residents are often the first to notice changes in fish and wildlife populations. Mechanisms should be developed to better solicit and integrate local traditional knowledge as a basic source of information.

Human Settlements, Demographics, and Political Organization
(from Minerals Management Service, 2008, and North Slope Borough, 2011)

Human communities that have been and could be affected by future offshore oil and gas development are located primarily along the coasts of the Beaufort and Chukchi Seas and include from east to west: Kaktovik, Nuiqsut, Atqasuk, Barrow, Wainwright, Point Lay, and Point Hope. Additional communities farther south along the Chukchi Sea coast, such as Kivalina, Kotzebue, and Shishmaref also could be impacted by development but are not discussed further here. The North Slope has a fairly homogeneous population of Iñupiat, approximately 72 percent in 1990 and 68.38 percent in 2000 of the population. The percentage in 2000 ranged from 89.1 percent Iñupiat in Nuiqsut to 64.0 percent Iñupiat in Barrow. Each of the Borough's communities, with the exception of Point Lay, has a city government. Although certain municipal powers were turned over to the North Slope Borough when it was formed in 1972, community governments play an important role in the administration of Borough programs. In addition, local governments administer some State and Federal programs, such as capital improvements and housing. This section provides a profile of the North Slope Borough and the communities that border the Beaufort and Chukchi Seas that have been and could be impacted by offshore oil and gas development.

The North Slope Borough. Prior to the discovery and development of oil and gas on the North Slope and the formation of the North Slope Borough (NSB) in 1972, the population of the five then-existing villages (that is, Barrow, Kaktovik, Anaktuvuk Pass, Point Hope, and Wainwright) totaled about 2,500 people. Each village had limited political power, social services, and infrastructure. Per capita and household incomes were low, and North Slope residents relied heavily on local subsistence resources for food, clothing, and heat. The majority of NSB growth since 1970 has been in the three communities established after the incorporation of the NSB; however, large investments have been made in the infrastructures of all NSB communities. Iñupiat society maintains a strong subsistence-based culture.

The formation of the NSB in 1972 was motivated, in part, by the desire to capture petroleum industry based property tax revenue for local improvement and to exercise a degree of control over the pattern of petroleum development through the permitting of onshore oil infrastructure. Other factors that contributed to the motivation include the exercise of local control over Federal education and health care and the providing of services by the State that were lacking. Communities deliberately transferred municipal power to the Borough government, including basic community services in 1974, education in 1975 with the formation of the North Slope School District, and public safety in 1976. The result has been a strong regional government.

The NSB provides nearly all municipal services to the villages, including the operation of basic services and facilities. The Borough's Capital Improvement Program (CIP) created most of the infrastructure that serves the needs of the communities. Through the provision of these services, the Borough either directly or indirectly provides the majority of full-time employment in the villages. The NSB government and the school district are the largest employers in the region. However, in the period from 1998 to 2003, NSB government employment declined as did employment in the CIP, primarily due to the completion of construction projects in communities outside of Barrow. Over the last 25 years, these services have improved the economic and social well-being for Borough residents in areas of health, social services, public safety, education, communications, and transportation. The Borough provides utilities in each of the communities, where a large majority of housing units now are connected to public water and sewer. The NSB Department of Health provides a hospital in Barrow and health clinics in outlying villages. Social services furnished by the Borough include housing, meals and transportation for seniors, mental health counseling, and day care. The Borough provides each of the villages with law enforcement, fire protection, and search and rescue services, with a combination of full-time employees and volunteers. Secondary-school facilities have been provided in each village, and postsecondary education opportunities have improved. The Borough owns and operates public airports in all the communities, except Barrow and Deadhorse where they are State operated, and fosters community well-being through creation and support of other institutions, such as the Commission on Iñupiaq History, Language, and Culture. Since peaking in 1986, oil tax revenues have declined as the value of oil production and pipeline infrastructure depreciates. As these revenues have declined, Borough expenditures have similarly declined.

Kaktovik. Incorporated in 1971, Kaktovik is the easternmost village in the NSB. Its 2006 population was 288; its population in 2004 of 284 was 84.0 percent Iñupiat. The village is on the north shore of Barter Island, one of the largest of a series of barrier islands along the north coast, situated between the Okpilak and Jago Rivers on the Beaufort Sea coast, and is located 300 mi east of Barrow. Kaktovik abuts the Arctic National Wildlife Refuge. Until the late 19th century, the island was a major trade center for the Iñupiat and was especially important as a bartering place for Iñupiat from Alaska and Inuit from Canada.

Nuiqsut. Nuiqsut sits on the west bank of the Nechelik Channel of the Colville River Delta, about 25 mi inland from the Arctic Ocean and approximately 150 mi southeast of Barrow. Its population in 2006 was 417; its 2000 population of 433 was 89.1 percent Iñupiat Eskimo. Nuiqsut, one of three abandoned Iñupiat villages in the North Slope region identified in the Alaska Native Claims Settlement Act, was resettled in 1973 by 27 families from Barrow. Today, Nuiqsut is experiencing rapid social and economic change due to the development of local infrastructure, the development of the Alpine oil producing facility, potential Alpine satellite development, and potential oil development in the National Petroleum Reserve, Alaska. Most of Nuiqsut's marine subsistence-harvest area lies adjacent to areas in the Beaufort Sea.

Barrow. Barrow is the largest community on the North Slope and is its regional center. In 1970, the Iñupiat population of Barrow represented 91 percent of the total population of Barrow, but by 1990, Iñupiat representation had decreased to 63 percent. Between 1980 and 1985, Barrow's population grew by 35 percent and by 2006, its population was 4,065. The dramatic change in population and demographics primarily is the indirect result of oil and gas development. Increased revenues from onshore oil development and production at Prudhoe Bay and in other smaller oil fields underwrote the NSB CIPs which, in turn, stimulated a boom in Barrow's economy and an influx of non-Alaskan Natives to the community. The social organization of the Barrow community has become diversified with the large increase in the number of immigrants of different ethnic groups. Traditional marine mammal hunts and other subsistence practices still are an active part of the culture. Barrow is the seat of Borough government and the largest regional community.

Atqasuk. Atqasuk is a small, predominantly Iñupiat community on the Meade River, about 60 mi south of Barrow. In 2000, there were 228 residents, 94.3 percent of whom were Iñupiat; in 2006, there were 237 community residents. The community was established in mid-1970 by Barrow residents who had traditional ties to the area. By July 1983, the population had increased to 231, a 166 percent increase since the first census in 1980. Social ties between Barrow and Atqasuk remain strong, and men from Atqasuk go to Barrow to join bowhead whaling crews. To a large degree, Atqasuk has avoided the rapid social and economic changes experienced by Barrow and Nuiqsut brought on by oil development activities, but future change could accelerate as a result of oil exploration and development in the Northwest NPR–A.

Wainwright. Wainwright is located on the Chukchi Sea 100 mi southwest of Barrow on the western boundary of the NPR–A. In 2000, there were 546 residents, 93 percent of whom were Iñupiat; in 2006, Wainwright's population was 517. All of Wainwright's subsistence marine resources are harvested offshore in the Chukchi Sea, and all of the community's terrestrial subsistence use areas are within NPR–A.

Point Lay. Point Lay is one of the more recently established Iñupiat villages on the Arctic coast, and has historically been occupied year-round by a small group of one or two families. The community has the smallest population of any community in the NSB. In 2000, there were 247 residents, 88.3 percent of whom were Iñupiat; in 2006, Point Lay's population was 235. It is the only unincorporated community in the NSB. About 90 mi southwest of Wainwright, the community sits on the Chukchi Sea coast at the edge of Kasegaluk Lagoon near the confluence of the Kokolik River and Kasegaluk Lagoon. The community was established in the 1920s and its resident population increased until the 1930s, when it began a slow decline, largely because of the decline in reindeer herding. By 1960, it was not included in the national census. The village was reestablished on a barrier island spit opposite the Kokolik River in the 1970s. Residents of Barrow, Wainwright, Point Hope, Kotzebue, and other Iñupiat with traditional ties to the area resettled there. The town then moved to its present mainland site south of the Kokolik Delta in 1981. The community is unique because its wild food dependence is relatively balanced between marine and terrestrial resources. Unlike the other communities, local hunters do not pursue the bowhead whale because the deeply indented shoreline and spring ice-lead patterns have prevented effective bowhead whaling. However, the village does participate in beluga whaling.

Point Hope. Point Hope had a population of 737 in 2006. In 2000, there were 757 residents, 90.6 percent of whom were Iñupiat. The community, 330 mi southwest of Barrow, is located on a large gravel spit that forms the westernmost extension of the northwest Alaska coast. Once called Tigaraq, it is one of the longest continuously occupied areas in Alaska. This likely is due to its proximity to marine mammal-migration corridors and favorable ice conditions that allow hunting in open leads early in the spring. Local government is the main employer of Point Hope residents. The city government was incorporated in 1966 and, in the early 1970s, the community moved, because of erosion and periodic storm-surge flooding, to its present location just east of the old settlement. Point Hope has better facilities than many other communities of the region, but concerns remain because of erosion and storm-surge flooding.

Tribal Governments. Kaktovik, Nuiqsut, Atqasuk, Barrow, Wainwright, Point Lay, and Point Hope also have either a traditional village or an Indian Reorganization Act (IRA) Tribal council. Historically, these Tribal governments provided some services and may partner with the Borough to manage and operate social-service programs. The Iñupiat Community of the Arctic Slope (ICAS), the regional Tribal government, recently has taken a more active and visible role in regional governance and in providing some services. Government-to-government consultations with these Tribal governments occur on major Federal actions directly affecting the Tribes, including OCS oil and gas actions.

Alaska Native Corporations. Collectively, village corporations are the third largest employer and the Arctic Slope Regional Corporation (ASRC) is the fourth largest employer in the region. The ASRC runs several subsidiary corporations and, along with village profit and not-for-profit corporations, has provided employment and other services to Borough communities. For example, ASRC and village corporations have provided employment and other public services to the communities, such as operation and maintenance of utilities and operation of stores, hotels, and restaurants, while nonprofit corporations primarily are involved in education, health/medical, public housing, and other community services through funding obtained from the Borough and Federal and State governments. Generally, much of the surface estate in and around the communities is owned by the village corporations, except in Barrow where land ownership is a mixture of public (Federal, State, Borough, Tribal, and village) and private (Alaska Native regional and village corporations and private individuals). Regional and village corporations are creating some employment through subsidiaries and joint ventures, and some companies involved in resource development have undertaken to increase local employment through training programs and other actions.

Local Traditional Knowledge

The information included in this report primarily is derived from “western” scientific studies. These are scientific observations, usually developed in a systematic fashion and often using instrumentation to record, understand, and predict the states of ecosystems and their dynamics (Huntington and others, 2004a). Science typically has a strong numeric component and attempts to quantify the variability associated with various scientific observations. In contrast, local traditional knowledge, also known as LTK, refers to knowledge gathered and maintained by groups of people, often indigenous people, based on intimate experience with their environment (Huntington and others, 2004a). Advocates of LTK have promoted its use in scientific research and ecological understanding (Huntington, 2000), and Huntington and others (2004a) argue that combining the two approaches can increase confidence in individual observations, broaden the scope of information about environmental change, and contribute to insights concerning mechanisms of change. Huntington and others (2004a) emphasize three characteristics of LTK: (1) it often emphasizes unusual events or conditions—these may be particularly relevant to safety; (2) the assessment of uncertainty (variability) is not explicitly addressed in LTK; and (3) it is typically local in spatial scale.

Because practitioners of LTK are usually local residents (and scientists often are not), LTK can be particularly useful in documenting changes in distribution and abundance of species (for example, increasing abundance of salmon in the Beaufort Sea), documenting subsistence harvest areas for various species (see S.R. Braund and Assoc., 2010a), and documenting changes in harvest patterns. But LTK also has been used to identify biases in survey design [see example for bowhead whale survey in Huntington (2000)] and problems associated with telemetry collar designs for tracking polar bears (G. Durner, U.S. Geological Survey, oral commun., 2010), and in combination with scientific information that has been used to more holistically define ranges and habitats used by animals over the course of their annual cycles (Huntington and others, 2004b).

S.R. Braund and Associates (2010b) recently conducted a literature review of North Slope marine LTK. This review includes information on the physical environment, public testimony of residents at hearings, subsistence use areas, and subsistence harvest studies.

Subsistence Resources

Generally, subsistence is considered hunting, fishing, and gathering for the primary purpose of acquiring traditional food. The Alaska National Interest Land Conservation Act (ANILCA) defines subsistence as the customary and traditional uses by rural Alaska residents of wild, renewable resources for direct personal or family consumption such as food, shelter, fuel, clothing, tools, or transportation; for the making and selling of handicraft articles out of nonedible byproducts of fish and wildlife resources taken for personal or family consumption; for barter or sharing for personal or family consumption; and for customary trade (16 U.S.C. § 3113). This ANILCA framework is the basis for all current documentation of Alaskan subsistence activity, both by State and Federal governments.

Subsistence activities are assigned the highest cultural values by the Iñupiat and provide a sense of identity in addition to being an important economic pursuit. Besides their dietary benefits, subsistence resources provide materials for personal and family use, and the sharing of resources that helps maintain traditional Iñupiat family organization. Subsistence resources also provide special foods for religious and social occasions, such as Nalukataq, which celebrates the bowhead whale harvest. The sharing, trading, and bartering of subsistence foods structure relationships among communities, while at the same time the giving of these foods helps maintain ties with family members elsewhere in Alaska. Additionally, subsistence provides a link to the market economy; many households within the communities earn cash from crafting whale baleen and walrus ivory and from harvesting fur-bearing mammals.

Subsistence harvest data are primarily from the Alaska Department of Fish and Game Community Subsistence Information System and the North Slope Borough (Bacon and others, 2009). Although subsistence-resource harvests differ from community to community in northern and northwestern Alaska, with a few local exceptions, the combination of marine mammals, large terrestrial mammals, fish and waterfowl are the primary groupings of resources harvested across the North Slope (fig. 3–17). Of the marine mammals, the bowhead whale is the preferred meat and the subsistence resource of primary importance because it provides a unique and powerful cultural basis for sharing and community cooperation. Of the terrestrial mammals, caribou are the most important (Bacon and others, 2009). Depending on the community, fish is the second or third most important resource after caribou and bowhead whales. Pinnipeds and various types of birds also are considered primary subsistence species. Waterfowl are particularly important during the spring, when they provide variety to the subsistence diet (Bacon and others, 2009). Although North Slope residents concentrate their harvests on certain high value target species and species groups, the overall subsistence harvest is quite diverse (table 3–3).

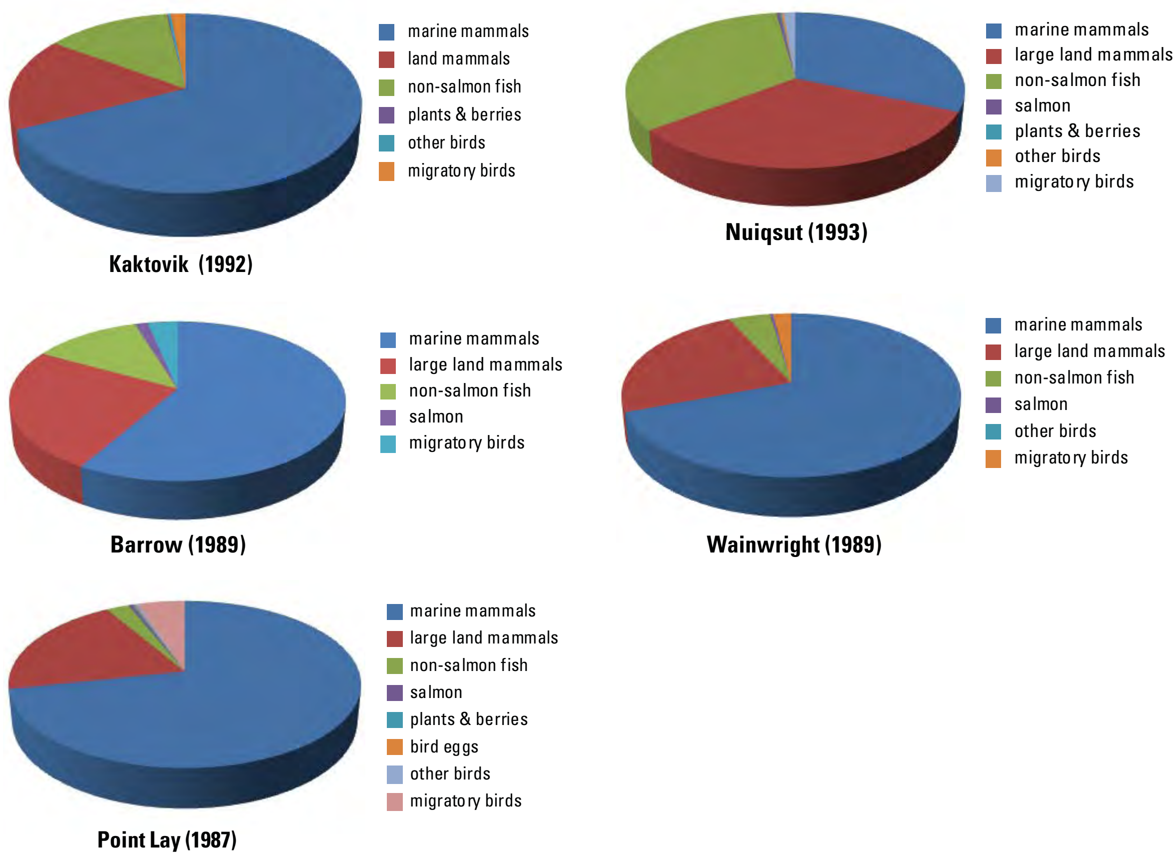


Figure 3–17. Estimated annual harvest of various subsistence resources (pounds) (data that make up these pie charts are relatively old, but still provide a relative sense of the importance of various resources in the subsistence economies of North Slope villages). Adapted from the Alaska Department of Fish and Game (2011), accessed April 18, 2011, at http://www.subsistence.adfg.state.ak.us/CSIS/.

Table 3–3. Species and numbers harvested by Barrow residents, 1987–90.

[3-year average data from Minerals Management Services (2008)]

Species	3-year average	Species	3-year average	Species	3-year average	Species	3-year average
Bowhead whale	9	Wolverine	2	Arctic char	83	Tomcod	65
Walrus	81	Arctic fox	129	Burbot	676	Sculpin	4
Bearded seal	174	Red fox	5	Lake trout	147	Geese	3,384
Ringed seal	394	Wolf	0	Northern pike	4	Non-specified	144
Spotted seal	3	Ermine	0	Salmon	788	Brant	440
Polar bear	21	Whitefish	28,683	Non-specified	169	White-front	2,795
Beluga whale	0	Non-specified	1,760	Chum	182	Snow	4
Caribou	1,595	Round	953	Pink	92	Canada	1
Moose	48	Broad	17,352	Silver	334	Eiders	6,087
Dall sheep	11	Humpback	1,840	King	12	Ptarmigan	1,378
Brown bear	1	Least cisco	5,819	Capelin	1,435	Other birds	30
Porcupine	2	Arctic cisco	958	Rainbow smelt	526		
Ground squirrel	14	Grayling	9,914	Arctic cod	8,321		

In addition to accurate, timely information on the composition of subsistence harvests by North Slope residents, information on where those harvests take place also is of high importance in planning industrial activities in coastal and marine areas of the Beaufort and Chukchi Seas. S.R. Braund and Associates (2010a) recently conducted a literature review of North Slope marine traditional knowledge and included maps showing subsistence harvest areas for important subsistence species, such as whales, seals, walrus, polar bears, waterfowl, fish, and invertebrates. Examples of maps for Kaktovik are shown in figures 3–18 and 3–19.

Ongoing work by USGS, in collaboration with BOEMRE's Alaska Region, is providing additional information and analysis on the human dimensions of fish use for subsistence communities bordering the Chukchi and Beaufort seas, including Canada. The following section is excerpted primarily from Thorsteinson and others (2011). In some cases, fish provides more of a dietary contribution than any other food source. In the Kotzebue Sound area, fully one-third to one-half of the total subsistence harvest by weight consists of fish (fig. 3–20). Although the inhabitants of the North Slope are often considered to depend much less on fishing and more on marine mammal hunting, significant harvests of fish are still made. The fact that fish comprise more than 10 percent of the total subsistence harvest of Barrow is remarkable, considering the number of bowhead whales harvested yearly at that location. Farther east at Nuiqsut, fish are the largest single contributors to the subsistence economy at nearly 40 percent of the total harvest.

Those areas less directly dependent on fish are mostly still reliant on them as a secondary resource in times of scarcity. Furthermore, fishing is an important family activity for much of the population not otherwise engaged in the hunting of sea mammals or caribou, including women, children, and elders. Previous research on Beaufort Sea and Chukchi Sea subsistence fisheries has to this point been limited in scope either geographically or chronologically: few studies have combined data for the U.S. and Canadian Arctic, and few include data from multiple years or otherwise longer-term perspectives than one or two season's worth of catches.

Ongoing USGS research (Thorsteinson and others, 2011) seeks to produce a synthetic, broad-view analysis of fishing in its larger regional, cultural, and temporal context. Multi-year catch reconstruction analyses have recently been published both for the Arctic coasts of Alaska and the Northwest Territories. This makes it possible to determine each community's "typical" local fishing tradition. Interviews with those currently or previously involved in fishing also provide an important contribution, particularly in the form of compilations of local traditional knowledge.

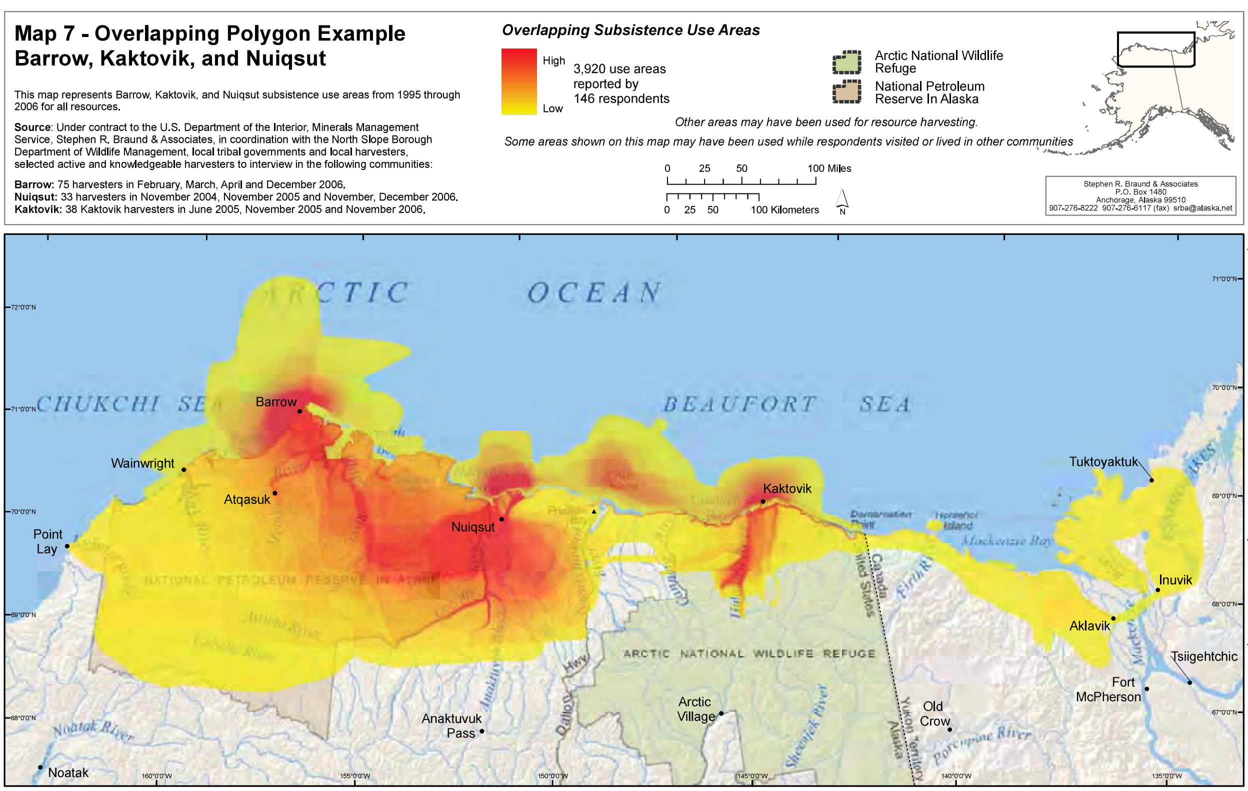


Figure 3–18. Overlapping subsistence use areas for Barrow, Kaktovik, and Nuiqsut. From S.R. Braund and Associates (2010a).

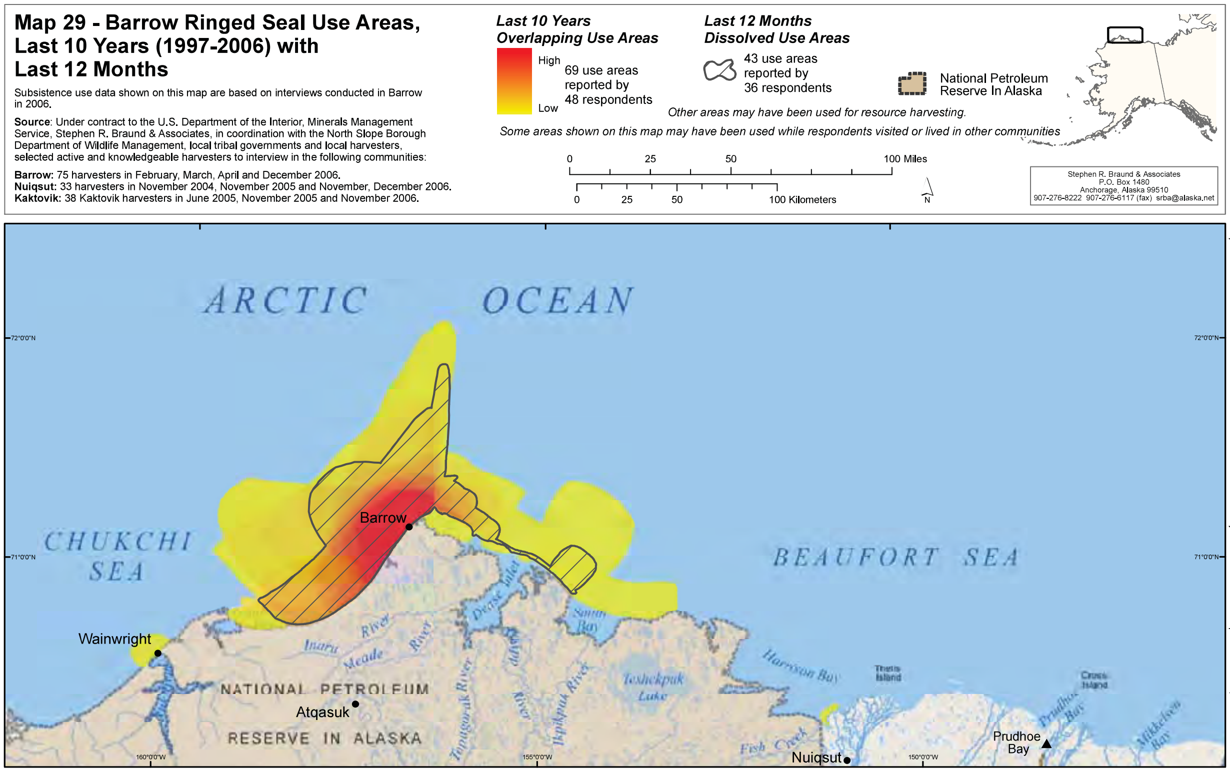


Figure 3–19. Subsistence use areas for ringed seals for the Barrow area. From S.R. Braund and Associates (2010a).

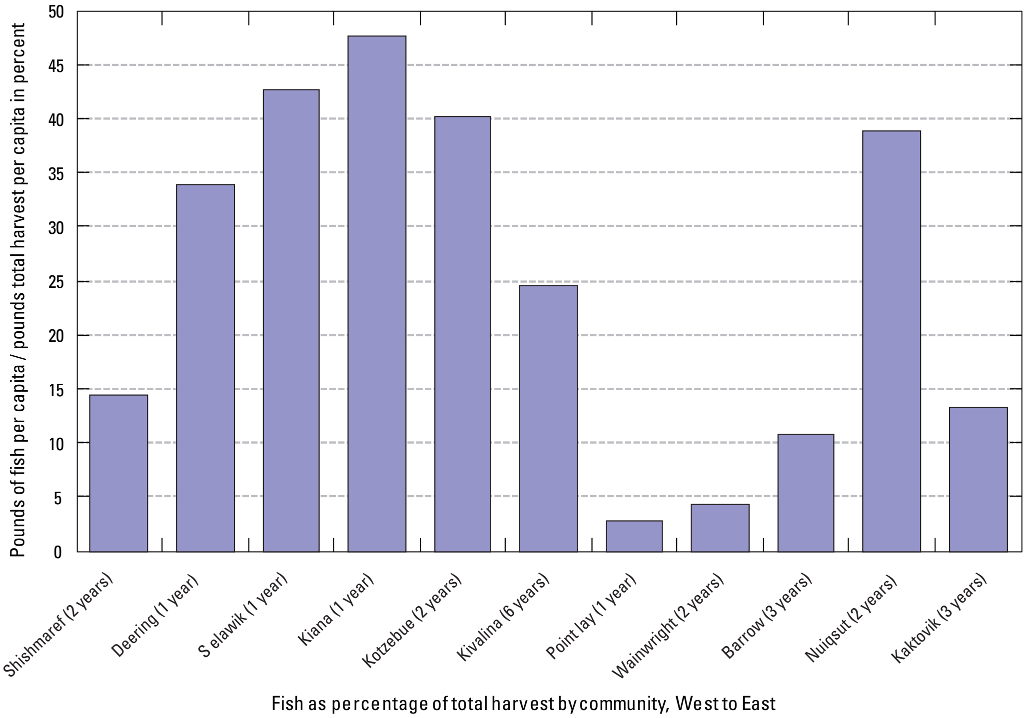
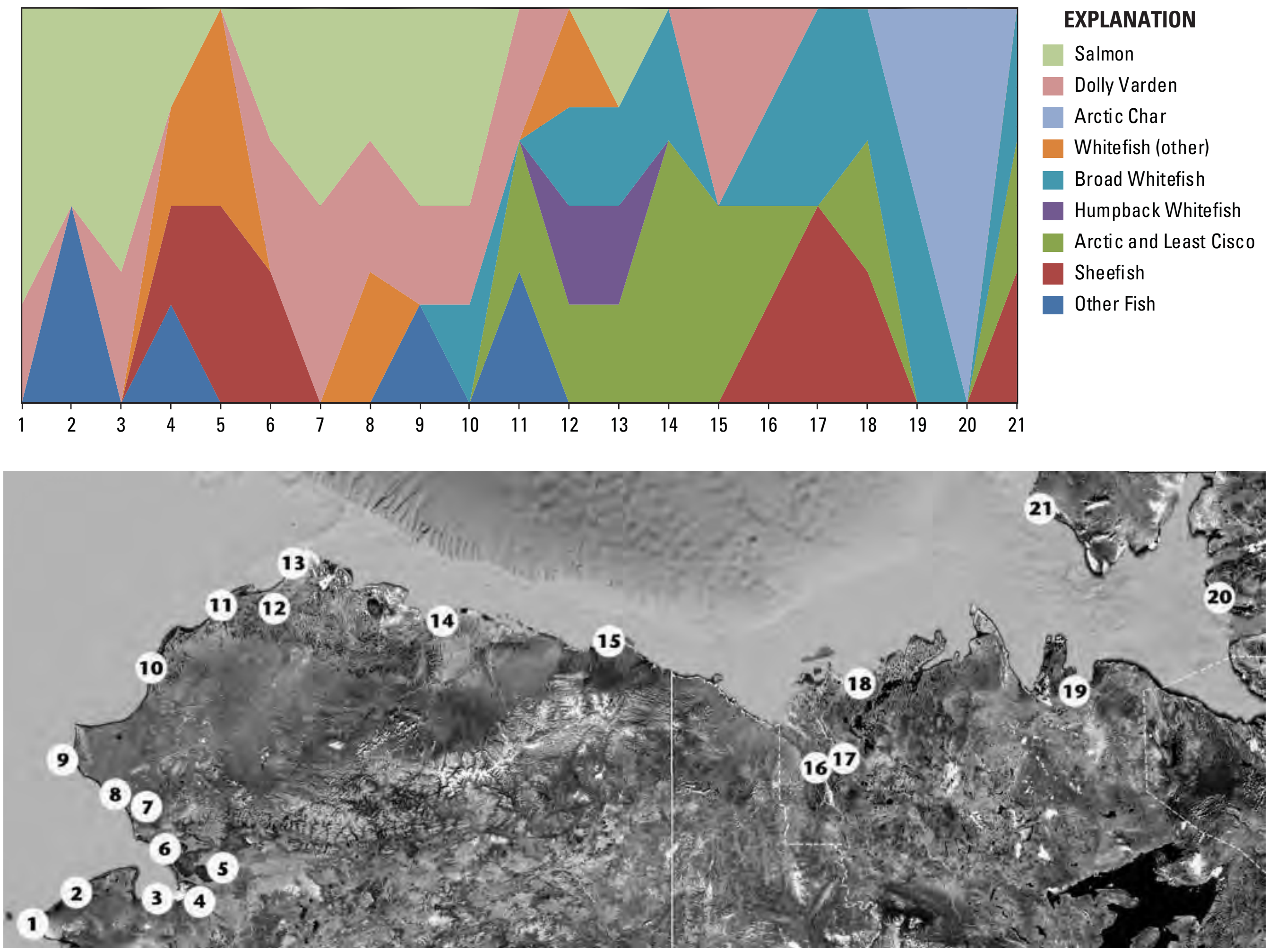


Figure 3–20. Fish as a percentage of total overall subsistence harvest by community, West to East. Based on harvest records of the Alaska Department of Fish and Game (2011), accessed April 18, 2011, at http://www.subsistence.adfg.state.ak.us/CSIS/.



Map No.	Community	Map No.	Community
1	Wales	12	Atqasuk
2	Shishmaref	13	Barrow
3	Deering	14	Nuiqsut
4	Buckland	15	Kaktovik
5	Selawik	16	Aklavik
6	Kotzebue	17	Inuvik
7	Noatak	18	Tuktoyaktuk
8	Kivalina	19	Paulatuk
9	Point Hope	20	Holman
10	Point Lay	21	Sachs Harbour
11	Wainwright		

Figure 3–21. Visualization of the major subsistence fish species for each numbered coastal community in the Beaufort and Chukchi Seas, including the Canadian Beaufort.

When the four most important marine and anadromous fish species for each community are visualized on a west-east axis (fig. 3–21), the relationship between geography and human fishing habits may be understood; specifically, the great variability in local fisheries becomes apparent both on the local and regional level. Now, as in the past, the vast majority of the total catch consists of species that are either anadromous (migrating from the ocean to rivers in order to spawn) or that are otherwise known to live in both fresh and salt water and to move between the two.

According to the Alaskan catch reconstruction study mentioned above, the total yearly subsistence harvest of fish from Wales to Kaktovik in 1950 was approximately the same as in 2006 (450–500 tons), with little deviation over several decades. In comparison, commercial harvests for the same area were extremely variable from year to year, with occasionally very large (about 3,000 tons) harvests in the 1970s and 1980s. Total commercial harvests have been declining since the late 1980s, unlike the comparatively stable subsistence harvest levels. Nearly the entire commercial harvest is from the southwestern Seward Peninsula/Kotzebue Sound region (fig. 3–21).

To put the harvest estimates in perspective, it is useful to compare them to the total weight of bowhead whales harvested by the same populations. In 2008, communities north of the Bering Strait harvested 32 bowhead whales. Using a standard individual weight of 23.4 tons from a sample with approximately the same average size, the total harvested whale biomass for that year may be estimated at 750 tons. Viewed in the light of the whale data, the estimated 1950–2006 yearly fish harvests amount to 60–70 percent of the total harvested whale biomass for that year.

Primary subsistence species. Salmon make a notable contribution to people's diets only as far north and east as Point Lay, although small numbers of all five salmon species are occasionally caught as far to the east as Amundsen Gulf. Generally speaking, the closer a community's proximity to the more temperate and productive Bering Sea, the greater the number of salmon species caught and the greater the contribution of salmon to the local population's diet. This corresponds directly to the distribution of spawning populations of various salmon species. Chum salmon (*Oncorhynchus keta*) have the widest range and are the type of salmon utilized to the greatest extent.

Dolly Varden trout (*Salvelinus malma*), another anadromous salmonid species, make a significant dietary contribution across a very large area. Communities from the Seward Peninsula east to Kaktovik rely heavily on this species. Reliance on this species by humans is heaviest from Kotzebue to Wainwright and in Kaktovik (this easternmost community being closest to the spawning populations of the Brooks Range rivers (Viavant, 2001). Dolly Varden are not normally found to the east of Kaktovik; communities to the east of the Babbage and Firth Rivers rely instead on a closely related species, Arctic char (*Salvelinus alpinus*).

Further north and east, a variety of whitefish and cisco species (genus Coregonus) gradually replace salmonids as the basis of the subsistence fishery. Sheefish (*Stenodus leucichthys*, also Inconnu), another coregonid species, are important in the area of the central Kotzebue Sound as well as in the Mackenzie Delta on the eastern North Slope.

3.08. Findings and Recommendations: Subsistence harvests are seasonally and regionally variable. Although general usage patterns are known, village surveys have been conducted intermittently. In some cases, the data are old enough and may no longer be representative of actual harvests.

Future work is needed to fully understand the environmental, ecological, and cultural context of Beaufort Sea and Chukchi Sea subsistence harvests. To predict or model with any degree of accuracy the future of Arctic subsistence, with or without the impact of hydrocarbon exploration and extraction, a greater understanding of the past and present will be necessary.

Because local patterns of resource exploitation are closely tailored to local environments and ecologies, they are potentially vulnerable to the effects of climate change and oil and gas development. The impact of climate change need not necessarily be harmful to human subsistence. A growing body of anecdotal evidence suggests that previously rare salmon species are appearing with greater frequency on the North Slope. New runs and greater numbers of salmon in the future could well provide the basis of new subsistence traditions. However, the unpredictable effects of climatic instability on fish and wildlife populations are not likely to be a net benefit to Arctic subsistence users in the near future.

Oil and gas exploration and development pose a potential hazard to native subsistence livelihoods. Anadromous fish, marine mammals, and marine birds are crucial to human subsistence across the study area and are potentially vulnerable to disturbance and (or) pollutants associated with exploration, drilling, and transportation. Many fish species (including those not directly sought after for human use) comprise a major portion of the diets of sea mammals and birds that in turn sustain human populations.

Subsistence users may be among the first to notice changes in abundance and distribution of fish and wildlife species as it relates to climate change, development, and other stressors. Local traditional knowledge should be more formally incorporated and integrated into resource assessments.

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Exhibit 4

Anne E. Gore and Pamela A. Miller, Broken Promises: The Reality of Oil Development in America's Arctic (Sept. 2009)

Broken Promises

The Reality of Oil Development in America's Arctic

– 2nd Edition –

The Wilderness Society

Contents

Cover photo: Joel Sartore
This page and opposite: Lincoln Else

The primary source of greenhouse gas pollution is the burning of fossil fuels.

Petroleum consumption alone accounted for 44% of U.S. CO_2 emissions in 2006.[3] Scientists believe that to avoid catastrophic changes affecting climate and ultimately life on Earth, we must reduce CO_2 in the atmosphere to 350 ppm, down from current levels of 380 ppm.[4] Only by dramatically reducing the amount of fossil fuels we extract and burn for energy can we meet this goal. According to the Intergovernmental Panel on Climate Change this will require nations like the United States to reduce their carbon emissions by 20-35% below 1990 levels by 2020, and 80-95% below 1990 levels by 2050.[5]

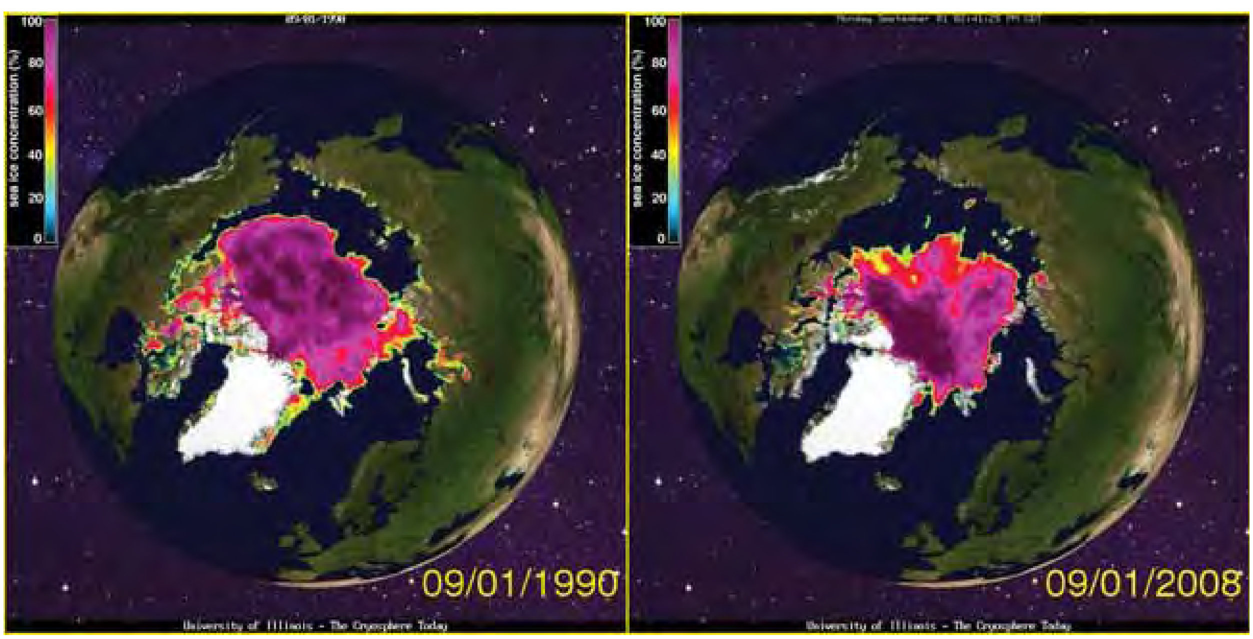
Alaska is one of the top greenhouse gas-emitting states in the nation.[6]

Despite having one of the lowest populations, Alaska released in 2005 the equivalent of 79 tons of greenhouse gases per resident, which is more than three times the national average,[7] and fifteen times more pollution than the average passenger vehicle emits in one year.[8] More than half of Alaska's industrial source greenhouse gas emissions are generated by British Petroleum (BP Exploration Alaska), which operates most of the Prudhoe Bay oil fields.[9]

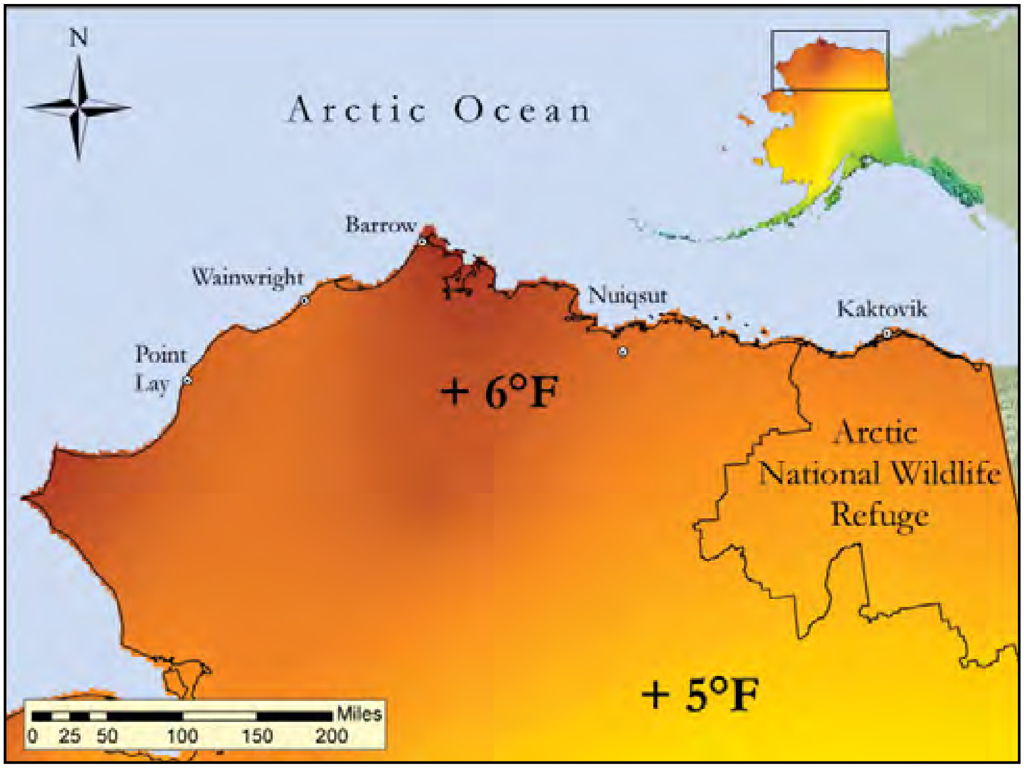
Climate change is already impacting Alaska.

Arctic regions are warming at twice the rate of other places on Earth.[10] Such dramatic increases in temperature have resulted in profound and visible changes to Alaska's land, water, wildlife, and people.

- ▷ Oil and gas development is a major source of greenhouse gases and a significant cause of climate change.
- ▷ Climate change is already adversely impacting Arctic ecosystems and indigenous people in Alaska.
- ▷ Continuing to extract fossil fuels in the Arctic will only add stress to already vulnerable ecosystems and indigenous communities.



Comparison satellite images of summer sea ice cover.
Source: University of Illinois – The Cryoshpere Today, http://igloo.atmos.uiuc.edu/cgi-bin/test/print.sh.



Arctic Alaska is already warming faster than other places in the world, and climate models predict temperatures will increase by as much as 6 degrees by 2040.

Among the more profound changes is the loss of sea ice, which is at the lowest levels in 800 years.[11] As a result of receding and thinning sea ice scientists have observed polar bears drowning and going hungry,[12] walruses forced onto land,[13] and sharp declines in numbers of ice-dependent sea birds.[14] Subsistence hunters have had to travel farther across thinner ice, and sometimes open seas, to access animals.[15] The loss of ice, coupled with melting permafrost, is accelerating coastal erosion, forcing communities to relocate, and threatening habitat for waterfowl, and caribou,[16] which are also important food sources for indigenous people. Also due to coastal erosion, an emergency clean-up was required in 2007 to plug an old oil exploration well after more than 300 feet of shoreline was lost in a few months.[17]

As temperatures continue to rise and precipitation patterns change, scientists expect lakes and wetlands to dry, fires to increase, and plant and animal distributions to change.[18] These anticipated changes have significant health, social and economic implications for people living in the Arctic, and beyond.[19] What is happening in the Arctic affects not just the wildlife and

According to current scientific consensus, it is the burning of oil (and other fossil fuels) that has contributed significantly to the Arctic's warming trend.[20]

people living there, but also has implications for global weather patterns and the survival of species that migrate to the Arctic from other parts of the world.[21]

America's Arctic contains important onshore and off-shore feeding, denning, calving, nursery, nesting, staging, and molting habitats for hundreds of species and contains some of the world's last wholly intact ecosystems. If we do not address climate change in the Arctic, and elsewhere, 30 percent of the world's species and one-fifth of the world's ecosystems could be gone by 2050.[22] The result of such losses could affect agriculture, medicines and building materials sourced from plants, jobs, and ways of life that we now take for granted.[23] Even oil production on the North Slope could be impacted by warming temper-atures, which have already reduced the number of days that ice roads can be used.[24]

Given what we know about the impacts of climate change to ecosystems, species, and cultures, it would be irresponsible to undertake new drilling activities that would accelerate such change and bring harm to wildlife and people.

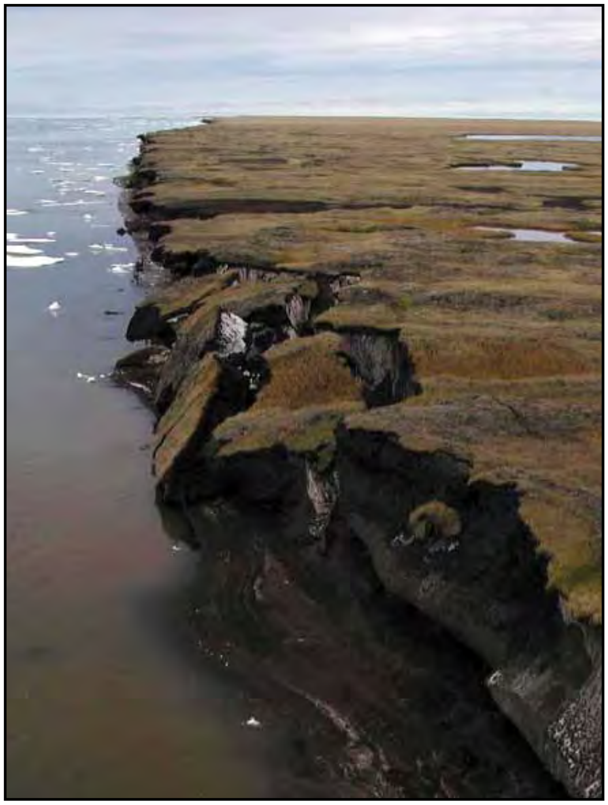


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Exhibit 5

U.S. Environmental Protection Agency Region 10, Technical Support Document, Review of Shell's Supplemental Ambient Air Quality Impact Analysis for the Discoverer OCS Permit Applications in the Beaufort and Chukchi Seas (June 24, 2011)

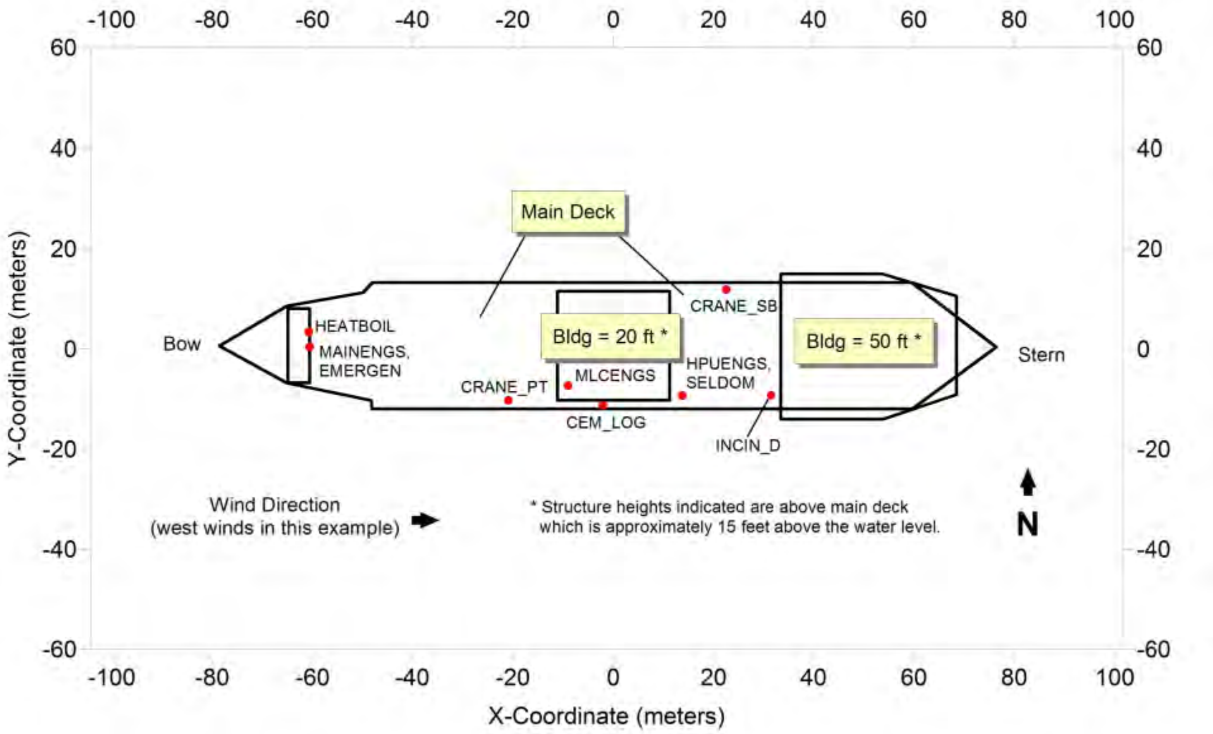
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
SEATTLE, WASHINGTON

TECHNICAL SUPPORT DOCUMENT
REVIEW OF SHELL'S
SUPPLEMENTAL AMBIENT AIR QUALITY IMPACT ANALYSIS
FOR THE DISCOVERER OCS PERMIT APPLICATIONS
IN THE BEAUFORT AND CHUKCHI SEAS

June 24, 2011

Contents

Figure 1 – Layout of Exhaust Stacks and Structures on the Discoverer



Region 10 reviewed Shell's characterization of the exhaust stacks and structure locations/heights used in the modeling demonstration and determined they were representative of the equipment and as described in Shell's permit application.

D.4 Shell Operating Scenarios - New Permit Conditions and Equipment

The impact evaluation in Shell's March 18, 2011 Submittal (Shell Offshore Inc. 2011c) included new proposed permit conditions and equipment not included in the 2010 Permits. The proposed changes include an emergency engine that was upgraded since issuance of the 2010 Permits, seldom used emergency equipment on the Discoverer drillship and Associated Fleet that was not identified in the applications for the 2010 Permits, a reduced restriction on the number of days the Discoverer can be an OCS source, new restrictions on the number of hours the MLC and HPU equipment can be utilized, installation of post combustion controls for particulate matter (PM) and NO_x on Ice Management Vessel #1, and a new operating mode for the Supply Ship.

One important difference in this latest application is the new operating mode of the Supply Ship. Shell is proposing that up to 8 resupply trips be made during the drilling season when the Discoverer is an OCS source. During the periods of resupply, the resupply ship will operate in dynamic positioning (DP) mode. Duration of DP mode operations can be up to 24 hours per resupply trip. Shell has modeled these emissions associated with resupply using the highest emitting candidate resupply ship with a fixed emission point near one of the Discoverer's two cranes. Shell has also modeled the transit emissions within 2km of the ship occurring the hour before and after DP mode operations. This new resupply scenario represents an increase in emissions from the 2010 Permits.

One of the ice management vessels will also be used as an anchor handler and for crew transport to and from the Discoverer. Anchor handling and crew transport will occur during open water conditions. In the

March 18, 2011 submittal (Shell Offshore Inc. 2011c) the ice management vessel use was only modeled during ice conditions. Shell has provided an additional modeling analysis (Shell Offshore Inc. 2011f) for anchor handler use in open water conditions. Again, this a change from the operating scenario described in the March 18 submittal.

Overall, these changes in permit restrictions have substantially decreased the overall emissions for all criteria pollutants both on an annual basis and hourly basis under 2011 Revised Draft Permits when compared to the 2010 Permits. A summary of the annual emissions changes resulting from the new operating restrictions and other operational changes, on an annual basis for the Beaufort and Chukchi, are summarized in Tables 2 and 3 below.

Table 2. Annual Comparison of Criteria Pollutants and Ammonia from the 2010 permit to the current submittal for the Beaufort[1]

Application	NOx (ton/yr)	$PM_{2.5}$ (ton/yr)	PM_{10} (ton/yr)	CO (ton/yr)	VOC (ton/yr)	SO_2 (ton/yr)	NH_3 (ton/yr)
Original	1,371	57	65	464	96	2	0.34
Updated[3]	336	21	22	154	43	1.3	0.52
Percent Change	-75%	-63%	-66%	-67%	-55%	-35%	53%

Table 3. Annual Comparison of Criteria Pollutants and Ammonia from the 2010 permit to the current submittal for the Chukchi[2]

Application	NOx (ton/yr)	$PM_{2.5}$ (ton/yr)	PM_{10} (ton/yr)	CO (ton/yr)	VOC (ton/yr)	SO_2 (ton/yr)	NH_3 (ton/yr)
Original	1,188	52	58	449	87	2	0.34
Updated[3]	336	21	22	154	43	1.3	0.52
Percent Change	-72%	-60%	-62%	-66%	-51%	-35%	53%

Note that there will be a slight increase (0.18 tons/year) in NH_3 emissions associated with the installation of SCR control equipment on Icebreaker #1. This does not change the prior analysis supporting the Beaufort 2010 Permit for the Alaska State Ambient Air Quality Standard for NH_3 that applies under the COA regulations when the source is operating in the OCS because the increase in emissions is so small. There will also be a slight increase in H_2SO_4 from Icebreaker #1, but the requirement to use only ULSD fuel in both the Discoverer and Associated Fleet still ensures that the PTE for H_2SO_4 will remain well below the Significant Emission Rate or SER.

In the Statement of Basis for the 2010 Permits, an impact analysis was performed for all criteria pollutants and averaging times in effect at the time the 2010 Permits were issued. This analysis was based on a SCREEN3 modeling effort, which is a screening model and not a refined model. In addition, the impact analysis performed to support the 2010 Permits assumed an ambient air boundary at the hull of the

[1] Original permit levels from the 2010 statement of basis (USEPA Region 10. 2010d)
[2] Original permit levels from the 2010 statement of basis (USEPA Region 10. 2010e)
[3] Updated values from Shell's May 19th Submittal (Shell Offshore Inc., 2011e)

Discoverer and the Associated Fleet. In the modeling submitted by Shell to support the 2011 Revised Draft Permits, Shell has assumed an ambient air boundary of 500 meters from the center of the Discoverer. Because Shell has identified additional equipment not included in the original permits (mainly the Supply Ship operating in dynamic positioning mode), Shell submitted an additional demonstration on May 19th, 2011 that included all other averaging times and pollutants (Shell Offshore Inc., 2011e).

This refined analysis also included updated background monitoring data for some pollutants because additional data was available and the latest guidance issued by EPA on how to use background data in an air impact analysis for the $PM_{2.5}$ standard (USEPA. 2010b) was also used.

D.4.1 Scenario Management

Because Shell is reducing the number of days the Discoverer can be an OCS source from the 2010 Permits, they incorporated the 120-day OCS limit in their modeling of NO_2, SO_2, PM_{10} and $PM_{2.5}$ impacts. To ensure the modeled results were not underestimated by their selection of when the 120-day period would occur, Shell modeled two 120-day periods during the drilling season: an "early season" period (July 1 through October 28th); and a "late-season" (August 3rd through November 30th). Shell then took the higher of the two impacts for comparison to the air quality standards.

Shell also incorporated the various levels of operation during a 30-day drilling sequence in their NO_2, SO_2, PM_{10} and $PM_{2.5}$ analysis. They did this by creating an AERMOD input file for each day and hour of the 120-day period (2,880 files) for each pollutant. They then ran AERMOD for each file and post-processed the results.

Shell used the full five month (153-day) meteorological period when modeling their CO and NH_3 impacts. They also used the worst-case emissions for each unit and assumed all units are operating concurrently. This is a conservative and therefore, acceptable, approach.

Shell prorated the period averages in order to estimate the annual average impacts. For example, to estimate the annual average NO_2, $PM_{2.5}$ or SO_2 impacts, Shell multiplied the 120-day average impact by 0.329 (120 drilling days out of 365 days in a year). Shell's approach for estimating the annual average impact is reasonable since there are no impacts during non-drilling periods.

D.5 Receptor Grid

A local Cartesian coordinate system was used by Shell to define its primary modeling domain and cover all its overwater drilling and support operations. Shell has used an ambient air boundary of 500 meters from the center point of the Discoverer. Surface elevations were set to 0.0 meters reflecting the lack of terrain in an overwater setting. The grid does not have a defined origin because drilling will occur in multiple locations within the specified permitted lease blocks. Having a local coordinate system allows emissions impacts to be placed at various lease block locations to analyze modeled impacts without having to redo modeling runs for each potential location. As discussed above, the prior screening modeling analysis assumed the ambient air boundary was at the hull of the Discoverer, while the refined analysis assumes a 500 meter boundary.

Figure 2 shows the receptor layout used in the modeling. The receptor grid extends out to 5 km, to characterize the pattern and location of maximum hourly impacts from the Discoverer and Associated Fleet. Shell used a 25 meter (m) spacing at the ambient air boundary. Shell constructed the rest of the grid as follows:

- 100-m spacing out to 1 km from the center of the Discoverer;
- 250-m spacing from 1 km to 5 km from the center of the Discoverer.