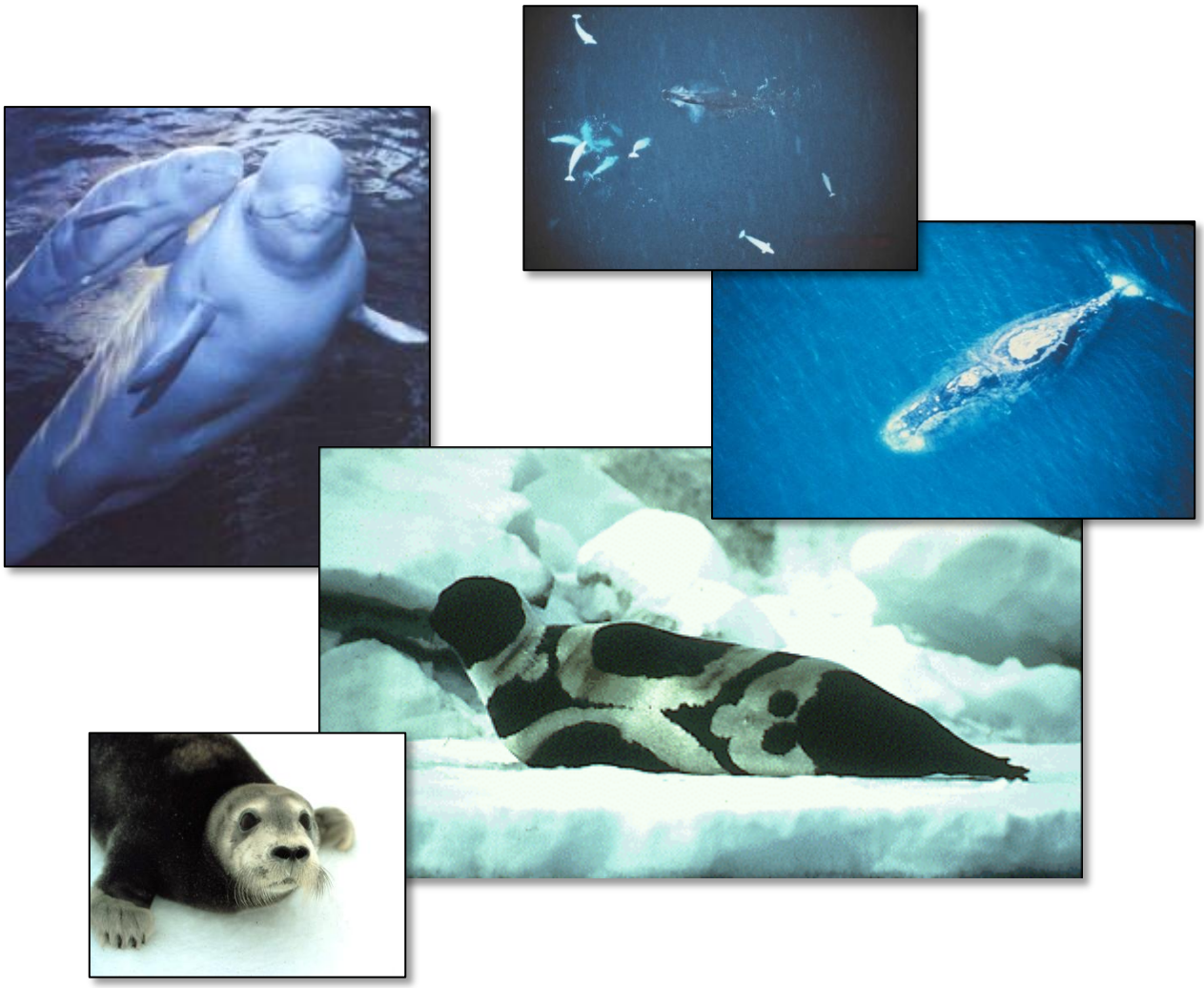
Effects of Oil and Gas Activities in the Arctic Ocean

Final Environmental Impact Statement

Volume 3: Figures and Appendices



October 2016

United States Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Office of Protected Resources

Effects of Oil and Gas Activities in the Arctic Ocean

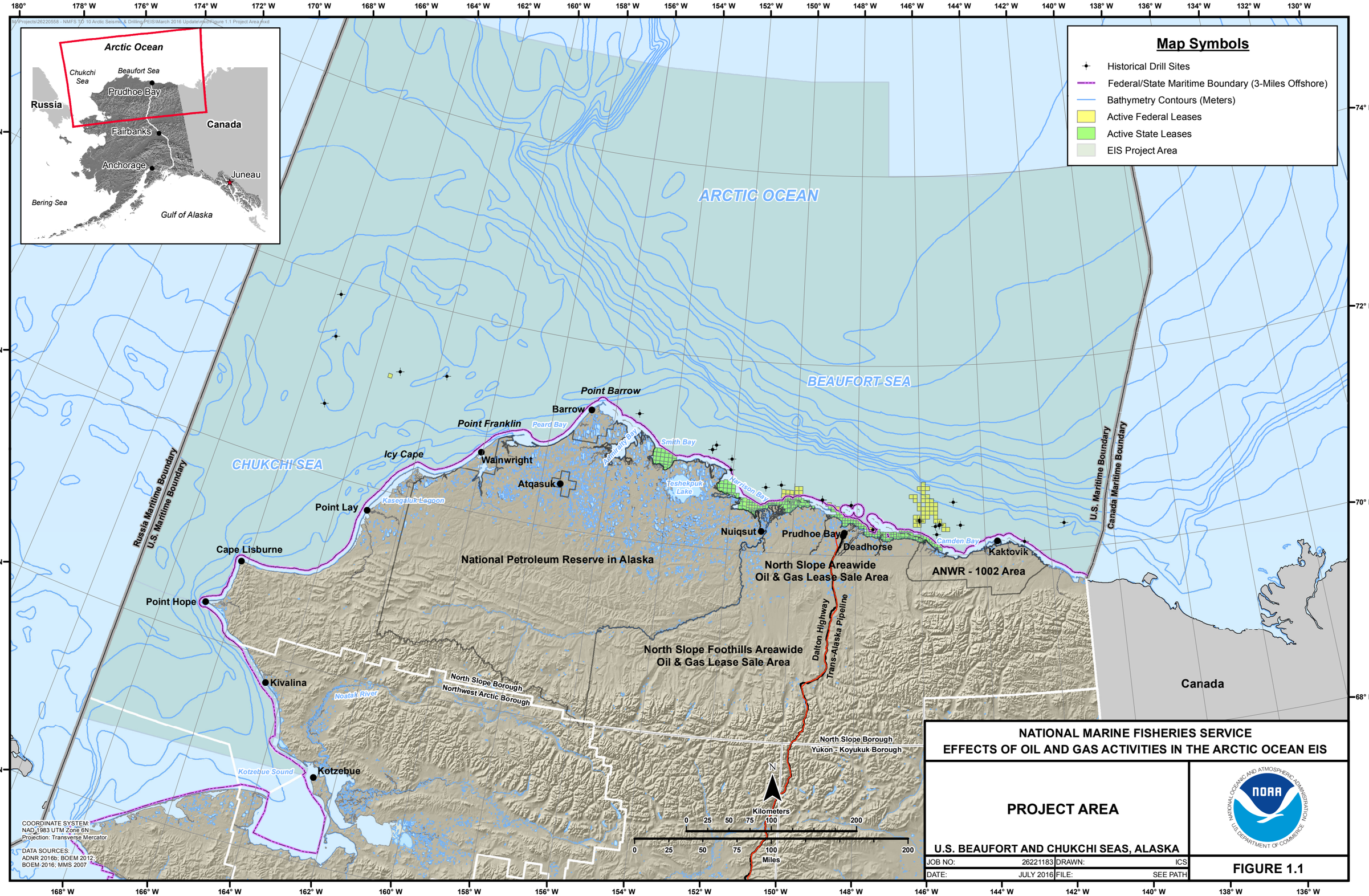
Final Environmental Impact Statement

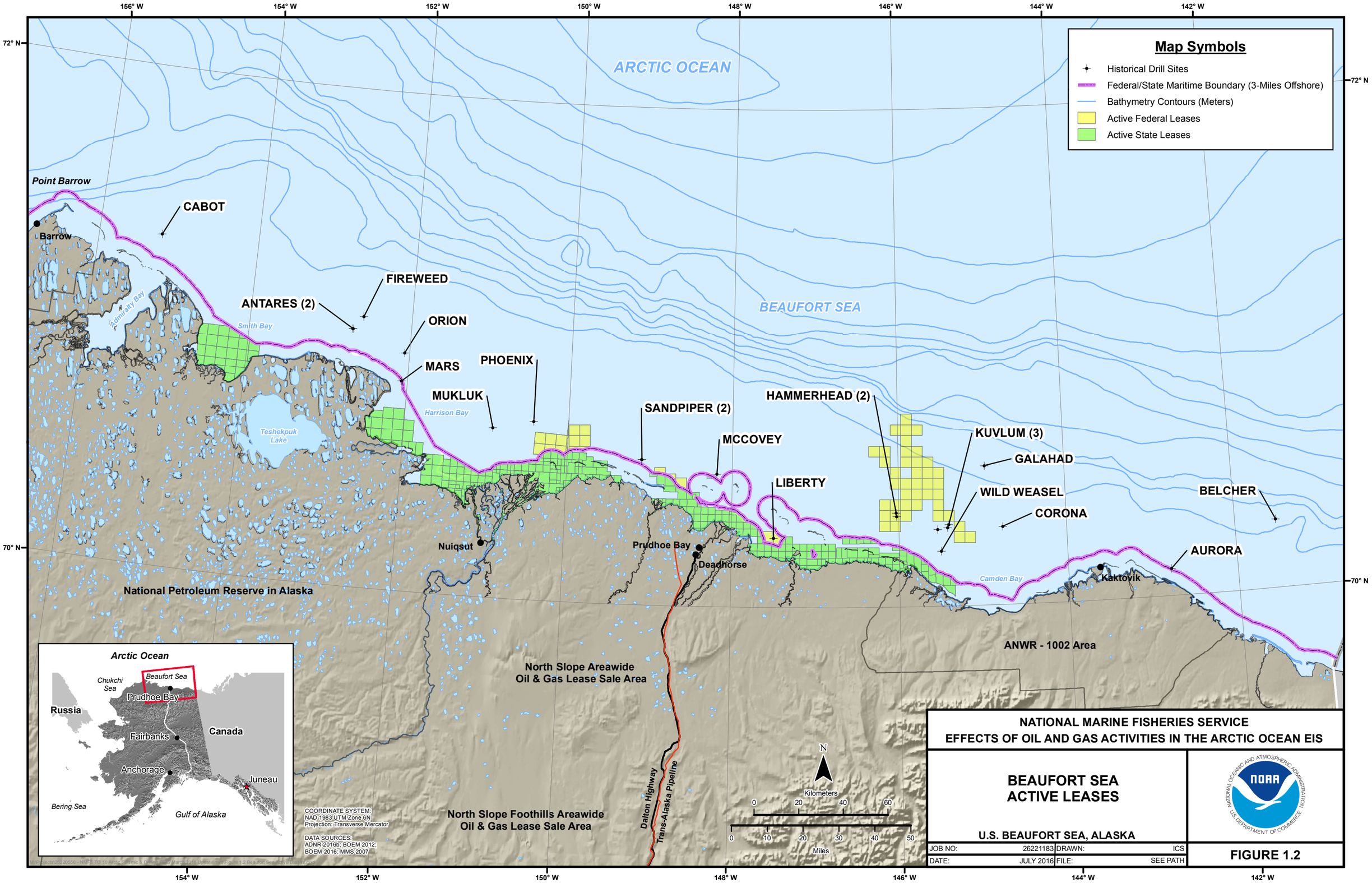
October 2016

Prepared by:
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Office of Protected Resources

FIGURES

CHAPTER 1 FIGURES


Arctic Ocean
Chukchi Sea
Beaufort Sea
Prudhoe Bay
Russia
Canada
Fairbanks
Anchorage
Juneau
Bering Sea
Gulf of Alaska
Map Symbols
Historical Drill Sites
Federal/State Maritime Boundary (3-Miles Offshore)
Bathymetry Contours (Meters)
Active Federal Leases
Active State Leases
EIS Project Area
ARCTIC OCEAN
BEAUFORT SEA
CHUKCHI SEA
Point Barrow
Barrow
Point Franklin
Peard Bay
Admiralty Bay
Smith Bay
Icy Cape
Wainwright
Atqasuk
Teshekpuk Lake
Harrison Bay
Kasegaluk Lagoon
Point Lay
Nuiqsut
Prudhoe Bay
Deadhorse
Camden Bay
Kaktovik
Cape Lisburne
Point Hope
National Petroleum Reserve in Alaska
North Slope Areawide Oil & Gas Lease Sale Area
ANWR - 1002 Area
North Slope Foothills Areawide Oil & Gas Lease Sale Area
Dalton Highway
Trans-Alaska Pipeline
Russia Maritime Boundary
U.S. Maritime Boundary
Canada Maritime Boundary
Kivalina
Noatak River
North Slope Borough
Northwest Arctic Borough
Yukon - Koyukuk Borough
Kotzebue Sound
Kotzebue
Canada
Kilometers
Miles
COORDINATE SYSTEM:
NAD 1983 UTM Zone 6N
Projection: Transverse Mercator
DATA SOURCES:
ADNR 2016b; BOEM 2012;
BOEM 2016; MMS 2007
NATIONAL MARINE FISHERIES SERVICE
EFFECTS OF OIL AND GAS ACTIVITIES IN THE ARCTIC OCEAN EIS
PROJECT AREA
U.S. BEAUFORT AND CHUKCHI SEAS, ALASKA
JOB NO: 26221183
DRAWN: ICS
DATE: JULY 2016
FILE: SEE PATH
FIGURE 1.1



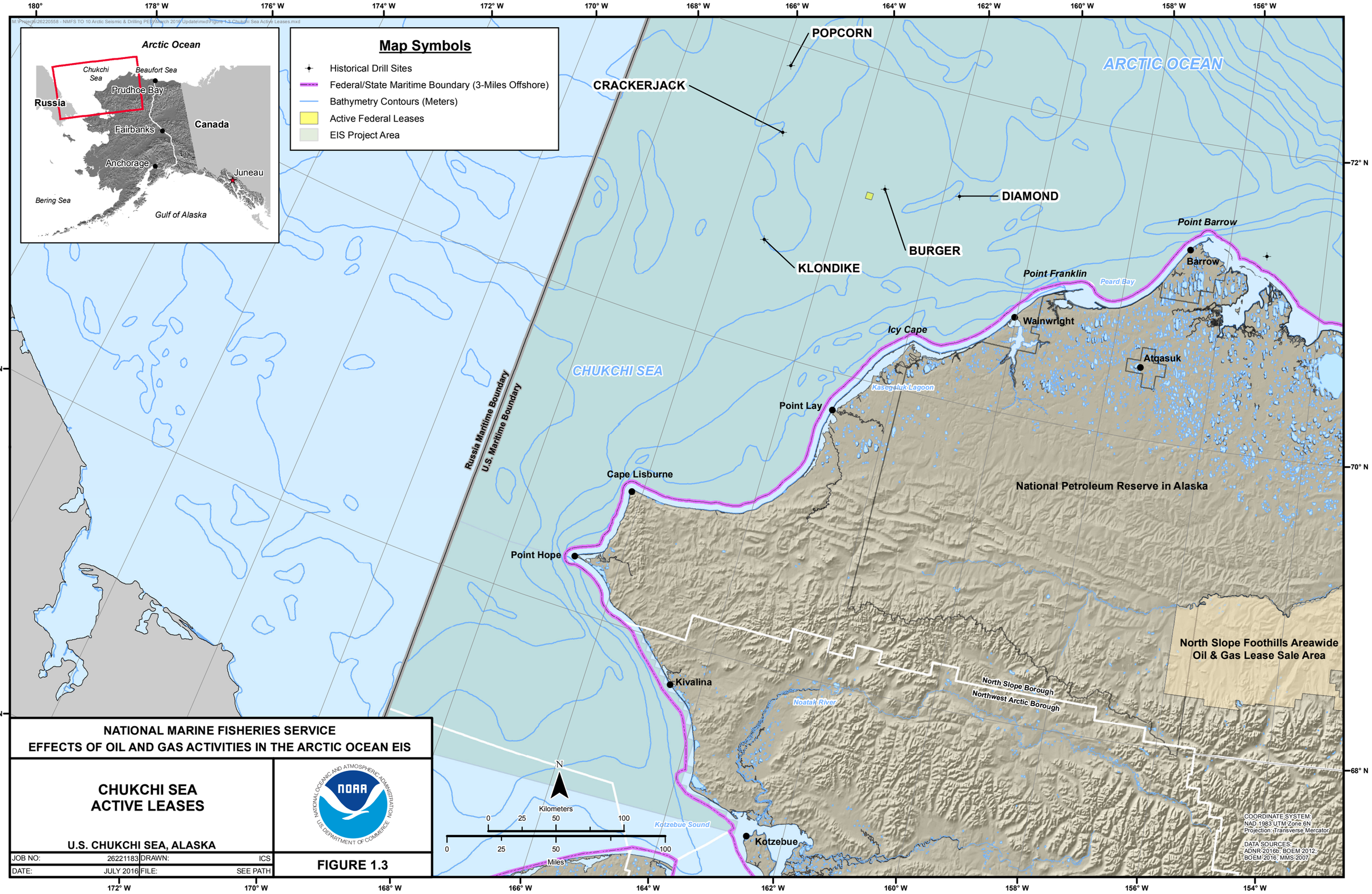
NATIONAL MARINE FISHERIES SERVICE
EFFECTS OF OIL AND GAS ACTIVITIES IN THE ARCTIC OCEAN EIS

BEAUFORT SEA ACTIVE LEASES

U.S. BEAUFORT SEA, ALASKA

JOB NO:	26221183	DRAWN:	ICS
DATE:	JULY 2016	FILE:	SEE PATH

FIGURE 1.2


M:\Proj\26220558 - NMFS TO 10 Arctic Seismic & Drilling PEIS\March 2016 Update\mxd\Figure 1.3 Chukchi Sea Active Leases.mxd
Arctic Ocean
Chukchi Sea
Beaufort Sea
Prudhoe Bay
Russia
Canada
Fairbanks
Anchorage
Juneau
Bering Sea
Gulf of Alaska
Map Symbols
Historical Drill Sites
Federal/State Maritime Boundary (3-Miles Offshore)
Bathymetry Contours (Meters)
Active Federal Leases
EIS Project Area
POPCORN
CRACKERJACK
DIAMOND
BURGER
KLONDIKE
ARCTIC OCEAN
CHUKCHI SEA
Russia Maritime Boundary
U.S. Maritime Boundary
Point Barrow
Barrow
Point Franklin
Peard Bay
Wainwright
Icy Cape
Atqasuk
Kasegaluk Lagoon
Point Lay
Cape Lisburne
Point Hope
National Petroleum Reserve in Alaska
North Slope Foothills Areawide Oil & Gas Lease Sale Area
Kivalina
North Slope Borough
Northwest Arctic Borough
Noatak River
Kotzebue Sound
Kotzebue
N
Kilometers
0 25 50 100
0 25 50 100
Miles
COORDINATE SYSTEM: NAD 1983 UTM Zone 6N Projection: Transverse Mercator
DATA SOURCES: ADNR 2016b; BOEM 2012; BOEM 2016; MMS 2007
180° 178° W 176° W 174° W 172° W 170° W 168° W 166° W 164° W 162° W 160° W 158° W 156° W
72° N
70° N
68° N
66° N
172° W 170° W 168° W 166° W 164° W 162° W 160° W 158° W 156° W 154° W
NATIONAL MARINE FISHERIES SERVICE
EFFECTS OF OIL AND GAS ACTIVITIES IN THE ARCTIC OCEAN EIS
CHUKCHI SEA ACTIVE LEASES
U.S. CHUKCHI SEA, ALASKA
JOB NO: 26221183 DRAWN: ICS
DATE: JULY 2016 FILE: SEE PATH
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
FIGURE 1.3

CHAPTER 2 FIGURES

Figure 2.1 Simple Illustration of a Marine Seismic Survey Operation using Streamers.
Source: EPA 2011

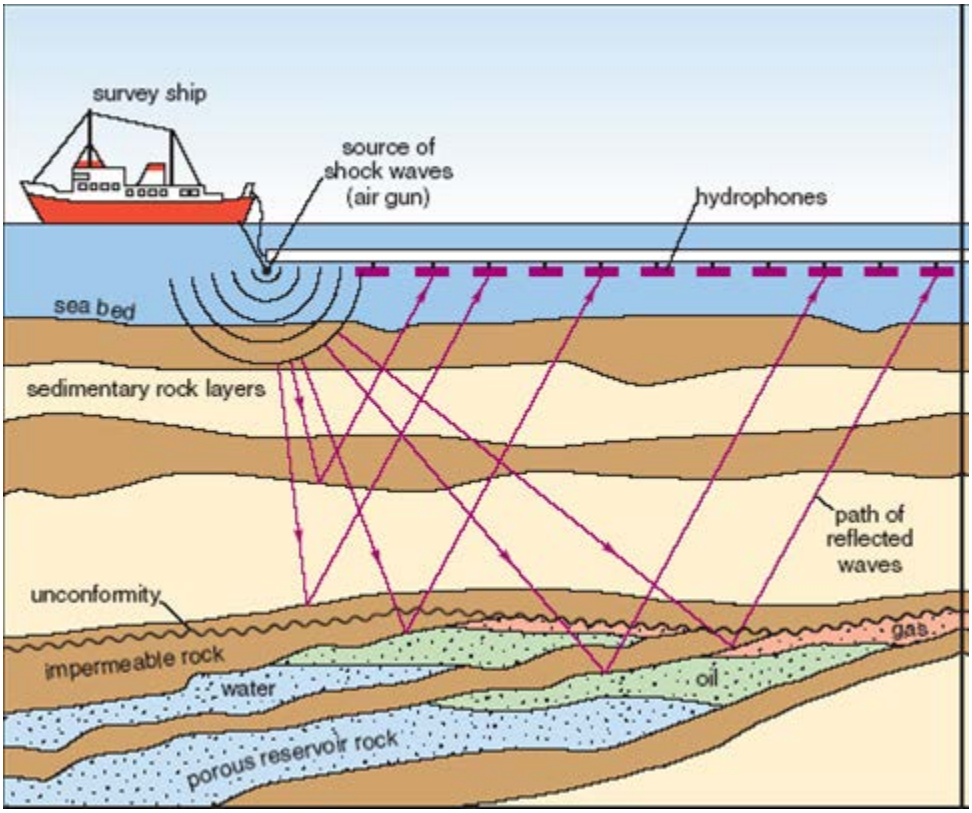
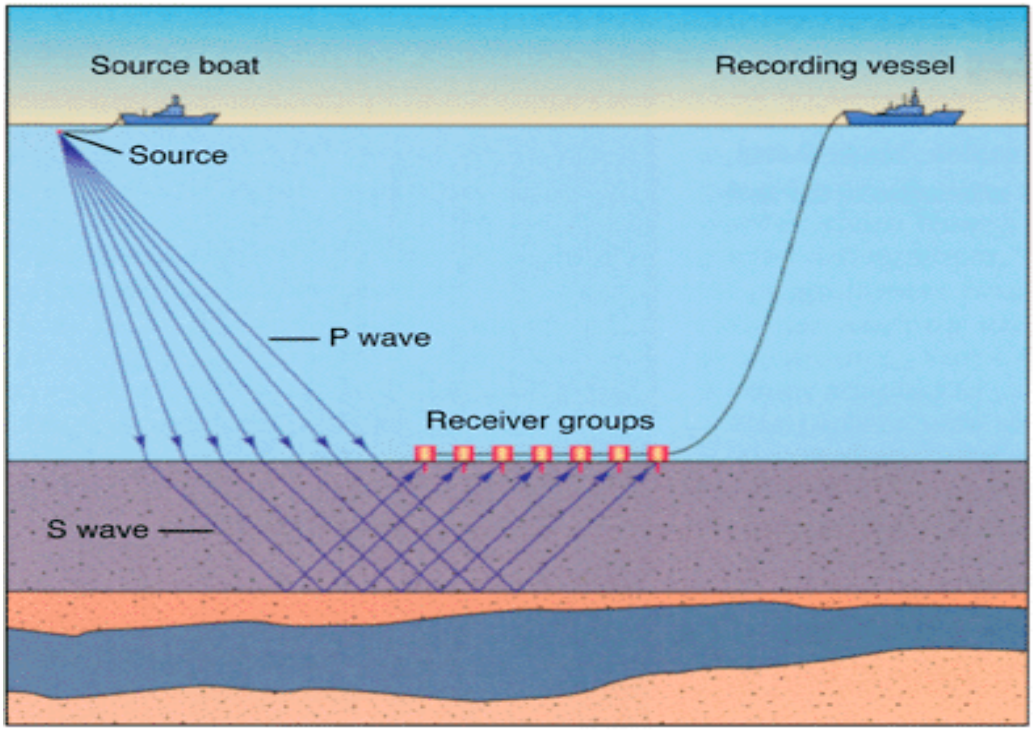


Figure 2.2 Illustration of Ocean Bottom Cable survey.

Source: Schlumberger 2011

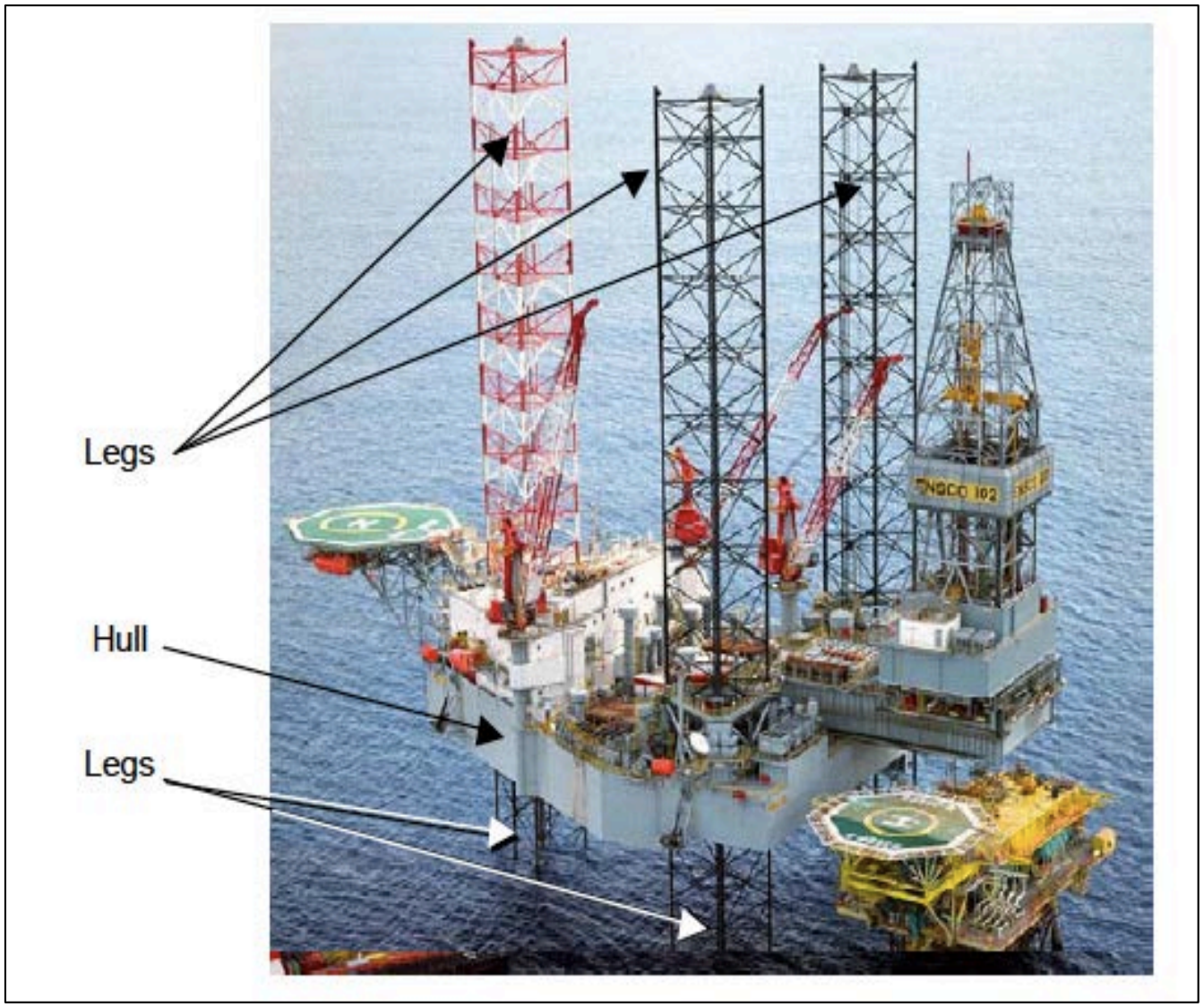


.

Figure 2.3 SDC operating in the Beaufort Sea.
Source: ICETECH 2010 Conference

Figure 2.4 Jackup Rig.

Source: Bennet & Associates LLC and Offshore Technology Development Inc. 2011



CHAPTER 3 FIGURES

Figure 3.1-1 General circulation map of the Beaufort and Chukchi seas.
Source: Weingartner and Danielson 2010

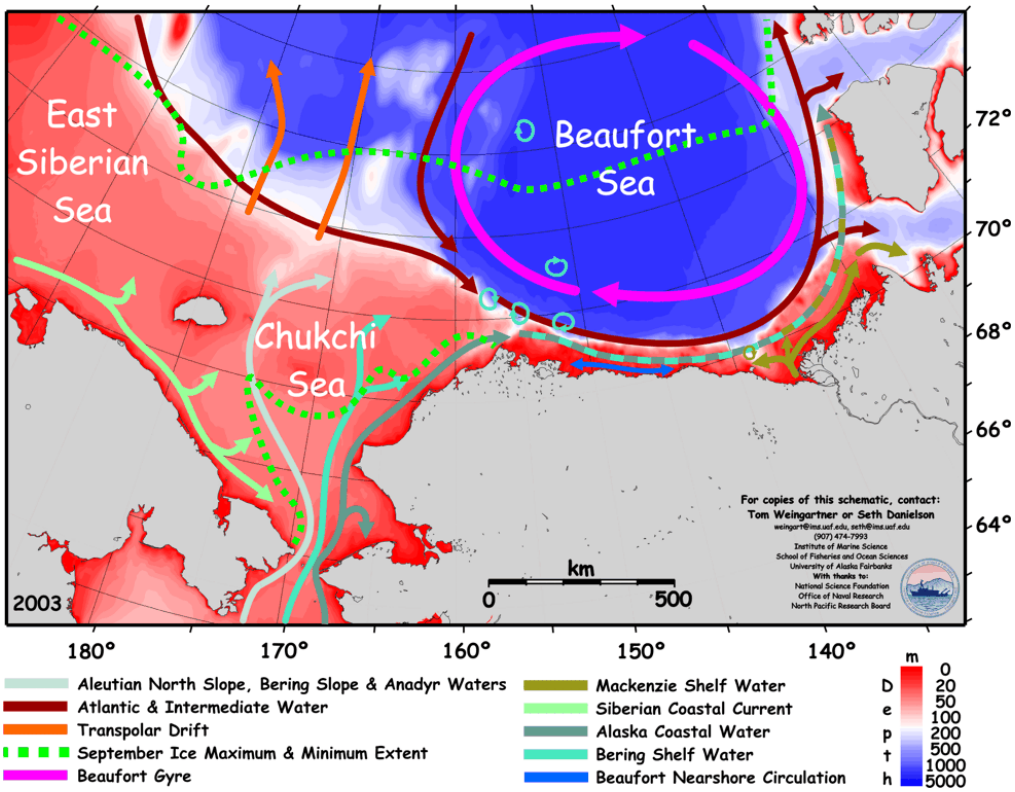


Figure 3.1-2 Bathymetry of the Beaufort Sea.
Source: Weingartner 2008

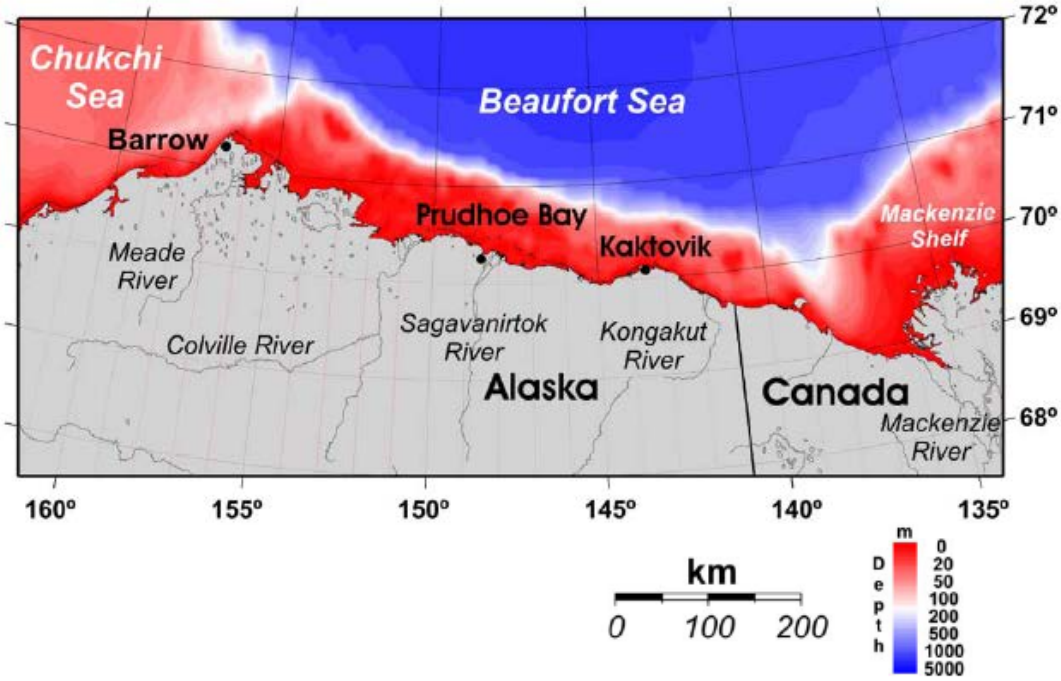


Figure 3.1-3 Schematic circulation map of the Beaufort and Chukchi shelves showing the flow of Bering Strait water through the Chukchi Sea along three principal pathways that are associated with distinct bathymetric features: the Herald Valley, the Central Channel, and Barrow Canyon.

Source: Weingartner and Danielson 2010

Three branches of the inflowing Pacific water are color-coded with navy blue (Anadyr Water) being the most nutrient-rich water and light blue (Alaska Coastal Water) being the least nutrient-rich. The Siberian Coastal Current (green) is present in summer and fall, but absent or weak in winter and spring. On the continental slope, the Pacific-origin water encounters Atlantic-origin Water (red) which is flowing counter-clockwise around the Arctic basin. Offshore of the slope, in the interior of the Canada Basin, is the clockwise wind-driven flow of the Beaufort Gyre (purple).

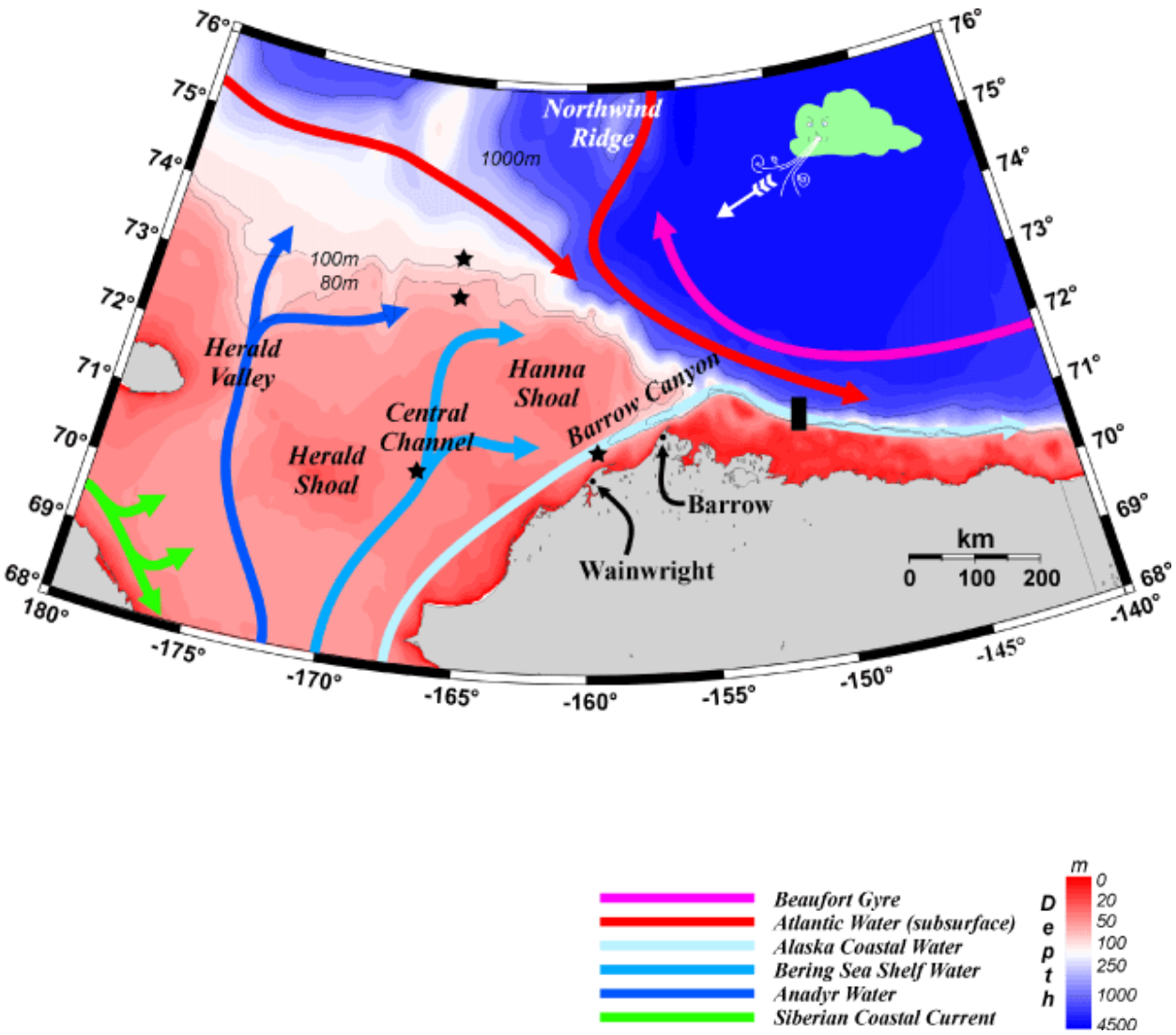
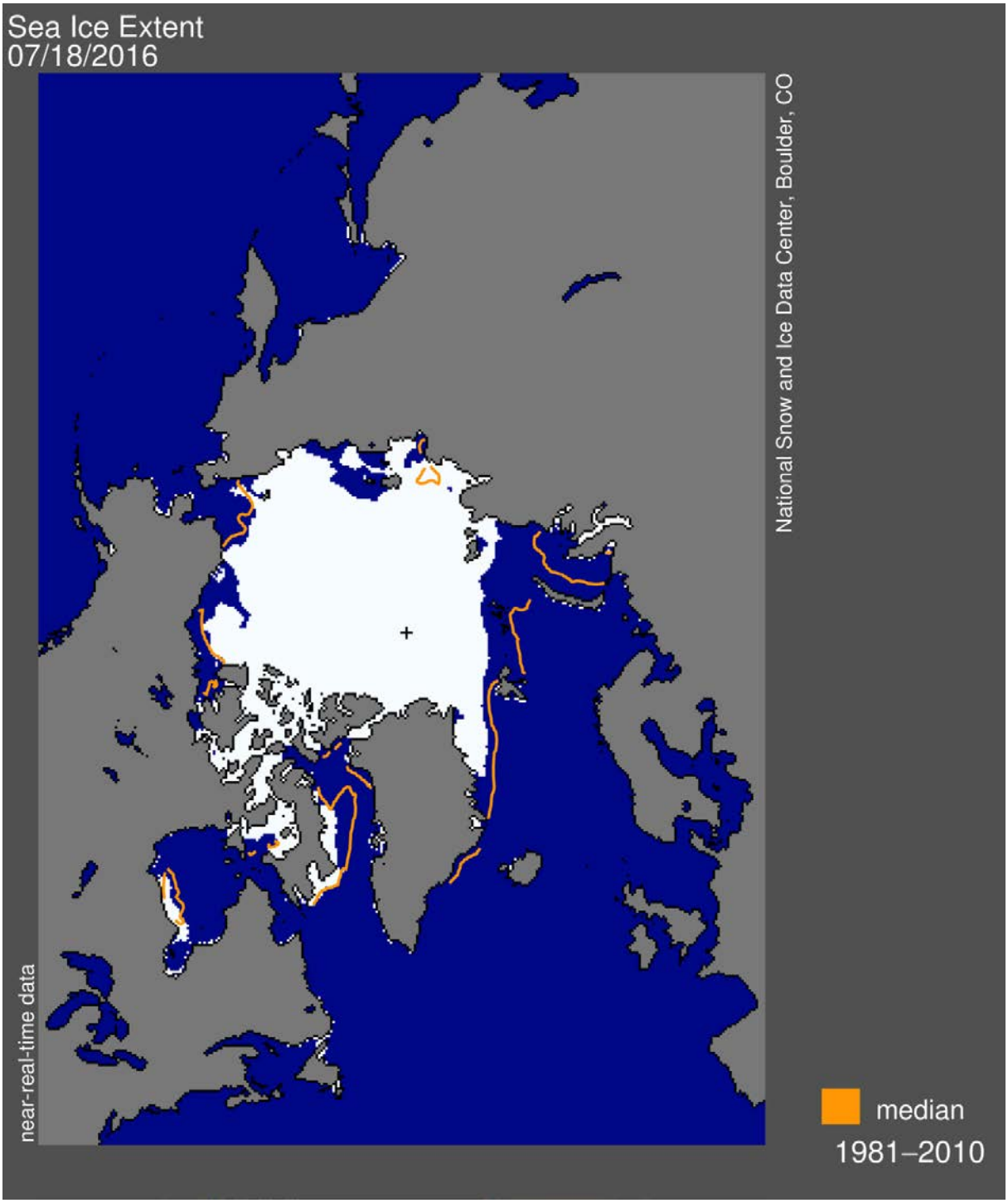


Figure 3.1-4 a) Sea Ice Extent

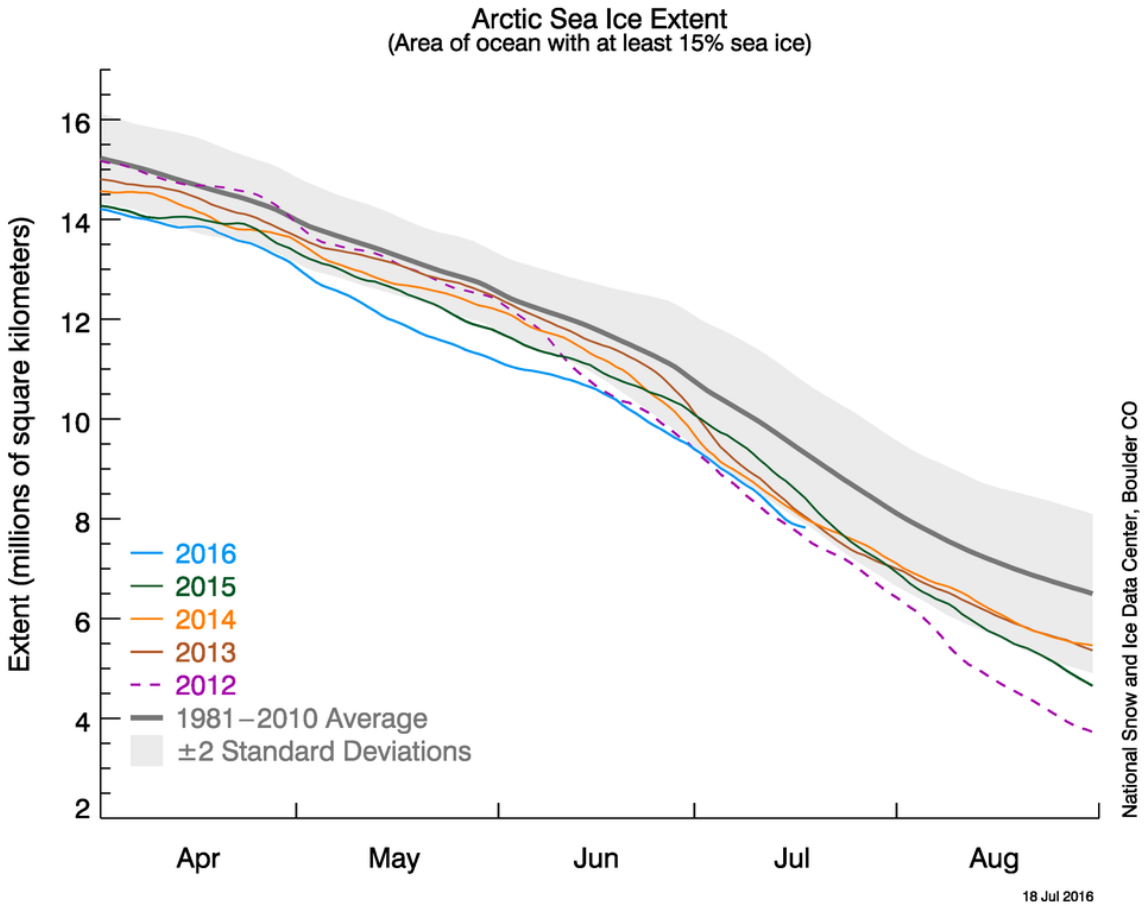
Arctic sea ice extent for July 18, 2016 was 7.82 million square kilometers (3.02 million square miles). The orange line shows the 1981 to 2010 median extent for that day. The black cross indicates the geographic North Pole.



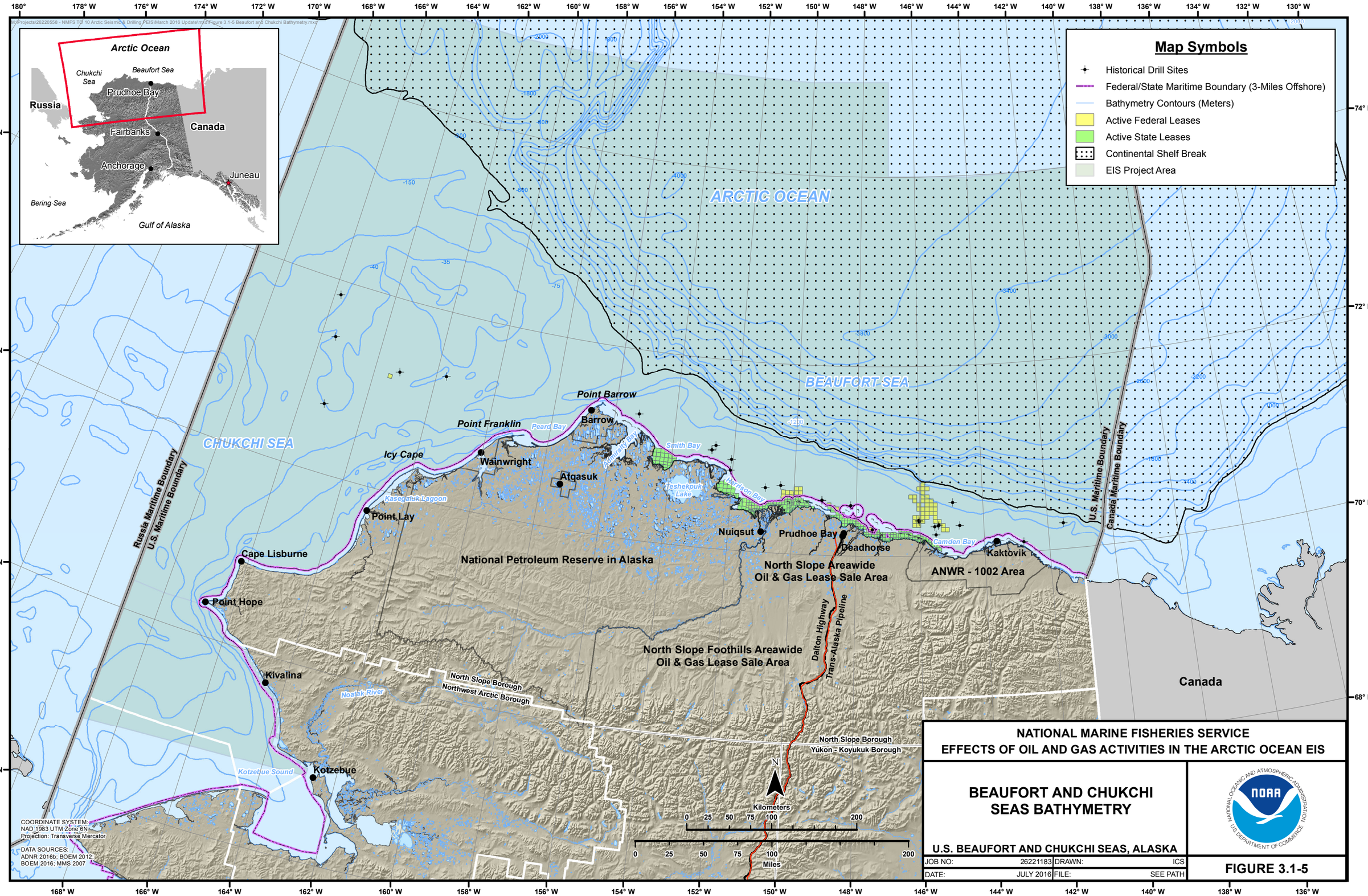
Source: NSIDC, 2016

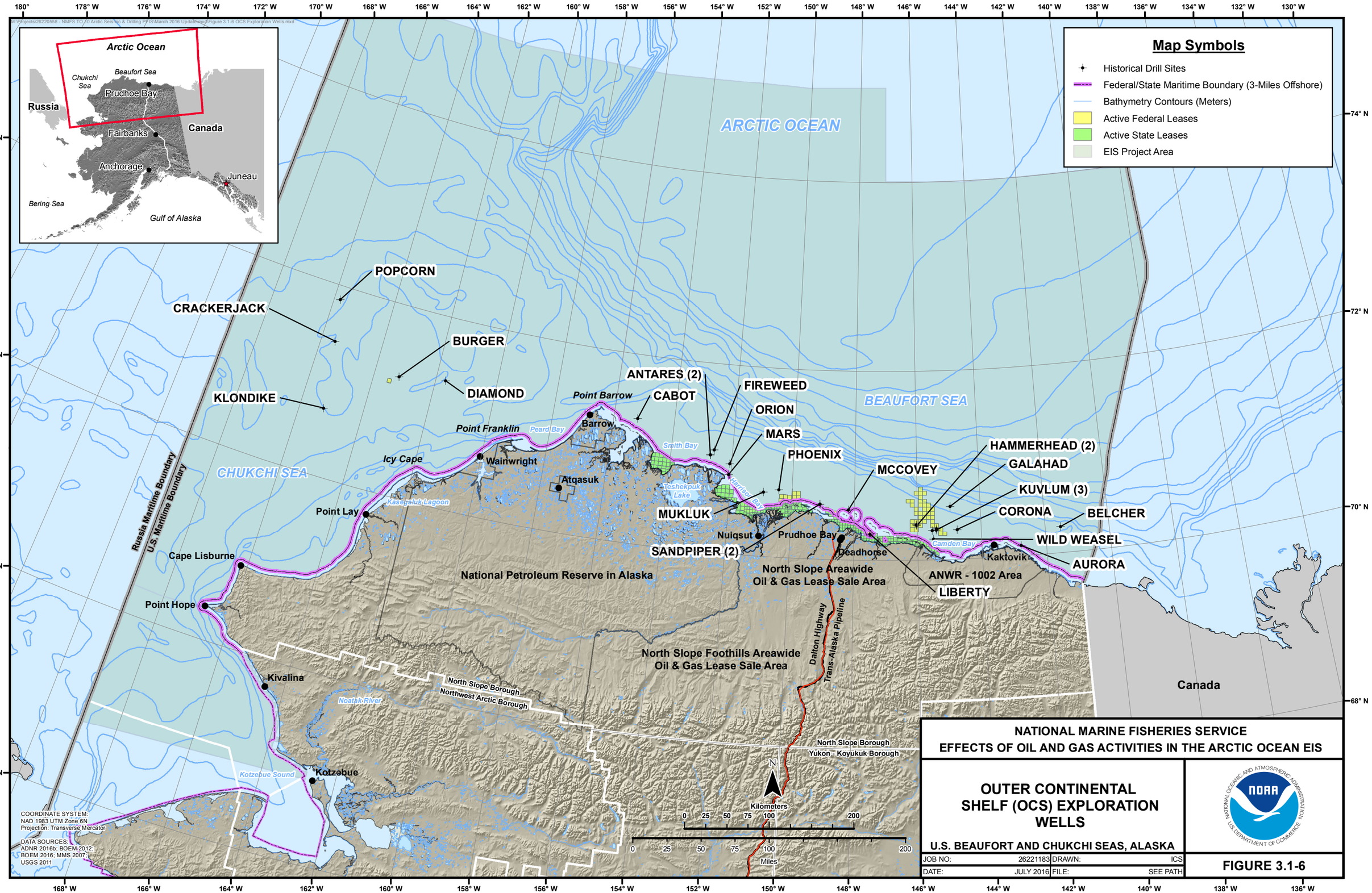
Figure 3.1-4 b) Sea Ice Extent

Figure 3.1-4b) The graph above shows Arctic sea ice extent as of July 18, 2016, along with daily ice extent data for four previous years. 2016 is shown in blue, 2015 in green, 2014 in orange, 2013 in brown, and 2012 in purple. The 1981 to 2010 average is in dark gray. The gray area around the average line shows the two standard deviation range of the data..



Source: NSIDC, 2016


Arctic Ocean
Chukchi Sea
Beaufort Sea
Prudhoe Bay
Russia
Canada
Fairbanks
Anchorage
Juneau
Bering Sea
Gulf of Alaska
Map Symbols
Historical Drill Sites
Federal/State Maritime Boundary (3-Miles Offshore)
Bathymetry Contours (Meters)
Active Federal Leases
Active State Leases
Continental Shelf Break
EIS Project Area
ARCTIC OCEAN
BEAUFORT SEA
CHUKCHI SEA
Point Barrow
Barrow
Point Franklin
Peard Bay
Icy Cape
Wainwright
Atqasuk
Admiralty Bay
Smith Bay
Teshekpuk Lake
Harrison Bay
Kasegaluk Lagoon
Point Lay
Nuiqsut
Prudhoe Bay
Deadhorse
Camden Bay
Kaktovik
Cape Lisburne
Point Hope
National Petroleum Reserve in Alaska
North Slope Areawide Oil & Gas Lease Sale Area
ANWR - 1002 Area
North Slope Foothills Areawide Oil & Gas Lease Sale Area
Dalton Highway
Trans-Alaska Pipeline
Kivalina
Noatak River
North Slope Borough
Northwest Arctic Borough
Yukon - Koyukuk Borough
Kotzebue Sound
Kotzebue
Russia Maritime Boundary
U.S. Maritime Boundary
Canada Maritime Boundary
Canada
Kilometers
Miles
COORDINATE SYSTEM:
NAD 1983 UTM Zone 6N
Projection: Transverse Mercator
DATA SOURCES:
ADNR 2016b; BOEM 2012;
BOEM 2016; MMS 2007
NATIONAL MARINE FISHERIES SERVICE
EFFECTS OF OIL AND GAS ACTIVITIES IN THE ARCTIC OCEAN EIS
BEAUFORT AND CHUKCHI SEAS BATHYMETRY
U.S. BEAUFORT AND CHUKCHI SEAS, ALASKA
JOB NO: 26221183
DRAWN: ICS
DATE: JULY 2016
FILE: SEE PATH
FIGURE 3.1-5


Map Symbols
Historical Drill Sites
Federal/State Maritime Boundary (3-Miles Offshore)
Bathymetry Contours (Meters)
Active Federal Leases
Active State Leases
EIS Project Area
Arctic Ocean
Beaufort Sea
Chukchi Sea
Prudhoe Bay
Russia
Canada
Fairbanks
Anchorage
Juneau
Bering Sea
Gulf of Alaska
ARCTIC OCEAN
BEAUFORT SEA
CHUKCHI SEA
POPCORN
CRACKERJACK
BURGER
DIAMOND
KLONDIKE
ANTARES (2)
CABOT
FIREWEED
ORION
MARS
PHOENIX
MCCOVEY
HAMMERHEAD (2)
GALAHAD
KUVLUM (3)
CORONA
BELCHER
WILD WEASEL
AURORA
MUKLUK
SANDPIPER (2)
LIBERTY
Point Barrow
Barrow
Point Franklin
Peard Bay
Smith Bay
Icy Cape
Wainwright
Atqasuk
Teshekpuk Lake
Harrison Bay
Kasegaluk Lagoon
Point Lay
Nuiqsut
Prudhoe Bay
Deadhorse
Camden Bay
Kaktovik
Cape Lisburne
Point Hope
Kivalina
Noatak River
Kotzebue Sound
Kotzebue
Russia Maritime Boundary
U.S. Maritime Boundary
National Petroleum Reserve in Alaska
North Slope Areawide Oil & Gas Lease Sale Area
ANWR - 1002 Area
North Slope Foothills Areawide Oil & Gas Lease Sale Area
Dalton Highway
Trans-Alaska Pipeline
North Slope Borough
Northwest Arctic Borough
Yukon - Koyukuk Borough
Canada
Kilometers
Miles
COORDINATE SYSTEM:
NAD 1983 UTM Zone 6N
Projection: Transverse Mercator
DATA SOURCES:
ADNR 2016b; BOEM 2012;
BOEM 2016; MMS 2007;
USGS 2011
NATIONAL MARINE FISHERIES SERVICE
EFFECTS OF OIL AND GAS ACTIVITIES IN THE ARCTIC OCEAN EIS
OUTER CONTINENTAL SHELF (OCS) EXPLORATION WELLS
U.S. BEAUFORT AND CHUKCHI SEAS, ALASKA
JOB NO: 26221183
DRAWN: ICS
DATE: JULY 2016
FILE: SEE PATH
FIGURE 3.1-6

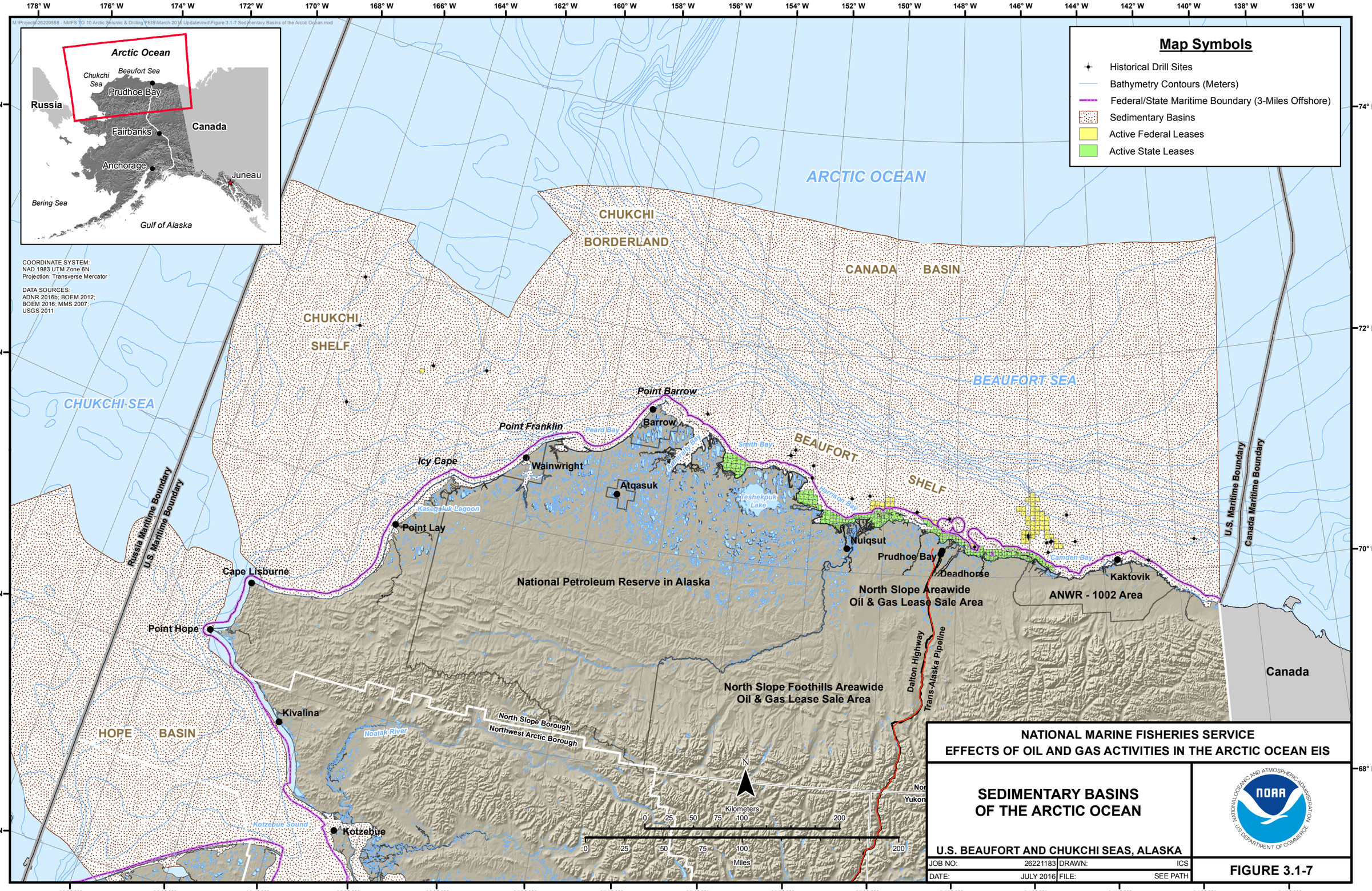

M:\Projects\26220558 - NMFS TO 10 Arctic Seismic & Drilling PEIS\March 2016 Update\mxd\Figure 3.1-7 Sedimentary Basins of the Arctic Ocean.mxd
Arctic Ocean
Chukchi Sea
Beaufort Sea
Prudhoe Bay
Russia
Canada
Fairbanks
Anchorage
Juneau
Bering Sea
Gulf of Alaska
COORDINATE SYSTEM:
NAD 1983 UTM Zone 6N
Projection: Transverse Mercator
DATA SOURCES:
ADNR 2016b; BOEM 2012;
BOEM 2016; MMS 2007;
USGS 2011
Map Symbols
Historical Drill Sites
Bathymetry Contours (Meters)
Federal/State Maritime Boundary (3-Miles Offshore)
Sedimentary Basins
Active Federal Leases
Active State Leases
ARCTIC OCEAN
CHUKCHI BORDERLAND
CANADA BASIN
CHUKCHI SHELF
BEAUFORT SEA
CHUKCHI SEA
Point Barrow
Barrow
Point Franklin
Peard Bay
Smith Bay
BEAUFORT SHELF
Icy Cape
Wainwright
Atqasuk
Teshekpuk Lake
Kasegaluk Lagoon
Point Lay
Nuiqsut
Prudhoe Bay
Deadhorse
Camden Bay
Kaktovik
Cape Lisburne
Point Hope
National Petroleum Reserve in Alaska
North Slope Areawide Oil & Gas Lease Sale Area
ANWR - 1002 Area
Canada
Russia Maritime Boundary
U.S. Maritime Boundary
U.S. Maritime Boundary
Canada Maritime Boundary
Dalton Highway
Trans-Alaska Pipeline
North Slope Foothills Areawide Oil & Gas Lease Sale Area
Kivalina
HOPE BASIN
Noatak River
North Slope Borough
Northwest Arctic Borough
Kotzebue Sound
Kotzebue
N
Kilometers
0 25 50 75 100 200
0 25 50 75 100 200
Miles
178° W 176° W 174° W 172° W 170° W 168° W 166° W 164° W 162° W 160° W 158° W 156° W 154° W 152° W 150° W 148° W 146° W 144° W 142° W 140° W 138° W 136° W
72° N 70° N 68° N 66° N
74° N 72° N 70° N 68° N
168° W 166° W 164° W 162° W 160° W 158° W 156° W 154° W 152° W 150° W 148° W 146° W 144° W 142° W 140° W
NATIONAL MARINE FISHERIES SERVICE
EFFECTS OF OIL AND GAS ACTIVITIES IN THE ARCTIC OCEAN EIS
SEDIMENTARY BASINS OF THE ARCTIC OCEAN
U.S. BEAUFORT AND CHUKCHI SEAS, ALASKA
JOB NO: 26221183
DRAWN: ICS
DATE: JULY 2016
FILE: SEE PATH
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
FIGURE 3.1-7

Figure 3.1-8 Sound Level Metrics.

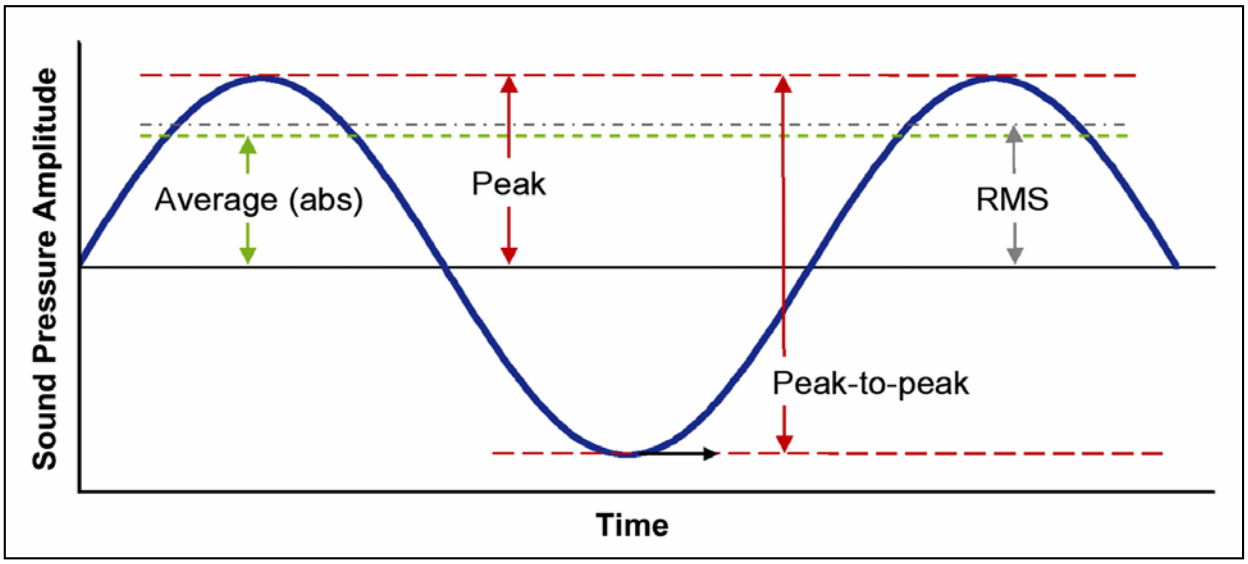


Figure 3.1-9a An audiogram of human hearing.
Source: Discovery of Sound in the Sea 2011

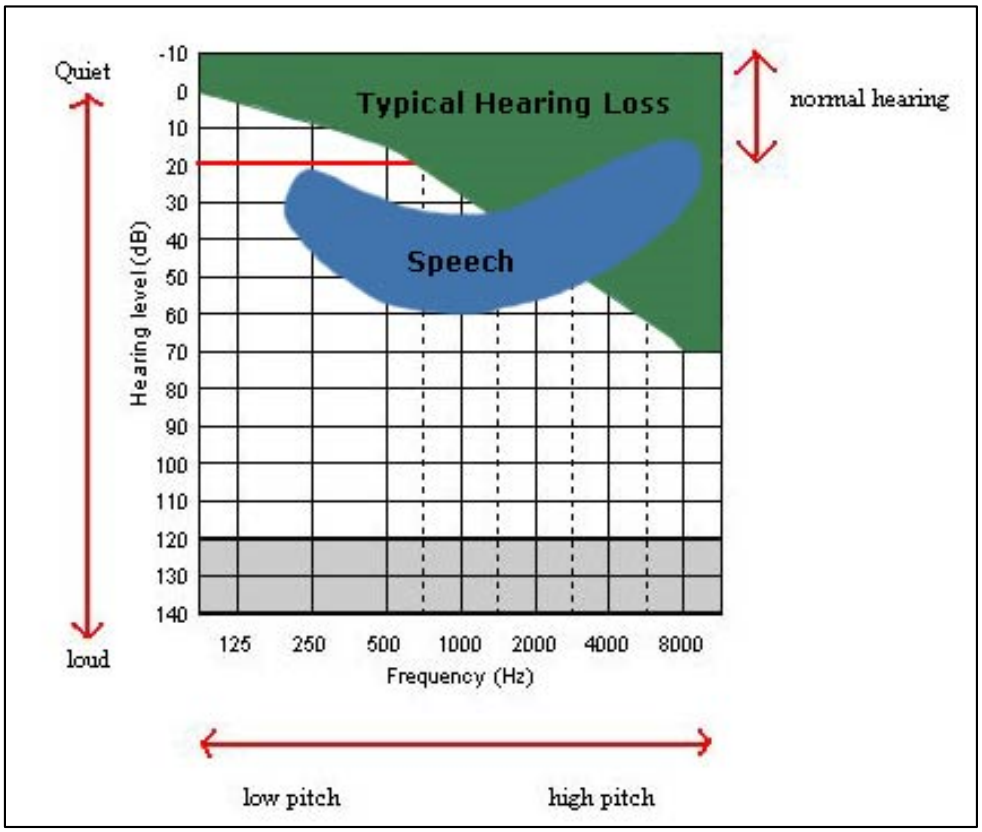


Figure 3.1-9b Graphic showing A-weighting function for human hearing.
Source: Harris 1998

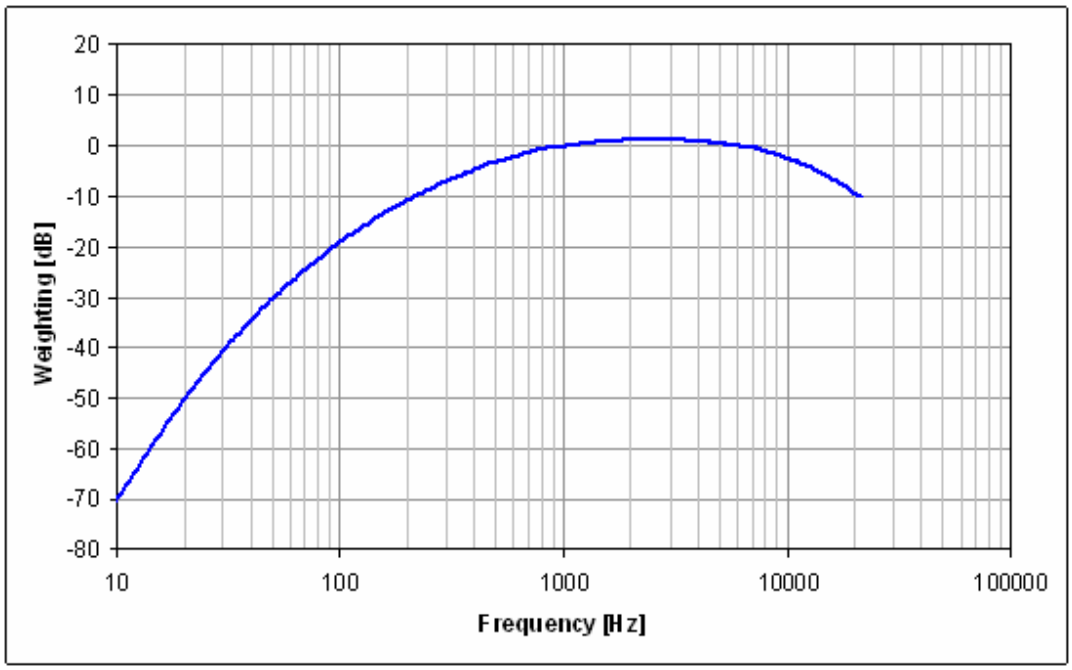


Figure 3.1-10 Hearing curves for some marine mammals in water and a typical human in air.

Source: Discovery of Sound in the Sea 2011

There are two sets of y-axes (vertical) because different reference pressures are used to measure sound in water (re 1 µPa; left axis) vs in air (re 20 µPa; right axis). Notice that the decibel values differ by 61.5 dB for the same value of intensity (watts/ m 2). The x-axis (horizontal) is the frequency of a sound on a logarithmic scale.

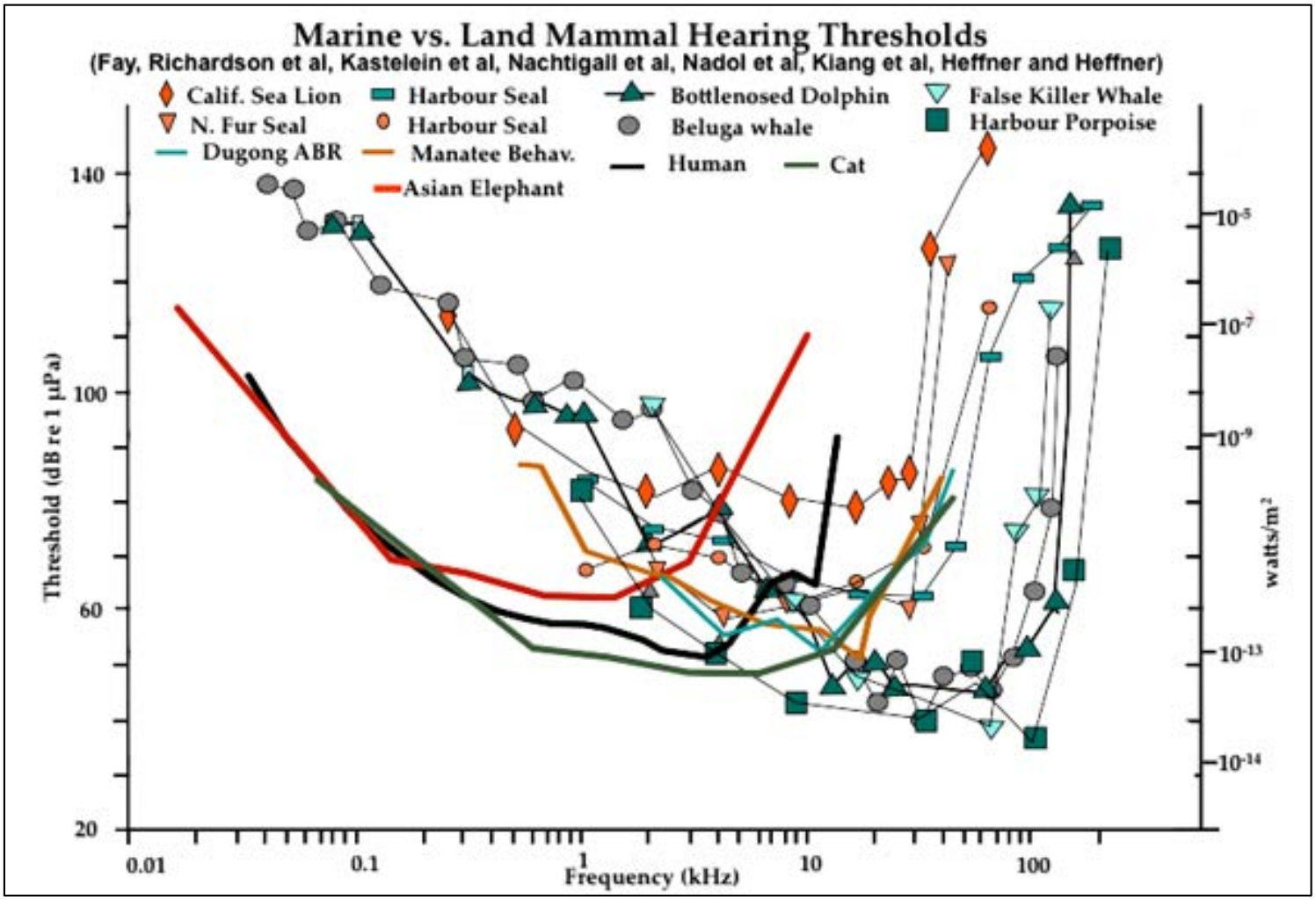


Figure 3.1-11 Graphic showing M-weighting functions for marine mammal hearing for (A) low, mid, and high frequency cetaceans, and (B) for pinnipeds in water and air.

Source: Southall et al. (2007)

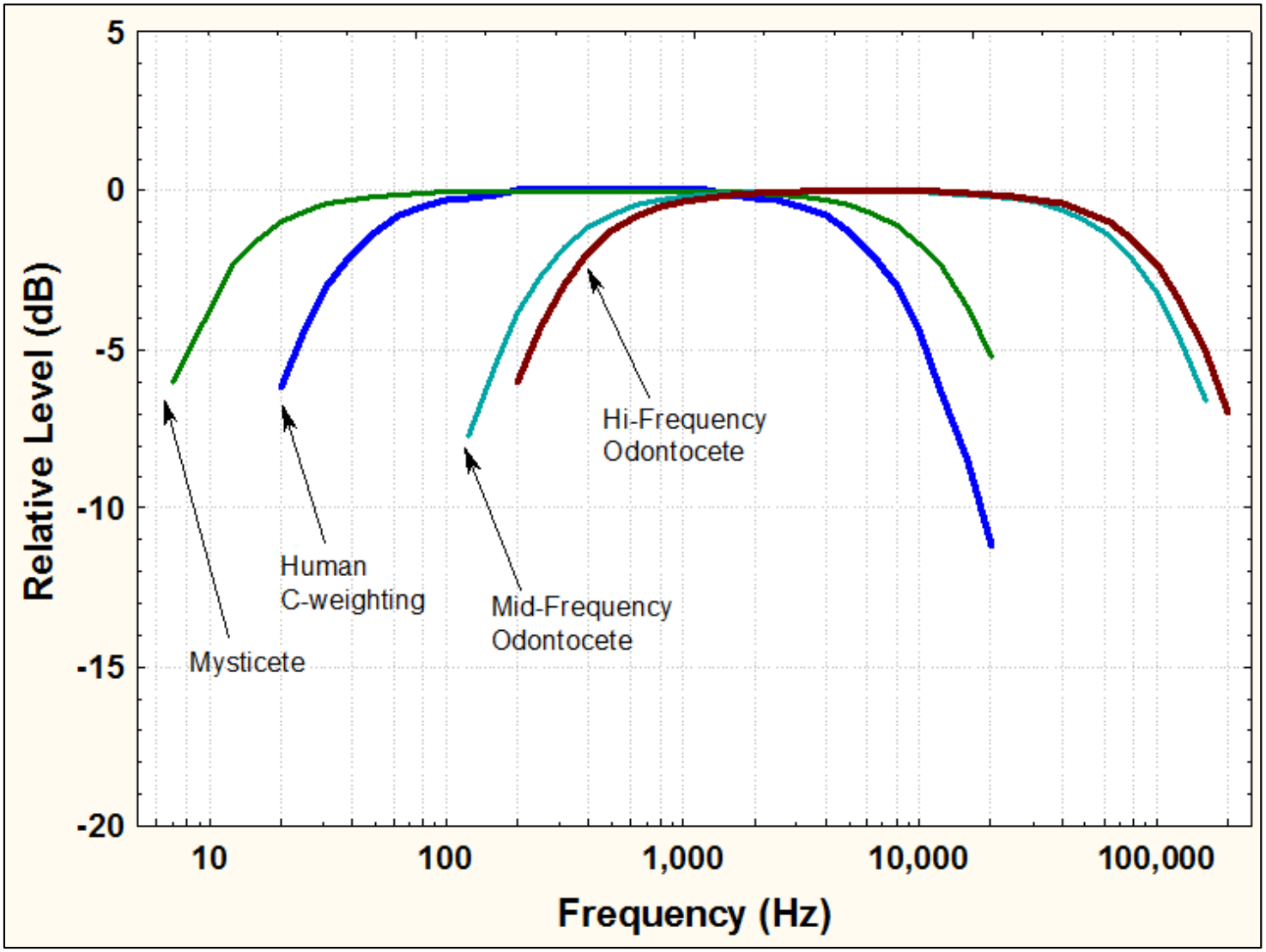


Figure 3.1-12 Prevailing underwater sound levels.

Source: NRC 2003a

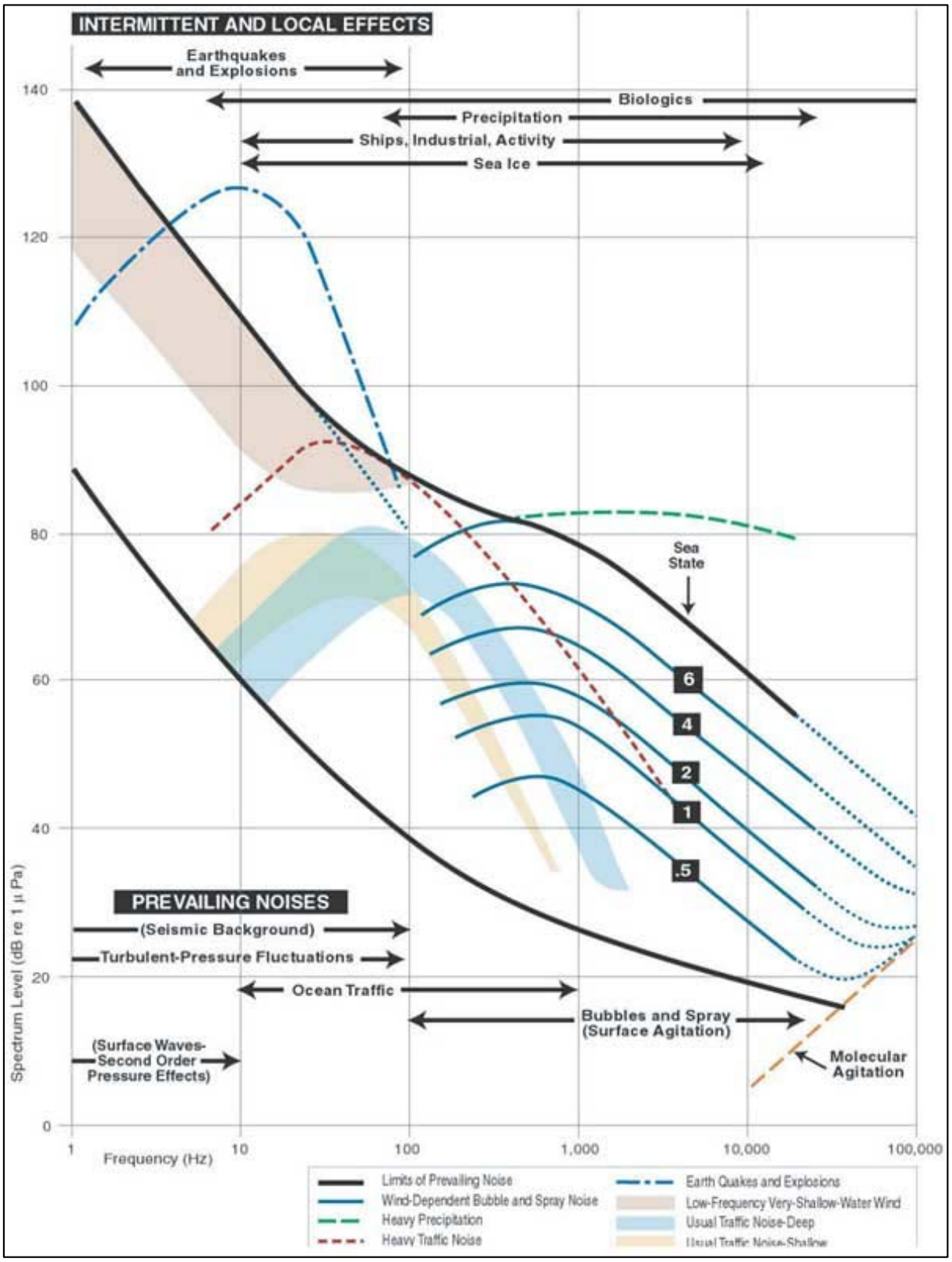
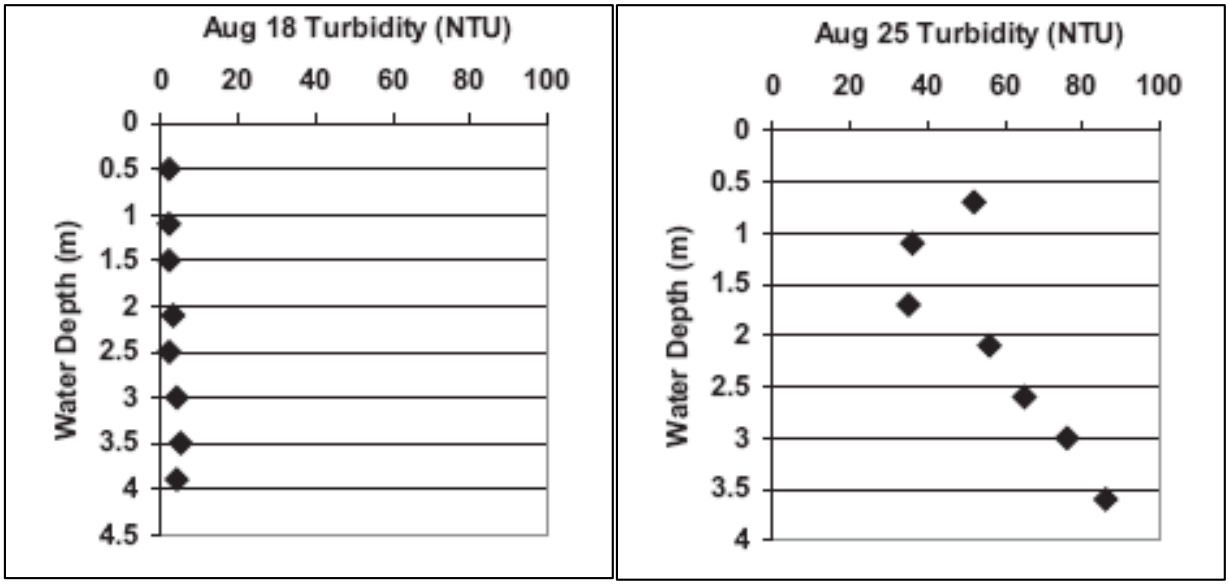


Figure 3.1-13 Depth profiles of natural turbidity levels measured in the nearshore Alaskan Beaufort Sea in 1999.

Source: Boehm 2001

Profile (a) shows turbidity levels before a storm event; profile (b) shows turbidity levels immediately following a storm event.



(a) (b)

Figure 3.1-14 Levels of Ecological Organization.

The dose-response model traditionally used in environmental impact assessment only considers the effects of stressors on individuals or populations. However, the value of ecosystem goods and services is usually derived from interactions among physical, chemical, and biological ecosystem components.

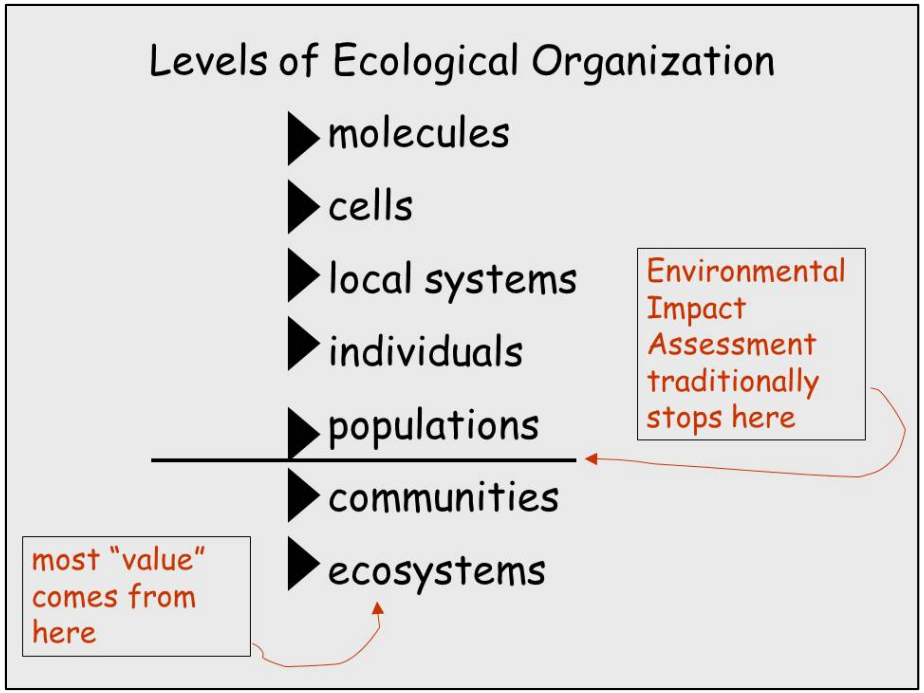
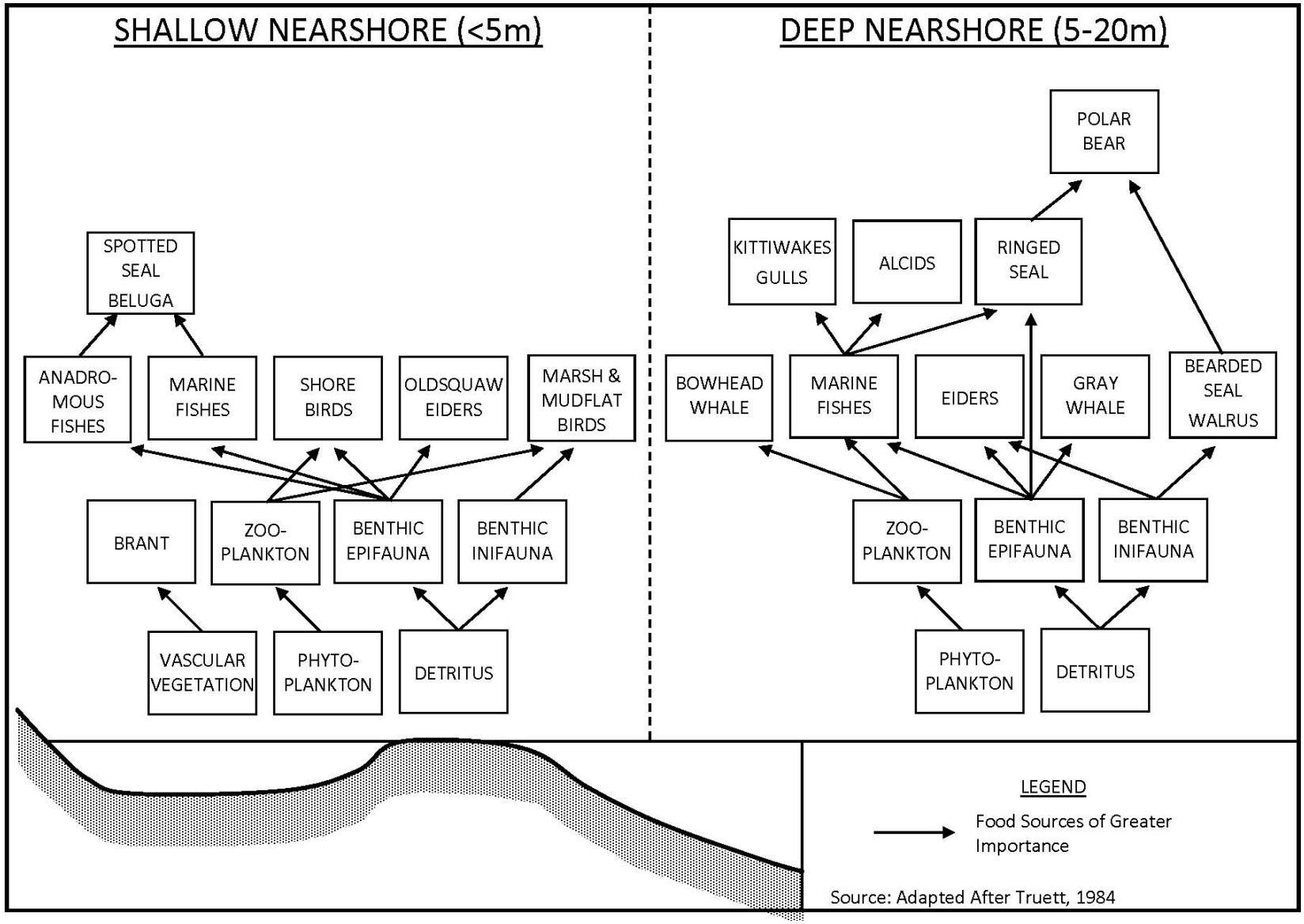
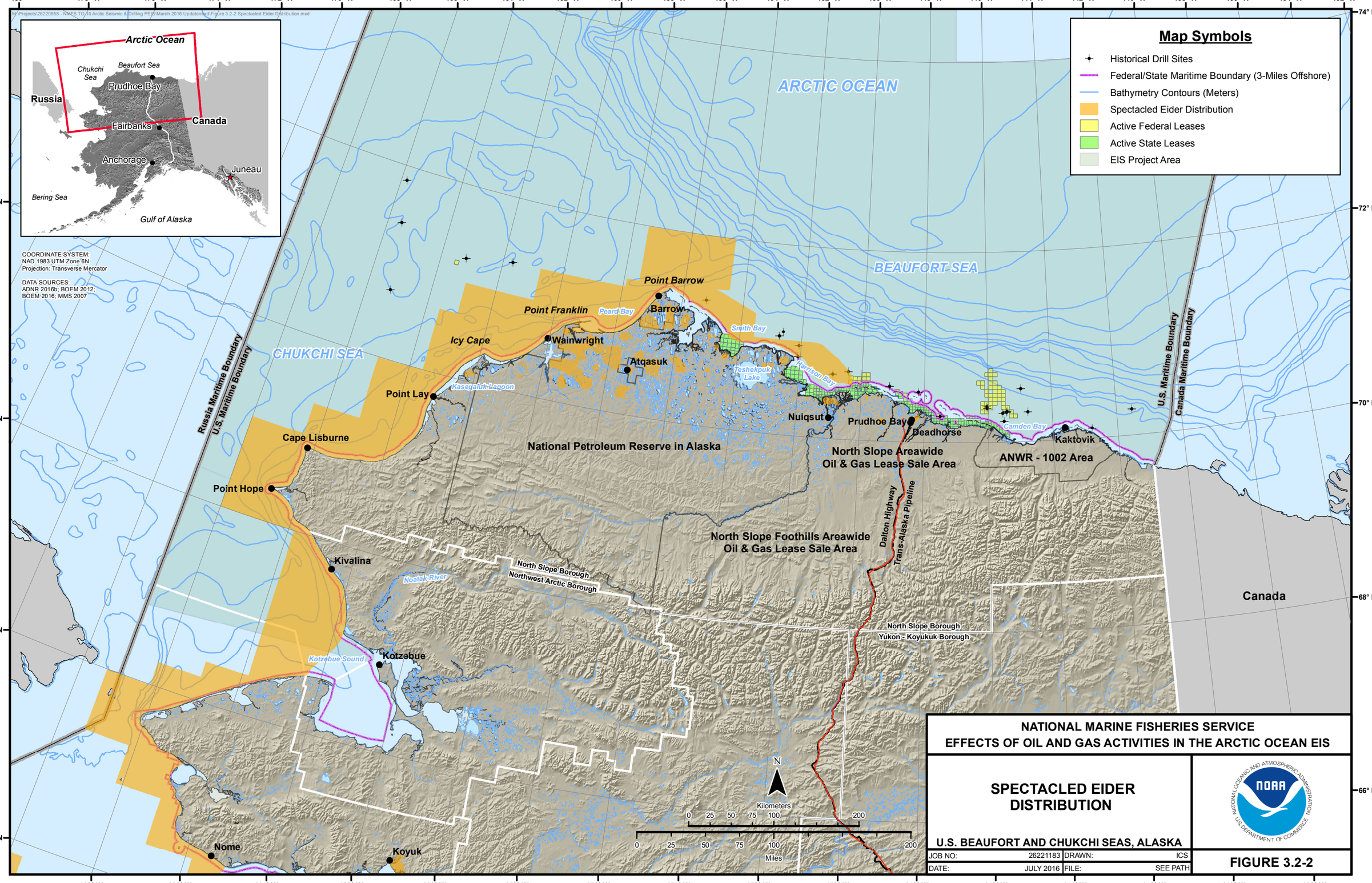


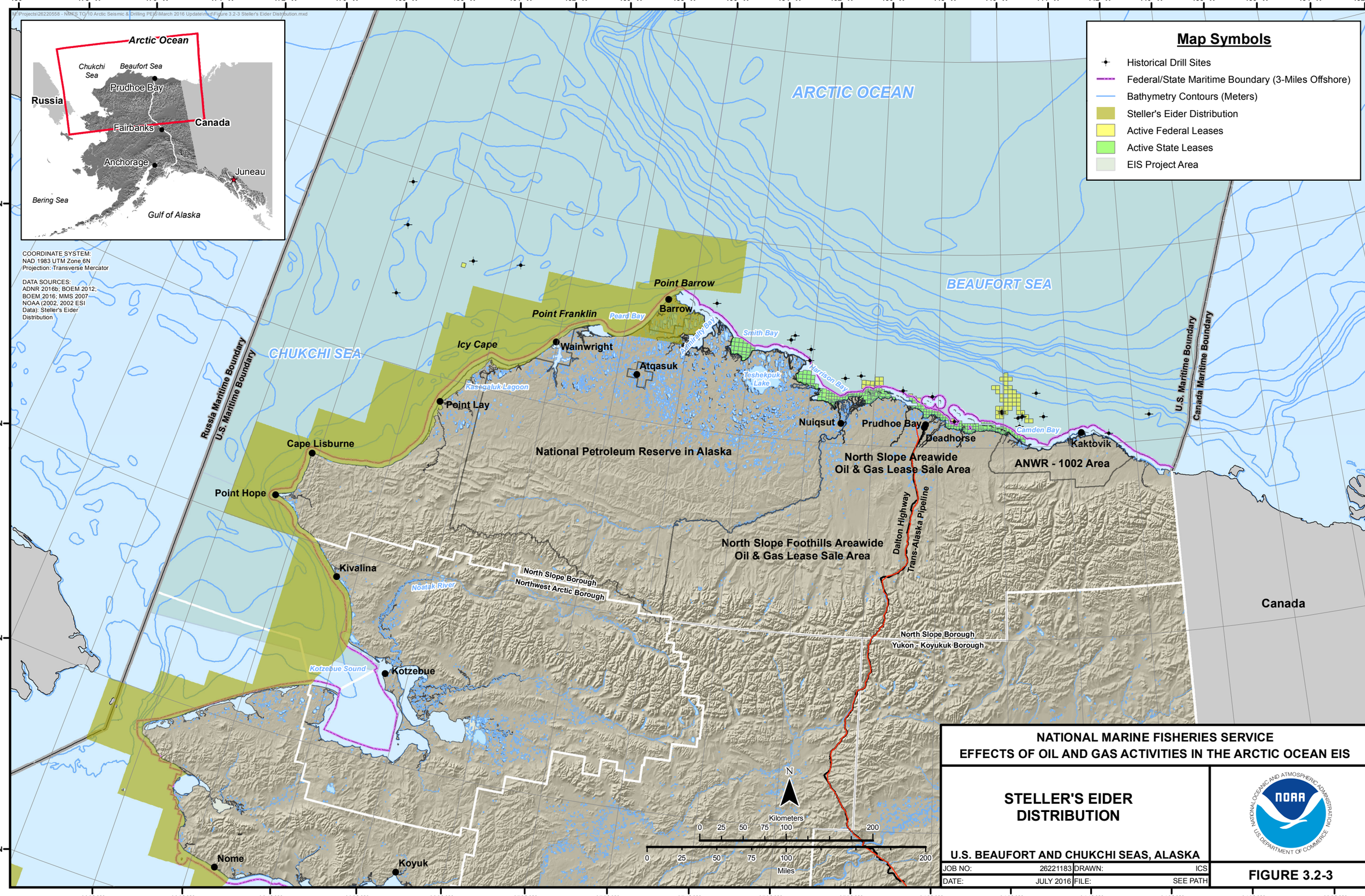
Figure 3.2-1 Simplified Food Web of the Arctic Ocean Ecosystem.



M:\Projects\26220558 - NMFS TO 16 Arctic Seismic & Drilling PEIS\March 2016 Updates\Figure 3.2-2 Spectacled Eider Distribution.mxd



M:\Projects\26220558 - NMFS TO 10 Arctic Seismic & Drilling PEIS\March 2016 Updates\Figure 3.2-3 Steller's Eider Distribution.mxd



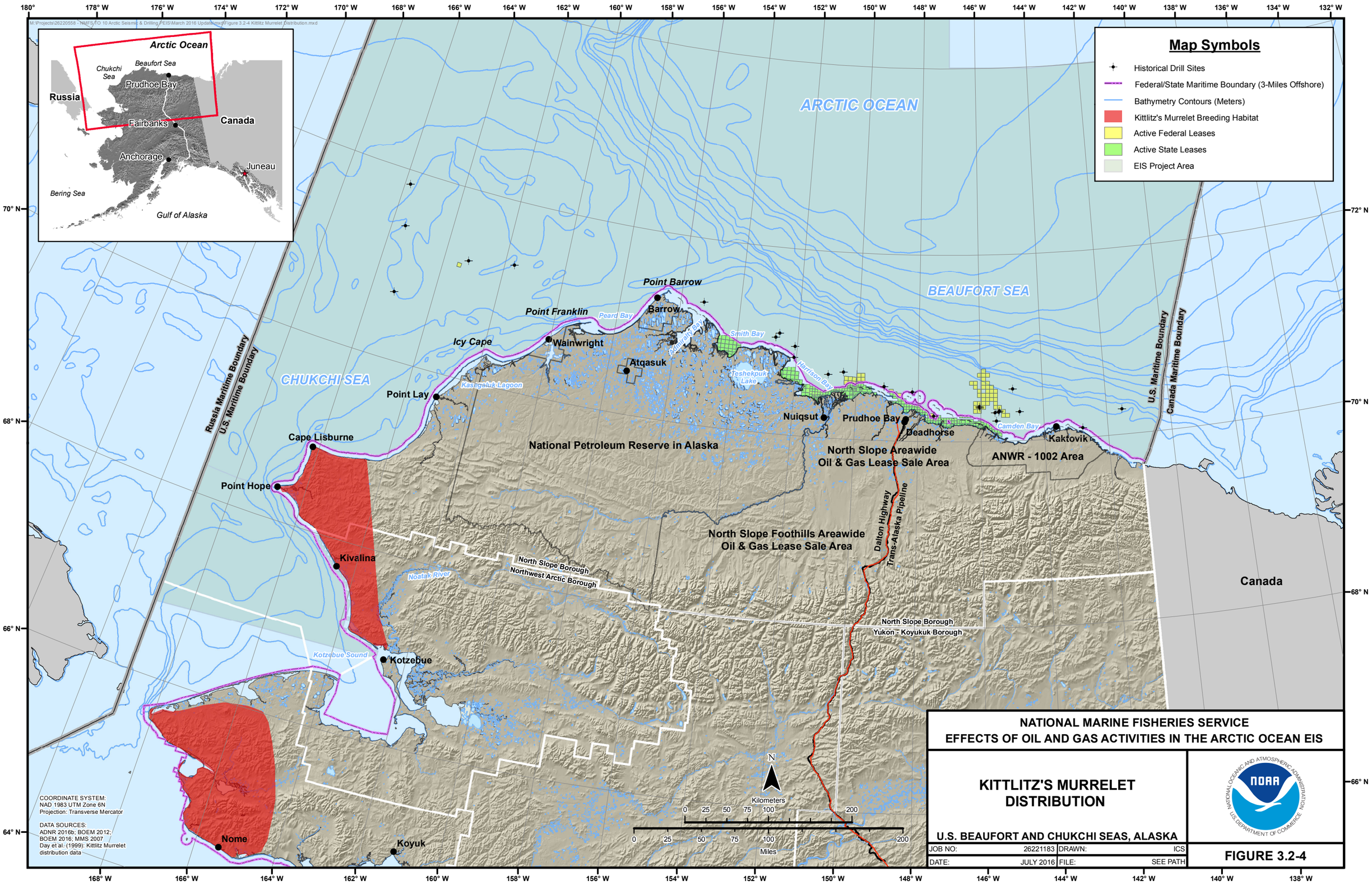
NATIONAL MARINE FISHERIES SERVICE
EFFECTS OF OIL AND GAS ACTIVITIES IN THE ARCTIC OCEAN EIS

STELLER'S EIDER DISTRIBUTION

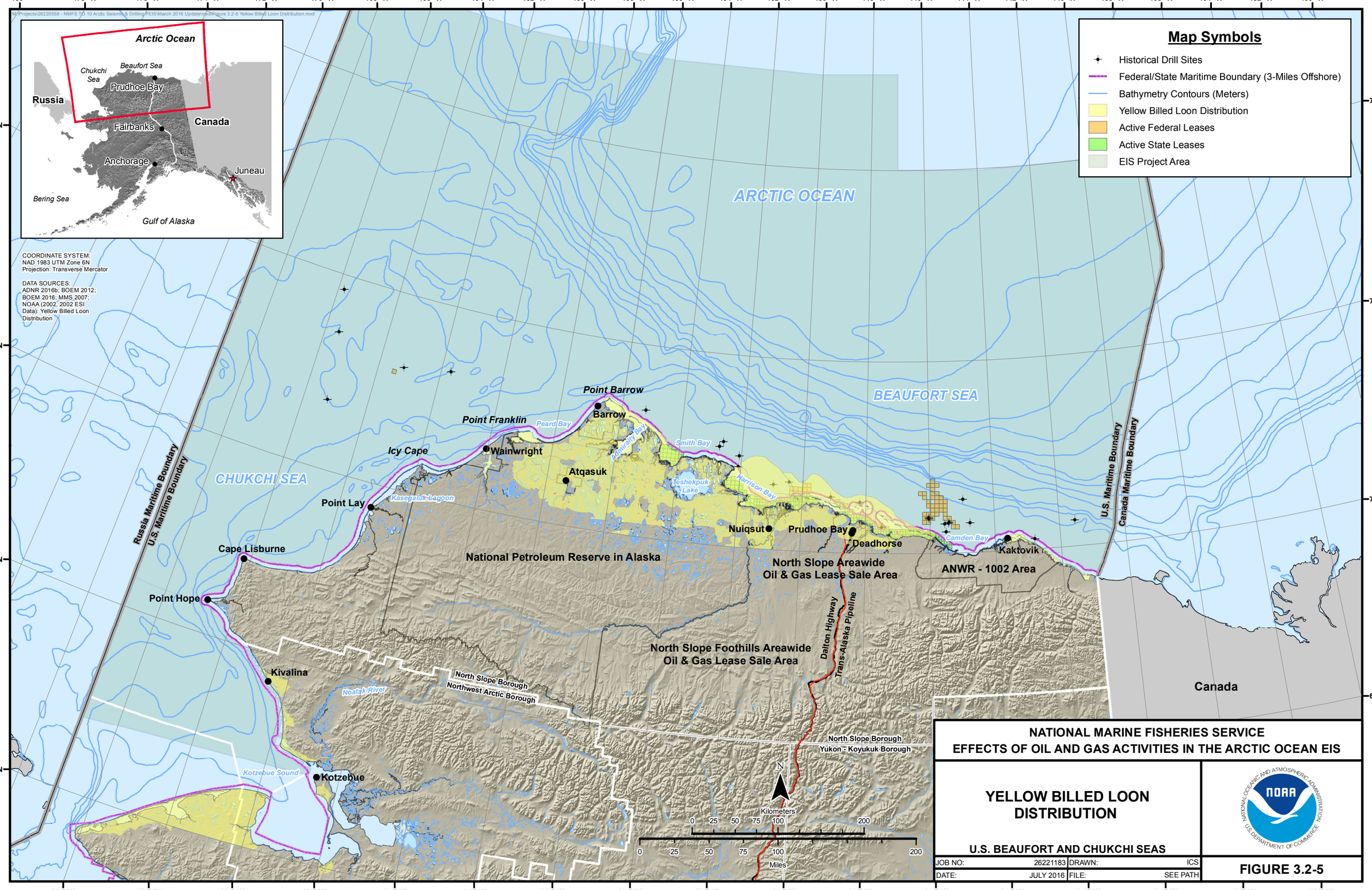
U.S. BEAUFORT AND CHUKCHI SEAS, ALASKA

JOB NO:	26221183	DRAWN:	ICS
DATE:	JULY 2016	FILE:	SEE PATH

FIGURE 3.2-3


Map Symbols
Historical Drill Sites
Federal/State Maritime Boundary (3-Miles Offshore)
Bathymetry Contours (Meters)
Kittlitz's Murrelet Breeding Habitat
Active Federal Leases
Active State Leases
EIS Project Area
Arctic Ocean
Beaufort Sea
Chukchi Sea
Prudhoe Bay
Russia
Canada
Fairbanks
Anchorage
Juneau
Bering Sea
Gulf of Alaska
ARCTIC OCEAN
BEAUFORT SEA
CHUKCHI SEA
Point Barrow
Barrow
Point Franklin
Peard Bay
Smith Bay
Icy Cape
Wainwright
Atqasuk
Teshekpuk Lake
Harrison Bay
Kasegaluk Lagoon
Point Lay
Nuiqsut
Prudhoe Bay
Deadhorse
Camden Bay
Kaktovik
Cape Lisburne
Point Hope
Kivalina
Noatak River
Kotzebue Sound
Kotzebue
Nome
Koyuk
National Petroleum Reserve in Alaska
North Slope Areawide
Oil & Gas Lease Sale Area
ANWR - 1002 Area
North Slope Foothills Areawide
Oil & Gas Lease Sale Area
Dalton Highway
Trans-Alaska Pipeline
North Slope Borough
Northwest Arctic Borough
North Slope Borough
Yukon - Koyukuk Borough
Russia Maritime Boundary
U.S. Maritime Boundary
U.S. Maritime Boundary
Canada Maritime Boundary
Canada
N
Kilometers
0 25 50 75 100 200
Miles
0 25 50 75 100 200
COORDINATE SYSTEM:
NAD 1983 UTM Zone 6N
Projection: Transverse Mercator
DATA SOURCES:
ADNR 2016b; BOEM 2012;
BOEM 2016; MMS 2007
Day et al. (1999): Kittlitz Murrelet
distribution data
NATIONAL MARINE FISHERIES SERVICE
EFFECTS OF OIL AND GAS ACTIVITIES IN THE ARCTIC OCEAN EIS
KITTLITZ'S MURRELET
DISTRIBUTION
U.S. BEAUFORT AND CHUKCHI SEAS, ALASKA
JOB NO: 26221183
DRAWN: ICS
DATE: JULY 2016
FILE: SEE PATH
FIGURE 3.2-4

M:\Projects\26220558 - NMFS TO 10 Arctic Seismic & Drilling EIS\March 2016 Update\mxd\Figure 3.2-5 Yellow Billed Loon Distribution.mxd



NATIONAL MARINE FISHERIES SERVICE
EFFECTS OF OIL AND GAS ACTIVITIES IN THE ARCTIC OCEAN EIS

YELLOW BILLED LOON DISTRIBUTION

U.S. BEAUFORT AND CHUKCHI SEAS

JOB NO:	26221183	DRAWN:	ICS
DATE:	JULY 2016	FILE:	SEE PATH

FIGURE 3.2-5