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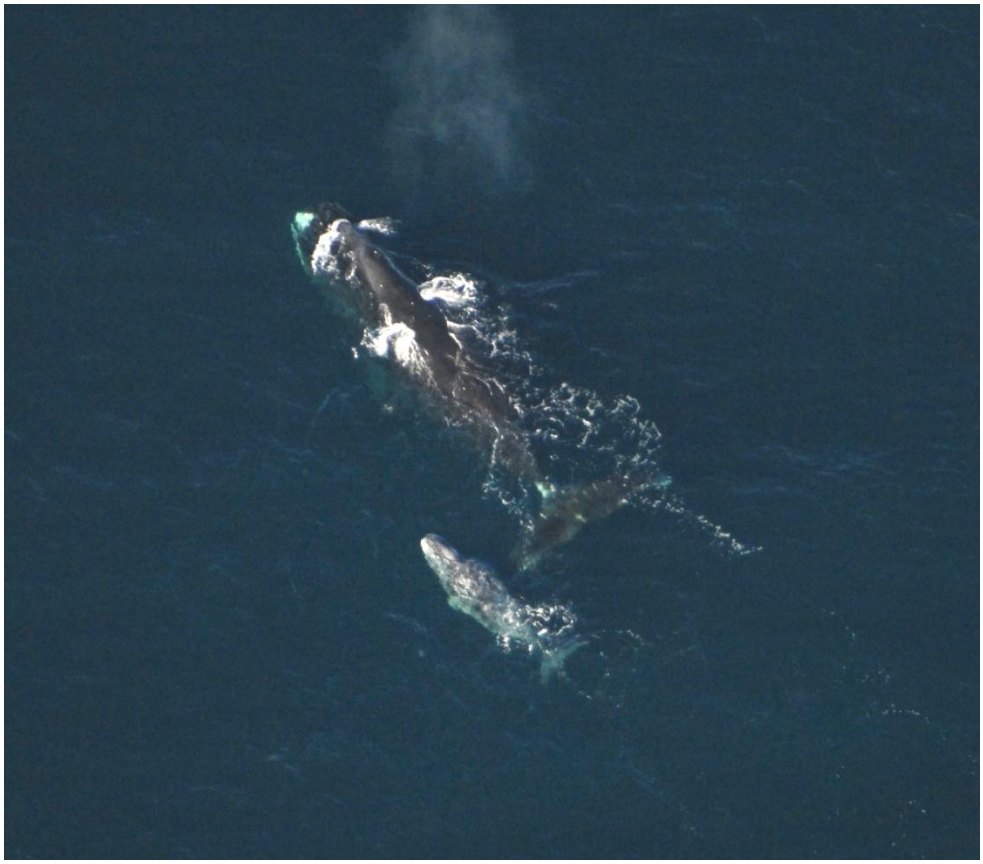
Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 2010



Annual Report

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Bowhead Whale Cow-Calf Pair
Beaufort Sea, Alaska
September 2010
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Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 2010

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ABSTRACT

This report describes field activities and data analyses for aerial surveys of bowhead whales (*Balaena mysticetus*) conducted during fall 2010 (1 September – 15 October) in the Beaufort Sea, between 140°W and 157°W, south of 72°N.

During September and October 2010, ice cover was extremely light. The study area was completely ice-free east of 147°W; ice coverage was limited to the western-central nearshore region of the study area. By the middle of September, broken floe ice remained in and north of Harrison Bay only. Freeze-up began in the nearshore areas (between barrier islands and shore, and in shallow areas seaward of the barrier islands) by early October, and most of the study area had 10-20% new ice by mid-October when the field season ended.

A total of 21 survey flights were conducted. There were 126 sightings of 178 bowhead whales observed during all (transect, search and circling) survey effort. Additionally, 2 gray whales (*Eschrichtius robustus*), 56 belugas (*Delphinapterus leucas*), 1 walrus (*Odobenus rosmarus*), 7 bearded seals (*Erignathus barbatus*), 278 unidentified pinnipeds, and 53 polar bears (*Ursus maritimus*) were observed during all survey effort. Total flight time was 96 hours, which included 39 hours of transect survey effort.

Sighting rates (number of whales per km surveyed) of bowhead whales on transect per survey block were highest in nearshore survey blocks in the eastern part of the study area (between 140°W and 143°W) and north of Deadhorse (146°W to 150°W), and the survey block northeast of Pt. Barrow (154°W to 157°W). Sighting rates of belugas on transect per survey block were highest in an offshore survey block north of Harrison Bay (150°W to 154°W). Sighting rate per depth zone for bowhead whales on transect was highest in the shallowest depth zone (≤ 20 m) in the western (154°-157°W) Alaskan Beaufort Sea and in the 21-50 m depth zone in the central-eastern (140°-154°W) Alaskan Beaufort Sea. Sighting rate per depth zone for belugas on transect was highest in the 201-2,000 m depth zone in the central-eastern Alaskan Beaufort Sea; belugas were not seen west of 154°W. Large groups of feeding bowhead whales were not seen northeast of Pt. Barrow (154°W to 157°W), unlike in previous years.

Median distance from on transect bowhead whale sightings to a normalized shoreline was 16.2 km (ranged from 1 to 29 km) in the East Region (140°-148°W), and 21.6 km (ranged from 2 to 79 km) in the West Region (148°-156°W). Median depth at on-transect sightings was 30 m (ranged from 13 to 49 m) in the East Region, and 20 m (ranged from 10 to 189 m) in the West Region. Compared to previous years with light ice coverage (i.e., 1982, 1986, 1987, 1989, 1990, 1993-2009), sightings were significantly closer to shore and in shallower water in the East Region.

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CONTENTS

Page

Abstract v
Introduction 1
Methods and Materials 3
Study Area 3
Equipment 5
Aerial Survey Design 6
Survey Flight Procedures 7
Data Entry 7
General Data Analyses 8
Analysis of the Bowhead Whale Migration Corridor 11
Sighting Rate and Relative Occurrence Analyses 14
Results 15
Environmental Conditions 15
Survey Effort 15
Bowhead Whale Observations 21
Sighting Summary 21
Sighting Rates 21
Habitat Associations 29
Behaviors 29
Distance from Shore 33
Depth at Sighting 38
Distribution of Bowhead Whales, 2010, Relative to Bowhead Whale Distribution in Previous Years with Light Ice Coverage 38
Other Marine Mammal Observations 38
Accomplishments 42
Discussion 47
Conclusions 47
Management Use of Real-Time Field Information 49
Management Use of Interannual Monitoring 51
Acknowledgments 52
Literature Cited 53

LIST OF FIGURES

Figure 1. Study area showing Survey Blocks 4
Figure 2. East and West Regions showing the normalized shoreline and selected IBCAO isobaths 13
Figure 3. Combined flight tracks, all effort, fall 2010 17
Figure 4. Combined flight tracks, all effort, 1-15 September 2010 18
Figure 5. Combined flight tracks, all effort, 16-30 September 2010 19
Figure 6. Combined flight tracks, all effort, 1-15 October 2010 20
Figure 7. Bowhead whale sightings, all effort, fall 2010 23

Page

Figure 8. Bowhead whale sightings, all effort, 1-15 September 2010 24
Figure 9. Bowhead whale sightings, all effort, 16-30 September 2010 25
Figure 10. Bowhead whale sightings, all effort, 1-15 October 2010 26
Figure 11. Sighting rates of bowhead whales, fall 2010 (bowhead whale sightings on transect/ km of transect surveyed). 27
Figure 12. Sighting rates of milling and feeding bowhead whales, fall 2010 (bowhead whale sightings on transect/km of transect surveyed) 31
Figure 13. Bowhead whale sightings in Block 12, all effort, on 20 September, 1 October and 10 October 2010 32
Figure 14. Wind speeds measured at Barrow, Alaska, prior to 20 September, 1 October and 10 October 2010 33
Figure 15. Bowhead whale sightings on transect, fall 2010, showing mean distance from the normalized shoreline 36
Figure 16. Bowhead whale sightings on transect excluding feeding, milling and resting whales, fall 2010, showing mean distance from the normalized shoreline 37
Figure 17. Gray whale sightings, all effort, fall 2010 39
Figure 18. Beluga sightings, all effort, fall 2010 40
Figure 19. Number of belugas and annual effort (hr), total and transect only, 1982-2010 43
Figure 20. Bearded seal sightings, all effort, fall 2010 44
Figure 21. Unidentified pinniped sightings, all effort, fall 2010 45
Figure 22. Polar bear sightings, all effort, fall 2010 46
Figure 23. Bowhead whale sightings on transect in years with light ice coverage, 1982-2010 48
Figure 24. Beluga sightings on transect in years with light ice coverage, 1982-2010 50

LIST OF TABLES

Table 1. Operational definitions of observed whale behaviors 9
Table 2. Aerial survey effort in the Beaufort Sea, 1 September-15 October 2010, by survey flight 16
Table 3. Summary of marine mammal sightings (number of sightings/number of individuals) during all effort, 1 September-15 October 2010, by survey flight 22
Table 4. Effort (total and transect only), bowhead whale sightings (number of sightings/number of individuals), and bowhead whale sighting rate (WPUE = transect whales per transect km surveyed) per Survey Block, fall 2010 28
Table 5. Effort (transect only), bowhead whale sightings (number of sightings/number of individuals) and sighting rate (WPUE = transect whales per transect km surveyed) per depth zone, western (west of 154°W) and central-eastern (east of 154°W) Alaskan Beaufort Sea, fall 2010 28
Table 6. Semimonthly summary of bowhead whales (number of sightings/number of individuals) observed during all effort, by percent ice cover present at sighting location, fall 2010 29
Table 7. Semimonthly summary of bowhead whales (number of sightings/ number of individuals) observed during all effort, by behavioral category, fall 2010 30

Page

Table 8. Central-tendency statistics for distance from shore (km) and depth (m) at bowhead whale transect sightings (September-October), by year and region, 1982-2010 34
Table 9. Effort, beluga sightings (number of sightings/number of individuals) and sighting rate (WPUE = transect whales per transect km surveyed) per Survey Block, fall 2010 41
Table 10. Effort, beluga sightings (number of sightings/number of individuals) and sighting rate (WPUE = transect whales per transect km surveyed) per depth zone, western (west of 154°W) and central-eastern (east of 154°W) Alaskan Beaufort Sea, fall 2010..... 42

LIST OF APPENDICES

Appendix A: Fall 2010 Ice Concentration Maps 59
Appendix B: Fall 2010 Bowhead Whale Sighting Data 69
Appendix C: Fall 2010 Daily Flight Summaries 75
Appendix D: Glossary of Abbreviations, Acronyms, and Initialisms 119

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INTRODUCTION

In 1953, the Outer Continental Shelf Lands Act (OCSLA) (43 USC 1331-1356) charged the U.S. Secretary of the Interior with the responsibility for administering minerals exploration and development of the Outer Continental Shelf (OCS). The Act empowered the Secretary to formulate regulations so that its provisions might be met. The OCSLA Amendments of 1978 (43 USC 1802) established a policy for the management of oil and natural gas in the OCS and for protection of the marine and coastal environments. The amended OCSLA states that the Secretary of the Interior shall conduct studies in areas or regions of sales to ascertain the "environmental impacts on the marine and coastal environments of the outer Continental Shelf and the coastal areas which may be affected by oil and gas development" (43 USC 1346).

Subsequent to the passage of the OCSLA, the Secretary of the Interior designated the Bureau of Land Management (BLM) as the administrative agency responsible for leasing submerged federal lands, and the Conservation Division of the U.S. Geological Survey for classification and evaluation of submerged federal lands and regulation of exploration and production. In 1982, the U.S. Minerals Management Service (MMS) assumed these responsibilities.

To provide information used in environmental impact statements and environmental assessments under the National Environmental Policy Act (NEPA) of 1969 (42 USC 4321-4347), and to assure protection of marine mammals under the Marine Mammal Protection Act (MMPA) of 1972 (16 USC 1361-1407) and the Endangered Species Act (ESA) of 1973 (16 USC 1531-1543), the BLM (and, later, MMS) funded numerous studies involving acquisition and analysis of marine mammal and other environmental data.

In June 1978, the BLM entered into an Endangered Species Act Section 7 consultation with the National Marine Fisheries Service (NMFS). The purpose of the consultation was to determine the likely effects of the proposed Beaufort Sea Oil and Gas Lease Sale on endangered bowhead (*Balaena mysticetus*) and gray whales (*Eschrichtius robustus*). NMFS determined that insufficient information existed to conclude whether the proposed Beaufort Sea sale was or was not likely to jeopardize the continued existence of bowhead and gray whales. In August 1978, NMFS recommended studies to the BLM that would fill the information needs identified during the Section 7 consultation. Subsequent Biological Opinions for leasing and exploration in the Beaufort Sea (Sales 71, 87, and 97) and the 1988 Arctic Region Biological Opinion (ARBO) used for Beaufort and Chukchi Sea sales (Sales 124, 126, 144, and 170) recommended continuing studies of whale distribution and OCS-industry effects on bowhead whales (USDOC, NOAA, NMFS 1982, 1983, 1987, and 1988) and monitoring of bowhead whale presence during periods when geophysical exploration and drilling are occurring. The current ARBO, issued by NMFS in 2006 for leasing and exploration in the Beaufort Sea, also recommended that whale distribution and acoustic monitoring studies during the fall migration continue to describe the impact of exploration and production activities on the migration path of bowhead whales in the Beaufort Sea.

Following several years when drilling was limited to the period 1 November through 31 March (USDOI, MMS 1979), variable 2-month seasonal-drilling restrictions on fall exploratory activity

in the joint Federal/State Beaufort Sea sale area were implemented. The MMS (Alaska OCS Region) adopted an endangered whale monitoring plan that required aerial surveys. The Diapir Field Sale 87 Notice of Sale (1984) states that "Bowhead whales will be monitored by the Government, the lessee, or both to determine their locations relative to operational sites as they migrate through or adjacent to the sale area" (USDOI, MMS 1984). Subsequent lease sales in the Beaufort Sea (Sales 97, 124, 144, 170, 186, 195, and 202) did not include a seasonal drilling restriction, but the Notice of Sale for each contained an Information to Lessees clause stating that "MMS intends to continue its area wide endangered whale monitoring program in the Beaufort Sea during exploration activities" (USDOI, MMS 1988, 1991, 1996, and 1998). Information gathered is used to help determine the extent, if any, of adverse effects on the species.

From 1979 to 1987, the MMS (formerly BLM) funded annual monitoring of endangered whales in arctic waters under Interagency Agreements with the Naval Ocean Systems Center and through subcontracts to SEACO, Inc. (Ljungblad et al. 1987). The MMS used agency personnel to perform fieldwork and reporting activities for the Beaufort Sea on an annual basis from 1987 to 2006 (Treacy 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2000, 2002a, 2002b, Monnett and Treacy 2005, and USDOI, MMS 2008). In 2007, an Interagency Agreement between MMS (U.S. Department of the Interior) and NMFS (specifically, the National Marine Mammal Laboratory [NMML], Alaska Fisheries Science Center) was established to authorize NMML to conduct the Bowhead Whale Aerial Survey Project (BWASP) surveys and assume partial responsibility for the management of the project. In 2008, NMML adopted full responsibility for all aspects of the BWASP surveys and related tasks (Clarke et al. 2011a, 2011b). The MMS is now the Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE).

The goals of the ongoing project are to

1) Define the annual fall migration of bowhead whales, significant inter-year differences, and long-term trends in the distance from shore and water depth at which whales migrate.

2) Monitor temporal and spatial trends in the distribution, relative abundance, habitat, and behaviors (especially feeding) of endangered whales in arctic waters.

3) Provide real-time data to MMS [now BOEMRE] and NMFS on the general progress of the fall migration of bowhead whales across the Alaskan Beaufort Sea, for use in protection of this endangered species.

4) Provide an objective, wide area context for management interpretation of the overall fall migration of bowhead whales and site-specific study results.

5) Record and map beluga distribution and incidental sightings of other marine mammals.

6) Determine seasonal distribution of endangered whales in planning areas of interest to MMS [now BOEMRE].

METHODS AND MATERIALS

Study Area

The aerial survey program was based on a design of north/south transects distributed randomly within established geographic blocks overlapping or near Beaufort Sea sale areas offshore of Alaska, an area commonly referred to as the North Slope. The present study included Beaufort Sea Survey Blocks 1 through 12 (Fig. 1) between 140°W and 157°W, south of 72°N, and north of the shoreline of Alaska. The study area encompasses approximately 107,500 km^2.

A large-scale Beaufort Gyre moves waters clockwise from the Canadian Basin westward in the deeper offshore regions. Seaward of the gyre is the eastward-flowing Beaufort Undercurrent, which flows subsurface in areas where bathymetry is 51 to 2,000 m (Aagaard 1984). In the nearshore shallow waters of the Beaufort inner shelf (≤ 50 m depth), currents tend to follow local wind patterns. In winter, currents are not substantial even when winds are strong. In summer, currents are much stronger and may flow either east or west, depending on prevailing winds. Based on analysis of modeled sea level and ice motion, wind-driven motion in the Arctic was found to alternate between anticyclonic and cyclonic circulation, with each regime persisting from 5 to 7 years (Proshutinsky and Johnson 1997, Johnson et al. 1999).

In the Beaufort Sea, landfast ice forms during the fall and may eventually extend up to 50 km offshore by the end of winter (Norton and Weller 1984). The pack ice, which includes multiyear ice averaging 4 m in thickness, with pressure ridges up to 50 m thick (Norton and Weller 1984), becomes contiguous with the new and shorefast ice in late fall, effectively closing off the migration corridor to westbound bowhead whales. From early November to mid-May, the Beaufort Sea normally remains almost completely covered by ice considered too thick for whales to penetrate. In mid-May, a recurring lead can form just seaward of the stable fast ice, followed by decreasing ice concentrations (LaBelle et al. 1983) and large areas of open water in summer. In recent years, the minimum area of the summer ice pack has been shrinking, setting records for new minimums in several years including 2007, 2008, 2009, and 2010 (National Snow and Ice Data Center 2007, 2008, 2009, 2010). The open water season has lengthened and the southern edge of the ice pack has been farther from Alaskan shorelines. The decrease in sea ice extent has been correlated with an increase in Arctic Ocean cloud cover (Eastman and Warren 2010).

Local weather patterns affect the frequency and effectiveness of all marine aerial surveys. The study area is in the arctic climate zone, with mean temperatures at Alaskan Beaufort Sea coastal locations ranging from -0.9°C to -0.1°C during September and from -9.7°C to -8.5°C during October (Brower et al. 1988). Mean temperatures measured at Barrow since 1972 have increased by 2.9°C (5.2°F), likely due to circulation changes (increased warm air advection from southern latitudes) or increased infrared back-radiation due to increased cloudiness, water vapor or CO_2 (Wendler et al. 2009). Total annual precipitation in the Alaskan Arctic has decreased since the late 1940s (Stafford et al. 2000), but the heaviest precipitation (snow and rain) occurs in September and October (Brower et al. 1988). Mean wind speed at Barrow and Barter Island

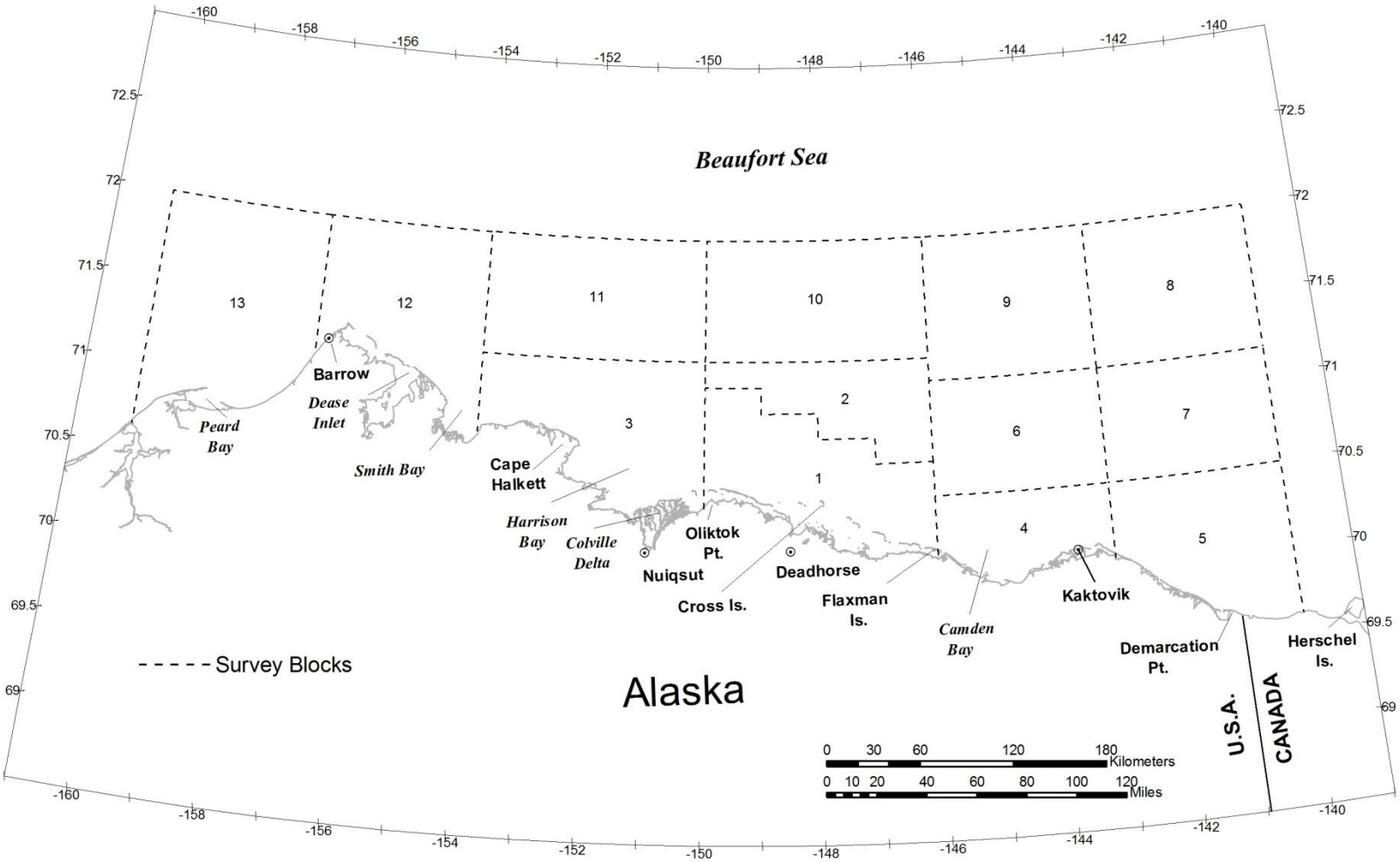

Figure 1. -- Study area showing Survey Blocks.

is from 5 to 6 m/s during September and 5 to 7 m/s during October (Brower et al. 1988). Wind speeds in September and October are generally higher than during other times of the year, perhaps because the open water and cooling land mass increase thermal instability (Wendler et al. 2009). Wind direction is predominantly easterly, which also drives the Beaufort Gyre, but winds occasionally reverse and shift to being westerly. The occurrence of storms during which at least one hourly reading of wind speed was > 15 m/s (approximately Beaufort wind force 7) has also increased since 1972 (Wendler et al. 2009). Highest annual mean wind speeds at Barrow were recorded since the early 1990s; the mean annual wind speed in 2006 was approximately 5.2 m/s (Fig. 3 in Wendler et al. 2009).

Sea state also affects visibility during aerial surveys. Surface waters in the Beaufort Sea are driven primarily by wind. Ocean waves are generally from northerly or easterly directions during September and October. Prior to 1997, significant wave heights were reduced by a factor of 4 from heights that would otherwise be expected during the open-water season because pack ice limited fetch. Since 1997, large expanses of open water have been present during some or all of the survey. Corresponding wave heights have been considerably higher during periods of high wind.

Equipment

Most BWASP surveys in 2010 were flown in a de Havilland Twin Otter Series 300 equipped for arctic operation and aerial surveys of whales, provided by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Aircraft Operations Center (AOC). Administrative support, NOAA Corp pilots, and an on-site mechanic were also provided by AOC. Additional surveys in the BWASP study area were flown in an Aero Commander 690A, provided by Northern Commanders and Clearwater Air, Inc., which was based in Barrow to conduct surveys in the northeastern Chukchi Sea for the Chukchi Offshore Monitoring in Drilling Area (COMIDA) project (Clarke et al. 2011c). Both aircraft were equipped with bubble windows that afforded complete trackline viewing. The pilot and copilot seats provided good forward and side viewing. Each observer was issued a hand-held clinometer for measuring the angle of inclination to sighting locations. Observers and pilots were linked with a common communication system. The Twin Otter aircraft's maximum time aloft under normal survey load was extended to approximately 7 hours through the use of a supplemental onboard fuel tank, while the Aero Commander’s maximum time aloft was approximately 5 hours.

A laptop computing system was used aboard the aircraft to store and analyze flight and observational data. The computer system was connected to a Garmin Global Positioning System (GPS) with an external antenna, independent of the aircraft GPS. Latitude, longitude, and flight altitude from the GPS were transmitted to the computer through a standard serial connection. Data were backed up to an onboard external hard drive. A custom mapping program permitted the data recorder to view the aircraft’s trackline in real time.

Onboard safety equipment included an impact-triggered emergency locator transmitter installed in the aircraft, an 8-person search and rescue life raft equipped with an emergency survival kit, a portable personal locator beacon, portable marine band and aircraft-band transceivers, and

orange immersion suits. All personnel underwent regular aircraft egress, wilderness first aid, and other safety training as required by AOC and NMML. Observers and pilots wore orange Mustang Constant Wear Aviation Dry Suit System MSF300 and Switlik personal flotation vests outfitted with personal locator beacons and other safety gear.

The U.S. Department of the Interior, National Business Center, Aviation Management Division "Automated Flight Following" (AFF) system was used by Anchorage-based Aviation Management Division personnel for "satellite-tracking" the project aircraft over the Alaskan Beaufort Sea. Aviation Management obtained current flight information in the form of maps for real-time visual tracking of the survey aircraft. An Iridium satellite phone was used to communicate aircraft position to Aviation Management each hour. In addition to these flight-following systems, the onboard transponder was set at a discrete identification code for radar tracking by air-traffic-control personnel.

Methodologies, equipment and standard procedures have been developed and refined over the duration of the BWASP project (1979-2010). Additional details of onboard equipment, data collection, and post-field analyses are described in detail elsewhere (e.g. Monnett and Treacy 2005; USDOI, MMS 2008; Clarke et al. 2011c).

Aerial Survey Design

Aerial surveys were primarily based out of Deadhorse, Alaska, from 1 September through 15 October 2010; the Aero Commander was based out of Barrow, Alaska, during the same time period. The field schedule was designed to monitor the progress of the fall bowhead whale migration across the Alaskan Beaufort Sea. Sightings of all marine mammals observed were recorded.

Daily flight patterns were based on sets of unique transect grids, computer-generated for each Survey Block or set of two Survey Blocks (for blocks oriented together on a north-south axis). Transect grids were derived by dividing each Survey Block into sections 30 minutes of longitude across. One of the minute marks along the northern edge of each section was selected at random and then connected by a straight line to a similarly selected endpoint along the southern edge of the same section. This procedure was followed for all sections of the Survey Block resulting in a series of transect lines. These transect legs were then connected alternately at their northernmost or southernmost ends to produce one continuous flight grid within each Survey Block.

The selection of Survey Blocks to be flown on a given day was nonrandom, based on reported or observed weather conditions over the study area and avoidance of recently surveyed areas. Weather permitting, the project attempted to distribute effort fairly evenly across the entire study area. A semimonthly flight-hour goal for each Survey Block was allocated proportionately for Survey Blocks east of 154°W. This was based on relative abundance of bowhead whales as determined from earlier fall migrations (1979-1986). Such allocations greatly favored survey coverage in inshore Survey Blocks 1 through 7 and 11 (Fig. 1) because bowhead whales were rarely sighted north of these blocks in previous surveys. The purpose of these survey-effort allocations was to increase the sample size of whale sightings within the primary migration

corridor, thus increasing the power of statistical analysis within these inshore blocks. Only data from transect legs were used to analyze the migration axis.

Survey Flight Procedures

During a typical flight, a search leg was flown to the target Survey Block, whereby a series of transect legs were flown, followed by a search leg back to Deadhorse. Transects were joined together by short search legs. Circling was initiated to further investigate cetacean sightings, as described below. Surveys generally were flown at a target altitude of 458 m, but could be flown as low as 305 m. Weather permitting, the higher altitude was maintained to maximize visibility and minimize potential disturbance to marine mammals. When cloud ceilings were less than 305 m or the wind force was above Beaufort 5, survey flights were redirected to Survey Blocks with better conditions. Survey flights were aborted when conditions consistently did not meet minimum altitude (305 m) or wind force (Beaufort 5) requirements. Survey speed was generally 204 km/h.

Primary observers were stationed on either side of the aircraft at bubble windows that permitted an unobstructed field of vision from the trackline directly below the aircraft to the horizon. The data recorder was primarily responsible for data entry but also functioned as a secondary observer. A clinometer was used to measure the angle of inclination to each sighting when the initial sighting location was abeam of the aircraft. Only sightings from primary observers were recorded as on transect; sightings by the data recorder, pilots, or occasional fourth observer were recorded as on search.

When cetaceans were encountered while surveying a transect line, the aircraft sometimes diverted from transect for brief (< 10 minute) periods and circled the whales to verify species, observe behavior, obtain better estimates of group size, and determine whether calves were present. Any new sightings of whales made while circling were recorded as on circling rather than as on transect. Sightings made off transect and not while circling were recorded as on search.

Survey effort over land or in areas where visibility was zero was designated deadhead and not incorporated into further analyses.

Data Entry

Customized, menu-driven data entry software was used to record all data in database format (MS-Access). Location data (date, time, latitude, longitude, altitude, and aircraft heading) and environmental conditions (sky conditions, visual impediments, visibility left and right, percent ice coverage, ice type, and wind force) were recorded at sightings, turning points, when environmental conditions changed, or otherwise at intervals of 5 minutes (in time). A complete data sequence was recorded for cetacean sightings, including location data, environmental conditions, survey type, species, total number (as well as low, high, and best estimate of group size), observer, swim direction (true), clinometer angle, number of calves, behavior, sighting cue, group classification, habitat, swim speed, whether it was a repeat sighting, and response to

aircraft. Reduced data sequences were used when recording other marine mammals. Position data only (date, time, latitude, longitude, and altitude) were automatically recorded every 30 seconds (in time) to provide a more complete record of the flight track.

The behavior, swim speed, and swim direction of observed whales represent what the pod as a whole was doing at the time it was first sighted. Behaviors were entered into 1 of 15 categories as noted during previous surveys (Table 1). The default behavior was "swimming", entered whenever an alternate behavior was not observed. Swimming speed was subjectively estimated by observing the time it took a whale to swim one body length. An observed swimming rate of one body length per minute corresponded to an estimated speed of 1 km/hr. One body length per 30 seconds was estimated at 2 km/hr, and so on. Swimming speed was recorded by relative category (i.e., still, 0 km/hr; slow, 0-2 km/hr; medium, 2-4 km/hr; or fast, > 4 km/hr). Group composition included categories single, pair, mixed group, etc., and was designed to provide additional information on group dynamics. Swim direction was recorded relative to the aircraft's heading, and then converted to actual swim direction via a module incorporated into the data collection software.

Wind force was recorded according to the Beaufort scale outlined in *Piloting, Seamanship, and Small Boat Handling* (Chapman 1971). Ice type was identified using terminology presented in Naval Hydrographic Office Publication Number 609 (USDOD, Navy 1956). Average ice cover within the field of view from the aircraft was estimated as a single percentage, regardless of ice type.

General Data Analyses

Preliminary field data analysis was performed by a computer program that provided daily summations of marine mammals observed, plus calculation of time and distance on transect, search, circling, and deadhead portions of the flight. The program provided options for editing the data file, calculating summary statistics on sightings and effort, and plotting the paths of one or more flights by Beaufort wind force.

The water depth at each bowhead whale sighting in the 1982-2010 database was derived from the International Bathymetric Chart of the Arctic Ocean (IBCAO; http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/arctic.html), which had a spatial resolution of 2 km squared; the spatial resolution after geoprocessing was 2.037 km squared.

Maps were prepared with application software (ArcGIS) based on Universal Transverse Mercator Zone 6 (central meridian = 147°W, reference lat. = 0.00000, false easting = 500000.00000, false northing = 0.00000, spheroid = GRS 80, scale factor = 0.99960). The natural coastline was adopted from the State of Alaska, Department of Natural Resources.

Environmental information, including wind speed and direction, ceiling, visibility, temperature, dew point, ice cover, and sea surface temperature was collected from numerous National Weather Service web sites and several other weather and climate-related web pages for the duration of the field season. Data were collected and stored electronically for both specific

Table 1. -- Operational definitions of observed whale behaviors.

Behavior	Definition
Breaching	Whale(s) launching upwards such that half to nearly all of the body is above the surface before falling back into the water, usually on its side, creating an obvious splash.
Cow-Calf	Calf nursing; cow-calf pairs swimming within 20 m of each other.
Diving	Whale(s) changing swim direction or body orientation relative to the water surface, resulting in submergence; may or may not include lifting the tail out of the water.
Feeding	Whale(s) diving repeatedly in a fixed area, sometimes with mud streaming from the mouth and/or defecation observed upon surfacing. Feeding behavior is further defined as synchronous diving and surfacing or echelon-formations at the surface with swaths of clearer water behind the whale(s), or as surface swimming with mouth agape.
Flipper-Slapping	Whale(s) floating on side, striking the water surface with pectoral flipper one or many times; usually seen within groups or when the slapping whale is touching another whale.
Log-Playing	Whale(s) milling or thrashing in association with a floating log.
Mating	Ventral-ventral orientation of two whales, often with one or more other whales present to stabilize the mating pair. Mating is often seen within a group of milling whales. Pairs may appear to hold each other with their pectoral flippers and may entwine their tails.
Milling	Whales moving slowly at the surface in close proximity (within 100 m) to other whales, often with varying headings. Also one whale slowly changing its heading.
Resting	Whale(s) floating at the surface with head, or head and back exposed, showing no movement; more commonly observed in heavy-ice conditions than in open water.
Rolling	Whale(s) rotating on the longitudinal axis, sometimes associated with mating.

Spy-Hopping	Whale(s) extending head vertically out of the water such that up to one-third of the body, including the eye, is above the surface.
Swimming	Whale(s) proceeding forward through the water propelled by tail.
Tail-Slapping	Whale(s) floating horizontally or head-downward in the water, waving tail back and forth above the water and striking the water surface; usually seen in group situations.
Thrashing	Whale(s) exhibiting rapid flexure or gyration in the water.
Underwater-Blowing	Whale(s) exhaling while submerged, thus creating a visible bubble.

locations (e.g., Deadhorse, Barter Island, Kuparak, Alpine, and the weather station at West Dock) and for the Beaufort Sea region.

Sea ice information was obtained from the National Weather Service Forecast Desk, Anchorage, Alaska (http://pafc.arh.noaa.gov/ice.php). Sea ice analyses were produced three days per week, and provide information on ice concentration (in tenths), age and thickness.

Survey effort and observed bowhead whale distribution were plotted semimonthly over the Beaufort Sea study area. Fall sightings of belugas, as well as incidental sightings of other marine mammals, were depicted on separate maps. Common and scientific names used for marine mammals in this report are taken from Rice (1998).

Whale sightings were shown on distribution maps regardless of the type of survey leg (transect, search, or circling) being conducted or the prevailing environmental conditions (sea state, ice cover, etc.) when the sightings were made. As with previous reports in this series (e.g., Monnett and Treacy 2005; USDOI, MMS 2008; Clarke et al. 2011a, 2011b), same-day repeat sightings or sightings of dead marine mammals were not included in summary analyses or maps. Where tables and figures exclude certain data, such exclusions are indicated in the captions.

Analysis of the Bowhead Whale Migration Corridor

The bowhead whale migration corridor was examined using the mean and median distance from shore of, and the median depth at, whales sighted on transects (Houghton et al. 1984). Treacy (1998) found that median and mean bowhead whale distance from shore values were only slightly different. Therefore, annual mean distance from shore was plotted in relation to the cumulative mean distance from shore for previous years starting in 1982, as described in greater detail below. Further comparisons of various subsets of data were based on statistical analyses of median distance from shore and depth at sighting, via the nonparametric Mann-Whitney *U*-test. This nonparametric test was used for these data because distributions generally did not fit assumptions necessary to use the two-sample *t*-test. The variances were not equal between subsets of data for both depth and distance from shore; in addition, the depth data were considerably skewed and the distance from shore data were slightly skewed, so neither distribution strictly met the assumption of normality. When assumptions of the *t*-test are seriously violated, the Mann-Whitney *U*-test may be more powerful than the two-sample *t*-test (Hodges and Liehman 1956, Zar 1984). Statistical tests were undertaken using *Statistica*™ StatSoft, Version 5.1 and ArcGIS, Version 9.3. Median distance from shore and depths for bowhead whale sightings in 2010, a year with light ice coverage, were compared with analogous values for combined data from previous years having light ice coverage (i.e., 1982, 1986, 1987, 1989, 1990, 1993-2009).

All bowhead whale sightings made while on transect, regardless of distance from the transect line, were included in this analysis. Distance from shore and water depth at bowhead whale

sightings were analyzed for two regions (Fig. 2), the boundaries of which correspond roughly to oceanographic patterns and the offshore extent of sampling, described in more detail below. Selected isobaths (10 m, 20 m, 30 m, 40 m, 50 m, 60 m, 100 m, 500 m, 1,000 m, 1,500 m, 2,000 m, 2,500 m, 3,000 m, and 3,500 m), derived from IBCAO data, were also included in Figure 2 for visual reference.

Oceanographic patterns common to waters off northern Alaska are reviewed in Moore and DeMaster (1997). In brief, cold saline Bering Sea Water and warm fresh Alaskan Coastal Water enter the Alaskan Beaufort Sea through Barrow Canyon. Both water masses are identifiable on the outer shelf (seaward of 50 m) as the eastward flowing Beaufort Undercurrent (Aagaard 1984). Bering Sea Water has been traced at least as far east as Barter Island (~143°W), but the Alaskan Coastal Water mixes with ambient surface waters as it moves eastward and is not clearly identifiable east of Prudhoe Bay (~147°-148°W). Therefore, the delineation between East and West Regions for this analysis occurs at 148°W, based upon association with the general distribution patterns of these water masses.

The northern extent of each region is based upon survey effort. The East Region extends from 140°W to 148°W and northward from the shore to 71°10' N, except between 146°W and 148°W where the region extends to 71°20' N. The northern boundary for this region corresponds with boundaries of Survey Blocks 2, 6, and 7 (Fig. 1), blocks with sufficient survey effort to support analyses (Treacy 1998). The West Region extends from 148°W to 156°W and northward from shore to 72°N, except between 148°W and 150°W where the region extends to 71°20' N due to the layout of Block 2. The northern boundary for this region corresponds with boundaries of Survey Blocks 2, 11, and 12 (Fig. 1). The eastern boundary (140°W) is the easternmost longitude of the Survey Blocks. The western cutoff at 156°W limits the analysis to bowhead whales seen in the Alaskan Beaufort Sea and avoids the influence of Barrow Canyon on bowhead whale depth distribution.

The shoreline used for the distance from shore analysis was ‘normalized’ from the actual Beaufort Sea shoreline to provide a standardization of distance-from-shore measures regardless of the mapping software being used to depict the distribution data. The ‘normalized’ shoreline was defined by straight-line connections between 11 points at specific shoreline or barrier island locations across Alaska’s North Slope between 156°W and 140°W (Fig. 2). The points used to ‘normalize’ the shoreline are as follows:

71.317°N, 156.000°W
70.883°N, 153.900°W
70.917°N, 153.115°W
70.817°N, 152.200°W
70.430°N, 151.000°W
70.550°N, 150.167°W
70.450°N, 147.950°W
69.967°N, 144.700°W
70.150°N, 143.250°W
69.650°N, 141.000°W
69.617°N, 140.000°W

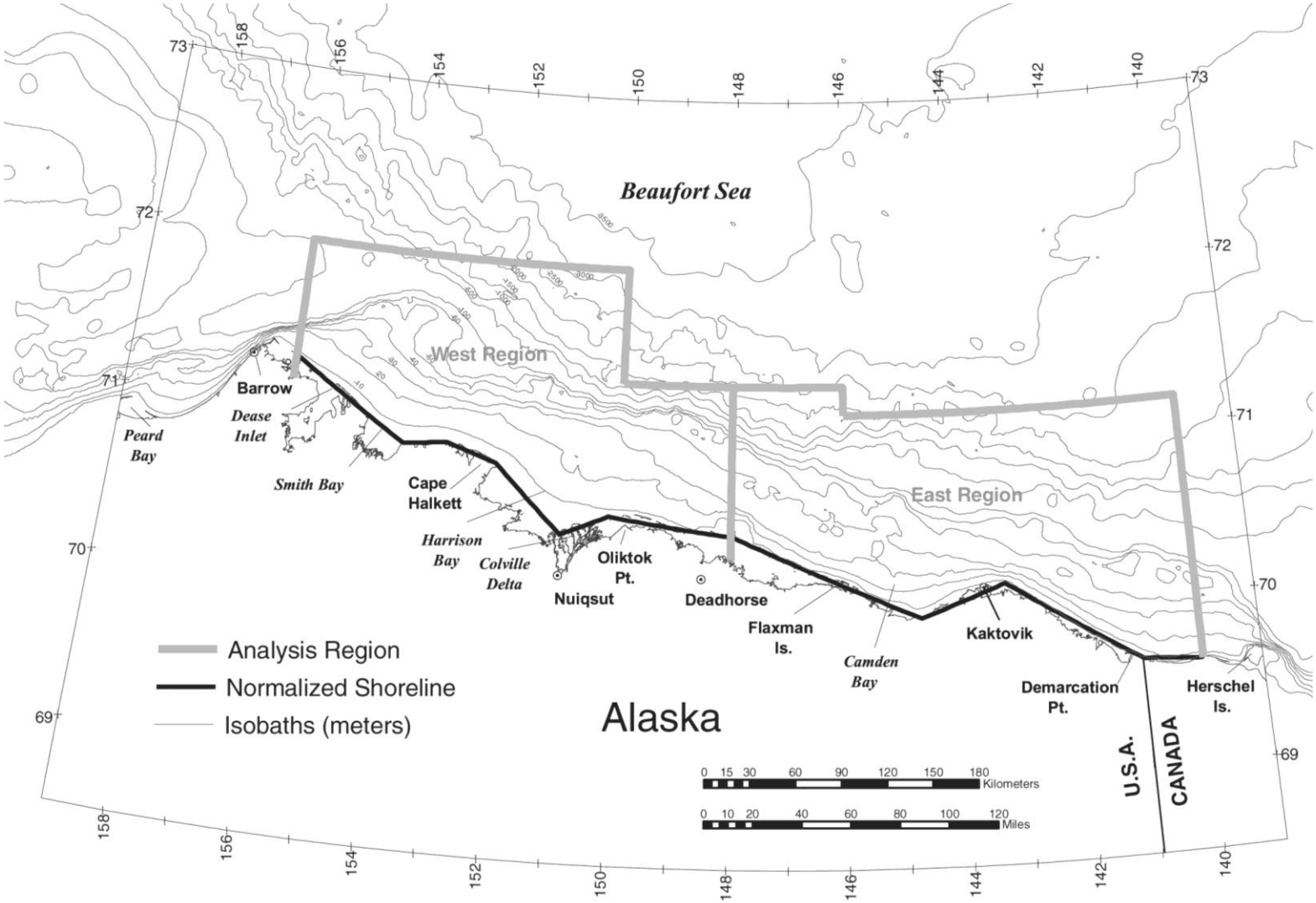

Figure 2. -- East and West Regions showing the normalized shoreline and selected IBCAO isobaths.

Two data subsets from BWASP 2010 were analyzed and are described below:

- All bowhead whale sightings on transect, regardless of behavior recorded. The analysis of this subset assumed that *all* bowhead whales in the Alaskan Beaufort Sea were migrating from the Canadian Beaufort Sea, where most bowhead whales are assumed to spend summer months, through the Alaskan Beaufort Sea enroute to wintering areas in the Bering Sea. Under this assumption, any feeding, milling, or resting behavior observed was considered temporary, and all whales were considered "migratory".

- All bowhead whale sightings on transect, *excluding* whales that were observed feeding, milling, or resting. These behaviors might be considered "non-migratory" and may influence, at least temporarily, the migratory path.

One caveat to this analysis is that analyzing the bowhead whale migration corridor based on number of sightings only may be biased because survey effort was often variable both within and across years and because sightings of a single animal were weighted equally to sightings of several animals. Therefore, there may be more sightings in areas with greater transect effort and fewer sightings in areas with less transect effort, even if the population density in the two areas is the same.

Sighting Rate and Relative Occurrence Analyses

Sighting rates quantify relative occurrence while accounting for heterogeneity in survey effort across the study area. Sighting rates were derived for three different spatial scales. Estimated total effort (transect, search, and circling combined, in kilometers) and transect effort only (in kilometers) per Survey Block were calculated to determine annual sighting rates (number of whales per unit effort, WPUE) for bowhead whales and belugas. Although Survey Blocks are arbitrary geographic areas, they provide a basis for interannual cross-comparisons. Effort over land, between barrier islands and the mainland, and north of the study area (north of 72°N) was not included in this sighting rate analysis. Estimated transect effort (km) per depth zone (≤ 20 m, 21-50 m, 51-200 m, and 201-2,000 m) was computed separately for two subareas. One subarea spanned 154°W to 157°W, and included Barrow Canyon and its surrounding area, which has noticeably different bathymetry than the rest of the BWASP study area (Fig. 2). The other subarea for the depth zone analysis spanned 140°W to 154°W, an area incorporating a well-defined continental shelf and slope. An additional sighting rate analysis was conducted at a finer-scale (5' latitude by 15' longitude), which used a grid matrix consisting of approximately equilateral grid cells superimposed across the study area. Bowhead whale sighting rates on this finer scale were calculated as the number of transect sightings per unit transect effort (SPUE) for each grid cell. An index of relative occurrence of feeding and milling behaviors, quantified as SPUE, was also calculated for the finer scale grid. The finer-scale grid analysis included transect effort within the barrier islands and north of 72°N. Sighting rates were not corrected for availability or perception bias (Buckland 2001).

RESULTS

Environmental Conditions

Sea ice coverage in the Alaskan Beaufort Sea was light during the BWASP 2010 survey period. Sea ice extent receded to the third lowest level since satellite measurements began in 1979 (National Snow and Ice Data Center 2010). The BWASP study area was completely ice-free east of 147°W during all of September (Fig. A-1 to A-4). West of 147°W, 20-80% broken floe ice persisted between shore and ~71.5°N (Fig. A-1) in early September. By the middle of September, broken floe ice remained in and north of Harrison Bay only (Fig. A-3). New ice started forming in shallow areas nearshore by early October and, by mid-October, 10-20% new ice was forming in most of the BWASP study area (Fig. A-7). Ice percentage and sea state for each bowhead whale sighting are presented in Appendix B. The absence of sea ice in most of the study area on potential survey days in 2010 led to generally poor survey conditions, including higher than preferred sea states, low ceilings and widespread fog. To examine interannual variability in bowhead whale and other marine mammal distribution and occurrence, 2010 data were compared to data from other years with light ice coverage.

Survey Effort

The fall field season was from 1 September to 15 October 2010 (Table 2). There were 21 flights, of which 14 were in September and 7 were in October. Two flights (229 and 235) were partitioned between the BWASP and adjacent COMIDA study areas; only survey effort east of 157°W was included here. Over 20,000 km were flown during 96 hours; 35% of total survey effort was on deadhead (non-usable survey time). The average survey flight was 983 km, ranging from 536 to 1,972 km. A total of 7,929 km of transect lines were flown in 39 hours. Transect effort constituted 38% of the total kilometers flown and 41% of the total flight hours. Survey flight lines are summarized in Figures 3 through 6. Coverage in early September was good in most of the study area (Fig. 4). Survey coverage in late September was not uniform (Fig. 5) due to very poor survey conditions, including fog, high winds, blowing snow, and widespread icing, which often hindered attempts to survey in offshore areas. Survey coverage in early October was limited to the western half of the study area as poor conditions prevented flying east of Survey Block 1 (Fig. 6). The BWASP aerial survey season ended on 15 October; the aircraft and observer team remained in Deadhorse until 18 October, but weather precluded any additional survey flights. Survey coverage was greatest in Blocks 1, 3, and 12, and lowest in Blocks 4, 6, and 7. Surveys in Blocks 8, 9, and 10 were not attempted in 2010 because conditions were not favorable for surveying offshore (high winds and low visibility). Flight lines, associated sea states, and sightings are presented for individual flights in Appendix C.

Table 2. -- Aerial survey effort in the Beaufort Sea, 1 September-15 October 2010, by survey flight. Semimonthly totals may not exactly match the sum for the time period due to rounding error.

Day	Flight Number	Transect (km)	Circling (km)	Search (km)	Deadhead (km)	Total (km)	Transect (hr)	Total (hr)
1 Sep	1	19	0	105	470	594	0.1	2.3
8 Sep	2	609	41	141	301	1,092	3.1	4.9
12 Sep	3	383	75	283	327	1,068	1.9	4.8
12 Sep	229	446	44	156	436	1,082	2.3	4.8
13 Sep	4	514	50	140	277	981	2.5	4.8
15 Sep	5	486	15	276	213	990	2.4	4.7
17 Sep	6	120	59	311	235	724	0.6	3.2
20 Sep	7	106	0	174	257	536	0.5	2.4
20 Sep	235	246	60	161	228	695	1.2	3.3
21 Sep	8	266	55	312	447	1,080	1.3	4.9
22 Sep	9	91	99	203	429	822	0.4	3.7
24 Sep	10	899	83	432	558	1,972	4.4	10.0
29 Sep	11	0	0	135	488	623	0.0	2.5
30 Sep	12	375	27	218	394	1,014	1.8	4.4
1 Oct	13	509	0	348	441	1,298	2.5	7.0
7 Oct	14	365	12	228	224	830	1.8	3.8
8 Oct	15	335	27	367	265	994	1.7	4.4
9 Oct	16	589	10	186	76	861	2.8	4.2
10 Oct	17	499	0	205	227	931	2.5	4.3
11 Oct	18	1,072	0	342	386	1,801	5.1	8.9
15 Oct	19	0	0	13	643	656	0.0	2.5
Semimonthly Effort Summary								
1-15 Sep		2,457	225	1,101	2,024	5,807	12.2	26.2
16-30 Sep		2,103	383	1,946	3,036	7,466	10.3	34.5
1-15 Oct		3,369	49	1,689	2,262	7,371	16.3	34.9
Total		7,929	657	4,736	7,322	20,644	38.8	95.6

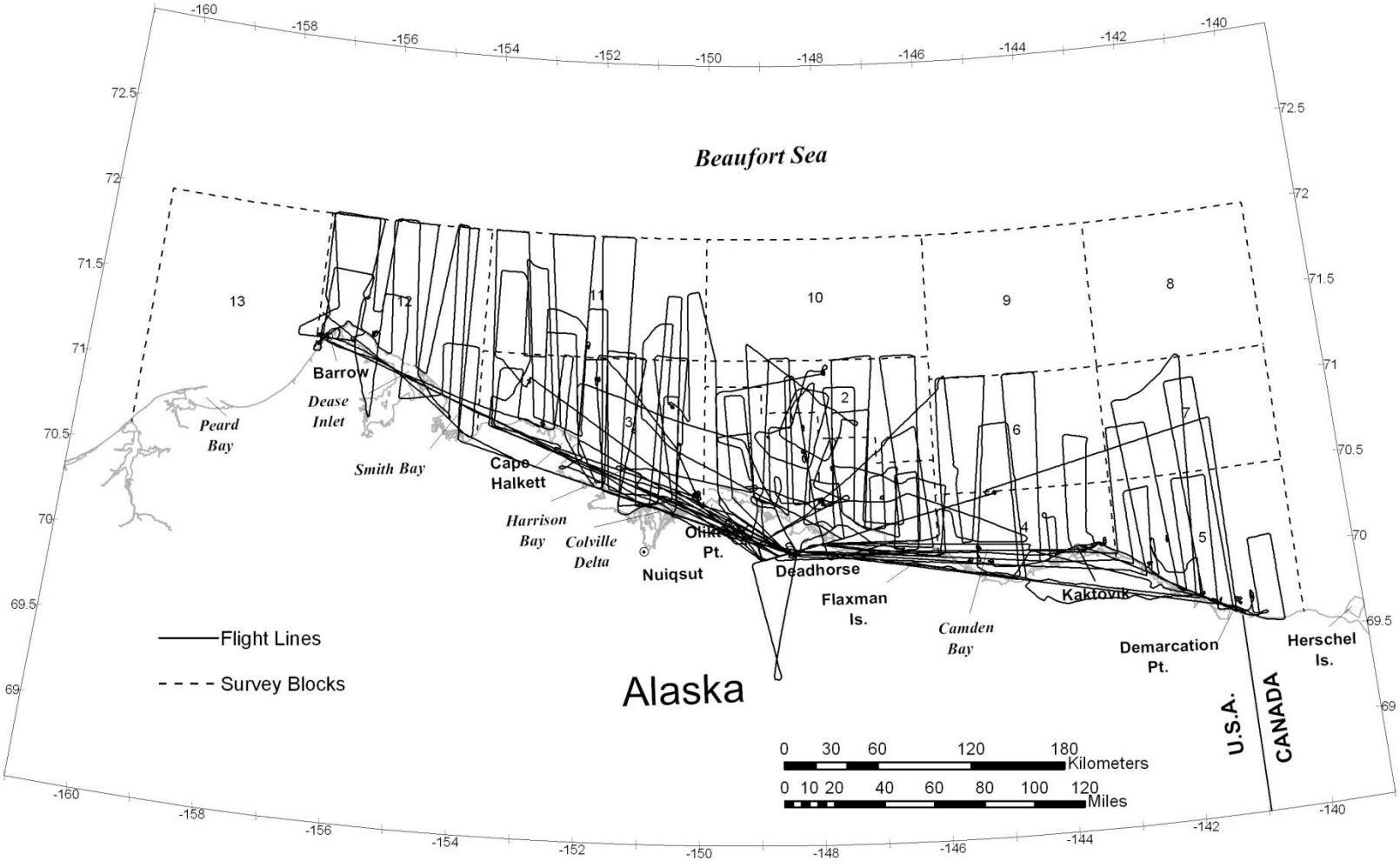

Figure 3. -- Combined flight tracks, all effort, fall 2010.

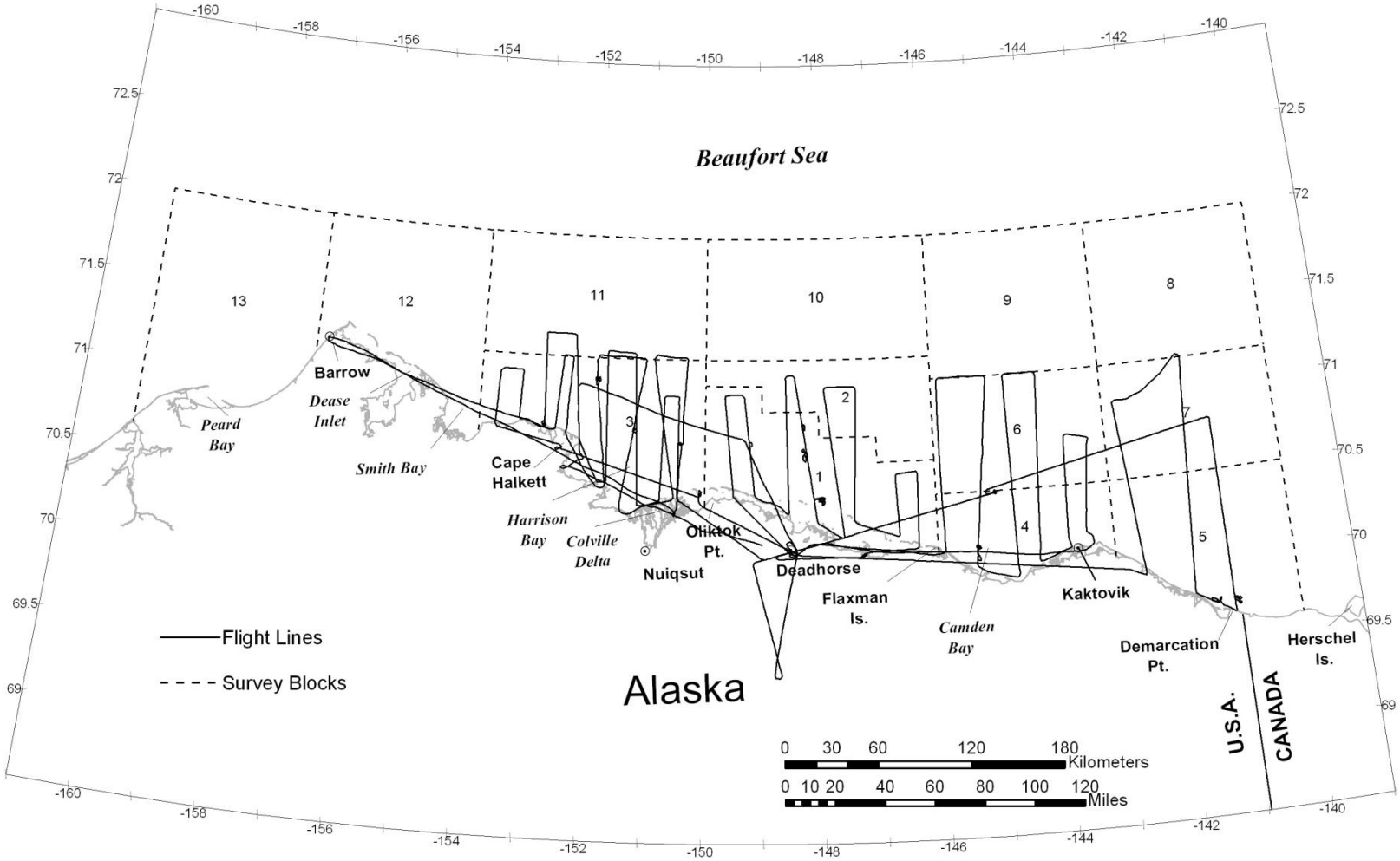

Figure 4. -- Combined flight tracks, all effort, 1-15 September 2010.

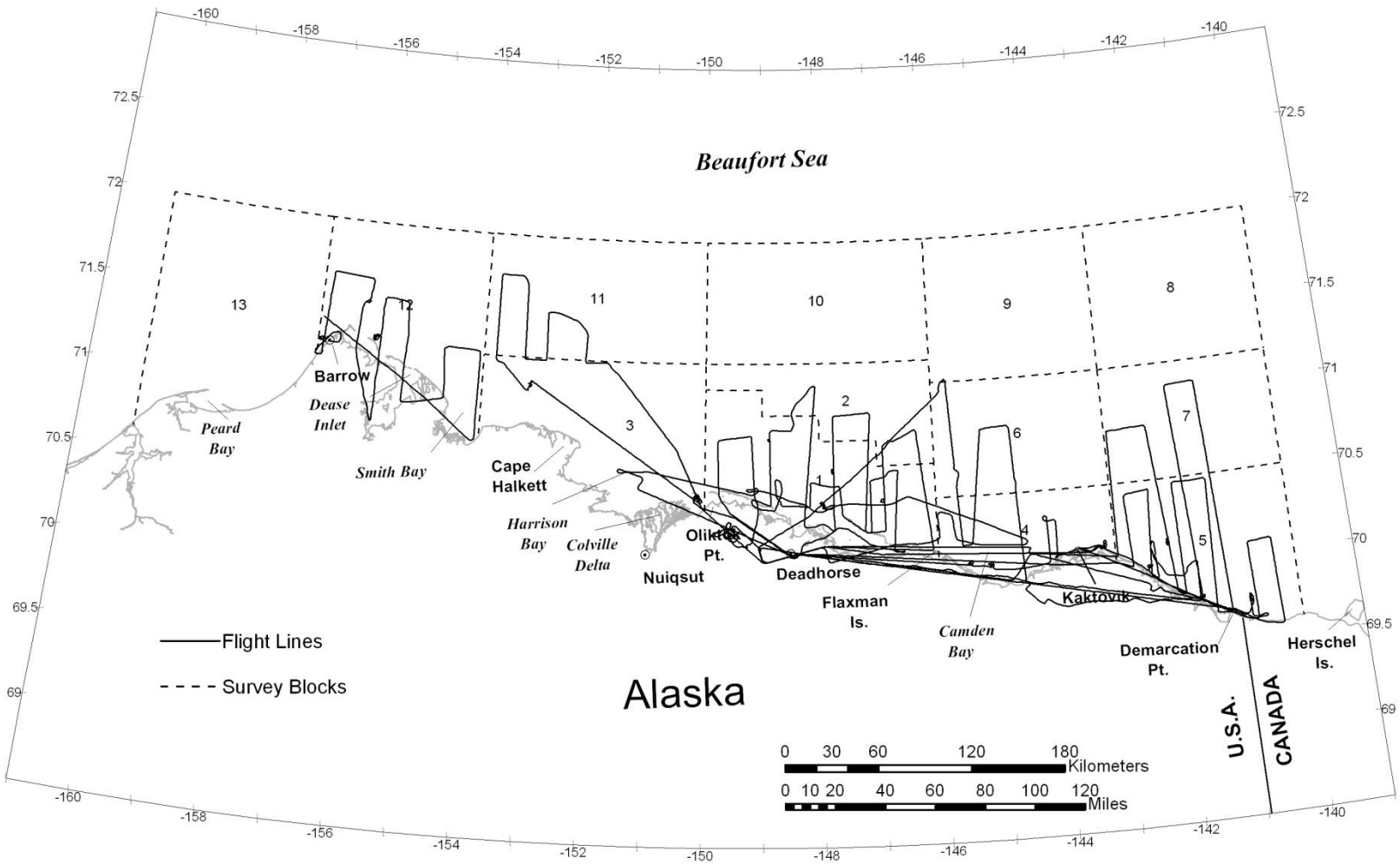

Figure 5. -- Combined flight tracks, all effort, 16-30 September 2010.

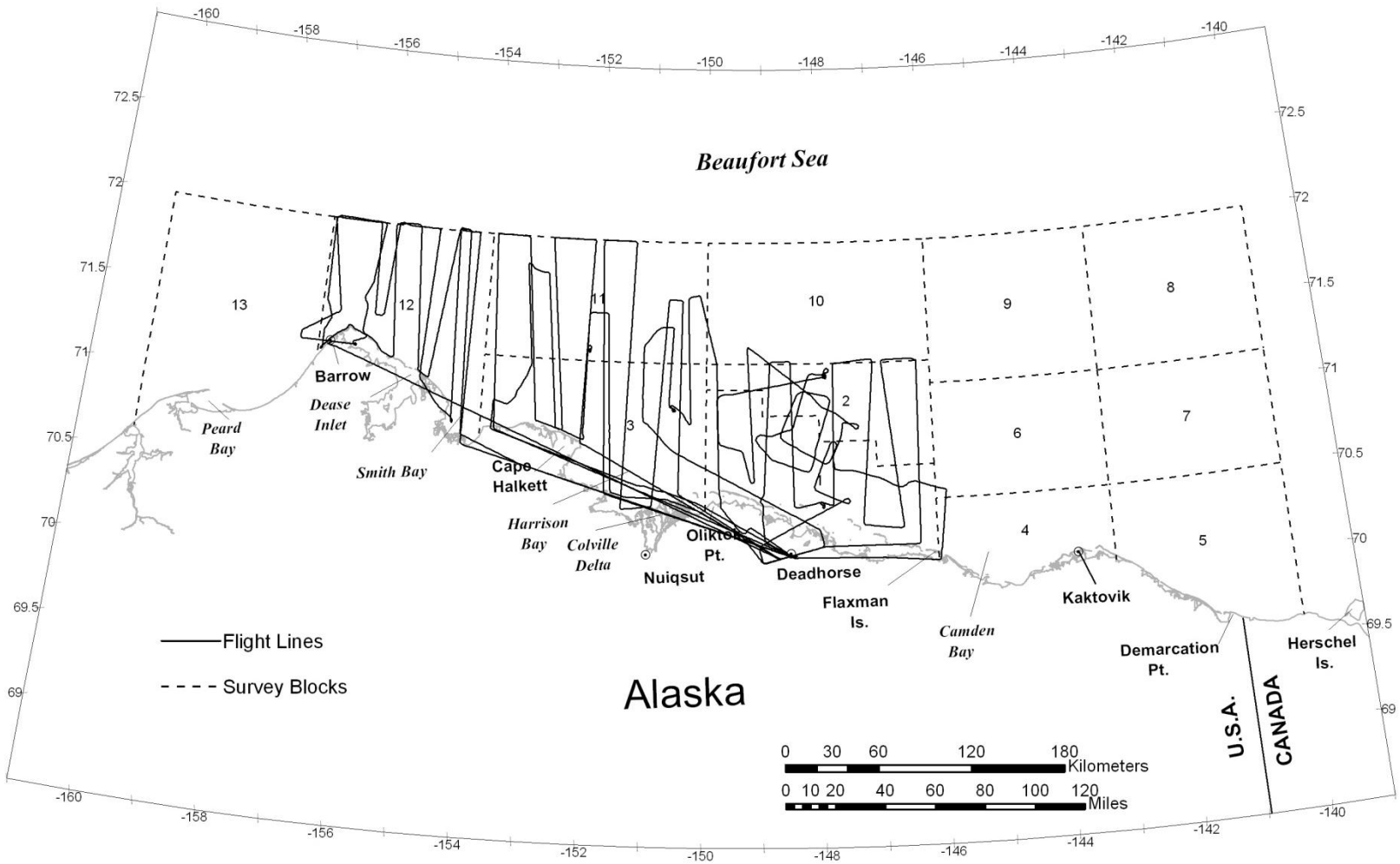

Figure 6. -- Combined flight tracks, all effort, 1-15 October 2010.

Bowhead Whale Observations

Sighting Summary

During fall 2010 surveys, 126 sightings of 178 bowhead whales were observed during all survey effort in the study area (Table 3). Bowhead whales were distributed throughout the nearshore regions of the survey area (Fig. 7). Bowhead whales were not seen in offshore Blocks 2, 6, 7, and 11, despite surveys conducted there in good weather, although one unidentified cetacean that was a probable bowhead whale was seen in Block 11 on 7 October (Appendix C). The greatest number of whales was seen in Block 5. Unlike 2009 and some previous years, no large groups of bowhead whales were observed in Block 12, despite survey effort there in late September and early October. Out of the 178 bowhead whales, 4 were identified as calves (Appendix B). The resulting seasonal calf ratio (number of calves/total whales) was 0.022. Locations of bowhead whale sightings are shown by semimonthly period in Figures 8 through 10.

Sighting Rates

In fall 2010, bowhead whales were seen from Point Barrow to Canada. Areas of highest fine-scale sighting rates (number of transect sightings/transect km surveyed in 5 km grid cells) were between Demarcation Point and Kaktovik (in Block 5), Camden Bay (in Block 4), the central Alaskan Beaufort Sea (in Block 1), and between Smith Bay and Pt. Barrow (in Block 12) (Fig. 11). There were 68 bowhead whale sightings on transect, ranging from 1 whale per sighting (n = 57) to 21 whales per sighting. The highest number of sightings on transect was in Block 5 with 29 sightings, followed by Block 1 with 18 sightings. The largest group of bowhead whales on transect (21 animals) was observed on 20 September, northwest of Smith Bay in Block 12.

Similar to the fine-scale sighting rate analysis, the highest sighting rates per Survey Block were in Block 5 (0.035 bowhead whales on transect/transect km flown), Block 12 (0.028 bowhead whales on transect/transect km flown) and Block 1 (0.024 bowhead whales on transect/transect km flown) (Table 4). Sighting rates using all bowhead whale sightings per Survey Block were similar to sighting rates using bowhead whales seen on transect only. Survey Block sighting rate analyses for previous years with light ice coverage in the 1980s and 1990s (e.g., Ljungblad et al. 1987; Treacy, 1988, 1990, 1991, 1994, 1995, 1996, 1997, 1998) analyzed total number of bowhead whales/survey hour flown, and did not remove non-surveyable time periods (due to lack of suitable visibility) or time spent surveying inside the barrier islands and north of 72°N. Nonetheless, the pattern of highest sighting rates per year is similar across all years. In recent years with light ice coverage (2006-2010), highest sighting rates were generally in coastal Survey Blocks (1, 3, 4, 5, and 12), and were usually correlated with large groups of bowhead whales in feeding or milling aggregations (Clarke et al. 2011b).

Sighting rate for bowhead whales in the central-eastern (140°-154°W) Alaskan Beaufort Sea subarea was highest in the 21-50 m depth zone (Table 5). Sighting rate for bowhead whales in the western (154°-157°W) Alaskan Beaufort Sea subarea was highest in the ≤ 20 m depth zone.

Table 3. -- Summary of marine mammal sightings (number of sightings/number of individuals) during all effort, 1 September-15 October 2010, by survey flight..

Day	Flight Number	Bowhead Whale	Gray Whale	Beluga	Unidentified Cetacean	Bearded Seal	Walrus	Unidentified Pinniped	Polar Bear
1 Sep	1	0	0	0	0	0	1/1	0	0
8 Sep	2	3/3	0	0	0	0	0	0	1/3
12 Sep	3	6/9	0	6/7	5/5	0	0	0	0
12 Sep	229	3/5	0	0	0	0	0	13/14	1/2
13 Sep	4	13/15	0	2/2	1/1	1/1	0	6/17	1/5
15 Sep	5	2/2	0	0	0	0	0	0	3/3
17 Sep	6	3/3	0	0	0	2/2	0	15/67	0
20 Sep	7	2/5	0	0	0	0	0	1/1	0
20 Sep	235	6/27	2/2	0	0	0	0	1/1	0
21 Sep	8	21/25	0	0	2/3	1/1	0	1/1	1/10
22 Sep	9	18/22	0	0	1/1	0	0	5/16	1/5
24 Sep	10	27/39	0	1/1	3/5	1/1	0	46/65	1/8
29 Sep	11	0	0	0	0	0	0	0	0
30 Sep	12	9/9	0	0	0	1/1	0	30/90	1/11
1 Oct	13	7/8	0	0	0	0	0	1/1	0
7 Oct	14	0	0	0	1/1	0	0	0	0
8 Oct	15	1/1	0	0	0	0	0	2/4	0
9 Oct	16	1/1	0	0	0	1/1	0	1/1	1/6
10 Oct	17	4/4	0	0	0	0	0	0	0
11 Oct	18	0	0	25/46	0	0	0	0	0
15 Oct	19	0	0	0	0	0	0	0	0
Semimonthly Sighting Summary									
1-15 Sep		27/34	0	8/9	6/6	1/1	1/1	19/31	6/13
16-30 Sep		86/130	2/2	1/1	6/9	5/5	0	99/241	4/34
1-15 Oct		13/14	0	25/46	1/1	1/1	0	4/6	1/6
Total		126/178	2/2	34/56	13/16	7/7	1/1	122/278	11/53

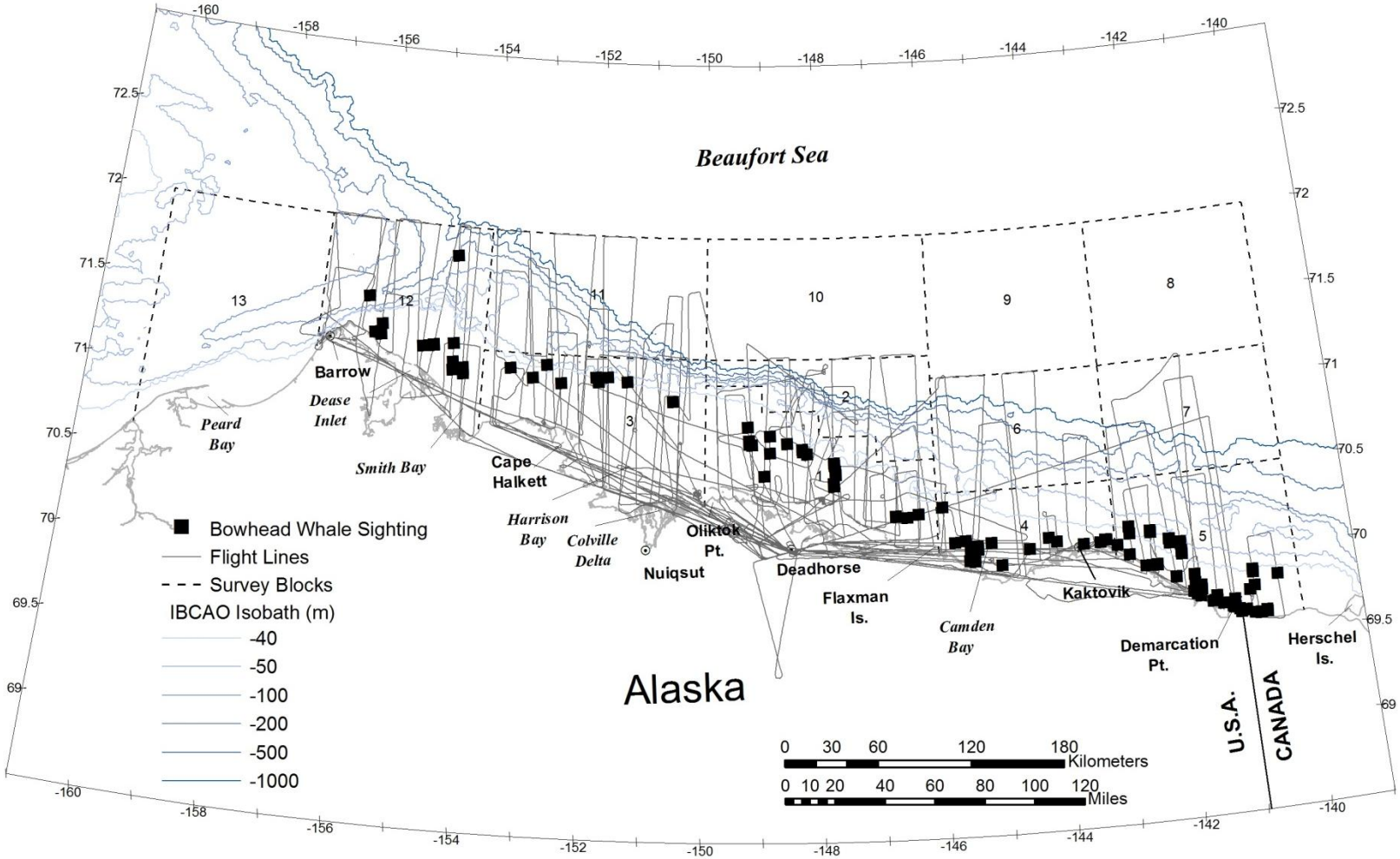

Figure 7. -- Bowhead whale sightings, all effort, fall 2010.

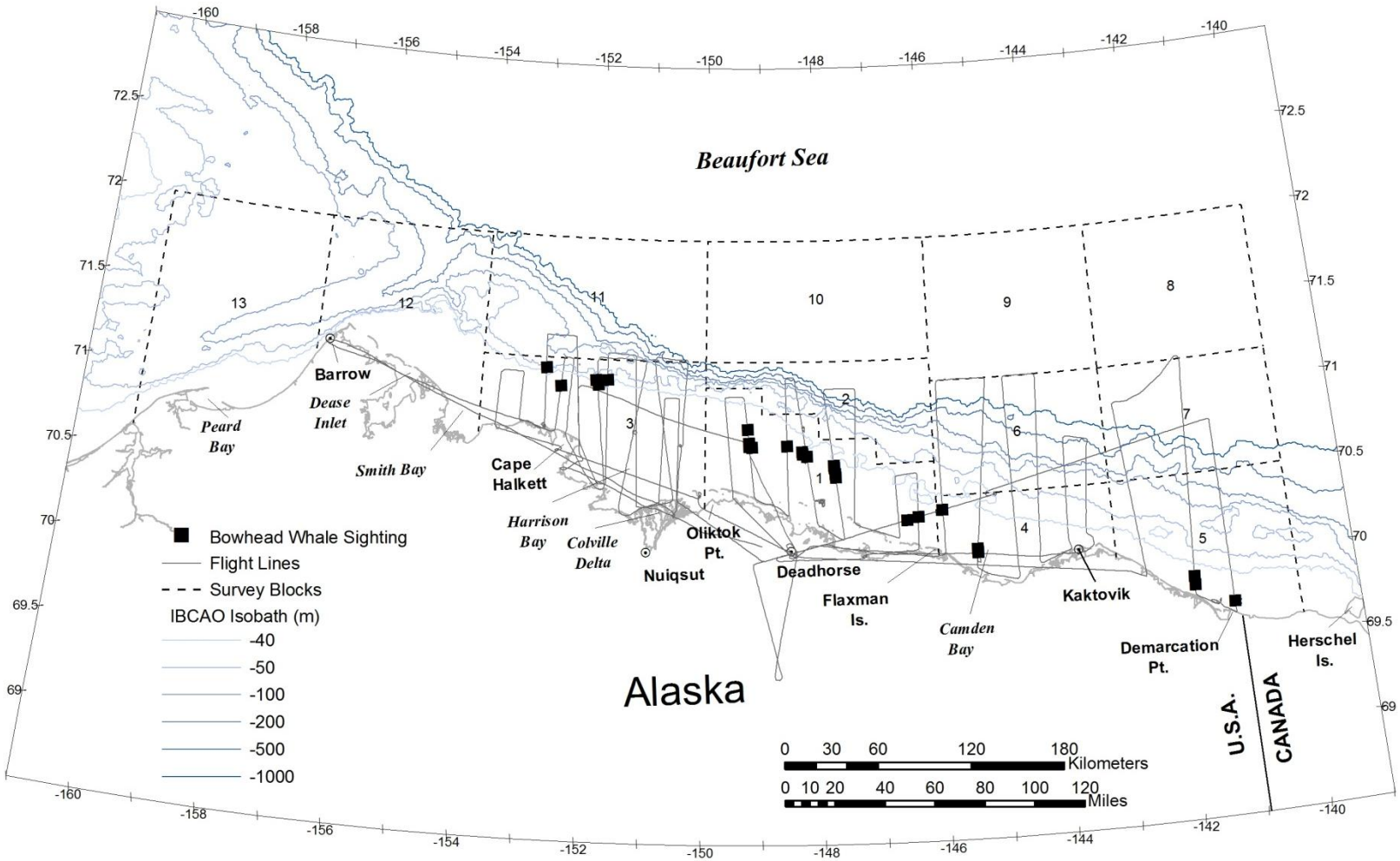

Figure 8. -- Bowhead whale sightings, all effort, 1-15 September 2010.

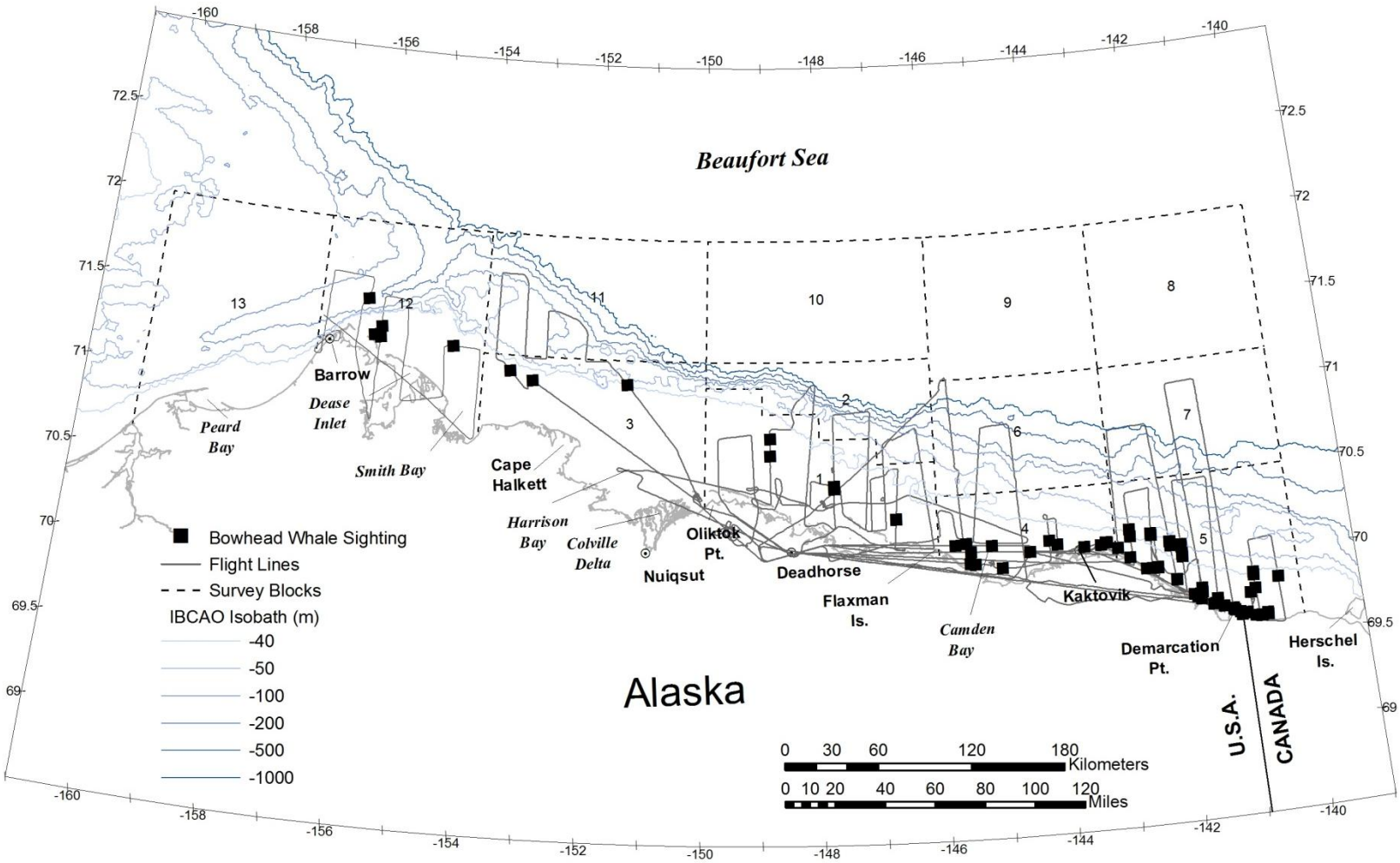

Figure 9. -- Bowhead whale sightings, all effort, 16-30 September 2010.

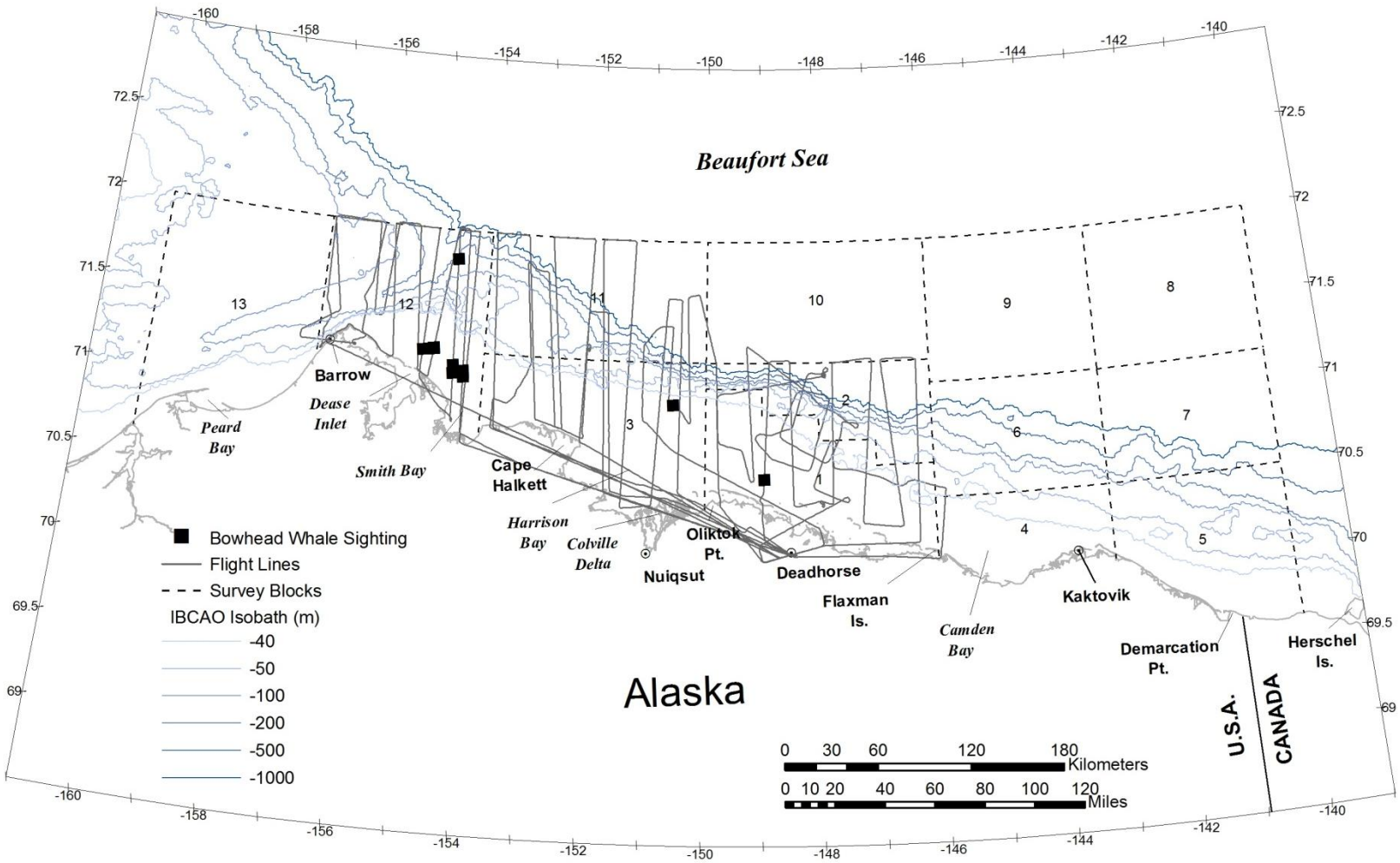

Figure 10. -- Bowhead whale sightings, all effort, 1-15 October 2010.

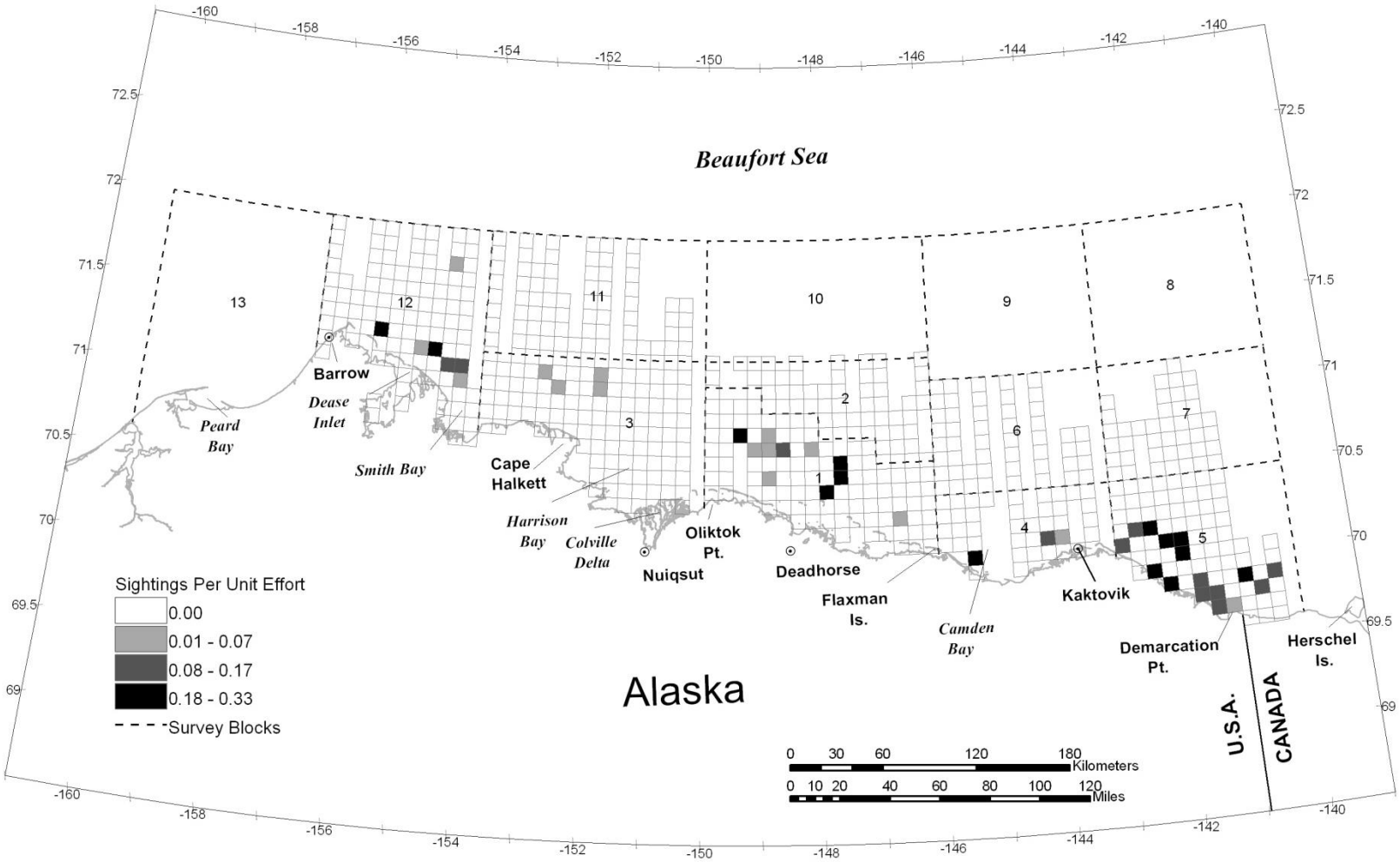

Figure 11. -- Sighting rates of bowhead whales, fall 2010 (bowhead whale sightings on transect/km of transect surveyed). Transect survey effort was not recorded in areas without grid lines.

Table 4. -- Effort (total and transect only), bowhead whale sightings (number of sightings/ number of individuals), and bowhead whale sighting rate (WPUE = transect whales per transect km surveyed) per Survey Block, fall 2010.

Survey Block	Total Effort (km)*	Total Bowheads	Transect Effort (km)*	Transect Bowheads	WPUE
1	2,036	24/38	1,246	18/30	0.0241
2	780	0	508	0	0.0000
3	3,304	9/11	1,823	4/4	0.0022
4	1,106	20/26	458	4/4	0.0087
5	1,515	56/64	910	29/32	0.0352
6	666	0	493	0	0.0000
7	458	0	335	0	0.0000
8	7	0	0	n/a	n/a
9	53	0	0	n/a	n/a
10	42	0	0	n/a	n/a
11	1,034	0	856	0	0.0000
12	1,573	17/39	1,207	13/34	0.0282
Total	12,573	126/178	7,836	68/104	0.0133

* Total effort differs from values in Table 2 because deadhead km were not included here; transect effort (km) differs slightly from values in Tables 2 and 5 because effort between barrier islands and the mainland were not included in the sighting rate per Survey Block analysis.

Table 5. -- Effort (transect only), bowhead whale sightings (number of sightings/number of individuals) and sighting rate (WPUE = transect whales per transect km surveyed) per depth zone, western (west of 154°W) and central-eastern (east of 154°W) Alaskan Beaufort Sea, fall 2010.

	West of 154°W			East of 154°W		
Depth Zone	Transect Effort (km)*	Transect Bowheads	WPUE	Transect Effort (km)*	Transect Bowheads	WPUE
≤20 m	**370**	**12/33**	**0.0892**	1,358	13/13	0.0096
21-50 m	236	0	0.0000	**2,702**	**42/57**	**0.0211**
51-200 m	525	1/1	0.0019	1,333	0	0.0000
201-2000 m	121	0	0.0000	1,085	0	0.0000
>2000 m	0	0	0.0000	211	0	0.0000
Total	1,252	13/34	0.0272	6,689	55/70	0.0105

* Transect effort (km) differs slightly from values in Tables 2 and 4 because effort between barrier islands and the mainland were included in the sighting rate per depth zone analysis.

Table 6. -- Semimonthly summary of bowhead whales (number of sightings/number of individuals) observed during all effort, by percent ice cover present at sighting location, fall 2010.

Percent Ice Cover	1-15 Sep	16-30 Sep	1-15 Oct	Total
0	16/21	78/117	13/14	107/152 (85%)
1-5	11/13	3/3	0	14/16 (9%)
6-10	0	5/10	0	5/10 (6%)
Total	27/34	86/130	13/14	126/178

Habitat Associations

Weekly ice coverage for the Alaskan Beaufort Sea during fall 2010 is included in Appendix A, and the percentage of ice cover visible from the aircraft at each bowhead whale sighting is included in Appendix B. Most bowhead whales were observed in 5% or less sea ice cover (Table 6).

Behaviors

Behaviors of 178 bowhead whales observed during all survey effort in fall 2010 are summarized in Table 7. The behavior most often recorded (68%) was swimming. Most swimming whales for which swim direction was recorded were heading west or northwest (60 whales, heading 238°-359° True). Feeding was recorded for 22 whales (12%). Feeding and milling were recorded in Blocks 1, 3, 5 and 12. Sighting rates of feeding and milling whales observed on transect are shown in Figure 12.

Block 12 is a well-documented bowhead whale feeding ground (Moore and Reeves 1993; Mocklin, 2009) and is the site of the BOEMRE-sponsored Bowhead Whale Feeding Ecology Study (BOWFEST). Preliminary results from BOWFEST indicate that krill are advected onto the Beaufort Sea shelf from the Beaufort Sea slope during sustained winds from the east or southeast, or possibly from Barrow Canyon during sustained winds from the north or northeast, whereupon the wind-driven, northwestward-flowing shelf current carries the krill toward Barrow (Ashjian et al. 2010). When winds weaken or change to blow from the south, the northeastward-flowing Alaska Coastal Current moves adjacent to the southern edge of Barrow Canyon, thereby blocking the offshelf movement of krill. This phenomenon results in the aggregation of krill at the western end of the Beaufort shelf near Barrow. The oceanographic response to the sequence of upwelling-favorable winds followed by weak or southerly winds produces conditions conducive to energetically efficient feeding by bowhead whales. Bowhead whale sightings in Block 12 in 2009 appeared to be consistent with the predicted mechanism (Clarke et al. 2011b).

Table 7. -- Semimonthly summary of bowhead whales (number of sightings/number of individuals) observed during all effort, by behavioral category, fall 2010.

Behavior	1-15 Sep	16-30 Sep	1-15 Oct	Total
Breach	0	1/1	0	1/1 (<1%)
Cow with calf	0	1/2	0	1/2 (1%)
Dive	0	4/4	1/1	5/5 (3%)
Feed	0	2/22	0	2/22 (12%)
Mill	5/10	6/10	0	11/20 (11%)
Rest	1/1	3/4	0	4/5 (3%)
Swim	21/23	68/85	12/13	101/121 (68%)
Tail slap	0	1/2	0	1/2 (1%)
Total	27/34	86/130	13/14	126/178

Surveys were conducted in Block 12 on three occasions during BWASP 2010, and bowhead whales were seen during each flight (Fig. 13). On 20 September, 27 bowhead whales were seen during marginal survey conditions (Beaufort 2 to 4, <1-3 km visibility) between Smith Bay and Pt. Barrow. Of the whales reported, 22 were feeding, all within the 20 m contour. The remaining 5 whales were scattered from 10 to 25 km offshore at depths ranging from 16 to 172 m. On 1 October, 8 bowhead whales were observed during acceptable survey conditions (Beaufort 3 to 6, 5-10 km visibility). All sightings were within the 20 m contour between Smith Bay and Dease Inlet. None of the whales were observed feeding. On 10 October, four bowhead whales were observed during marginal survey conditions. None of the whales were observed feeding; three of the whales were within the 20 m contour, while the fourth whale was approximately 70 km offshore in water >180 m deep.

Information on wind speed, wind direction, and other environmental variables, were collected three times per day for Barrow from the National Weather Service, Alaska Aviation Weather Unit web site (http://aawu.arh.noaa.gov/), and plotted for several days preceding the BWASP bowhead whale sighting events in Block 12 (Fig. 14). Winds prior to the 20 September sighting event (22 feeding whales, 5 non-feeding whales) were variable, but predominantly easterly and ~10 kts or less for the six days prior to and including 10 September. Winds prior to the 1 October sighting event (eight non-feeding whales) were east-northeasterly and strong (15-20 kts) from 26-29 September, then changed to variable and light (<10 kts) from 29 September through early 1 October. Winds were weak (5-8 kts) and from the south prior to the sighting event on 10 October (four non-feeding whales). The lack of large feeding bowhead whale aggregations (other than the one group of 22 whales) in this area on 20 September and 10 October was not surprising, based on the lack of strong easterlies prior to these dates. However, the lack of feeding bowhead whale aggregations on 1 October was surprising, as wind conditions appeared to be conducive to krill aggregation.

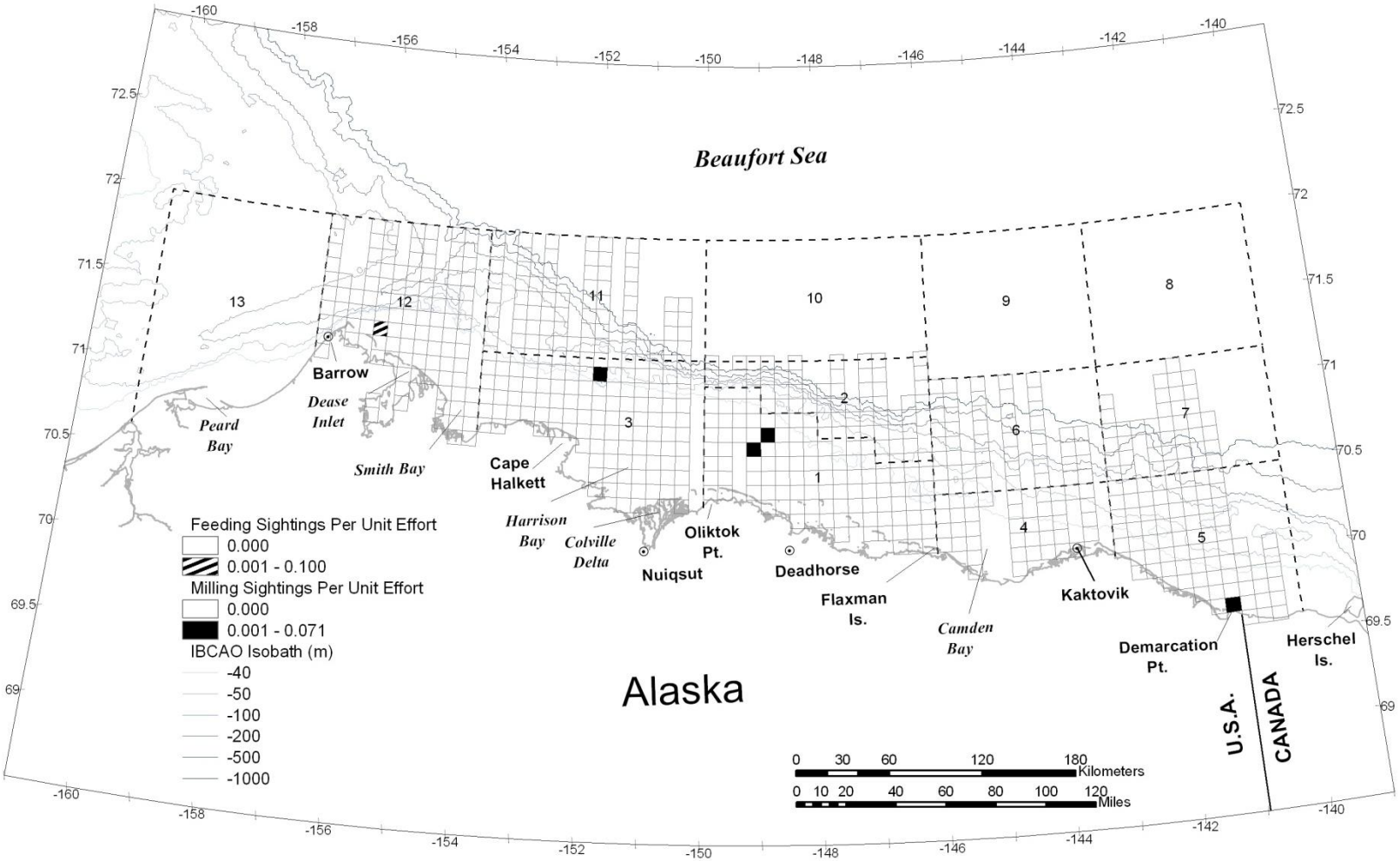

Figure 12. -- Sighting rates of milling and feeding bowhead whales, fall 2010 (bowhead whale sightings on transect/km of transect surveyed). Transect survey effort was not recorded in areas without grid lines.

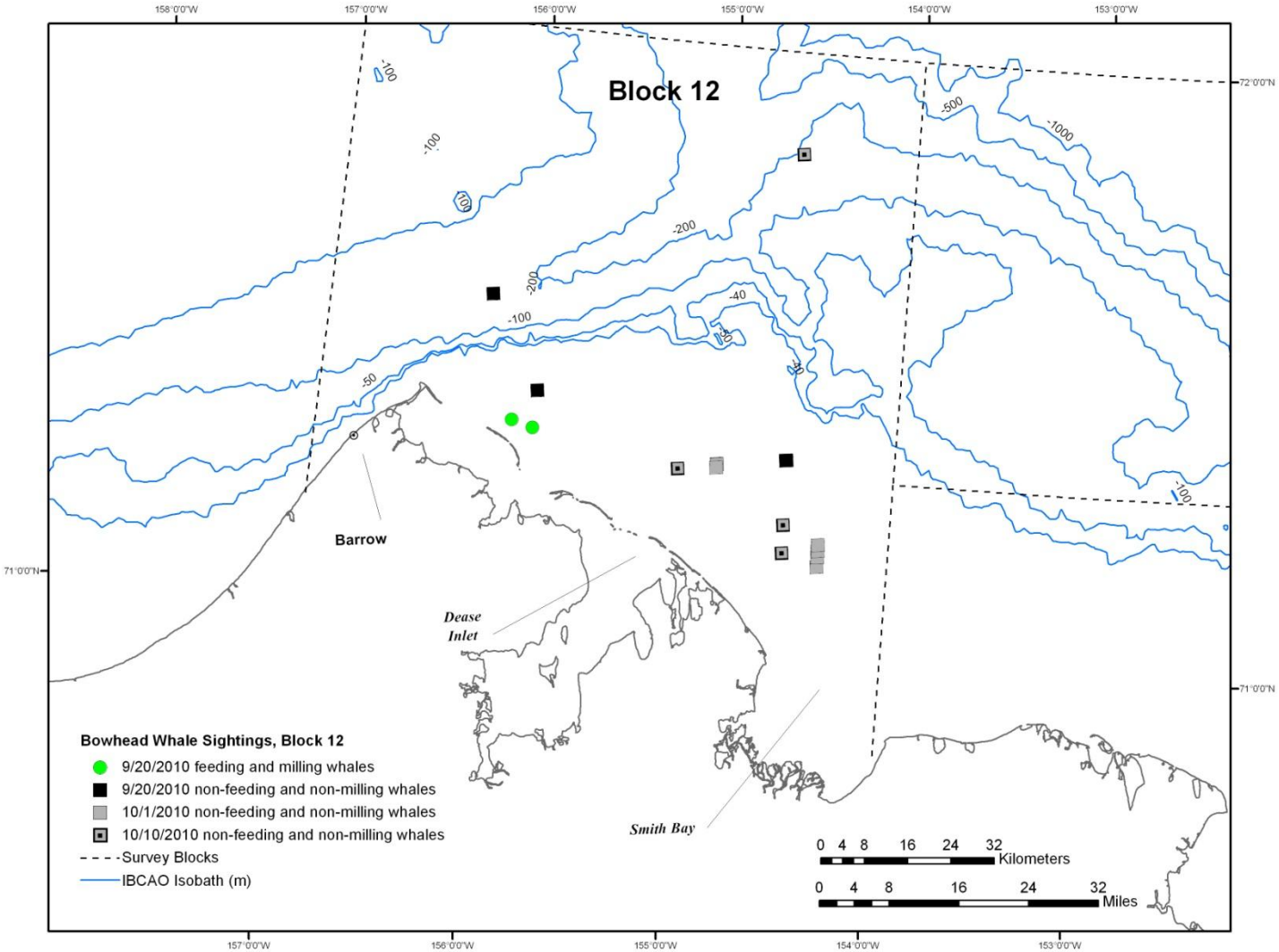

Figure 13. -- Bowhead whale sightings in Block 12, all effort, on 20 September, 1 October and 10 October 2010.

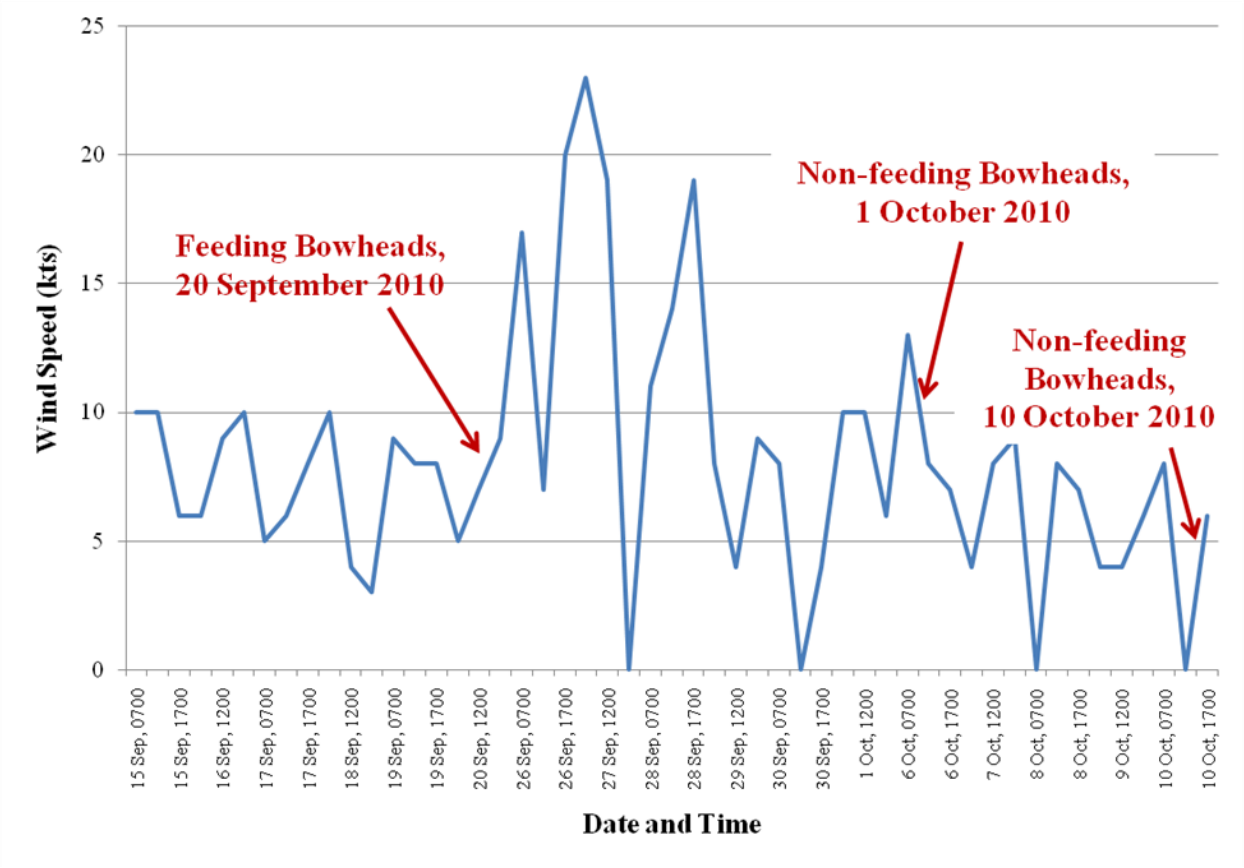

Figure 14. -- Wind speeds measured at Barrow, Alaska, prior to 20 September, 1 October and 10 October 2010.

Marine mammal observers and flight crew watched for sudden overt changes (e.g., an abrupt dive, course diversion, or cessation of initial behavior observed) in whale behavior that may indicate a response to the survey aircraft. No bowhead whales were observed to have responded to the aircraft.

Distance from Shore

Distances from shore of 2010 bowhead whale transect sightings were measured, using ArcGIS, as the distance due north of the normalized shoreline. Mean distance of locations of *all* bowhead whale transect sightings to the normalized shoreline in 2010 was 14.2 km (SD = 8.6) in the East Region, and 28.3 km (SD = 15.5) in the West Region (Table 8; Fig. 15). Mean distance of locations of "migrating" bowhead whale transect sightings (i.e., excluding those sightings of feeding, milling, or resting whales) was 14.5 km (SD = 8.6) in the East Region, and 27.6 km (SD = 15.5) in the West Region (Fig. 16). Mann-Whitney *U*-test of significant difference between medians indicated no difference between median distances of all sightings versus median distances of only those sightings considered "migrating" in the East (Z = -0.100, P = 0.9201) or West (Z = 0.297, P = 0.7665) Regions.

Table 8. -- Central-tendency statistics for distance from shore (km) and depth (m) at bowhead whale transect sightings (September-October), by year and region, 1982-2010.

			Distance from shore (km)				Depth (m)			
Year	Region	TrSi	Median	Mean	SD	Min-Max	Median	Mean	SD	Min-Max
1982*	East	29	35.4	35.2	7.44	25-52	42	43	6.29	35-57
	West	27	40.1	41.4	15.47	14-84	31	92	207.03	14-1041
1983	East	14	84.8	83.4	14.91	57-115	804	916	718.72	65-1953
	West	15	47.5	56.4	25.14	24-122	68	313	597.95	21-2166
1984	East	23	33.3	35.8	22.43	2-98	44	77	104.86	18-508
	West	36	42	41.4	17.71	8-73	40	48	33.24	13-189
1985	East	10	28.1	29.3	14.62	2-56	39	38	7.31	23-51
	West	7	49.5	51.2	28.07	13-86	36	193	348.59	16-975
1986*	East	30	23.4	24.7	15.06	1-55	41	38	18.22	7-92
	West	19	34.3	36.8	21.29	4-80	28	78	117.51	10-490
1987*	East	34	30.5	32.9	17	6-79	39	53	45.72	15-223
	West	8	28.3	27.9	15.5	6-46	26	23	10.04	8-32
1988	East	6	26.2	29.1	20	5-66	49	92	123.39	23-343
	West	8	57.6	58.5	5.96	50-67	50	50	6.57	41-63
1989*	East	6	49.38	58.3	24.72	31-91	61	196	219.75	47-509
	West	17	33	28	15.82	7-64	20	19	8.2	6-34
1990*	East	93	31.6	31.5	12.53	8-78	42	48	33.05	20-285
	West	6	33.1	36.8	12.66	25-60	32	33	11.47	20-51
1991	East	15	51.3	52.5	20.23	22-79	55	122	108.45	35-387
	West	6	42.3	48.8	19.97	29-76	42	97	94.29	26-230
1992	East	12	36.1	39.2	11.94	24-60	54	51	6.07	40-59
	West	13	57.1	53.5	14.71	23-74	51	54	27.82	14-121
1993*	East	55	26.1	29	15.79	6-81	41	58	96.59	11-717
	West	35	23.9	28.1	12.38	11-62	20	23	9.29	11-49
1994*	East	32	27.3	35.1	18.57	12-74	47	80	175.67	31-1038
	West	3	17.9	22.3	11.6	14-35	12	22	16.74	12-41
1995*	East	94	27.2	29.8	14.93	3-99	42	52	68.74	15-628
	West	44	35.9	41.1	24.43	6-108	31	107	259.75	7-1233
1996*	East	13	27.9	26.3	10.45	14-53	29	38	9.16	15-48
	West	15	39.9	39	15.22	19-63	35	37	16.93	19-82
1997*	East	35	9.3	13.8	11.33	3-43	22	24	11.97	11-50
	West	145	23.6	25.6	11.33	1-57	20	25	21.42	5-189
1998*	East	103	20.4	22.1	12.61	3-68	32	34	12	7-83
	West	113	18.5	23.6	17.53	1-120	15	38	170.85	5-1815

			Distance from shore (km)				Depth (m)			
Year	Region	TrSi	Median	Mean	SD	Min-Max	Median	Mean	SD	Min-Max
1999*	East	68	36.4	35.3	11.5	1-59	50	51	20.94	8-171
	West	68	33	36.2	16.21	8-74	31	43	42.94	11-210
2000*	East	26	34	39.3	20.86	13-100	41	82	122.01	28-559
	West	19	9.3	16.2	18.23	1-78	11	32	81.58	4-367
2001*	East	16	31.5	29.7	112.2	12-48	46	43	8.73	27-53
	West	2	na	41.9	42.31	12-72	29	29	26.17	10-47
2002*	East	16	14.8	19	16.62	2-61	29	28	13.13	0-50
	West	23	33.9	35.6	12.31	10-57	24	27	12.17	11-61
2003*	East	33	34.7	29.8	19.3	4-65	40	39	16.75	12-92
	West	41	30.5	32.4	18.38	7-86	23	58	74.28	8-291
2004*	East	67	21.5	24.2	11.63	2-73	39	43	48.36	6-423
	West	60	23.1	23.5	10.4	1-66	20	31	35.68	4-211
2005*	East	19	28.1	26.4	14.15	3-45	42	39	12.39	12-57
	West	27	38.3	39.8	20.37	5-74	33	59	71.51	10-285
2006*	East	45	34.3	39.3	22.42	4-92	44	196	445.99	8-1868
	West	46	39.2	37.2	19.63	3-74	32	40	34.06	7-204
2007*	East	49	21.8	23.2	14.43	1-74	34	43	54.2	14-403
	West	6	25.7	25.7	64.8	15-35	23	23	8.55	12-35
2008*	East	25	21.3	20.5	10.65	6-38	29	27	7.68	12-40
	West	37	18.4	22.6	13.92	3-57	15	17	6.91	3-33
2009*	East	9	6.6	20.2	21.1	3-57	21	30	19.77	11-56
	West	42	16.9	23.1	17.06	5-87	17	30	44.67	9-245
2010*	East	43	16.2	14.2	8.64	1-29	30	30	11.13	13-49
	West	25	21.6	28.3	15.51	2-79	20	32	34.22	10-189

TrSi – number of bowhead whale sightings on transect
SD – standard deviation
* – light ice coverage

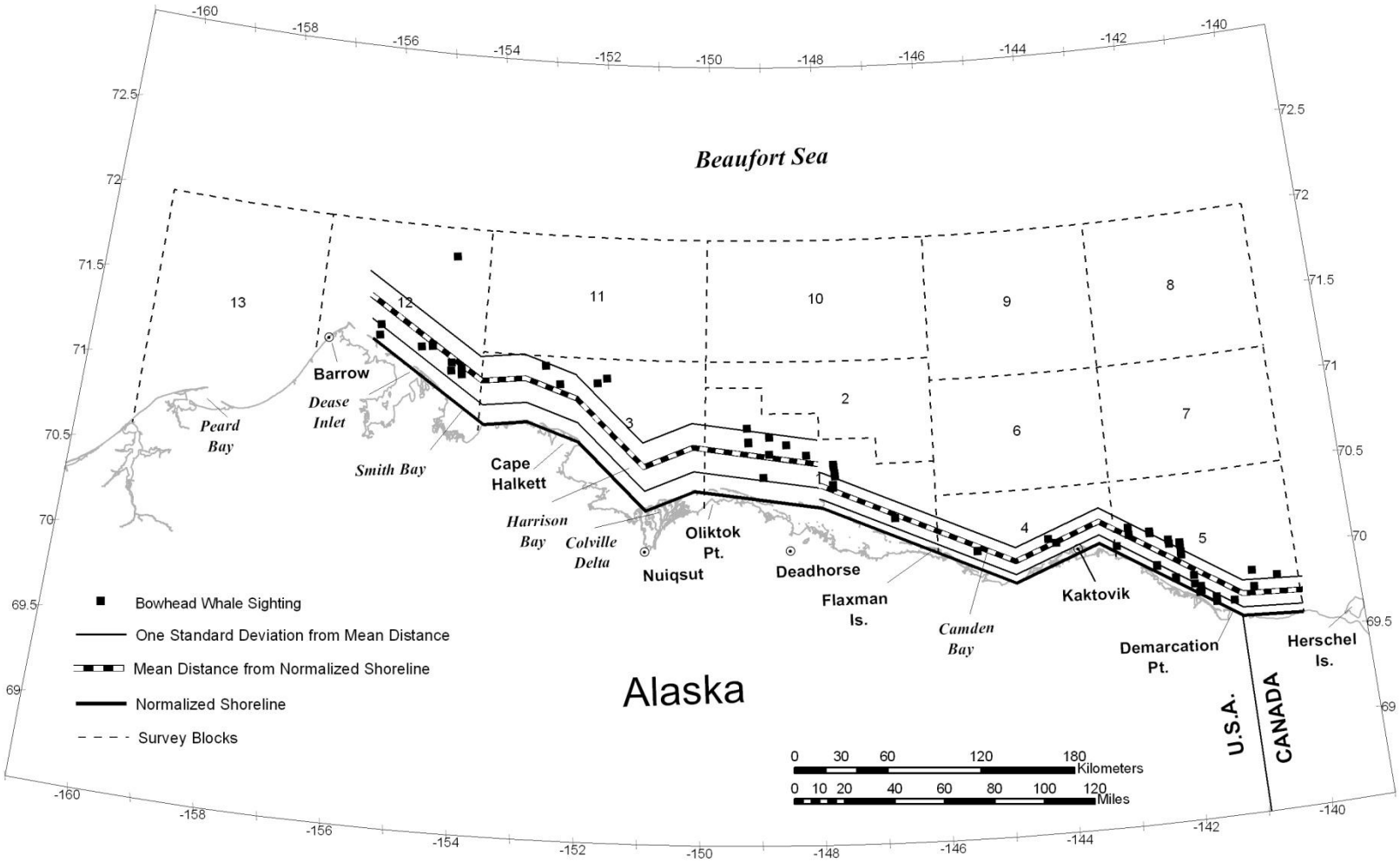

Figure 15. -- Bowhead whale sightings on transect, fall 2010, showing mean distance from the normalized shoreline.

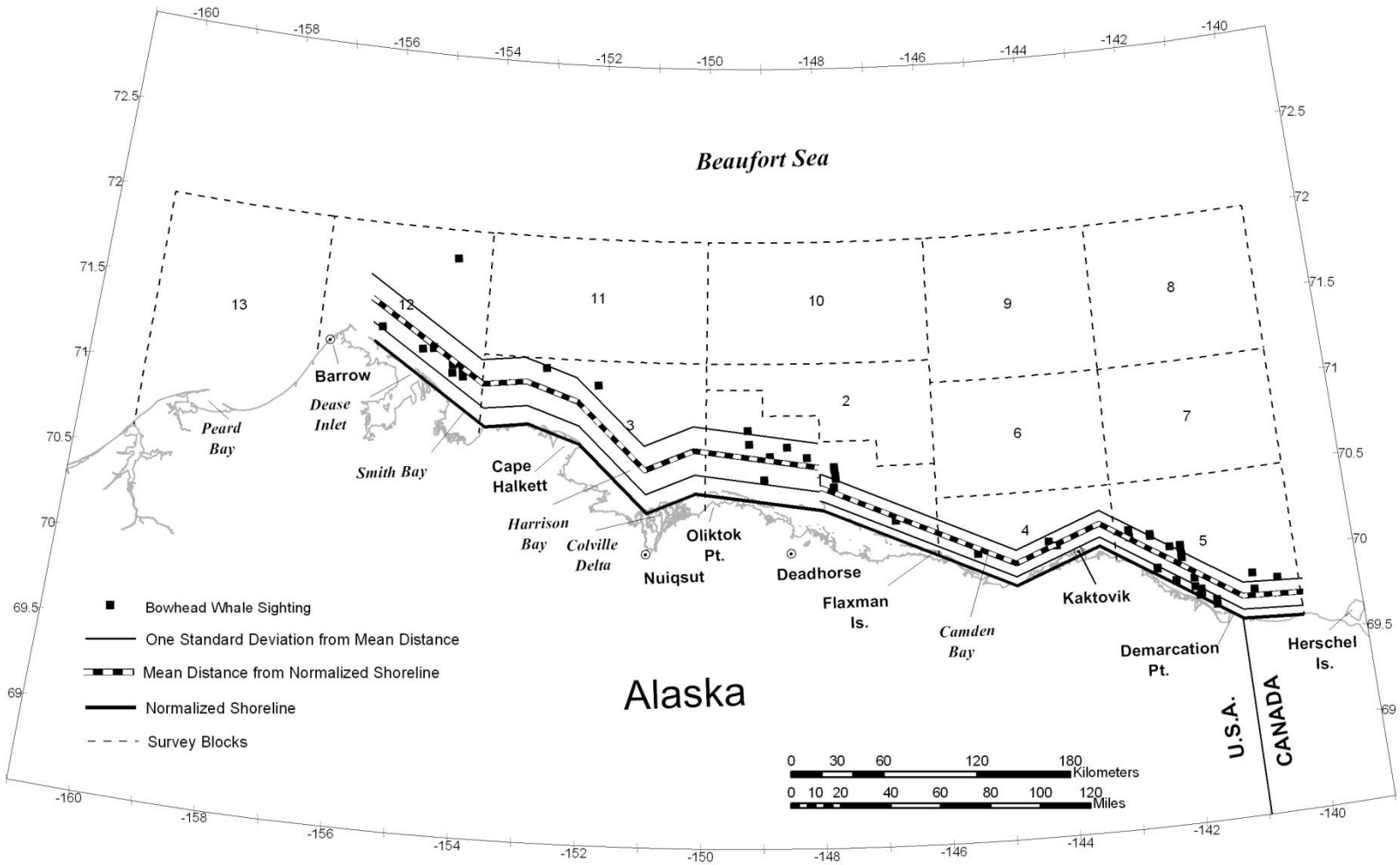

Figure 16. -- Bowhead whale sightings on transect excluding feeding, milling and resting whales, fall 2010, showing mean distance from the normalized shoreline.

Depth at Sighting

Mean depth at sightings of *all* bowhead whales on transect was 30 m (SD = 11.1, range 13-49 m) in the East Region, and 32 m (SD = 34.2, range 10-189 m) in the West Region (Table 8). Mean depth of "migrating" bowhead whales on transect was 30 m (SD = 11.1, range 13-49) in the East Region and 33 m (SD = 38.1, range 14-189 m) in the West Region. Mann-Whitney *U*-test of significant difference of medians indicates no difference between median depths of all sightings versus median depths of only those sightings considered "migrating" in the East (Z = -0.068, P = 0.9455) and West (Z = 0.148, P = 0.8820) Regions.

Based on the lack of significant difference between all bowhead whale sightings in 2010 and sightings limited to those whales considered "migrating," additional analyses of the bowhead whale migration corridor incorporated all sightings and were not limited to only those animals considered actively "migrating".

Distribution of Bowhead Whales, 2010, Relative to Bowhead Whale Distribution in Previous Years with Light Ice Coverage

In order to evaluate whether significant displacements occurred in the bowhead whale migratory corridor during 2010, estimates of median depth at sighting and distance of sightings from the normalized shoreline were compared with data from previous years having light ice coverage (i.e., 1982, 1986, 1987, 1989, 1990, 1993-2009). Median distance from shore during previous years with light ice coverage for bowhead whale sightings was 27 km in the East Region and 26 km in the West Region; the median water depth at sightings was 40 m in the East Region and 21 m in the West Region. Neither the median depth nor distance from shore analysis were corrected for effort.

In 2010, bowhead whales in the East Region were significantly closer to shore (16.2 km vs. 27.0 km, Z = 6.300, P = 0.00000) and in significantly shallower water (30 m vs. 40 m, Z = 4.733, P = 0.000002) than in previous years with light ice coverage.

In the West Region, there was no significant difference in distance from shore of bowhead whale sightings between 2010 (22.0 km) and previous years with light ice coverage (26.0 km), nor was there any significant difference in depth at bowhead whale sightings between 2010 (20 m) and previous years with light ice coverage (21 m).

Other Marine Mammal Observations

There were 2 sightings of 2 gray whales in fall 2010 (Fig. 17). Both gray whales were close to shore, west of Barrow.

There were 34 sightings of 56 belugas in fall 2010 (Fig. 18). Belugas were seen along the slope in Blocks 2, 7 and 11. Sighting rate was highest in Block 11 (0.048 belugas on transect per transect km flown; Table 9). Sighting rate per depth zone was highest in the 201-2,000 m

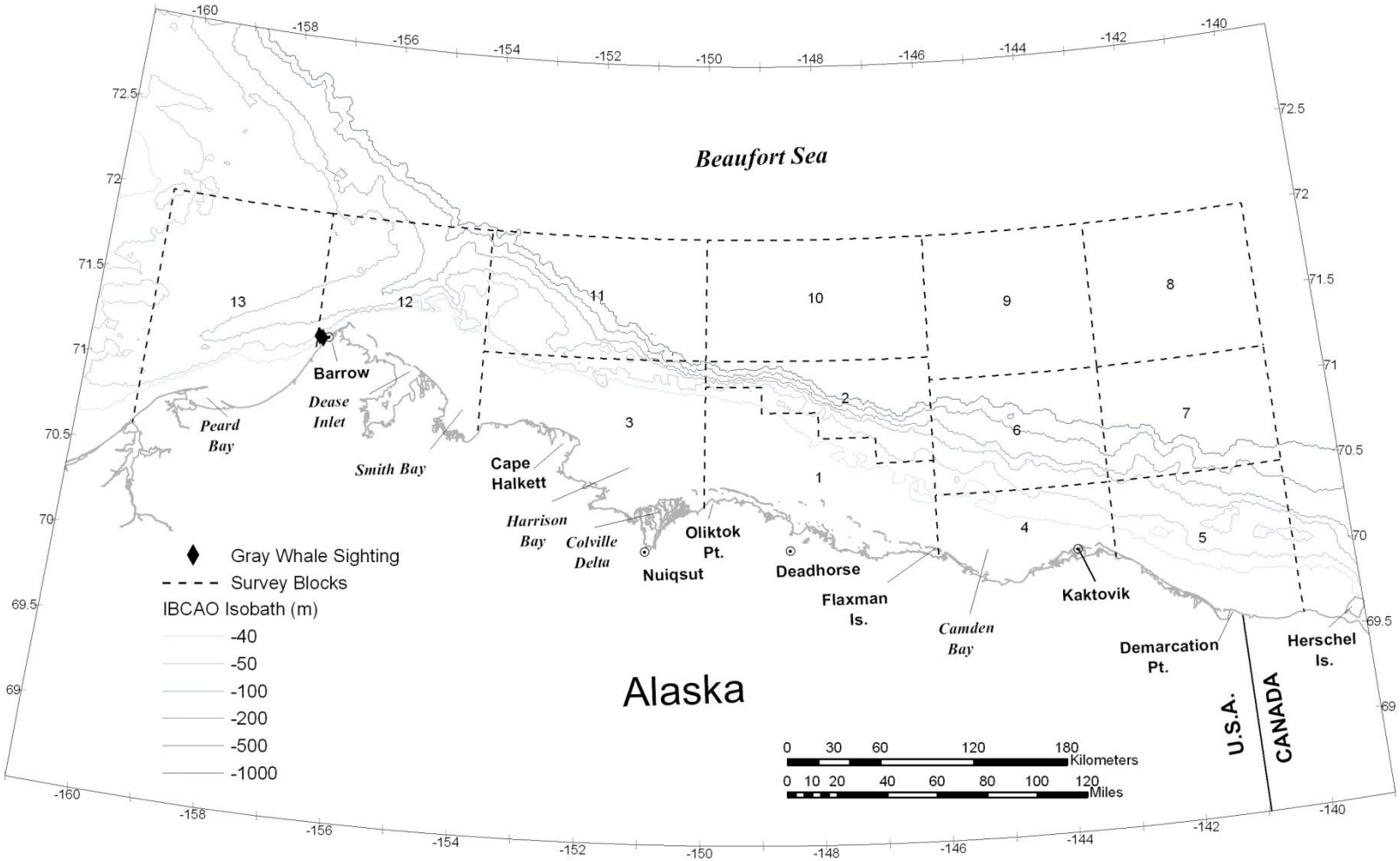

Figure 17. -- Gray whale sightings, all effort, fall 2010.

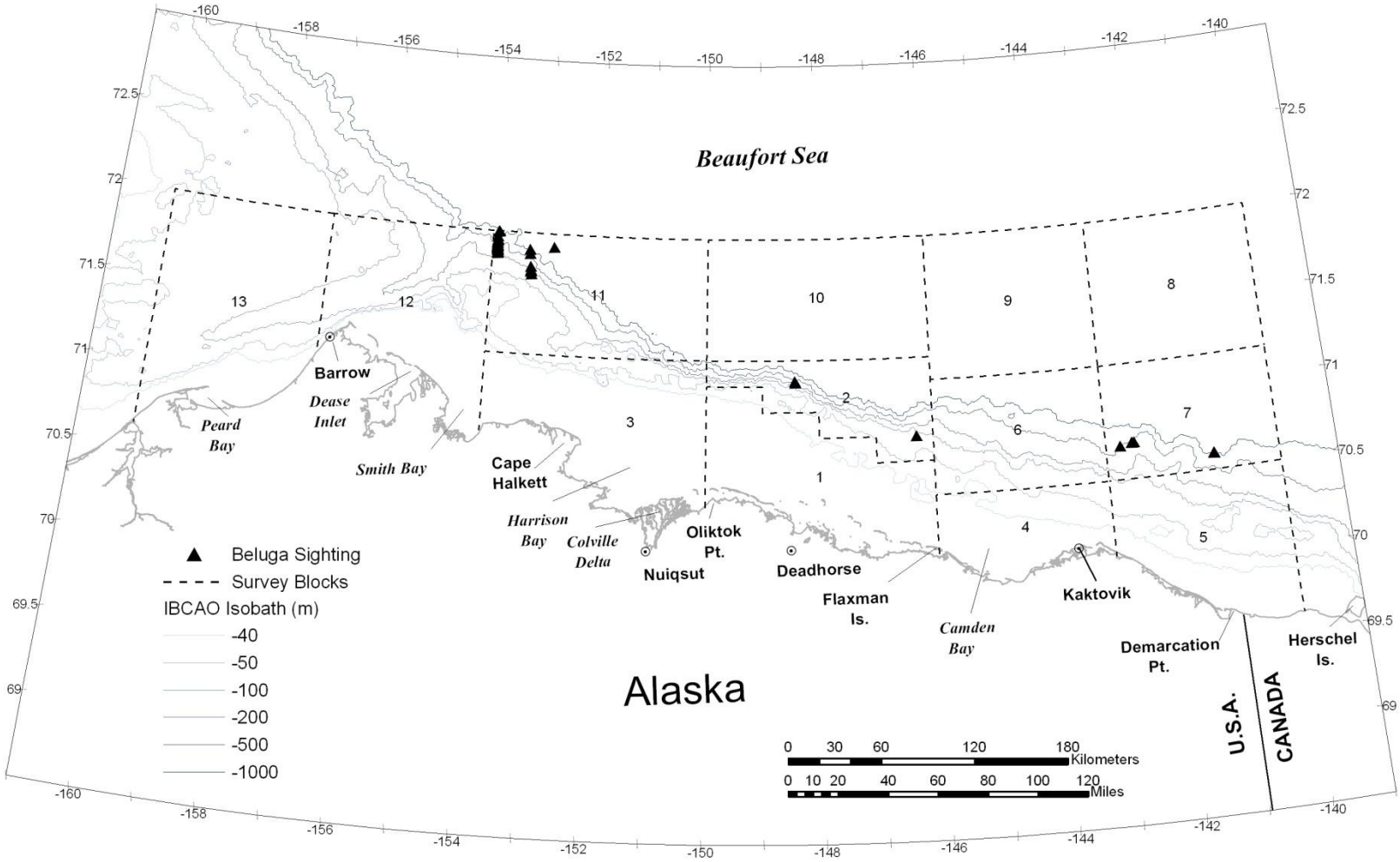

Figure 18. -- Beluga sightings, all effort, fall 2010.

Table 9. -- Effort, beluga sightings (number of sightings/number of individuals) and sighting rate (WPUE = transect whales per transect km surveyed) per Survey Block, fall 2010.

Survey Block	Transect Effort (km)*	Transect Belugas	WPUE
1	1,246	0	0.0000
2	508	3/3	0.0059
3	1,823	0	0.0000
4	458	0	0.0000
5	910	0	0.0000
6	493	0	0.0000
7	335	2/2	0.0060
8	0	n/a	n/a
9	0	n/a	n/a
10	0	n/a	n/a
11	**856**	**22/41**	**0.0479**
12	1,207	0	0.0000
Total	7,836	27/46	0.0059

* Transect effort (km) differs slightly from values in Table 2 and 5 because effort between barrier islands and the mainland were not included in the sighting rate per Survey Block analysis.

contour for the central-eastern subarea of the BWASP region (Table 10); belugas were not observed in the western subregion. Belugas are usually associated with ice (Moore et al. 2000), however all belugas seen in 2010 were in ice-free water. Beluga sighting rates were similar to those observed during BWASP surveys in 2007 and 2008 (Fig. 19). Beluga sighting rates in recent years, aside from 2009, have been lower than during historical BWASP survey years, possibly due to the retreat of the summer sea ice beyond the extent of the study area.

There was one sighting of one walrus on 1 September 2010, at 71.145°N, 152.188°W, swimming in an area of 20% broken floe ice.

Bearded seals (7 sightings of 7 seals) and unidentified pinnipeds (122 sightings of 278 seals) were distributed across the Alaskan Beaufort Sea (Figs. 20, 21) primarily east of 154°W; few pinnipeds were seen in Block 12. Pinnipeds were seen both on the shelf and in deeper areas of the slope. Unidentified pinnipeds included sightings of small pinnipeds that could not be identified to species due to the altitude of the aircraft (> 1,000 feet), and likely included spotted (*Phoca largha*) and ringed (*Pusa hispida*) seals. The distributions of ringed and spotted seals overlap in the Alaskan Beaufort Sea (Boveng et al. 2009, Angliss and Allen 2009); behaviors and physical characteristics observable from survey altitude are not distinguishable enough to allow positive species identification (D. Rugh and D. Withrow, NMML-AFSC, 7600 Sand Point Way NE, Seattle, WA 98115, pers. commun., 8 December 2009).

Table 10. -- Effort, beluga sightings (number of sightings/number of individuals) and sighting rate (WPUE = transect whales per transect km surveyed) per depth zone, western (west of 154°W) and central-eastern (east of 154°W) Alaskan Beaufort Sea, fall 2010.

	West of 154°W			East of 154°W		
Depth Zone	Transect Effort (km)*	Transect Belugas	WPUE	Transect Effort (km)*	Transect Belugas	WPUE
≤ 20 m	370	0	0.0000	1,358	0	0.0000
21-50 m	236	0	0.0000	2,702	0	0.0000
51-200 m	525	0	0.0000	1,333	3/4	0.0030
201-2000 m	121	0	0.0000	**1,085**	**24/42**	**0.0387**
> 2000 m	0	n/a	n/a	211	0	0.0000
Total	1,252	0	0.0000	6,689	27/46	0.0069

* Transect effort (km) differs slightly from values in Tables 2 and 9 because effort between barrier islands and the mainland were included in the sighting rate per depth zone analysis.

There were 11 sightings of 53 polar bears seen on 9 of 21 flights from 1 September to 15 October 2010; some of the bears may have been seen repeatedly (Fig. 22). All but two polar bears were sighted near or on shore between Kaktovik and Smith Bay. Two bears were sighted approximately 30 kilometers north of Oliktok in Harrison Bay, swimming in an area of 10% broken floe ice. Multiple bears were seen on Cross Island on several days: 5 bears on 13 September, 10 bears on 21 September, 8 bears on 24 September, and 6 bears on 9 October. Polar bears were also sighted near Kaktovik on three occasions: 3 bears on 8 September, 5 bears on 22 September, and 11 bears on 30 September.

Accomplishments

Results from the 2010 BWASP field season were presented by NMFS personnel at several venues, including:

Ferguson, M., J. Clarke, C. Christman, S. Grassia and A. Brower. 2011. A tale of two seas: lessons from multi-decadal aerial surveys for cetaceans in the Beaufort and Chukchi Seas. Presentation: Alaska Marine Science Symposium, Anchorage, Alaska, 17-21 January 2011.

Ferguson, M., J. Clarke, C. Christman, S. Grassia and A. Brower. 2011. Aerial surveys for marine mammals in the Beaufort and Chukchi Seas. Presentation: Arctic Open-Water Meeting, Anchorage, Alaska, 7-9 March 2011; and 2011 Alaska Scientific Review Group Meetings, Seattle, Washington, February 2011.

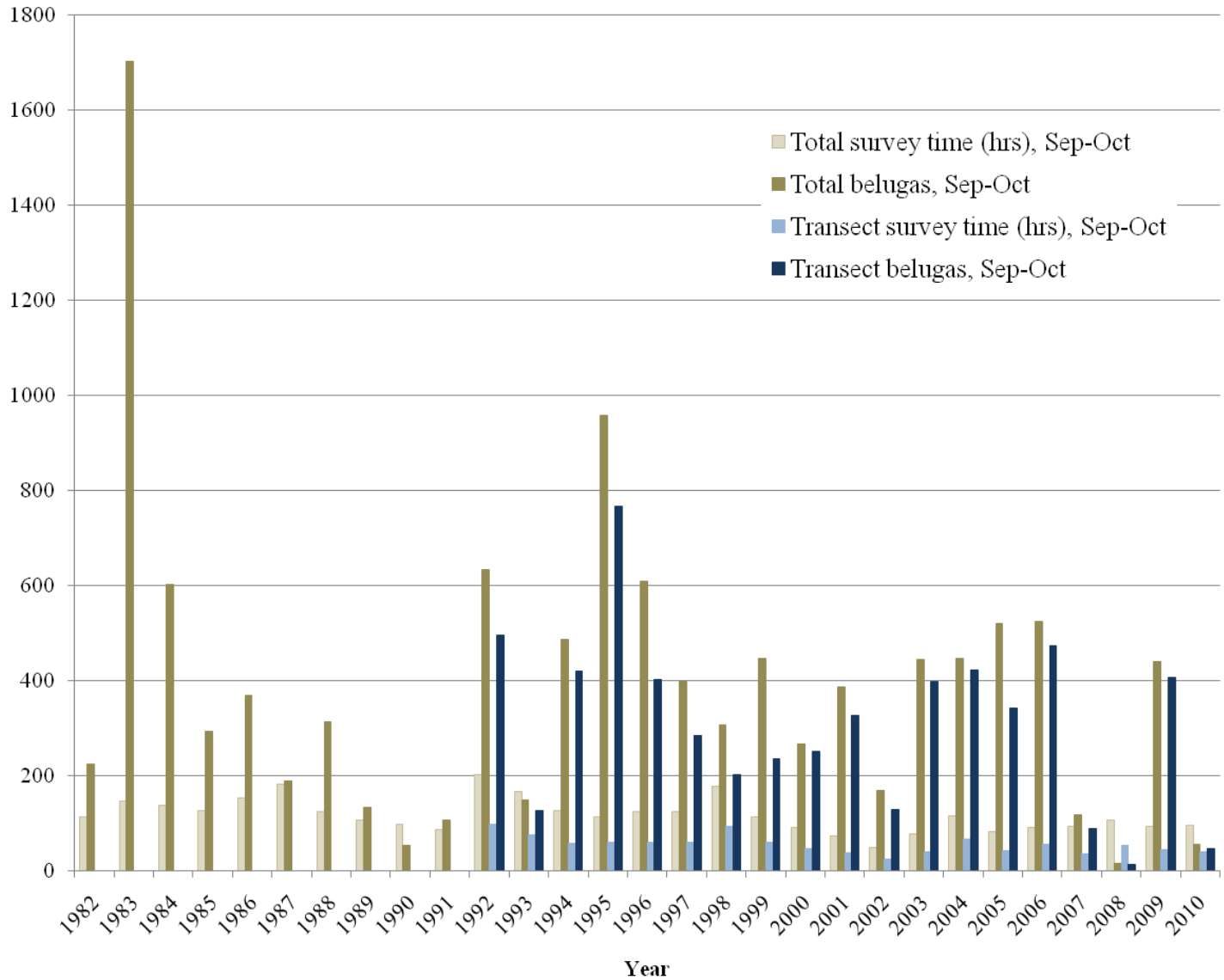

Figure 19. -- Number of belugas and annual effort (hr), total and transect only, 1982-2010. Transect data not available for 1982-1991.

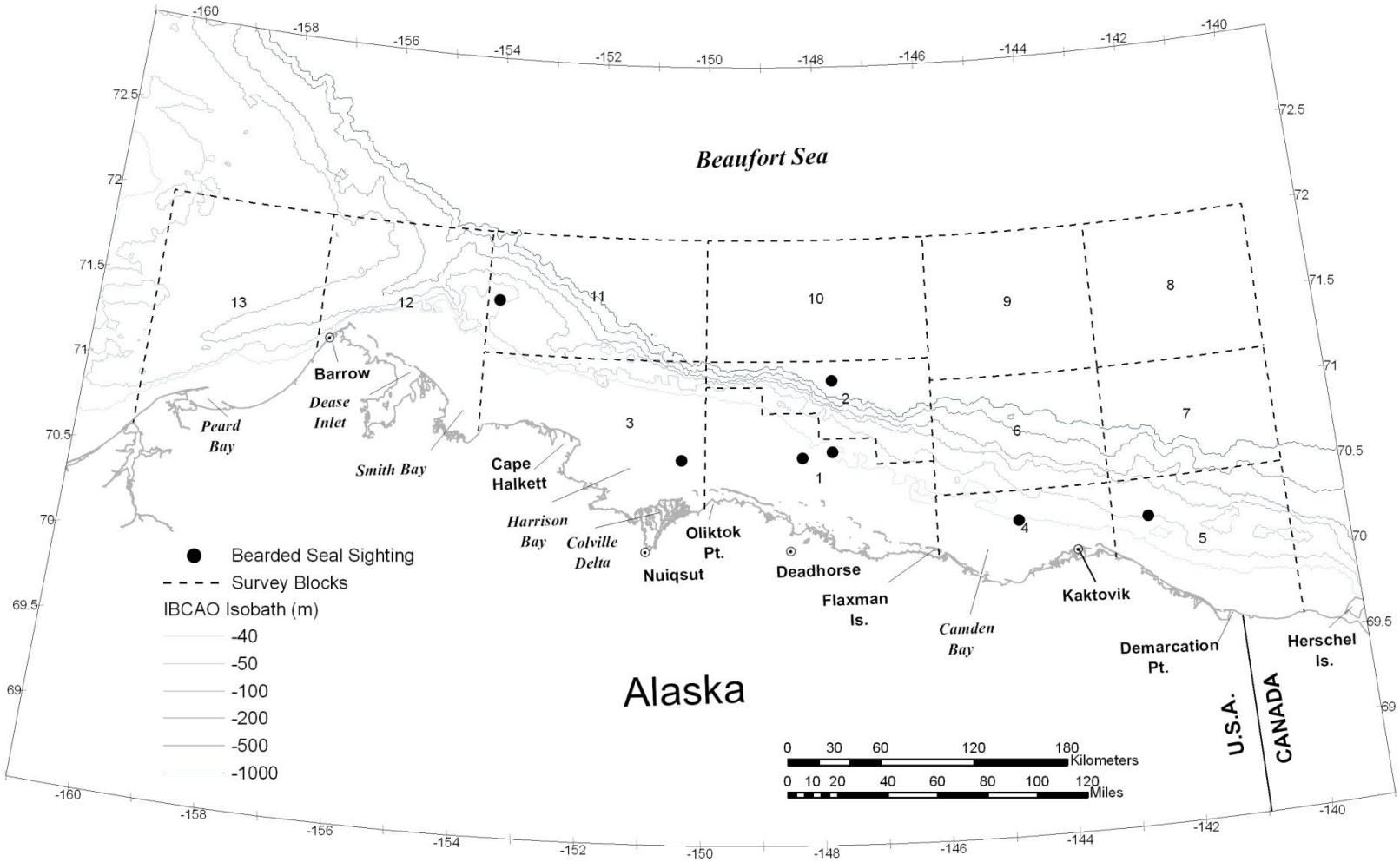

Figure 20. -- Bearded seal sightings, all effort, fall 2010.

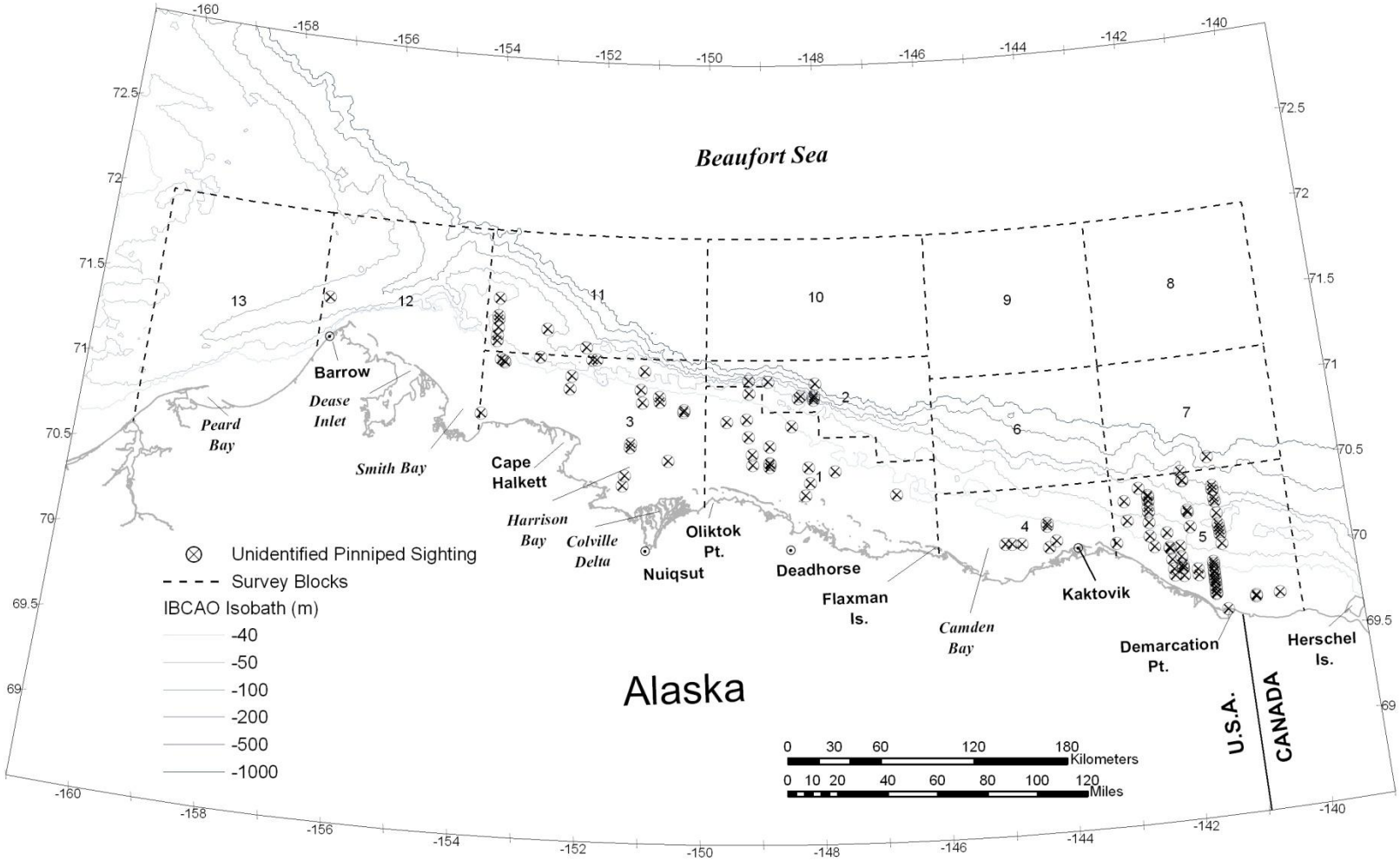

Figure 21. -- Unidentified pinniped sightings, all effort, fall 2010.

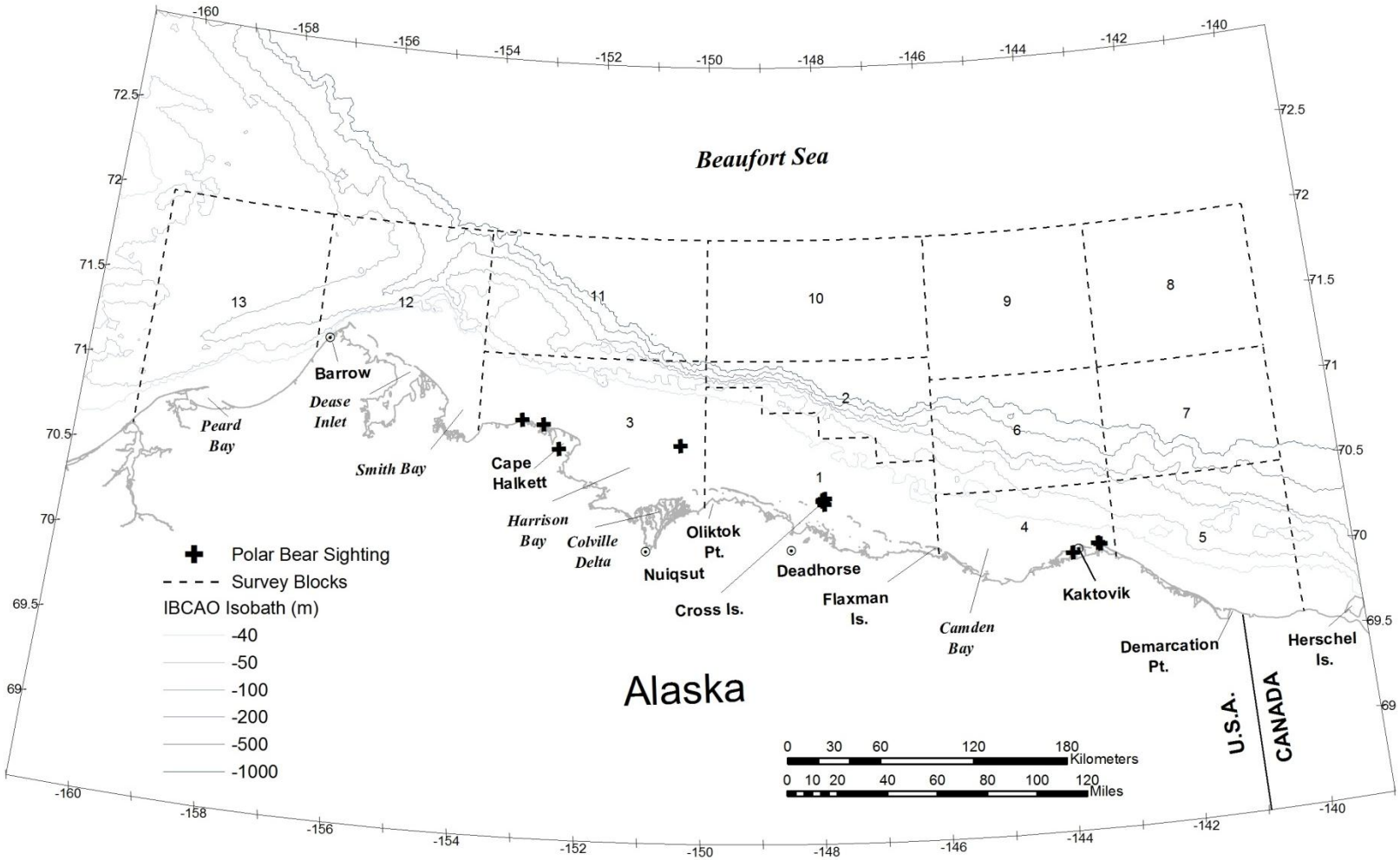

Figure 22. -- Polar bear sightings, all effort, fall 2010.

Grassia, S., J. Clarke, M. Ferguson, C. Christman and A. Brower. 2011. Distribution, relative abundance and behaviors of bowhead whales in the Alaskan Beaufort and northeastern Chukchi Seas – Autumn, 2007-2010. Poster: Alaska Marine Science Symposium, Anchorage, Alaska, 17-21 January 2011.

BWASP data were incorporated into analyses for publication in refereed journals, including:

Ferguson, M.C. *In press.* Quantifying spatial characteristics of the Bowhead Whale Aerial Survey Project (BWASP) survey design. *Journal of Cetacean Research and Management*.

Okkonen, S., C. Ashjian, R. Campbell, J. Clarke, S. Moore and K. Taylor. 2011. Satellite observations of circulation features associated with the Barrow area bowhead whale feeding hotspot. *Remote Sensing of Environment* 115: 2168-2174.

DISCUSSION

Conclusions

Ice conditions in 2010 were very light, similar to conditions observed in 2007, 2008, and 2009, with little to no ice in most of the study area during the field season. Environmental conditions related to large expanses of relatively warm water overlaid by colder air temperatures include low ceilings, fog, and high sea states. These conditions were often encountered during BWASP 2010, particularly east of 146°W and after 15 September, making it very difficult to complete transects in offshore areas. Survey effort was inconsistent throughout the study area; on several occasions, segments of transects were started close to shore and were aborted after only a few kilometers (e.g., flights 7, 8, 9, Appendix C). This inconsistent survey effort likely influenced the central tendency analysis of the offshore distribution of bowhead whales. In 2010, bowhead whale sightings were significantly closer to shore and in shallower water in the East Region of the Alaskan Beaufort Sea compared to previous years with light ice coverage (Fig. 23). While the trend for more coastal locations of bowhead whales is potentially related to higher concentrations of bowhead whale prey near the coastline, few of the whales in the East Region were observed feeding. This underscores the limits of the current central tendency analysis, which was not weighted by survey effort. Ferguson and Clarke (*in review*) used generalized additive models (GAMs) to quantify bowhead whale encounter rate (number of whales/km) as a function of geographic coordinates to derive statistics for the median depth of the migration. The median depth statistics from this analysis incorporated number of whales (instead of number of sightings) and were weighted by survey effort. This methodology will be used in the future to describe the annual fall bowhead whale migration derived from BWASP survey data.

Changes to the arctic marine environment observed over the past several decades (increasing mean annual temperatures, increasing mean annual wind speed, increasing storm frequency, decreasing annual ice; Wendler et al., 2009) accelerated in the 2000s (Walsh, 2008), perhaps most noticeably in the record-low sea ice extent observed in 2007 (National Snow and Ice Data Center 2007). The arctic summer and fall seasons are predicted to have continued decreasing

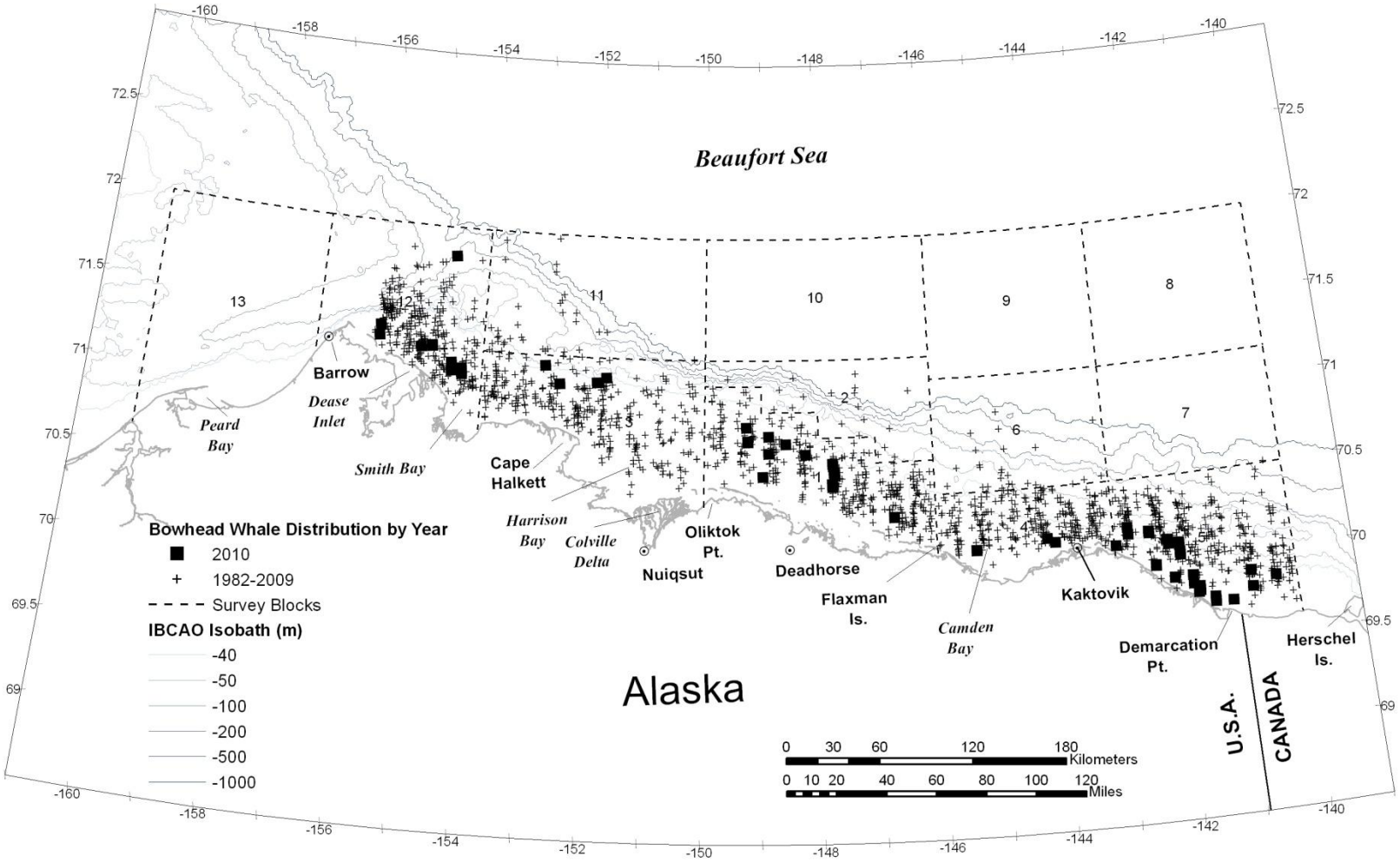

Figure 23. -- Bowhead whale sightings on transect in years with light ice coverage, 1982-2010.

ice coverage and younger ice, and associated climatic impacts (e.g., Simmonds et al. 2008), and these changes have likely impacted or will impact most marine mammal species (Kovacs et al. 2011). Comparisons in marine mammal distribution between time periods that span three decades (1982-2010) should be interpreted with caution because different ecological mechanisms could have been acting during this time.

Bowhead whale depth preference in 2010 based on sighting rates, uncorrected for availability or perception bias, was for very shallow waters (≤ 20 m) in the western subregion of the study area. This preference was also noted in 2009, when hundreds of feeding bowhead whales were seen in October in this subregion. Far fewer feeding bowhead whales were seen in 2010, but one group of 21 feeding whales was enough to influence the depth preference statistic. In the central-eastern subregion, depth preference was for the 21-50 m depth zone. Approximately 55% of all bowhead whales sighted on-effort were in the 21-50 m depth zone, while only 37% of total transect effort was in this depth zone, indicating a strong preference for shelf waters in areas other than Block 12.

The lack of feeding bowhead whales in Block 12 on 1 October was unexpected based on wind conditions prior to that date. However, oceanographic samples collected during BOWFEST (late August through mid-September) indicated that in 2010 water temperatures were warm, krill abundances were low, and abundances of chaetognaths, ctenophores, medusae and small copepods were high (Ashjian et al. 2011). Although the BOWFEST team hypothesized that krill advected to the Beaufort Shelf were possibly late in arriving in 2010, it is also possible that krill densities remained lower than in previous years, which would make this area less likely to attract large groups of feeding bowhead whales.

Distribution of beluga sightings in 2010 was similar to that documented in previous years with light ice coverage (Fig. 24). Beluga depth preference in the eastern and central Alaskan Beaufort Sea, based on sighting rates uncorrected for availability or perception bias, was for slope and basin waters (> 200 m), which is consistent with what Moore et al. (2000) found for beluga data collected in the 1980s.

Management Use of Real-Time Field Information

The BOEMRE issues various permits to industry for gas and oil exploration, including vessel geophysical permits for on-water exploration using an array of deep-seismic airguns; vessel geological-geophysical permits for shallow-seismic exploration using an airgun; on-ice geophysical permits using VIBROSEIS technology; both vessel and on-ice geological permits for obtaining core samples; and permits to drill for gas and oil. Although there was no offshore oil and gas activity in the Alaskan Beaufort Sea in 2010, BWASP aerial survey data were made available to representatives of oil companies, the North Slope Borough Department of Wildlife Management, and the general public on a near real-time basis to encourage data transfer and enhance management via a web site maintained by NMML, (http://www.afsc.noaa.gov/nmml/cetacean/bwasp/index.php).

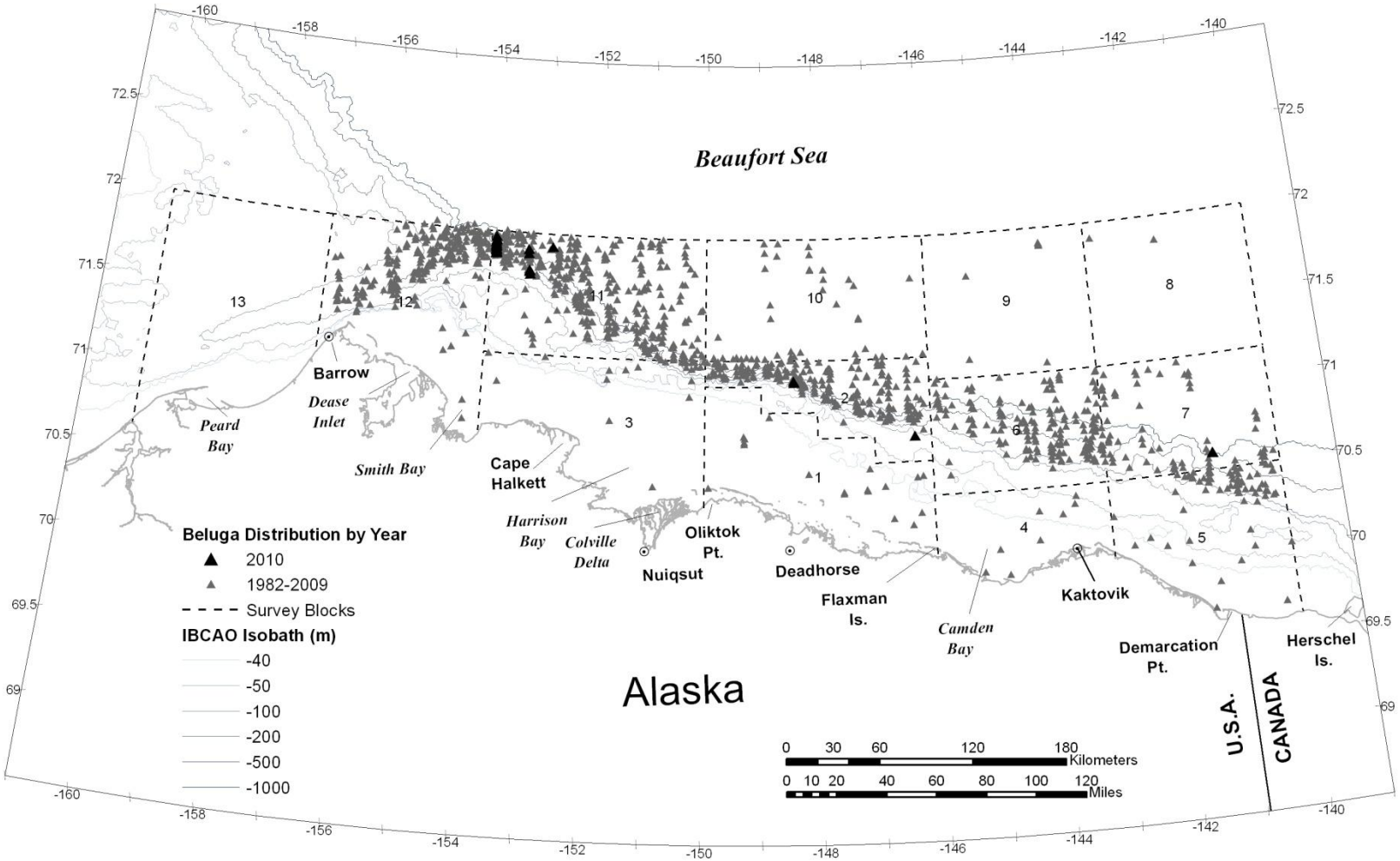

Figure 24. -- Beluga sightings on transect in years with light ice coverage, 1982-2010.

Management Use of Interannual Monitoring

The BOEMRE bowhead whale monitoring study began in 1979 and has continued every year up to the present. While some aspects of this study have been updated, the data recorded have remained remarkably consistent (especially data from 1982-2010), thus permitting many direct comparisons across years. Such continuous, long-term, broad-scale, aerial monitoring of a large whale migration is indeed unique. In addition to the accomplishments specifically mentioned in the results, the BWASP historical dataset has been used by industry, government and academic entities (e.g., Manly et al. 2007, Schick and Urban 2000, Givens et al. 2010).

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The Twin Otter aircraft was provided by the NOAA Aircraft Operations Center (AOC), Tampa, FL, via Interagency Agreement No. M07RG13263 between MMS and NOAA AOC. Nancy Ash, Phil Eastman, and the AOC Programs Office were instrumental in assisting with aircraft arrangements and preparations. Surveys were capably and safely flown by Dave Cowan, Jason Mansour, and Michael (Sandor) Silagi. We are especially appreciative of the timely and comprehensive response by AOC and NMML to an incident in the field that had the potential to severely undermine the BWASP 2010 season. However, under the efficient direction of Jim Kelley (AOC) and Dave Withrow (NMML), appropriate measures were implemented to allow BWASP to safely resume surveys with minimal downtime. On-site aircraft mechanical support was provided by Sean Campbell, Mike Merek, and Ron Pauley; Bald Mountain provided a hangar at Deadhorse airport.

The Aero Commander aircraft was provided by Northern Commanders, Spokane, WA, via Intra-agency Agreement No. M09PG00021 with the Department of the Interior, Aviation Management Division. The aircraft was based in Barrow to conduct COMIDA aerial surveys; its crew, Clearwater Air, Inc. pilots Stan Churches, Andy Harcombe, and Chris Palm, enthusiastically embraced providing additional coverage of the BWASP study area in addition to the COMIDA tasks.

Real-time monitoring via satellite tracking of survey flights was provided by Jan Bennett and Lark Wuerth of the Department of the Interior, National Business Center, Aviation Management Division.

Robyn Angliss, Phil Clapham and Julie Mocklin (NMFS) reviewed the report. The NMFS Alaska Fisheries Science Center (AFSC) Publications Unit assisted with preparing this report for publication.

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APPENDIX A: FALL 2010 ICE CONCENTRATION MAPS

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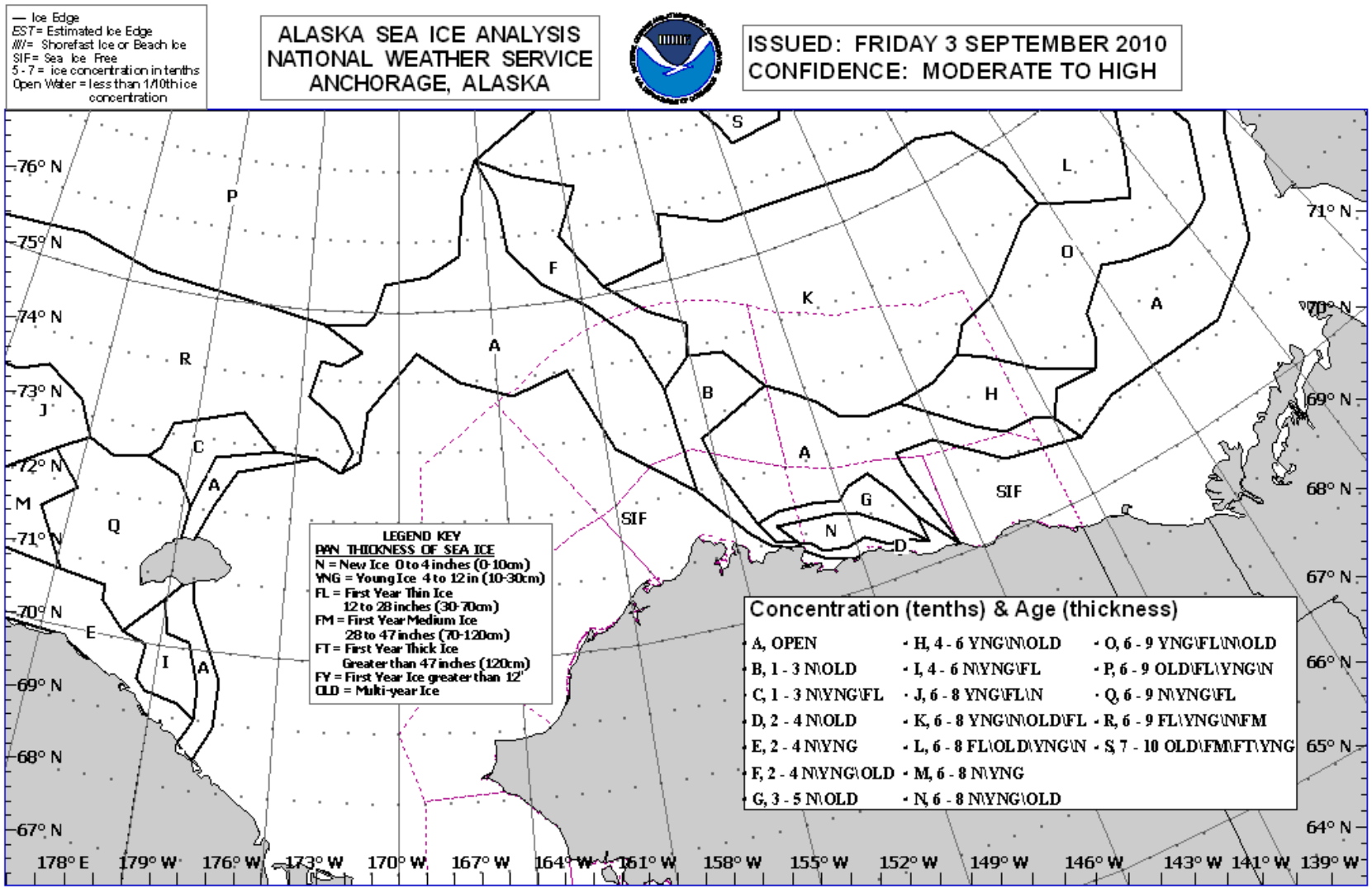

Figure A-1. -- Ice concentrations in the Alaskan Beaufort Sea, 3 September 2010.

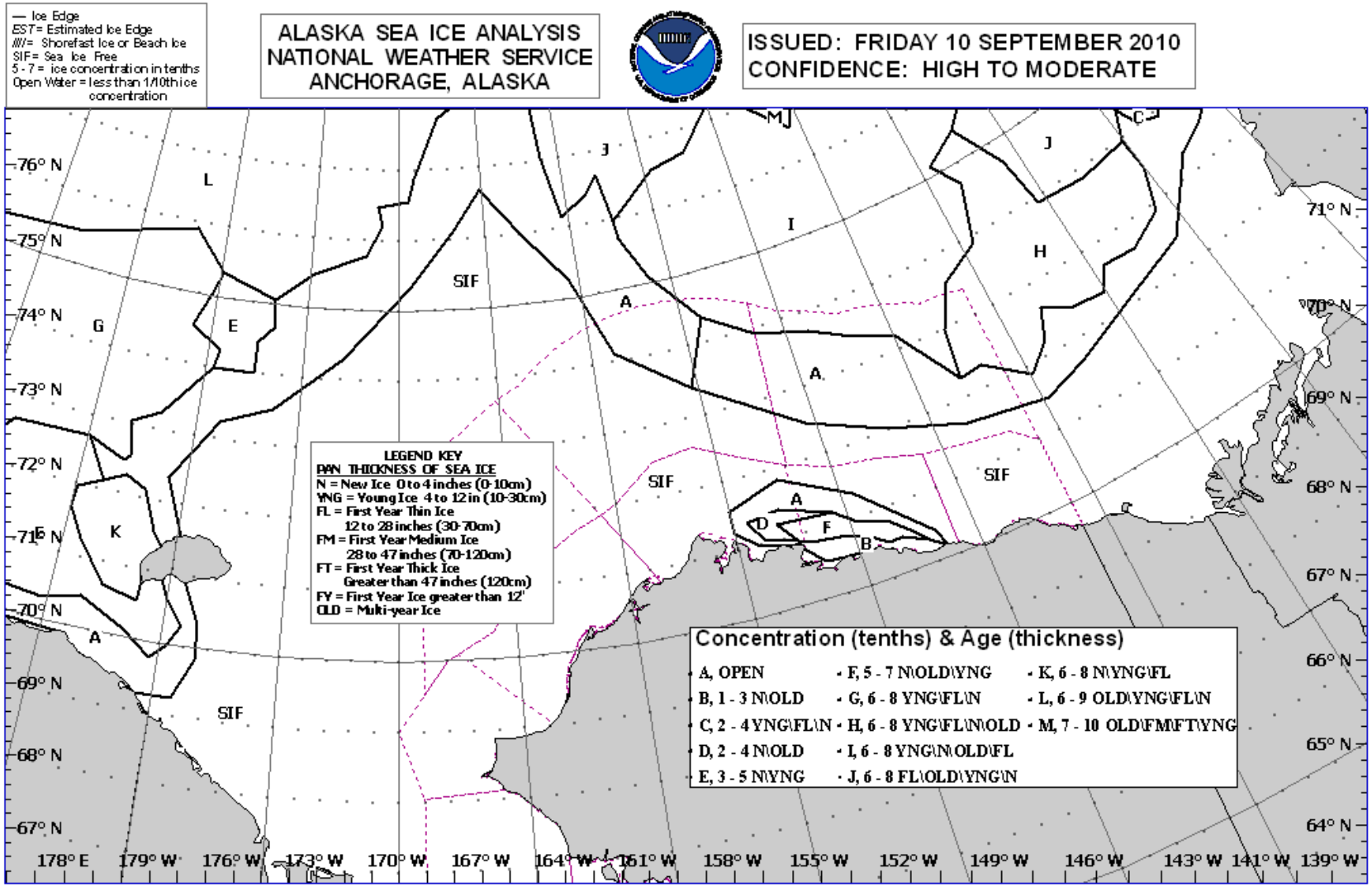

Figure A-2. -- Ice concentrations in the Alaskan Beaufort Sea, 10 September 2010.

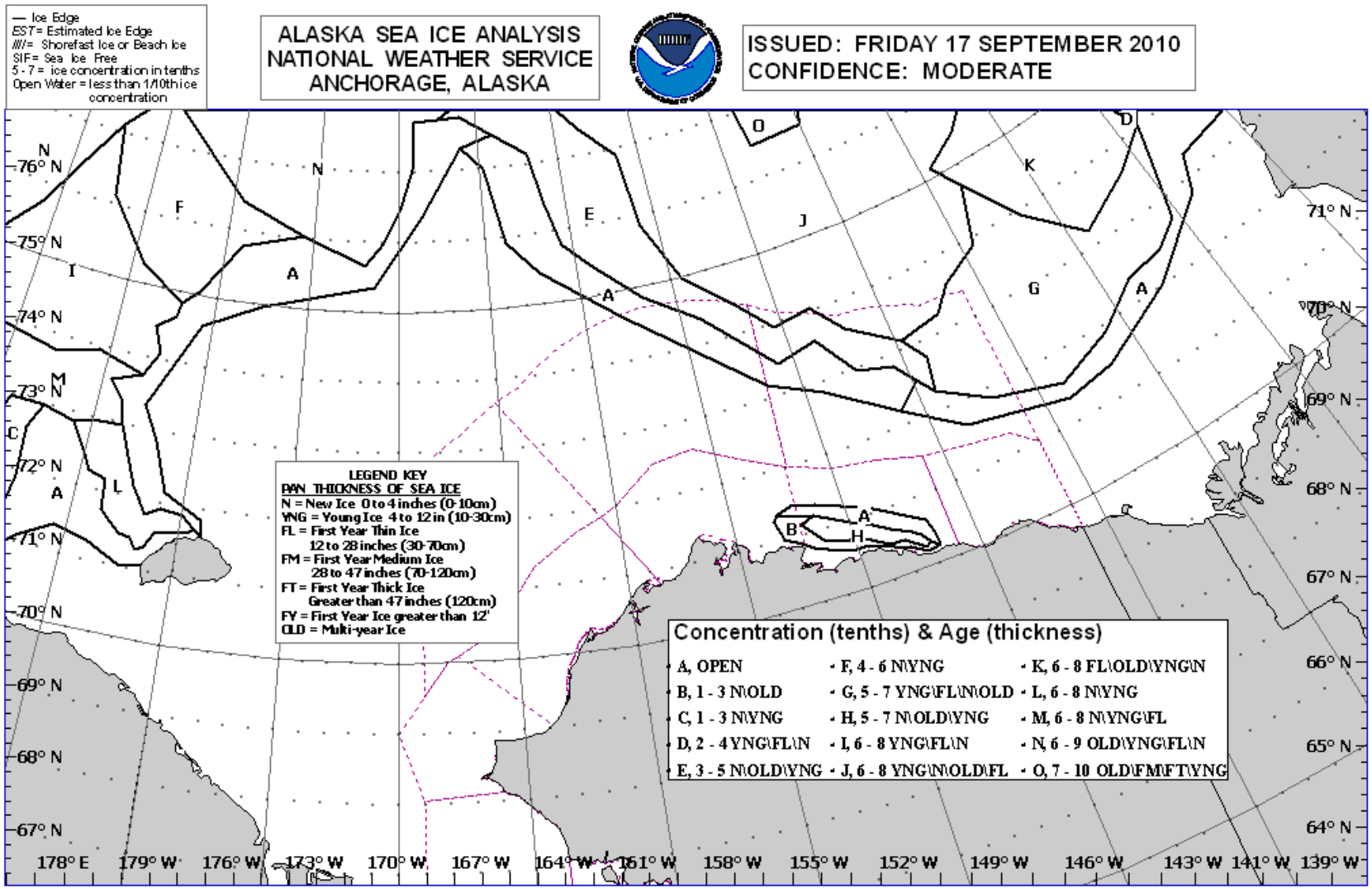

Figure A-3. -- Ice concentrations in the Alaskan Beaufort Sea, 17 September 2010.

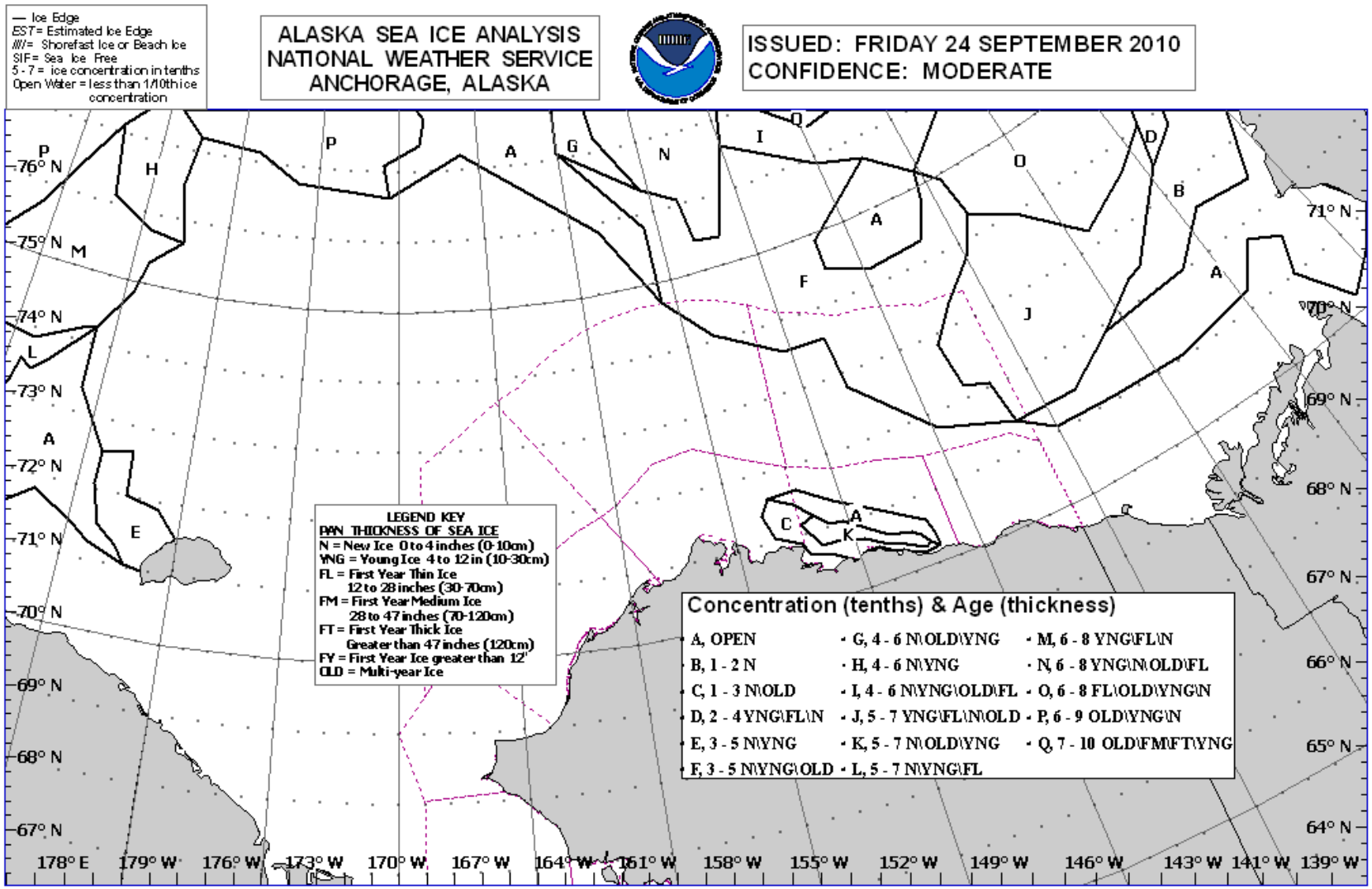

Figure A-4. -- Ice concentrations in the Alaskan Beaufort Sea, 24 September 2010.

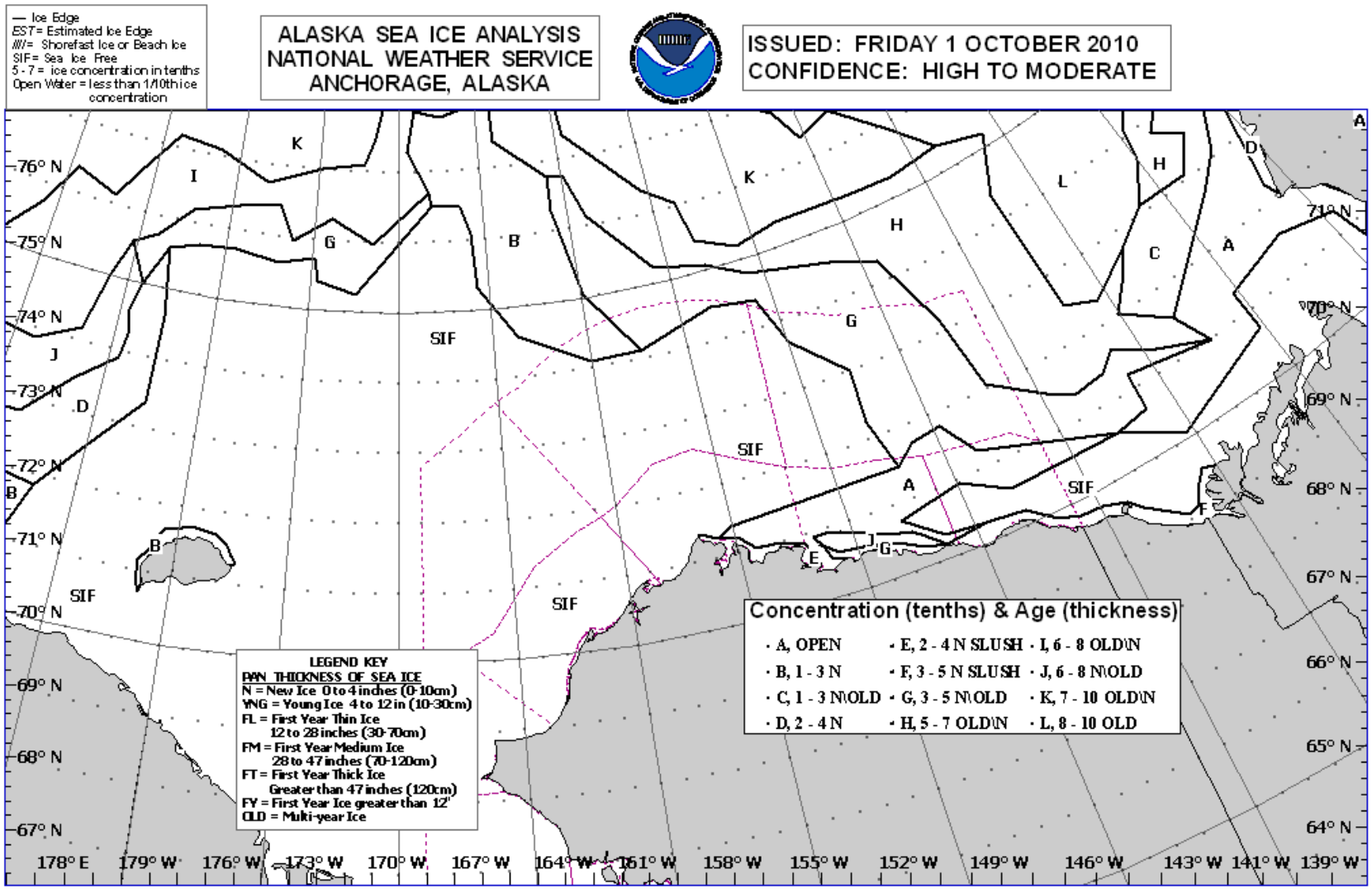

Figure A-5. -- Ice concentrations in the Alaskan Beaufort Sea, 1 October 2010.

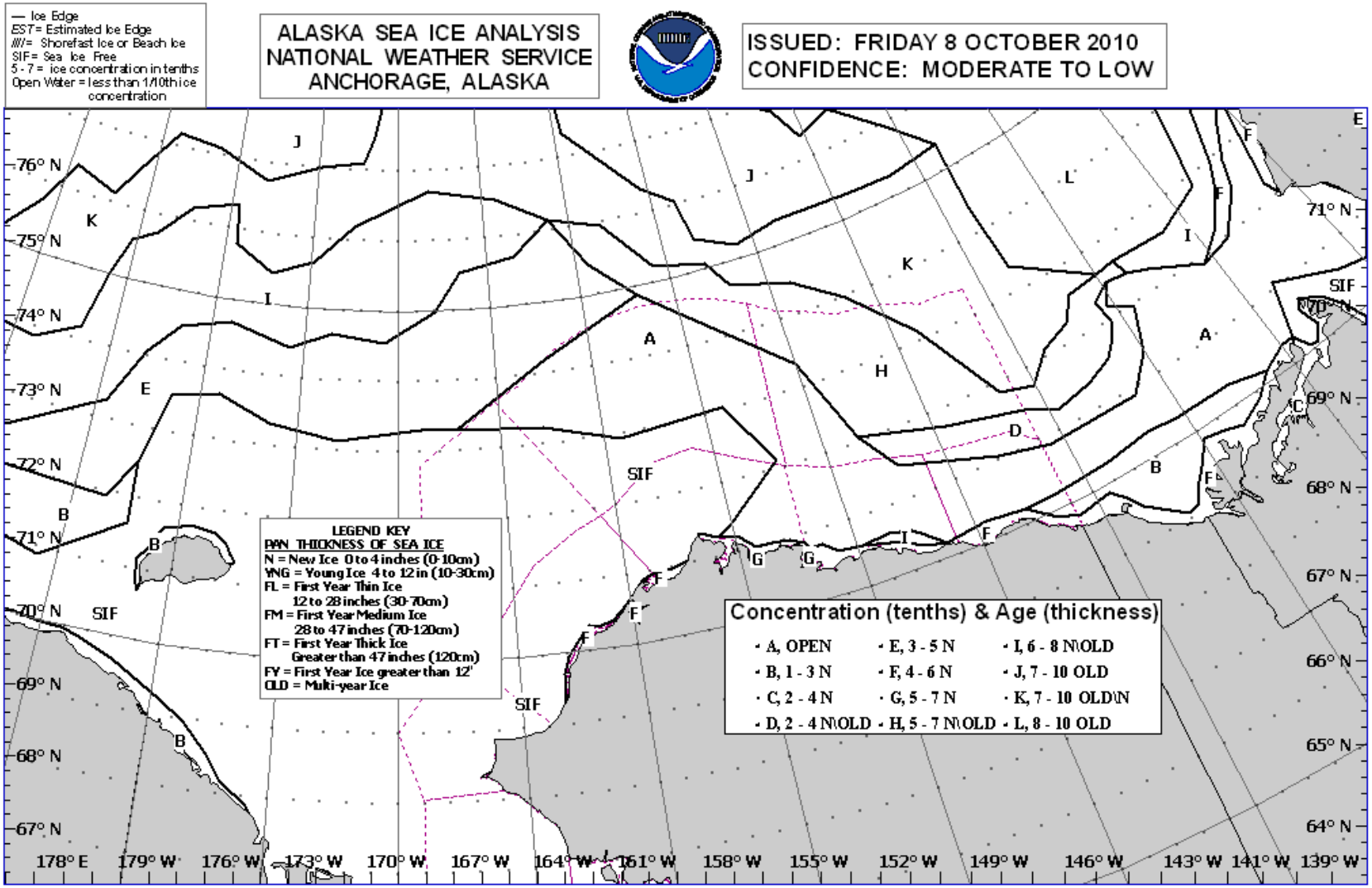

Figure A-6. -- Ice concentrations in the Alaskan Beaufort Sea, 8 October 2010.

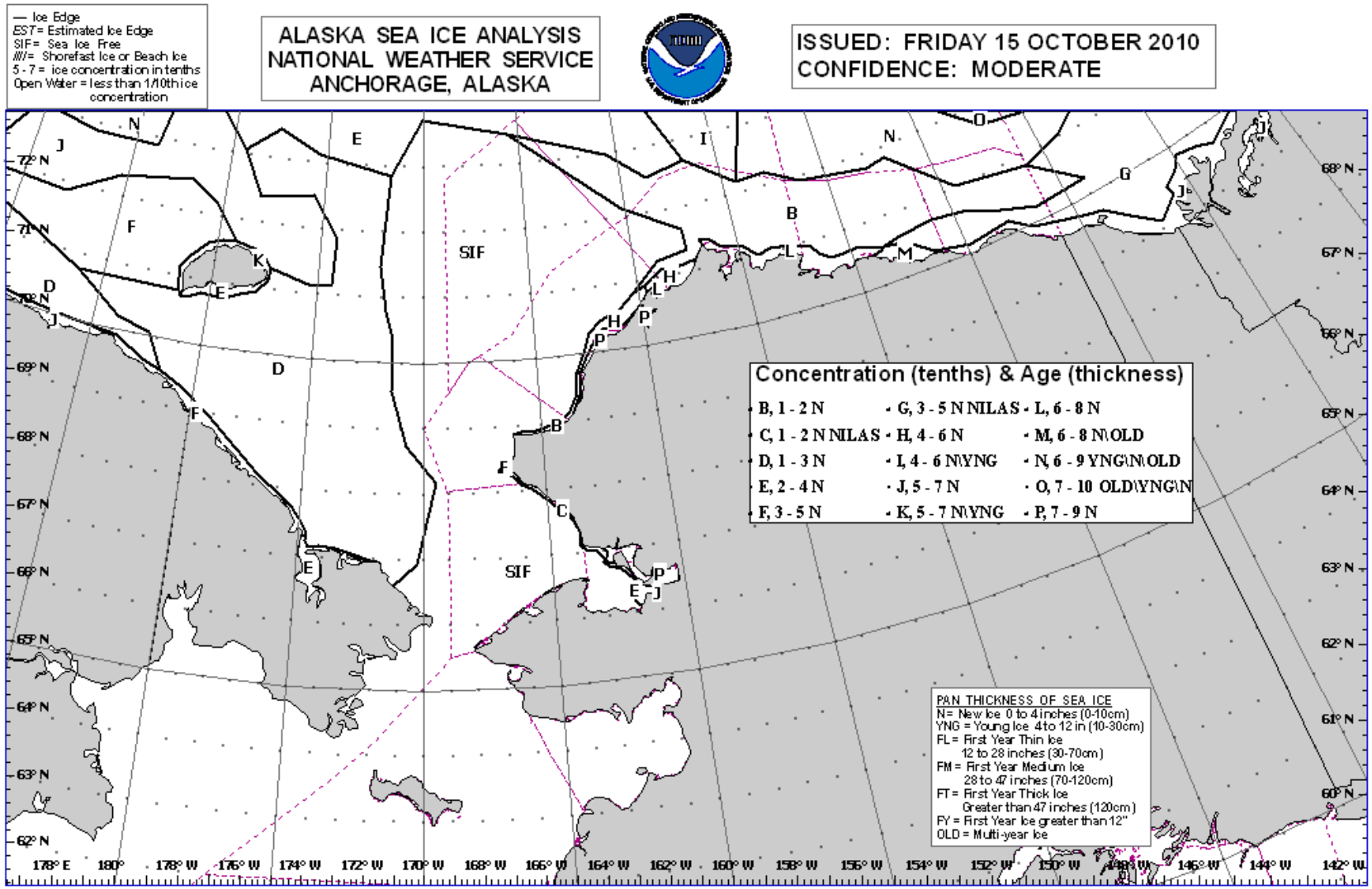

Figure A-7. -- Ice concentrations in the Alaskan Beaufort Sea, 15 October 2010.

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APPENDIX B: FALL 2010 BOWHEAD WHALE SIGHTING DATA

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Flight No.	Day	Total Whales	No. Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Beaufort Sea State
2	8 Sep	1	0	70º09.8'	145º19.5'	swim	186º	0	2
2	8 Sep	1	0	70º09.7'	145º19.6'	swim	*	0	2
2	8 Sep	1	0	70º11.0'	145º19.6'	swim	*	0	2
3	12 Sep	1	0	69º54.5'	141º43.2'	swim	333º	0	3
3	12 Sep	1	0	69º51.5'	141º43.6'	swim	303º	0	3
3	12 Sep	3	1	69º44.1'	141º05.8'	mill	*	0	2
3	12 Sep	1	0	70º25.1'	145º53.8'	swim	317º	0	2
3	12 Sep	2	0	70º23.0'	146º18.8'	mill	*	0	2
3	12 Sep	1	0	70º22.1'	146º30.4'	swim	316º	0	2
229	12 Sep	3	0	71º11.0'	151º58.0'	swim	*	1	3
229	12 Sep	1	0	71º09.4'	151º55.2'	swim	24º	2	3
229	12 Sep	1	0	71º08.4'	152º35.4'	rest	97º	0	3
4	13 Sep	1	0	70º54.8'	149º15.4'	swim	294º	0	2
4	13 Sep	1	0	70º49.9'	149º13.8'	swim	174º	0	2
4	13 Sep	2	0	70º49.6'	149º13.7'	mill	*	0	2
4	13 Sep	2	0	70º48.4'	149º10.9'	mill	*	0	2
4	13 Sep	1	0	70º48.9'	149º13.7'	swim	*	0	2
4	13 Sep	1	0	70º48.9'	148º33.6'	swim	329º	0	1
4	13 Sep	1	0	70º45.3'	148º13.1'	swim	*	5	2
4	13 Sep	1	0	70º46.9'	148º17.7'	swim	*	5	2
4	13 Sep	1	0	70º46.0'	148º17.2'	swim	*	5	2
4	13 Sep	1	0	70º37.8'	147º43.1'	swim	263º	5	2
4	13 Sep	1	0	70º39.0'	147º43.6'	swim	293º	5	2
4	13 Sep	1	0	70º41.1'	147º44.3'	swim	83º	5	2
4	13 Sep	1	0	70º41.9'	147º44.6'	swim	173º	5	2
5	15 Sep	1	0	71º14.4'	152º51.8'	swim	119º	5	5
5	15 Sep	1	0	71º11.1'	151º45.4'	mill	*	5	4
6	17 Sep	1	0	71º09.7'	153º05.7'	swim	212º	1	2
6	17 Sep	1	0	71º12.6'	153º30.3'	swim	316º	1	2
6	17 Sep	1	0	71º09.8'	151º24.3'	swim	197º	1	2
7	20 Sep	3	0	70º22.6'	146º42.2'	swim	304º	0	2
7	20 Sep	2	0	70º22.9'	146º42.2'	swim	304º	0	2
235	20 Sep	1	0	71º33.1'	156º09.6'	swim	348º	0	3
235	20 Sep	21	0	71º20.3'	155º52.9'	feed	*	0	3
235	20 Sep	1	0	71º20.9'	155º59.4'	feed	*	0	3
235	20 Sep	1	0	71º24.0'	155º52.5'	swim	303º	0	3
235	20 Sep	1	0	71º19.6'	154º33.7'	swim	5º	0	3
235	20 Sep	2	0	71º19.6'	154º33.4'	swim	275º	0	3
8	21 Sep	1	0	69º44.4'	141º27.6'	rest	*	0	3

Flight No.	Day	Total Whales	No. Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Beaufort Sea State
8	21 Sep	1	0	69º39.5'	141º00.9'	swim	295º	0	3
8	21 Sep	1	0	69º39.7'	140º56.8'	swim	*	0	3
8	21 Sep	1	0	69º38.3'	140º42.1'	swim	349º	0	4
8	21 Sep	1	0	69º38.4'	140º35.1'	mill	*	0	4
8	21 Sep	2	0	69º39.1'	140º35.7'	mill	*	0	4
8	21 Sep	1	0	69º38.5'	140º44.7'	swim	268º	0	4
8	21 Sep	1	0	69º38.5'	140º44.9'	swim	28º	0	4
8	21 Sep	1	0	69º38.5'	140º45.5'	swim	268º	0	4
8	21 Sep	1	0	69º38.6'	140º47.7'	dive	88º	0	4
8	21 Sep	2	0	69º46.7'	140º49.9'	swim	*	0	5
8	21 Sep	1	0	69º40.1'	140º55.5'	swim	295º	0	4
8	21 Sep	1	0	69º40.5'	141º02.4'	swim	358º	0	4
8	21 Sep	1	0	69º41.4'	141º07.7'	breach	*	0	4
8	21 Sep	1	0	69º41.7'	141º08.9'	swim	*	0	4
8	21 Sep	2	0	69º42.1'	141º08.8'	swim	*	0	4
8	21 Sep	1	0	69º43.2'	141º17.9'	swim	26º	0	4
8	21 Sep	1	0	69º44.5'	141º25.3'	swim	27º	0	3
8	21 Sep	1	0	69º44.6'	141º25.6'	swim	118º	0	3
8	21 Sep	2	0	69º46.7'	141º39.2'	tail slap	*	0	3
8	21 Sep	1	0	70º13.0'	145º31.7'	swim	323º	0	3
9	22 Sep	2	0	70º06.0'	145º28.5'	swim	157º	0	2
9	22 Sep	1	0	70º05.6'	145º23.4'	mill	*	0	2
9	22 Sep	1	0	70º05.6'	145º23.1'	mill	*	0	2
9	22 Sep	1	0	70º03.9'	144º56.2'	swim	187º	0	2
9	22 Sep	1	0	70º12.1'	144º06.7'	swim	59º	0	2
9	22 Sep	1	0	70º10.6'	143º58.7'	swim	301º	0	2
9	22 Sep	1	0	70º08.8'	143º31.5'	swim	38º	0	2
9	22 Sep	2	0	70º09.0'	143º14.7'	swim	*	0	2
9	22 Sep	1	0	70º09.8'	143º09.0'	swim	*	0	2
9	22 Sep	1	0	70º09.6'	143º08.2'	swim	*	0	2
9	22 Sep	2	0	70º09.8'	143º09.5'	swim	*	0	2
9	22 Sep	1	0	70º03.7'	142º46.4'	dive	*	0	3
9	22 Sep	2	0	69º59.4'	142º30.8'	swim	312º	0	3
9	22 Sep	1	0	69º59.3'	142º27.9'	dive	*	0	3
9	22 Sep	1	0	69º59.0'	142º19.2'	swim	300º	0	3
9	22 Sep	1	0	69º59.2'	142º19.2'	swim	300º	0	3
9	22 Sep	1	0	69º59.3'	142º19.2'	swim	330º	0	3
9	22 Sep	1	0	69º48.3'	141º39.2'	swim	120º	0	2
10	24 Sep	1	0	69º50.9'	140º20.7'	swim	89º	0	3

Flight No.	Day	Total Whales	No. Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Beaufort Sea State
10	24 Sep	1	0	69º53.6'	140º45.1'	swim	88º	0	3
10	24 Sep	1	0	69º52.6'	140º45.0'	swim	358º	0	3
10	24 Sep	1	0	69º48.0'	140º44.6'	swim	298º	0	2
10	24 Sep	1	0	69º44.5'	141º23.7'	swim	121º	0	2
10	24 Sep	1	0	69º46.1'	141º23.5'	swim	121º	0	2
10	24 Sep	1	0	70º06.3'	141º54.1'	swim	299º	0	2
10	24 Sep	1	0	70º06.2'	141º54.1'	swim	239º	0	2
10	24 Sep	1	0	70º05.4'	141º54.1'	swim	359º	0	2
10	24 Sep	1	0	70º03.1'	141º53.9'	swim	358º	0	2
10	24 Sep	1	0	70º02.8'	141º53.9'	swim	358º	0	2
10	24 Sep	1	0	70º01.9'	141º53.8'	swim	209º	0	2
10	24 Sep	1	0	69º54.2'	142º01.8'	swim	117º	0	2
10	24 Sep	1	0	69º54.3'	142º01.9'	swim	117º	0	2
10	24 Sep	1	0	70º06.3'	142º04.8'	swim	355º	0	2
10	24 Sep	2	1	70º07.8'	142º05.2'	rest	*	0	2
10	24 Sep	1	0	70º07.7'	142º04.9'	swim	*	0	2
10	24 Sep	1	0	70º07.5'	142º57.8'	rest	*	0	2
10	24 Sep	3	0	70º08.7'	144º27.0'	mill	*	0	2
10	24 Sep	1	0	70º11.8'	145º05.4'	swim	94º	0	2
10	24 Sep	2	0	70º12.6'	145º42.8'	swim	304º	0	2
10	24 Sep	3	0	70º45.7'	148º51.8'	swim	300º	0	2
10	24 Sep	2	0	70º51.5'	148º51.9'	mill	*	0	2
10	24 Sep	1	0	70º33.9'	147º45.4'	swim	240º	10	1
10	24 Sep	5	0	70º34.7'	147º45.4'	swim	300º	10	1
10	24 Sep	2	1	70º34.8'	147º45.4'	cow/calf	300º	10	1
10	24 Sep	1	0	70º34.8'	147º45.4'	swim	300º	10	1
12	30 Sep	1	0	70º10.8'	142º44.3'	swim	267º	0	1
12	30 Sep	1	0	70º13.3'	142º44.6'	swim	267º	0	1
12	30 Sep	1	0	70º11.3'	142º23.2'	swim	333º	0	2
12	30 Sep	1	0	70º10.6'	142º23.3'	swim	33º	0	2
12	30 Sep	1	0	69º47.7'	141º42.8'	swim	186º	0	2
12	30 Sep	1	0	69º48.9'	141º37.6'	swim	266º	0	3
12	30 Sep	1	0	69º50.3'	141º37.8'	dive	117º	0	3
12	30 Sep	1	0	69º48.5'	141º45.9'	swim	30º	0	4
12	30 Sep	1	0	70º10.0'	145º27.1'	swim	273º	10	1
13	1 Oct	1	0	71º09.3'	154º21.4'	swim	89º	0	4
13	1 Oct	1	0	71º10.3'	154º21.5'	swim	269º	0	4
13	1 Oct	1	0	71º10.9'	154º21.5'	swim	148º	0	4
13	1 Oct	1	0	71º11.5'	154º21.6'	swim	238º	0	4

Flight No.	Day	Total Whales	No. Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Beaufort Sea State
13	1 Oct	1	0	71º18.6'	154º54.8'	swim	7º	0	5
13	1 Oct	1	0	71º18.6'	154º54.8'	swim	37º	0	5
13	1 Oct	2	1	71º18.3'	154º54.9'	swim	36º	0	5
15	8 Oct	1	0	71º03.2'	150º35.2'	swim	184º	0	4
16	9 Oct	1	0	70º37.7'	148º58.0'	swim	94º	0	2
17	10 Oct	1	0	71º49.9'	154º36.4'	swim	90º	0	4
17	10 Oct	1	0	71º13.2'	154º32.8'	swim	268º	0	5
17	10 Oct	1	0	71º10.4'	154º32.5'	dive	358º	0	5
17	10 Oct	1	0	71º17.8'	155º06.7'	swim	243º	0	5

* Not recorded

APPENDIX C: FALL 2010 DAILY FLIGHT SUMMARIES

1 September 2010, Flight 1

Flight was an attempted survey of Block 3. Survey conditions were poor, with widespread low ceilings and fog precluding survey effort in most of the study area. Sea state ranged from Beaufort 1-3, and visibility ranged from 0-5 km. Ice cover was 0-20% broken floe. One walrus was seen.

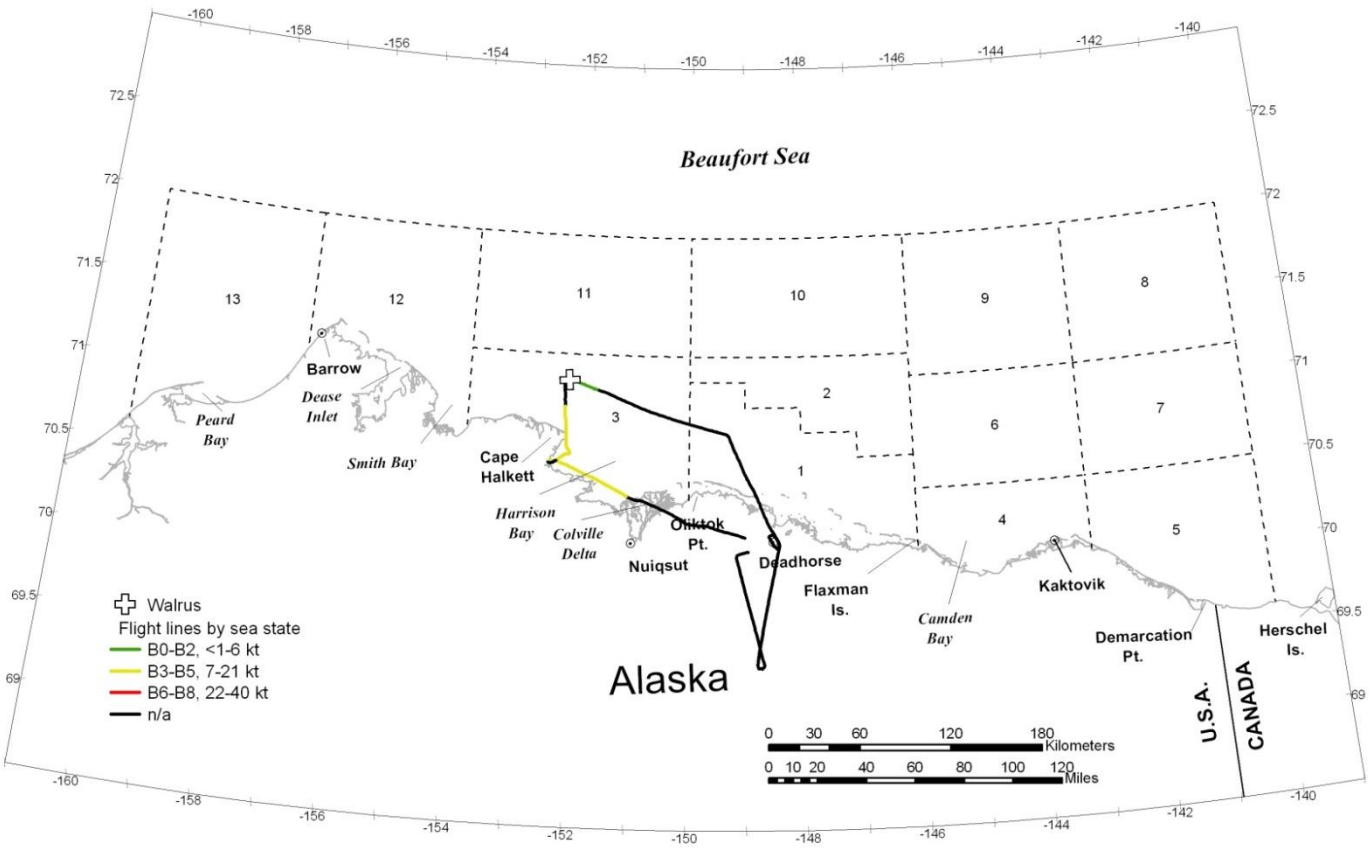

Figure C-1. -- Flight 1 survey track, depicted by sea state, and all sightings.

8 September 2010, Flight 2

Flight was a transect survey of Blocks 4 and 6. Survey conditions were very good, with partly cloudy to overcast skies, sea state Beaufort 2-3, and visibility from 5-10 km. No ice was observed in the survey area. Bowhead whales were sighted in Camden Bay and polar bears were seen near the village of Kaktovik. Whaling boats from Kaktovik were seen at the southern end of the easternmost transect, and were diverted around to avoid possible interference with subsistence whaling activities.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
2	9/8/10 12:45	70.163	-145.326	bowhead	swim	1	0	4
2	9/8/10 12:45	70.161	-145.326	bowhead	swim	1	0	4
2	9/8/10 12:52	70.183	-145.327	bowhead	swim	1	0	4

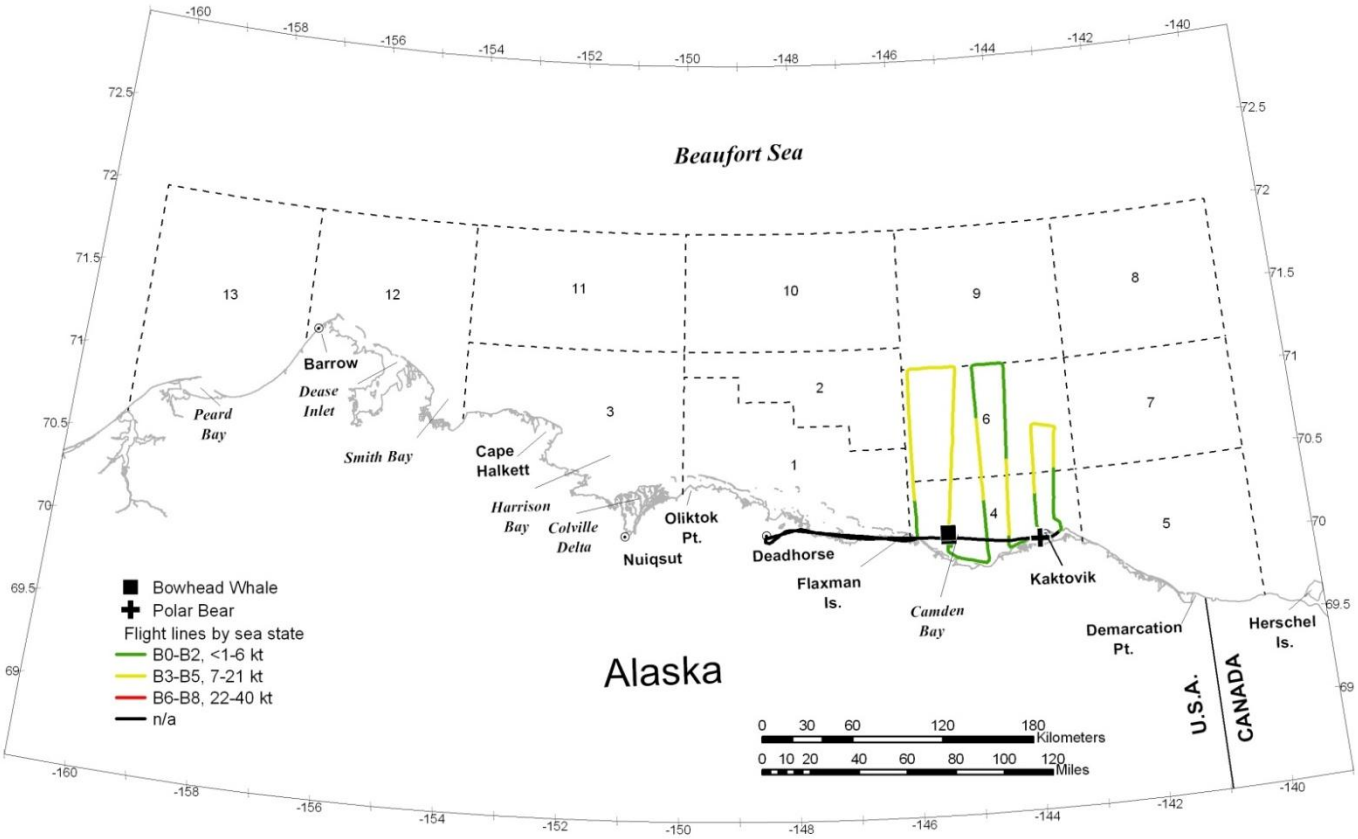

Figure C-2. -- Flight 2 survey track, depicted by sea state, and all sightings.

12 September 2010, Flight 3

Flight was a transect survey of the western half of Blocks 5 and 7. Survey conditions were good, with partly cloudy to overcast skies, and sea state Beaufort 1-4. Visibility ranged from 0-10 km. Low ceilings and fog precluded surveying areas farther east. Ice cover in Block 1 was 10-40% broken floe; there was no ice in Blocks 5 and 7. Bowhead whales, including one calf, and unidentified cetaceans were sighted near Demarcation Point and in Blocks 1 and 4 during the search survey back to Deadhorse. Belugas were sighted offshore in Block 7.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
3	9/12/10 16:16	69.908	-141.720	bowhead	swim	1	0	5
3	9/12/10 16:17	69.858	-141.727	bowhead	swim	1	0	5
3	9/12/10 16:23	69.740	-141.446	unidentified cetacean	swim	1	0	5
3	9/12/10 16:39	69.735	-141.097	bowhead	mill	3	1	5
3	9/12/10 17:16	70.597	-141.127	beluga	swim	1	0	7
3	9/12/10 17:16	70.602	-141.128	beluga	swim	1	0	7
3	9/12/10 17:37	70.715	-142.492	beluga	rest	1	0	7
3	9/12/10 17:37	70.713	-142.531	beluga	swim	2	0	7
3	9/12/10 17:37	70.712	-142.535	beluga	rest	1	0	7
3	9/12/10 17:39	70.697	-142.744	beluga	swim	1	0	7
3	9/12/10 18:02	70.519	-145.011	unidentified cetacean	swim	1	0	4
3	9/12/10 18:18	70.418	-145.896	bowhead	swim	1	0	4
3	9/12/10 18:21	70.391	-146.225	unidentified cetacean	swim	1	0	1
3	9/12/10 18:22	70.384	-146.314	bowhead	mill	2	0	1
3	9/12/10 18:23	70.376	-146.410	unidentified cetacean	rest	1	0	1
3	9/12/10 18:24	70.368	-146.506	bowhead	swim	1	0	1
3	9/12/10 18:24	70.365	-146.533	unidentified cetacean	mill	1	0	1

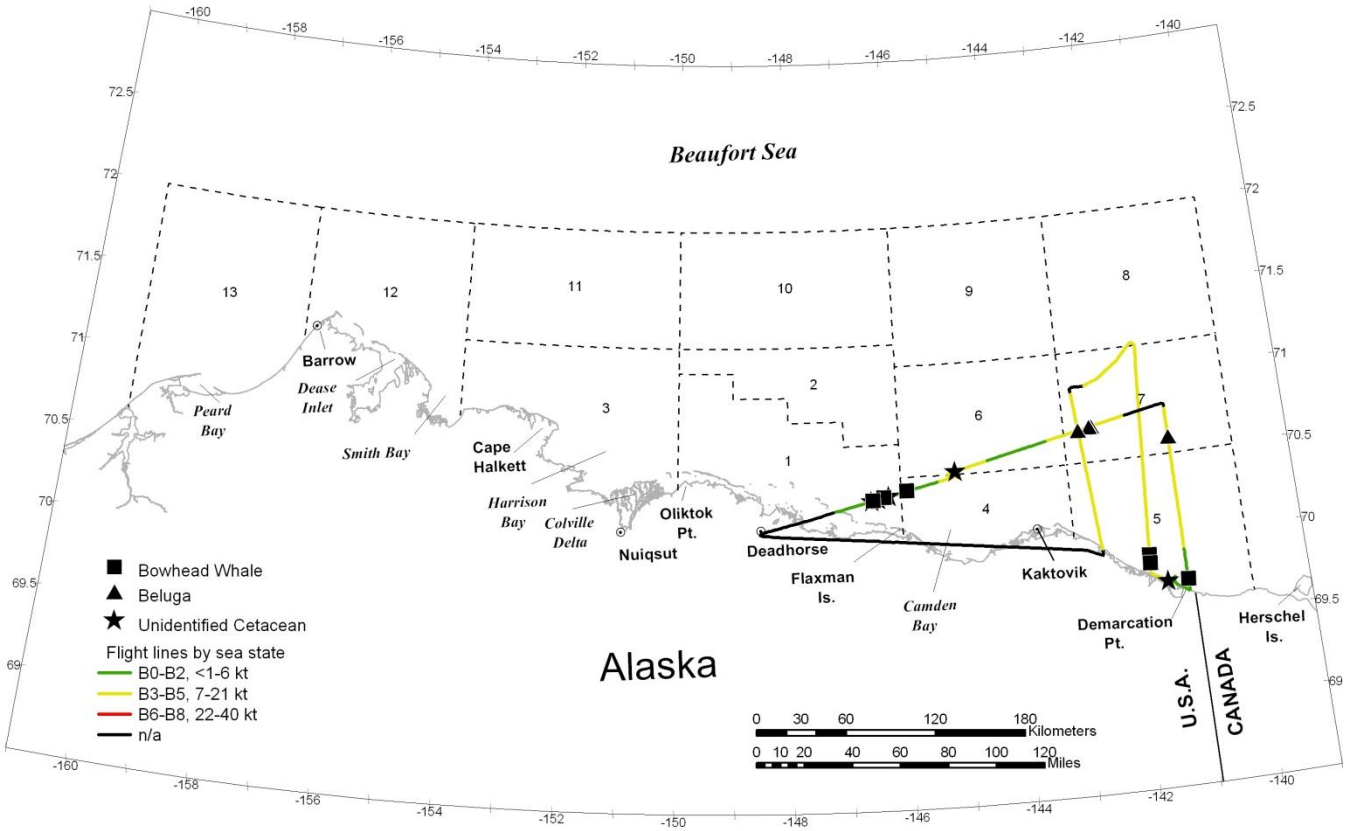

Figure C-3. -- Flight 3 survey track, depicted by sea state, and all sightings.

12 September 2010, Flight 229

Flight was a transect survey of Block 3, flown by the COMIDA aircraft and team based out of Barrow. Survey conditions were good, with partly cloudy to overcast skies, sea state Beaufort 1-4, and visibility from 5-10 km. Ice cover was 0-30% broken floe. Bowhead whales were seen north of Cape Halkett. Unidentified pinnipeds were seen scattered throughout the survey area, and two polar bears were seen swimming in Harrison Bay, approximately 30 km offshore in area of 10% broken floe ice.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
229	9/12/10 16:54	71.183	-151.967	bowhead	swim	3	0	3
229	9/12/10 17:04	71.157	-151.920	bowhead	swim	1	0	3
229	9/12/10 18:05	71.139	-152.590	bowhead	rest	1	0	3

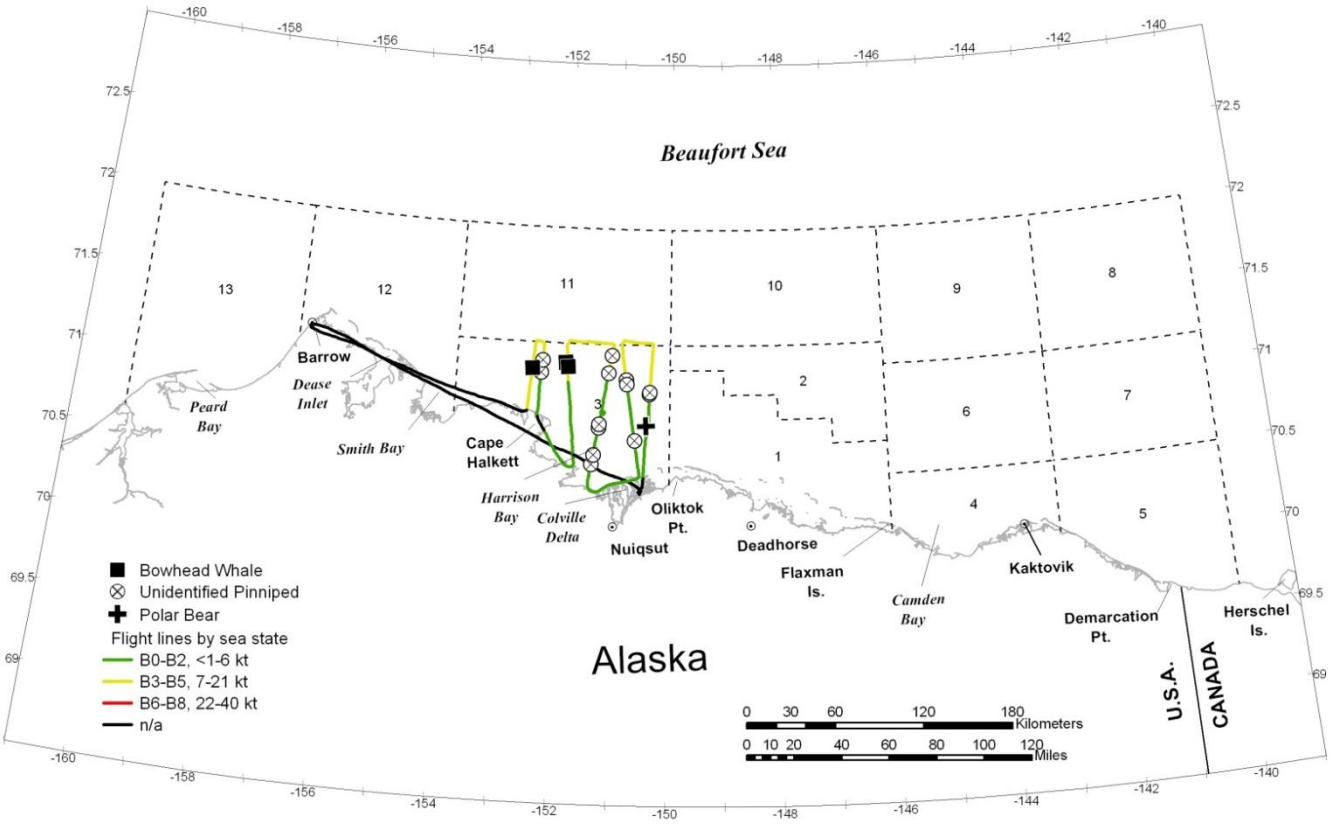

Figure C-4. -- Flight 229 survey track, depicted by sea state, and all sightings.

13 September 2010, Flight 4

Flight was a transect survey of Block 1, with partial coverage of Block 2. Survey conditions were fair, with sea state Beaufort 1-3, and visibility ranging from 0-5 km. Low ceilings and fog precluded survey effort in most of Block 2. Ice cover was 0-50% broken floe. Bowhead whales and unidentified cetaceans were seen scattered throughout Block 1; belugas were sighted in Block 2. One bearded seal and several unidentified pinnipeds were seen scattered throughout the survey area, and five polar bears were seen in the surf near Cross Island.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
4	9/13/10 10:54	70.913	-149.256	bowhead	swim	1	0	1
4	9/13/10 10:57	70.832	-149.231	bowhead	swim	1	0	1
4	9/13/10 10:57	70.827	-149.229	bowhead	mill	2	0	1
4	9/13/10 10:58	70.807	-149.182	bowhead	mill	2	0	1
4	9/13/10 11:00	70.815	-149.228	bowhead	swim	1	0	1
4	9/13/10 11:31	70.815	-148.559	bowhead	swim	1	0	1
4	9/13/10 11:46	71.184	-148.411	beluga	swim	1	0	2
4	9/13/10 11:46	71.175	-148.408	beluga	swim	1	0	2
4	9/13/10 11:55	70.915	-148.289	unidentified cetacean	swim	1	0	1
4	9/13/10 12:06	70.754	-148.218	bowhead	swim	1	0	1
4	9/13/10 12:14	70.782	-148.296	bowhead	swim	1	0	1
4	9/13/10 12:15	70.767	-148.287	bowhead	swim	1	0	1
4	9/13/10 13:03	70.631	-147.719	bowhead	swim	1	0	1
4	9/13/10 13:04	70.650	-147.726	bowhead	swim	1	0	1
4	9/13/10 13:05	70.685	-147.739	bowhead	swim	1	0	1
4	9/13/10 13:06	70.698	-147.744	bowhead	swim	1	0	1

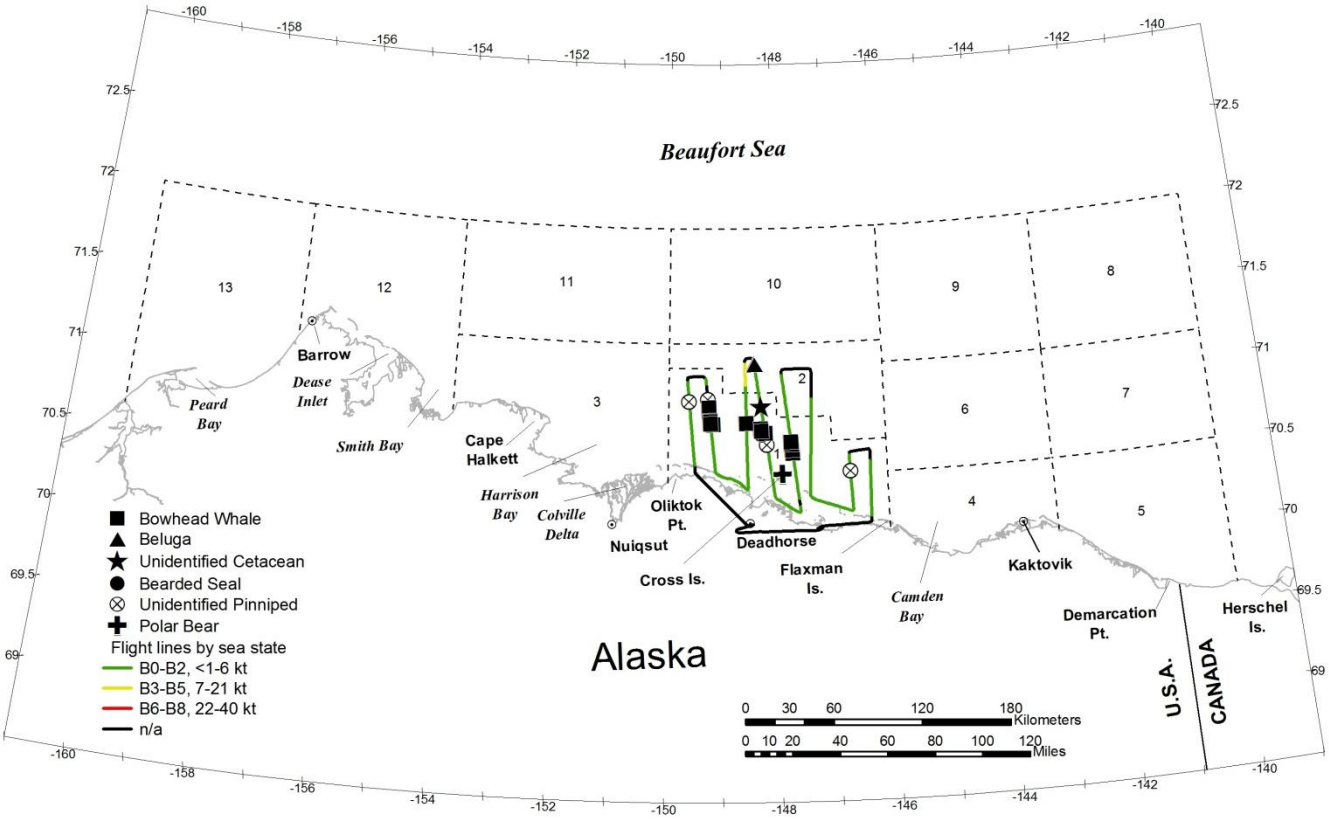

Figure C-5. -- Flight 4 survey track, depicted by sea state, and all sightings.

15 September 2010, Flight 5

Flight was a transect survey of Block 3, with partial coverage of Block 11. Survey conditions were fair, with overcast skies, sea state Beaufort 2-6, and visibility ranging from 3-10 km. High sea states precluded survey effort in most of Block 11. Ice cover was 0-10% broken floe. Bowhead whales were seen north of Cape Halkett. Three polar bears were seen onshore between Harrison Bay and Smith Bay.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
5	9/15/10 12:32	71.240	-152.863	bowhead	swim	1	0	3
5	9/15/10 13:34	71.185	-151.756	bowhead	mill	1	0	3

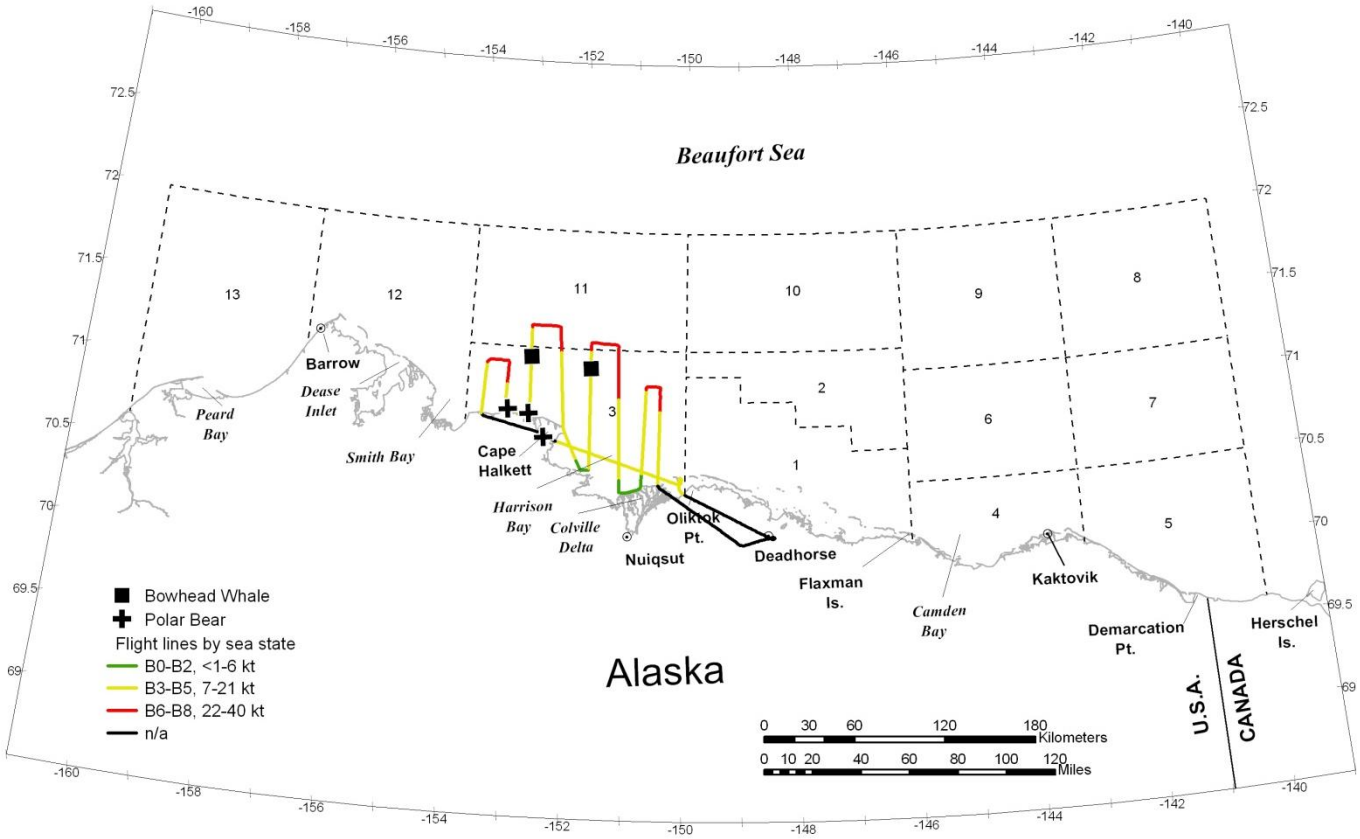

Figure C-6. -- Flight 5 survey track, depicted by sea state, and all sightings.

17 September 2010, Flight 6

Flight was a transect survey of portions of Block 11. Survey conditions were fair, with overcast skies, sea state Beaufort 1-2, and visibility ranging from 0-10 km. Low ceilings and fog precluded survey effort in most of the study area. Ice cover was 0-40% broken floe. Bowhead whales were seen during search surveys to and from Block 11. Bearded seals and unidentified pinnipeds were seen scattered throughout the area surveyed.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
6	9/17/10 17:23	71.161	-153.095	bowhead	swim	1	0	3
6	9/17/10 17:34	71.210	-153.505	bowhead	swim	1	0	3
6	9/17/10 18:48	71.163	-151.404	bowhead	swim	1	0	3

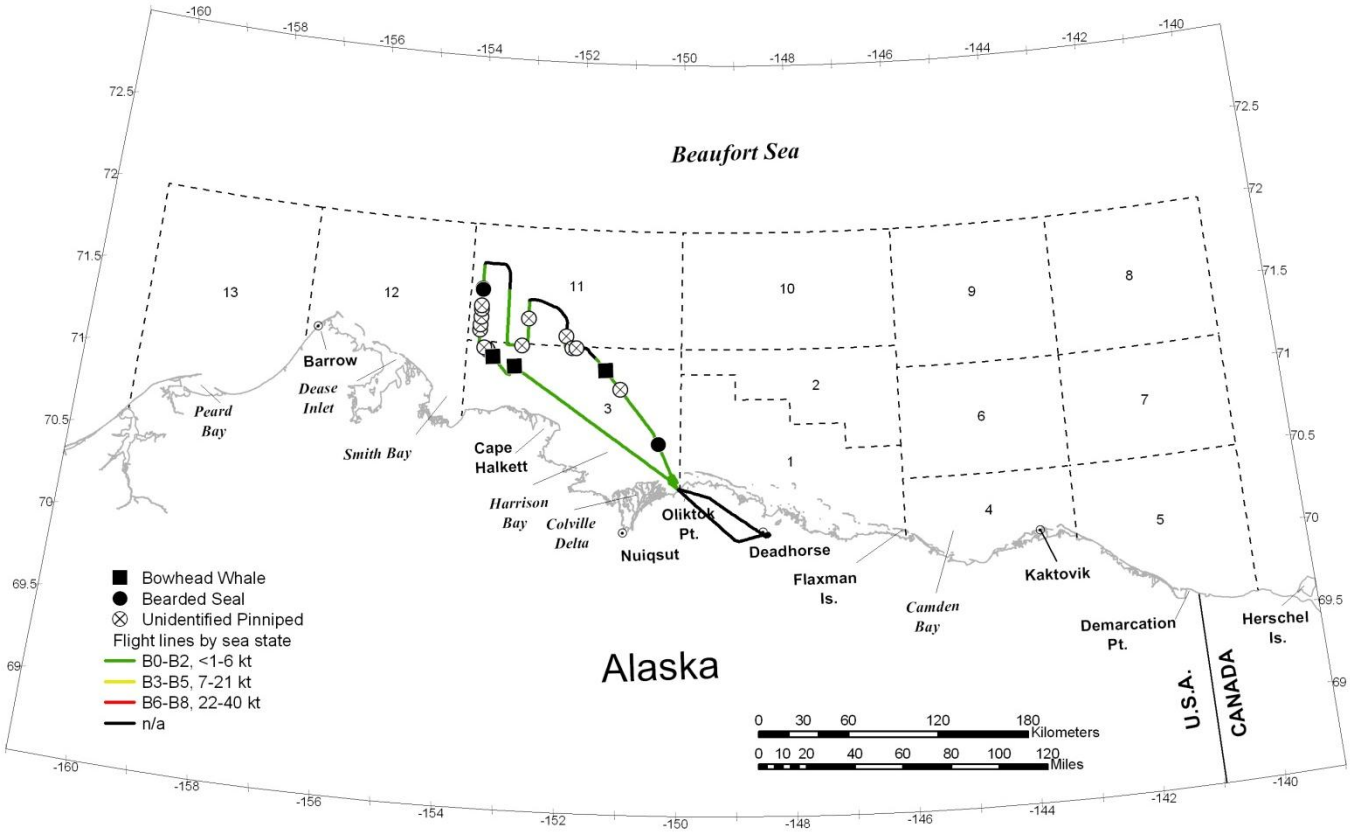

Figure C-7. -- Flight 6 survey track, depicted by sea state, and all sightings.

20 September 2010, Flight 7

Flight was a transect survey of portions of Block 1. Survey conditions were fair, with overcast skies, sea state Beaufort 1-3, and visibility ranging from 0-5 km. Low ceilings and snow showers precluded survey effort in most of the study area. Ice cover was 0-50% broken floe. Bowhead whales were seen in the eastern half of Block 1. One unidentified pinniped was also seen.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
7	9/20/10 11:48	70.377	-146.704	bowhead	swim	3	0	1
7	9/20/10 11:48	70.381	-146.703	bowhead	swim	2	0	1

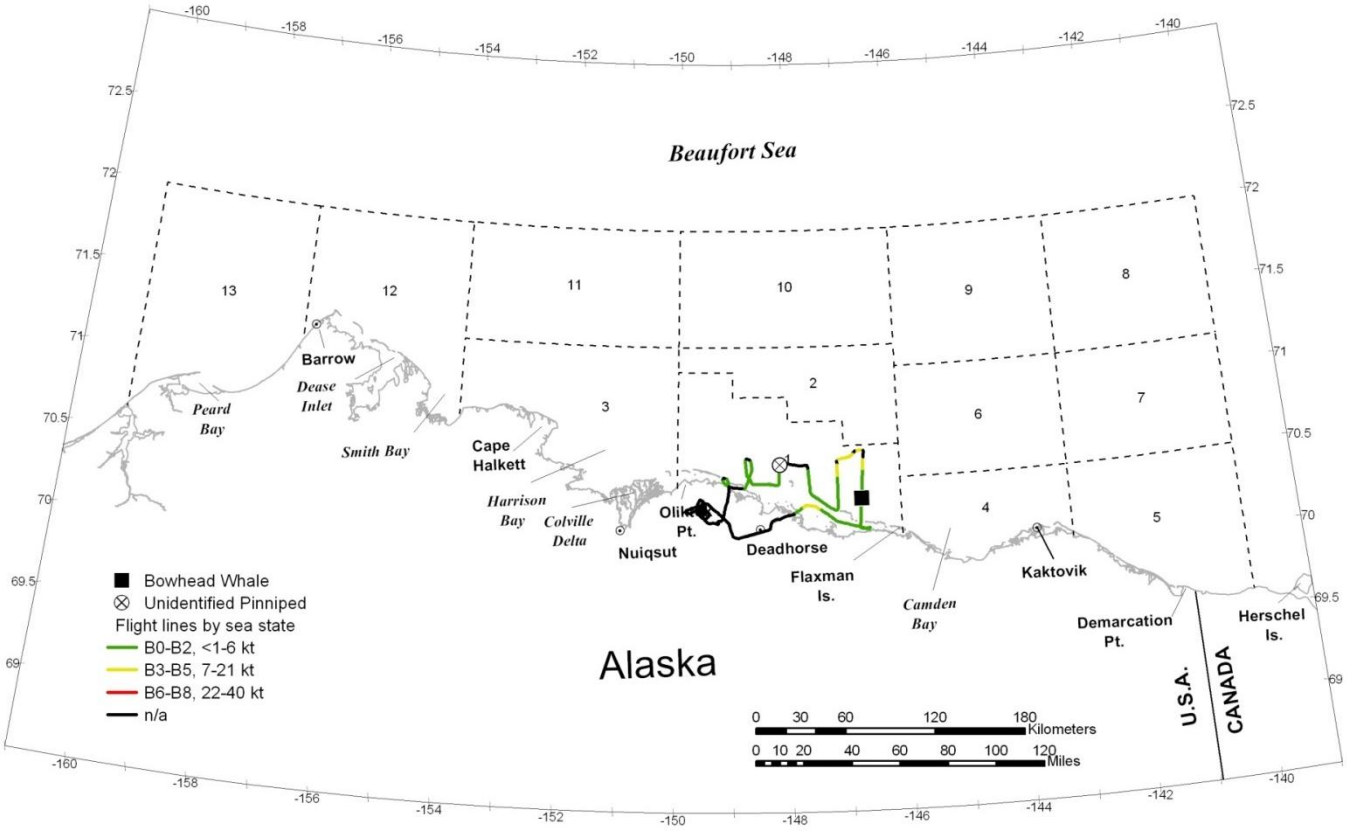

Figure C-8. -- Flight 7 survey track, depicted by sea state, and all sightings.

20 September 2010, Flight 235

Flight was a transect survey of Block 12, flown by the COMIDA aircraft and team based out of Barrow. Survey conditions were fair, with overcast skies, sea state Beaufort 2-4, and visibility from 0-3 km. Extensive haze and low ceilings precluded survey effort in the remainder of Block 12. No ice was present in the area surveyed. Bowhead whales were seen between Smith Bay and Pt. Barrow, including one group of 21 feeding whales. Two gray whales were seen west of Barrow, feeding. One unidentified pinniped was also seen.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
235	9/20/10 9:56	71.285	-156.907	gray whale	feed	1	0	12
235	9/20/10 9:58	71.291	-156.965	gray whale	feed	1	0	12
235	9/20/10 10:27	71.551	-156.159	bowhead	swim	1	0	12
235	9/20/10 11:10	71.339	-155.881	bowhead	feed	21	0	12
235	9/20/10 11:14	71.349	-155.990	bowhead	feed	1	0	12
235	9/20/10 11:27	71.401	-155.875	bowhead	swim	1	0	12
235	9/20/10 12:16	71.326	-154.561	bowhead	swim	1	0	12
235	9/20/10 12:16	71.326	-154.557	bowhead	swim	2	0	12

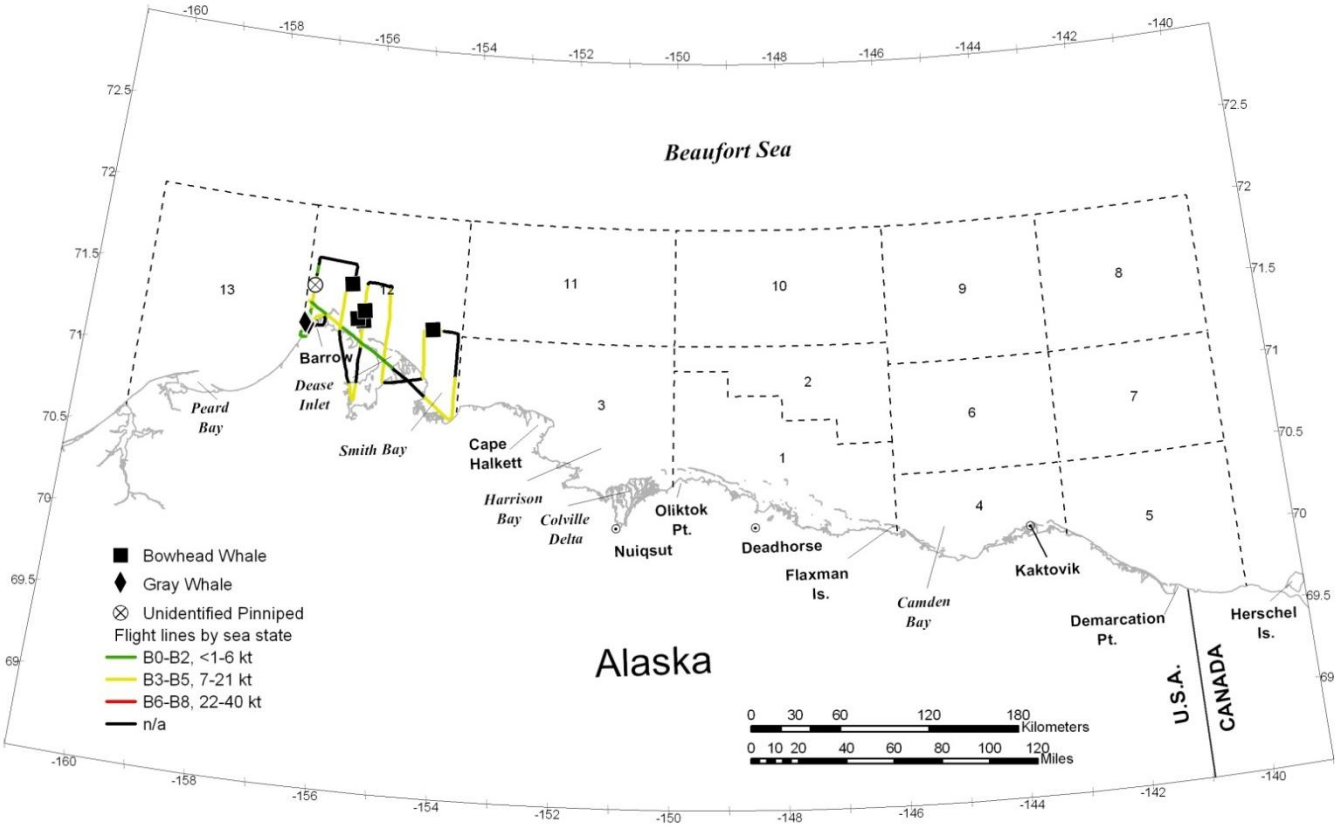

Figure C-9. -- Flight 235 survey track, depicted by sea state, and all sightings.

21 September 2010, Flight 8

Flight was a transect survey of portions of Blocks 4, 5, and 6. Survey conditions were fair, with overcast skies, sea state Beaufort 2-5, and visibility ranging from 0-10 km. Low ceilings and snow showers precluded additional survey effort, particularly in Block 5 where only very short sections of transect extremely close to shore were possible. Ice cover in Block 1 was 0-50% broken floe; there was no ice in other areas surveyed. Bowhead whales and unidentified cetaceans were seen very close to shore near Demarcation Point in eastern Block 5, and a single bowhead was seen in Block 4. One bearded seal and an unidentified pinniped were also seen. Ten polar bears were seen on and near Cross Island.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
8	9/21/10 10:35	69.740	-141.460	bowhead	rest	1	0	5
8	9/21/10 10:39	69.659	-141.015	bowhead	swim	1	0	5
8	9/21/10 10:40	69.662	-140.947	bowhead	swim	1	0	5
8	9/21/10 10:45	69.631	-140.778	unidentified cetacean	swim	2	0	5
8	9/21/10 10:46	69.638	-140.702	bowhead	swim	1	0	5
8	9/21/10 10:47	69.639	-140.585	bowhead	mill	1	0	5
8	9/21/10 10:48	69.651	-140.595	bowhead	mill	2	0	5
8	9/21/10 10:49	69.642	-140.745	bowhead	swim	1	0	5
8	9/21/10 10:49	69.642	-140.748	bowhead	swim	1	0	5
8	9/21/10 10:49	69.642	-140.758	bowhead	swim	1	0	5
8	9/21/10 10:50	69.643	-140.795	bowhead	dive	1	0	5
8	9/21/10 10:54	69.764	-140.843	unidentified cetacean	.	1	0	5
8	9/21/10 10:54	69.778	-140.832	bowhead	swim	2	0	5
8	9/21/10 11:02	69.668	-140.925	bowhead	swim	1	0	5
8	9/21/10 11:04	69.674	-141.040	bowhead	swim	1	0	5
8	9/21/10 11:05	69.690	-141.128	bowhead	breach	1	0	5
8	9/21/10 11:05	69.696	-141.149	bowhead	swim	1	0	5
8	9/21/10 11:05	69.701	-141.147	bowhead	swim	2	0	5

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
8	9/21/10 11:09	69.720	-141.298	bowhead	swim	1	0	5
8	9/21/10 11:11	69.742	-141.421	bowhead	swim	1	0	5
8	9/21/10 11:11	69.743	-141.427	bowhead	swim	1	0	5
8	9/21/10 11:14	69.779	-141.654	bowhead	tail slap	2	0	5
8	9/21/10 12:49	70.216	-145.529	bowhead	swim	1	0	4

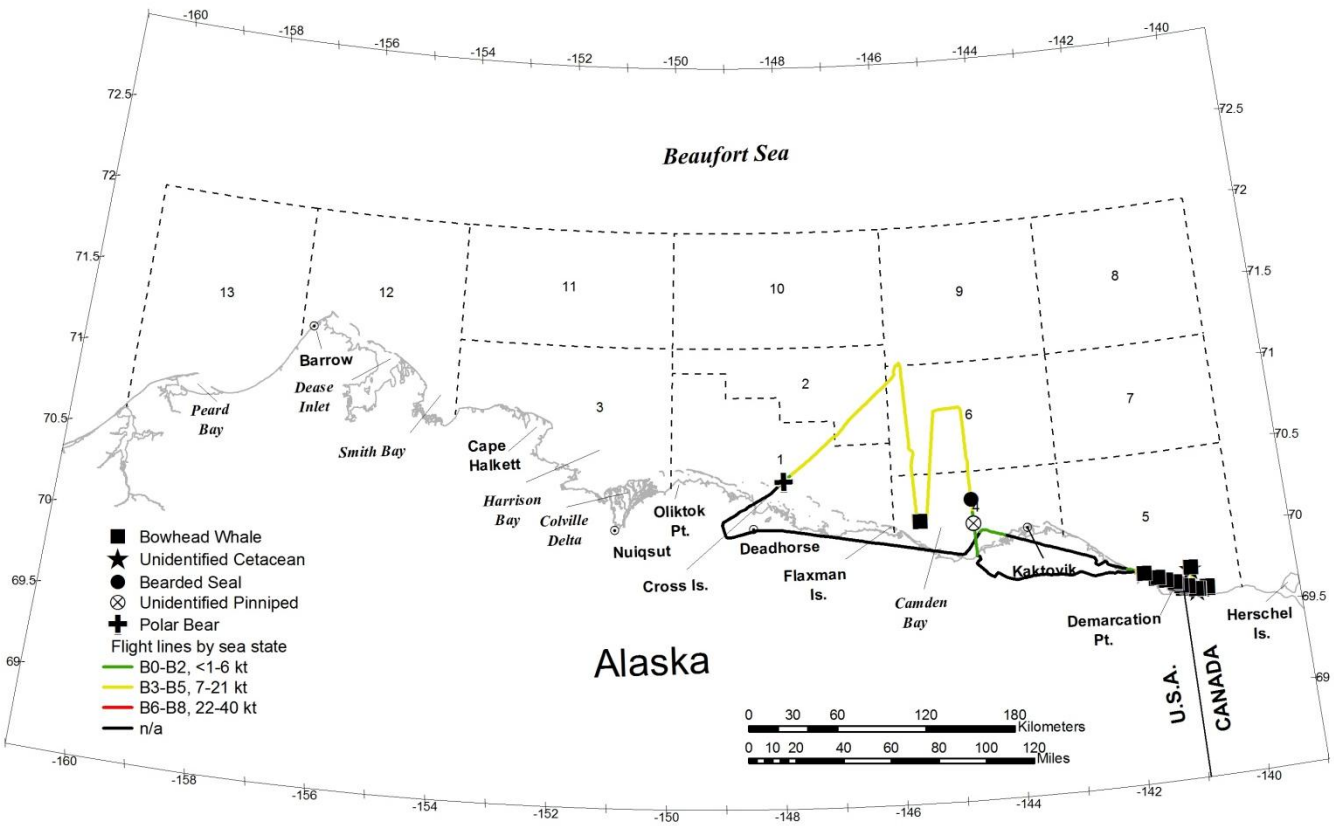

Figure C-10. -- Flight 8 survey track, depicted by sea state, and all sightings.

22 September 2010, Flight 9

Flight was a transect survey of portions of Blocks 4 and 5. Survey conditions were fair, with overcast skies, sea state Beaufort 2-3, and visibility ranging from 0-10 km. Low ceilings and snow showers precluded additional survey effort, such that only very short sections of transects were possible in both Block 4 and 5. There was no ice in the area surveyed. Bowhead whales and unidentified cetaceans were seen very close to shore scattered between Demarcation Point and Flaxman Island. Unidentified pinnipeds were also seen. Five polar bears were seen near Kaktovik.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
9	9/22/10 11:52	70.100	-145.476	bowhead	swim	2	0	4
9	9/22/10 12:03	70.093	-145.391	bowhead	mill	1	0	4
9	9/22/10 12:03	70.093	-145.385	bowhead	mill	1	0	4
9	9/22/10 12:06	70.085	-145.121	unidentified cetacean	dive	1	0	4
9	9/22/10 12:14	70.065	-144.936	bowhead	swim	1	0	4
9	9/22/10 12:27	70.201	-144.112	bowhead	swim	1	0	4
9	9/22/10 12:41	70.176	-143.979	bowhead	swim	1	0	4
9	9/22/10 12:49	70.147	-143.525	bowhead	swim	1	0	4
9	9/22/10 12:52	70.151	-143.245	bowhead	swim	2	0	4
9	9/22/10 12:54	70.163	-143.150	bowhead	swim	1	0	4
9	9/22/10 12:54	70.160	-143.137	bowhead	swim	1	0	4
9	9/22/10 12:58	70.163	-143.158	bowhead	swim	2	0	4
9	9/22/10 13:11	70.061	-142.773	bowhead	dive	1	0	5
9	9/22/10 13:15	69.989	-142.513	bowhead	swim	2	0	5
9	9/22/10 13:16	69.988	-142.465	bowhead	dive	1	0	5
9	9/22/10 13:25	69.983	-142.321	bowhead	swim	1	0	5
9	9/22/10 13:25	69.987	-142.321	bowhead	swim	1	0	5
9	9/22/10 13:25	69.989	-142.321	bowhead	swim	1	0	5
9	9/22/10 13:52	69.805	-141.653	bowhead	swim	1	0	5

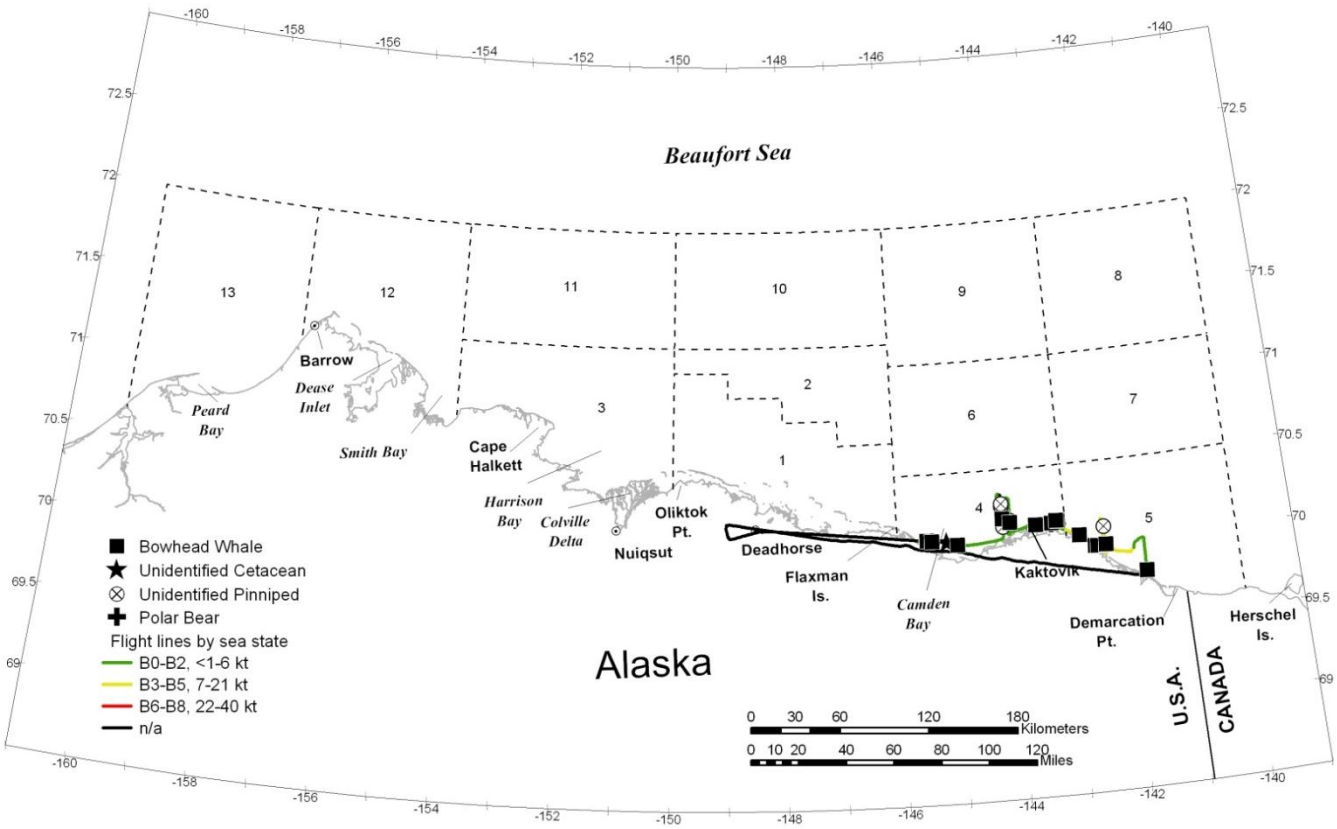

Figure C-11. -- Flight 9 survey track, depicted by sea state, and all sightings.

24 September 2010, Flight 10

Flight was a transect survey of portions of Blocks 1, 2, 5 and 7. Survey conditions were fair, with partly cloudy or overcast skies throughout the study area. Sea state in Blocks 5 and 7 was Beaufort 2-6, with visibility ranging from 3-10 km. High sea states offshore prevented transects from being completed. Sea state in Blocks 1 and 2 was Beaufort 1-3, and visibility ranged from 0-10 km. Low ceilings precluded additional survey effort offshore. There was no ice in Blocks 2, 5 and 7; ice cover in Block 1 was 0-60% broken floe. Bowhead whales, including two calves, and unidentified cetaceans were seen in Blocks 1, 4 (during search survey) and 5. One beluga was seen offshore in Block 2. Unidentified pinnipeds were scattered throughout the area surveyed; one bearded seal was also seen. Eight polar bears were seen on Cross Island.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
10	9/24/10 11:02	69.849	-140.345	bowhead	swim	1	0	5
10	9/24/10 11:21	69.894	-140.751	bowhead	swim	1	0	5
10	9/24/10 11:21	69.877	-140.750	bowhead	swim	1	0	5
10	9/24/10 11:24	69.800	-140.743	bowhead	swim	1	0	5
10	9/24/10 11:39	69.742	-141.394	bowhead	swim	1	0	5
10	9/24/10 11:40	69.768	-141.392	bowhead	swim	1	0	5
10	9/24/10 12:21	70.106	-141.902	bowhead	swim	1	0	5
10	9/24/10 12:21	70.104	-141.902	bowhead	swim	1	0	5
10	9/24/10 12:22	70.090	-141.901	bowhead	swim	1	0	5
10	9/24/10 12:23	70.052	-141.899	bowhead	swim	1	0	5
10	9/24/10 12:23	70.046	-141.898	bowhead	swim	1	0	5
10	9/24/10 12:24	70.032	-141.897	bowhead	swim	1	0	5
10	9/24/10 12:34	69.903	-142.031	bowhead	swim	1	0	5
10	9/24/10 12:34	69.905	-142.031	bowhead	swim	1	0	5
10	9/24/10 12:41	70.104	-142.081	bowhead	swim	1	0	5
10	9/24/10 12:41	70.130	-142.087	bowhead	rest	2	1	5
10	9/24/10 12:46	70.128	-142.081	bowhead	swim	1	0	5
10	9/24/10 13:43	70.124	-142.964	bowhead	rest	1	0	5
10	9/24/10 13:58	70.144	-144.451	bowhead	mill	3	0	4
10	9/24/10 14:06	70.197	-145.091	bowhead	swim	1	0	4
10	9/24/10 14:12	70.211	-145.713	bowhead	swim	2	0	4
10	9/24/10 16:27	70.762	-148.863	bowhead	swim	3	0	1

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
10	9/24/10 16:30	70.858	-148.866	bowhead	mill	2	0	1
10	9/24/10 17:38	70.564	-147.756	bowhead	swim	1	0	1
10	9/24/10 17:39	70.578	-147.756	bowhead	swim	5	0	1
10	9/24/10 17:39	70.580	-147.756	bowhead	cow with calf	2	1	1
10	9/24/10 17:39	70.581	-147.756	bowhead	swim	1	0	1
10	9/24/10 17:42	70.675	-147.755	unidentified cetacean	.	1	0	1
10	9/24/10 18:57	70.851	-146.284	beluga	swim	1	0	2

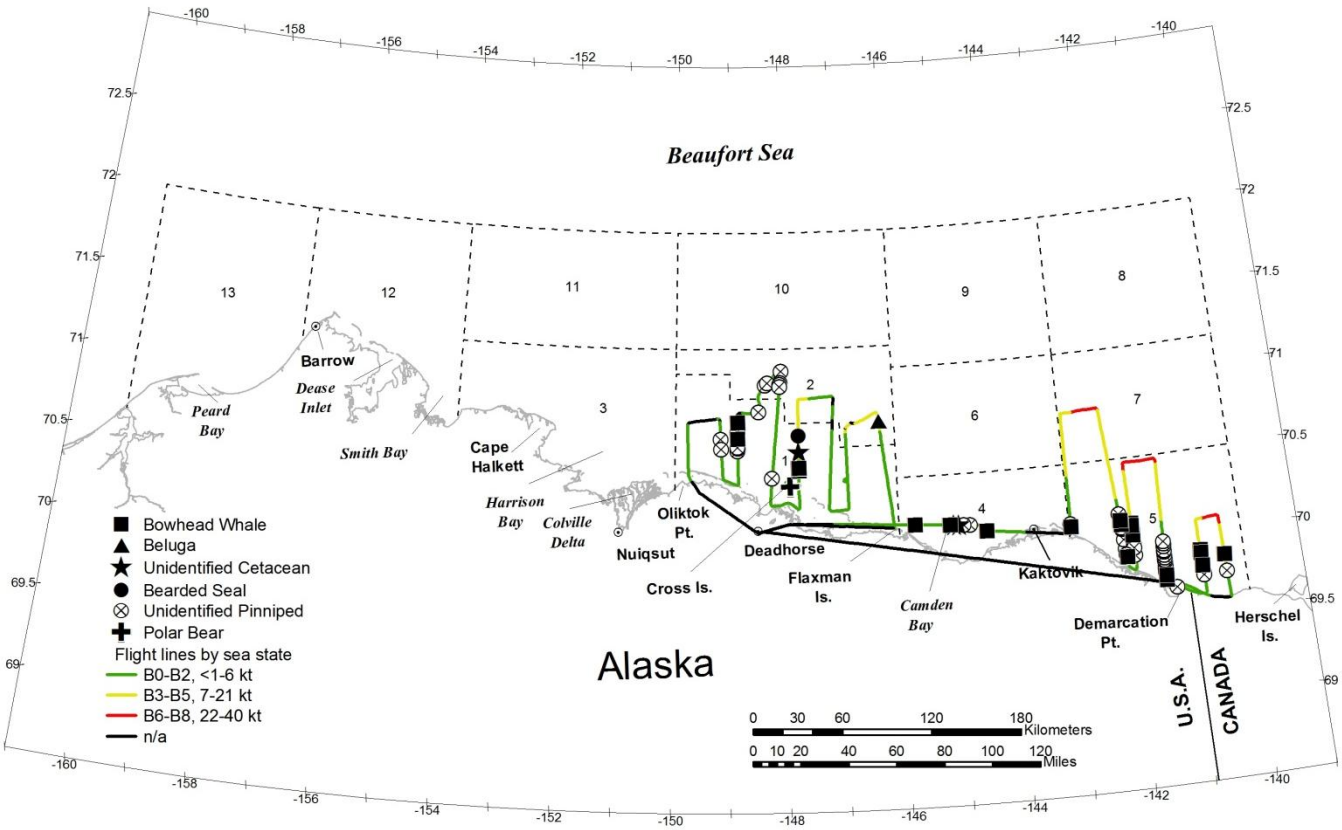

Figure C-12. -- Flight 10 survey track, depicted by sea state, and all sightings.

29 September 2010, Flight 11

Flight was a search survey of nearshore areas in an attempt to find an area suitable for transects. Survey conditions were very poor, with low ceilings and high sea states (Beaufort 5-8). Visibility ranged from 0-10 km. Ice cover in was 0-30% broken floe. There were no sightings.

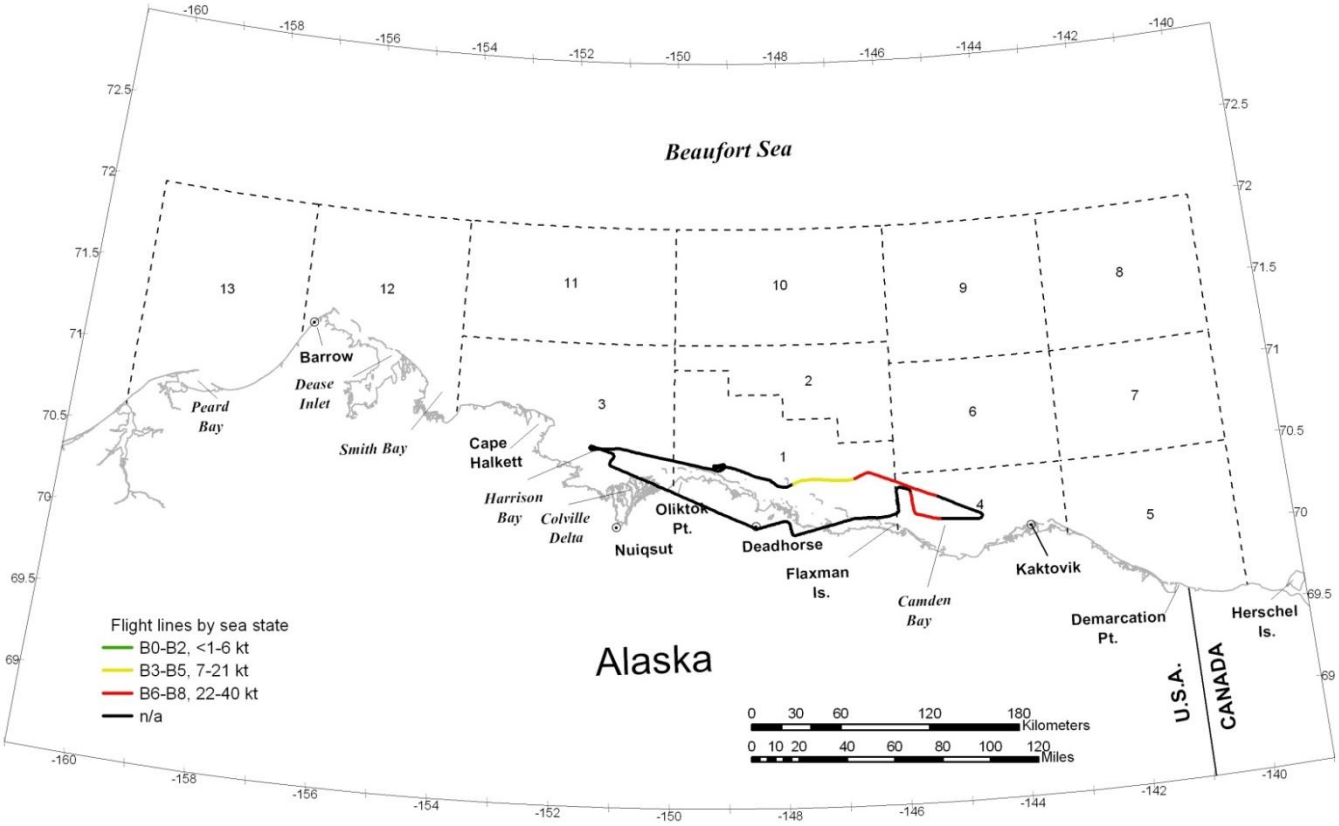

Figure C-13. -- Flight 11 survey track, depicted by sea state.

30 September 2010, Flight 12

Flight was a transect survey of portions of Blocks 5 and 7. Survey conditions were fair, with partly cloudy or overcast skies throughout the study area. Sea state in Blocks 5 and 7 was Beaufort 2-6, with visibility ranging from 3-10 km. Low ceilings offshore prevented transects from being completed. Ice cover was 0-20% broken floe and grease ice. Bowhead whales were seen in Blocks 5 and 4 (during search survey back to Deadhorse). Unidentified pinnipeds were scattered throughout the area surveyed; one bearded seal was also seen. Eleven polar bears were seen near Kaktovik.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
12	9/30/10 16:04	70.181	-142.738	bowhead	swim	1	0	5
12	9/30/10 16:06	70.222	-142.744	bowhead	swim	1	0	5
12	9/30/10 16:25	70.188	-142.387	bowhead	swim	1	0	5
12	9/30/10 16:26	70.177	-142.389	bowhead	swim	1	0	5
12	9/30/10 16:42	69.795	-141.714	bowhead	swim	1	0	5
12	9/30/10 16:45	69.814	-141.626	bowhead	swim	1	0	5
12	9/30/10 16:46	69.839	-141.630	bowhead	dive	1	0	5
12	9/30/10 18:18	69.808	-141.766	bowhead	swim	1	0	5
12	9/30/10 19:01	70.167	-145.452	bowhead	swim	1	0	4

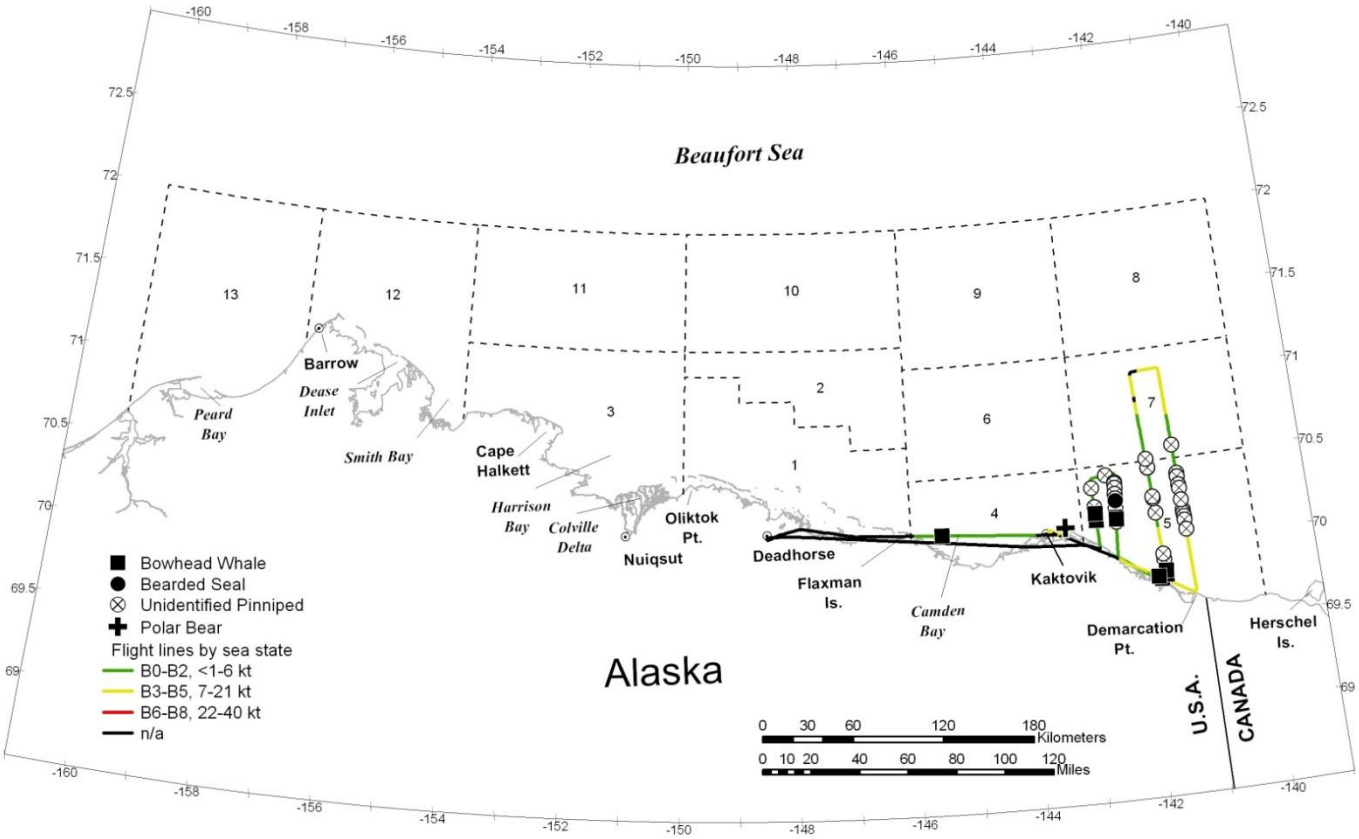

Figure C-14. -- Flight 12 survey track, depicted by sea state, and all sightings.

1 October 2010, Flight 13

Flight was a transect survey of Block 12. Survey conditions were good, with partly cloudy or overcast skies. Sea state was Beaufort 0-2 nearshore and in bays where new ice was forming, and Beaufort 3-6 offshore. Visibility varied from 5-10 km. New ice was forming in shallow bays, and there was no ice seaward of the barrier islands. Bowhead whales, including one calf, were seen north of Smith Bay. One unidentified pinniped was also seen.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
13	10/1/10 11:18	71.155	-154.357	bowhead	swim	1	0	12
13	10/1/10 11:19	71.172	-154.358	bowhead	swim	1	0	12
13	10/1/10 11:19	71.182	-154.359	bowhead	swim	1	0	12
13	10/1/10 11:19	71.191	-154.360	bowhead	swim	1	0	12
13	10/1/10 12:11	71.311	-154.913	bowhead	swim	1	0	12
13	10/1/10 12:11	71.310	-154.913	bowhead	swim	1	0	12
13	10/1/10 12:11	71.304	-154.915	bowhead	swim	2	1	12

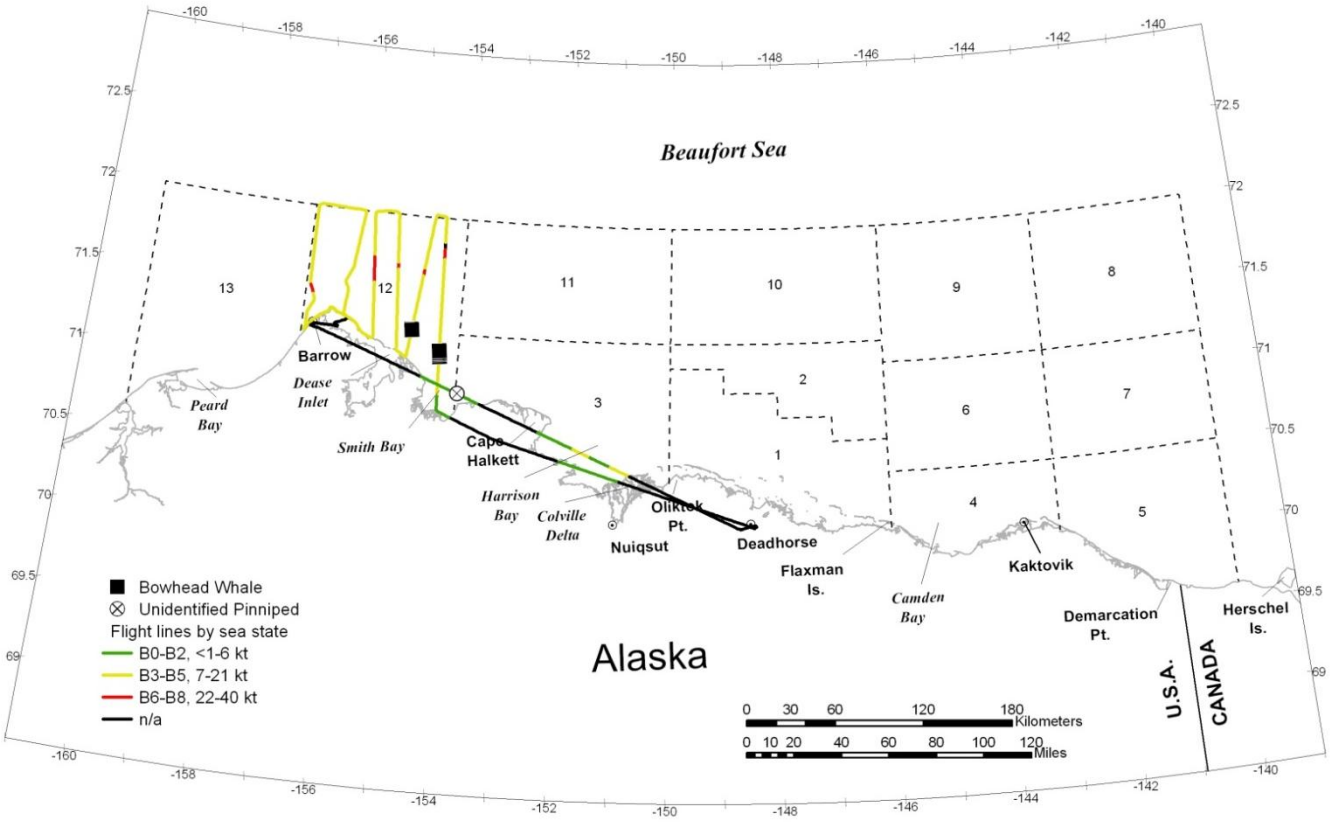

Figure C-15. -- Flight 13 survey track, depicted by sea state, and all sightings.

7 October 2010, Flight 14

Flight was a transect survey of portions of Blocks 3 and 11. Survey conditions were good, with partly cloudy or overcast skies. Sea state was Beaufort 0-2 nearshore and in bays where new ice was forming, and Beaufort 3-6 offshore. Visibility varied from 0-10 km. New ice was forming in shallow bays, and there was no ice seaward of the barrier islands. One unidentified cetacean (probable bowhead whale) was seen in Block 11.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
14	10/7/10 13:03	71.367	-152.152	unidentified cetacean	swim	1	0	11

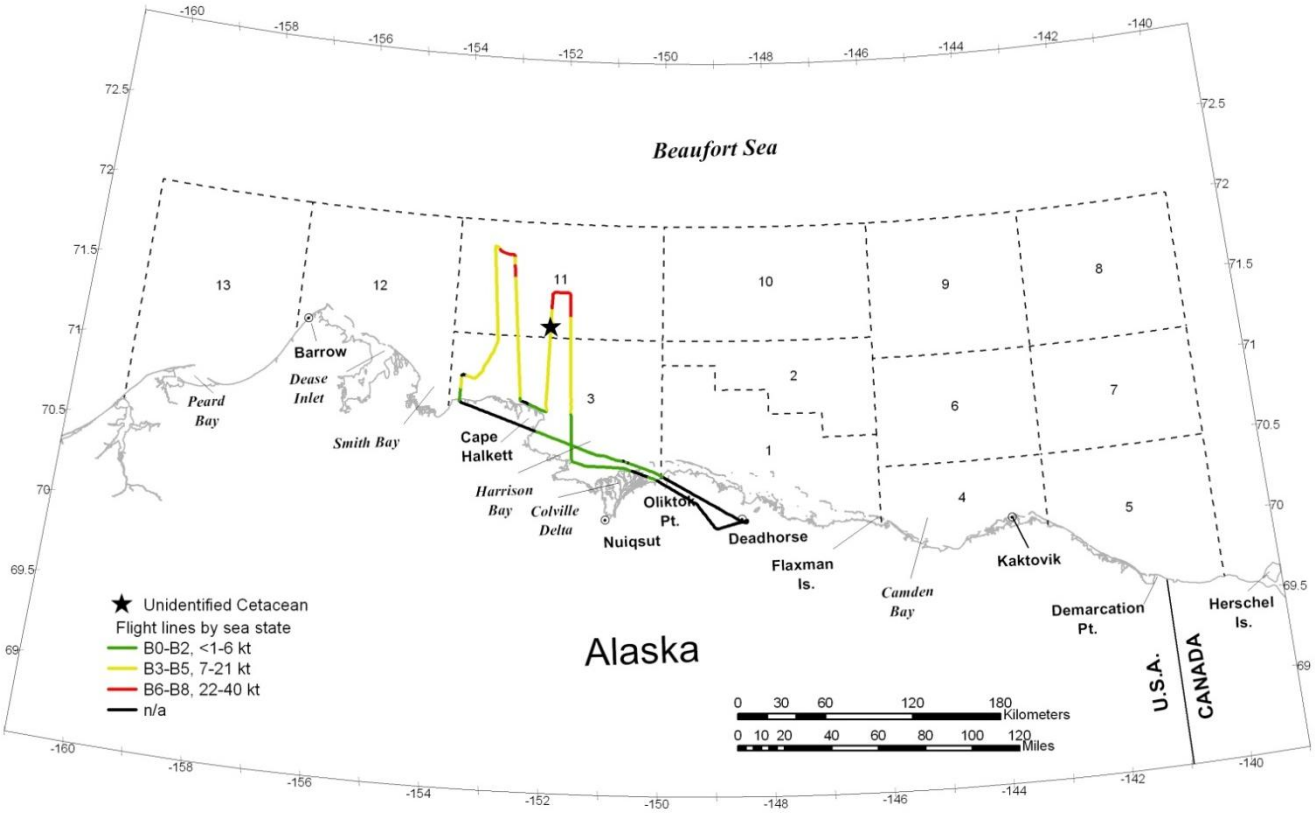

Figure C-16. -- Flight 14 survey track, depicted by sea state, and all sightings.

8 October 2010, Flight 15

Flight was a transect survey of portions of Blocks 1, 2, 3, 4, 6 and 11. Survey conditions were fair, with partly cloudy or overcast skies. Sea state was Beaufort 1 nearshore and inside of barrier islands where new ice was forming, and Beaufort 2-7 offshore. Visibility ranged from 0-10 km. Transects were truncated around areas of high sea states and impaired visibility. New ice was forming in shallow bays, and there was no ice seaward of the barrier islands. One bowhead whale and two unidentified pinnipeds were seen.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
15	10/8/10 13:03	71.054	-150.587	bowhead	swim	1	0	3

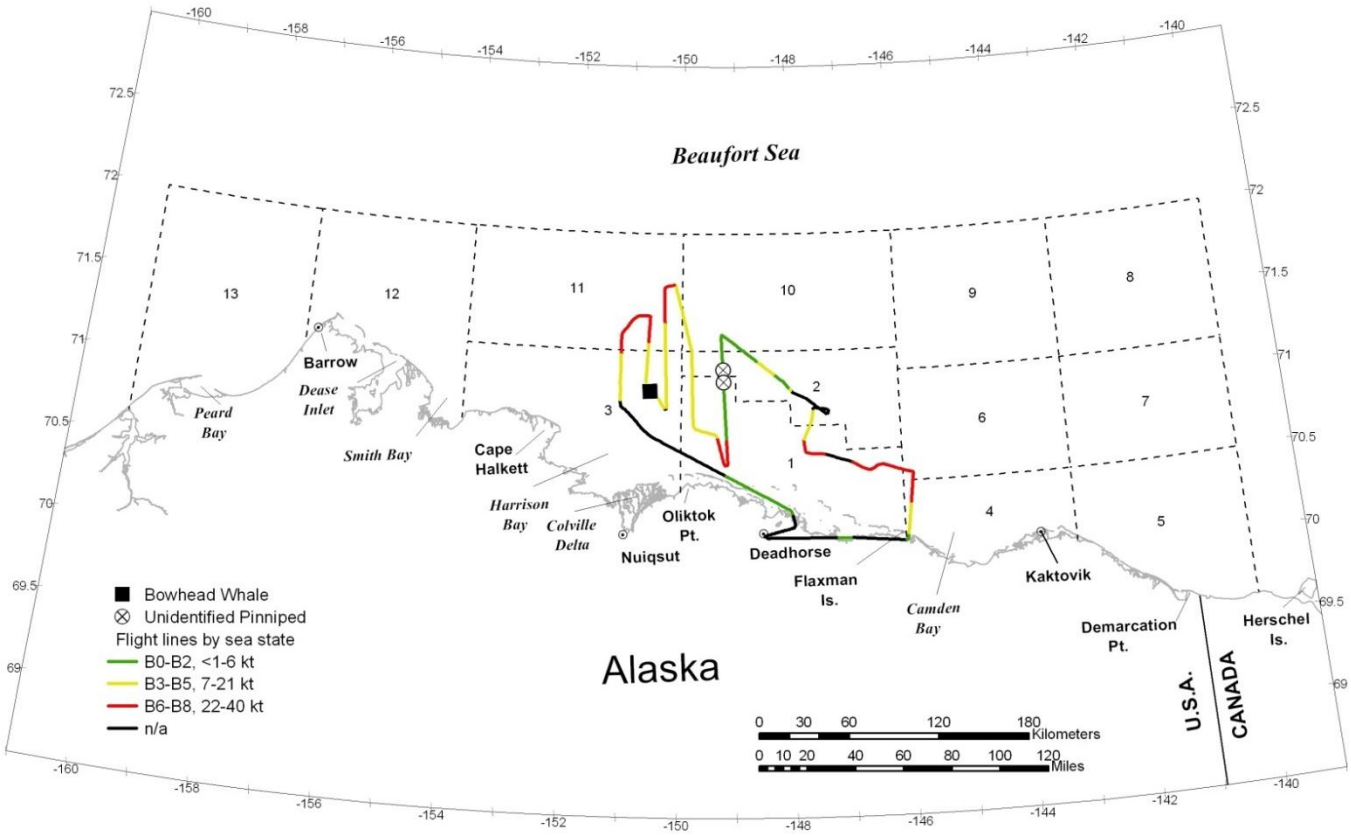

Figure C-17. -- Flight 15 survey track, depicted by sea state, and all sightings.

9 October 2010, Flight 16

Flight was a transect survey of portions of Blocks 1 and 2. Survey conditions were good, with partly cloudy or overcast skies. Sea state was Beaufort 0 nearshore and inside the barrier islands where new ice was forming and Beaufort 1-5 offshore, with visibility ranging from 0-10 km. Transects were truncated around areas of high sea states and impaired visibility. Broken floe and new ice were present nearshore, from 0-90%. One bowhead whale, one bearded seal, and one unidentified pinniped were seen. Six polar bears were seen on Cross Island.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
16	10/9/10 14:23	70.628	-148.966	bowhead	swim	1	0	1

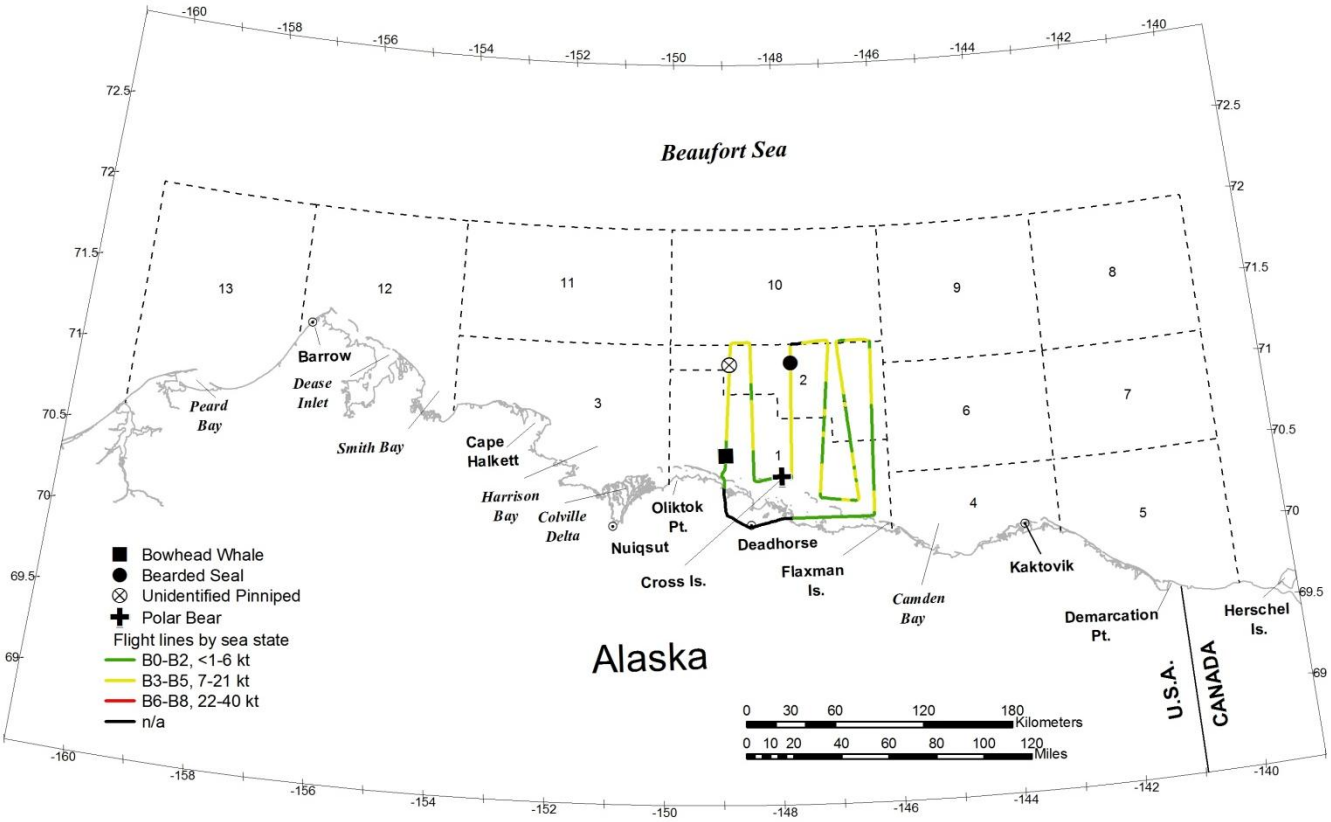

Figure C-18. -- Flight 16 survey track, depicted by sea state, and all sightings.

10 October 2010, Flight 17

Flight was a transect survey of Block 12. Survey conditions were good, with partly cloudy or overcast skies. Sea state was Beaufort 0 nearshore and inside the barrier islands where new ice was forming and Beaufort 1-5 offshore, with visibility ranging from 0-10 km. Snow squalls were frequently encountered, which impacted overall survey effort. New ice was present nearshore. Bowhead whales were seen north of Smith Bay and Dease Inlet, and one bowhead whale was near the north edge of Block 12. Whaling boats from Barrow were seen at the southern ends of transects, so transects were truncated to avoid possible interference with subsistence whaling activities.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
17	10/10/10 11:48	71.832	-154.607	bowhead	swim	1	0	12
17	10/10/10 12:09	71.220	-154.546	bowhead	swim	1	0	12
17	10/10/10 12:10	71.173	-154.541	bowhead	dive	1	0	12
17	10/10/10 12:33	71.297	-155.112	bowhead	swim	1	0	12

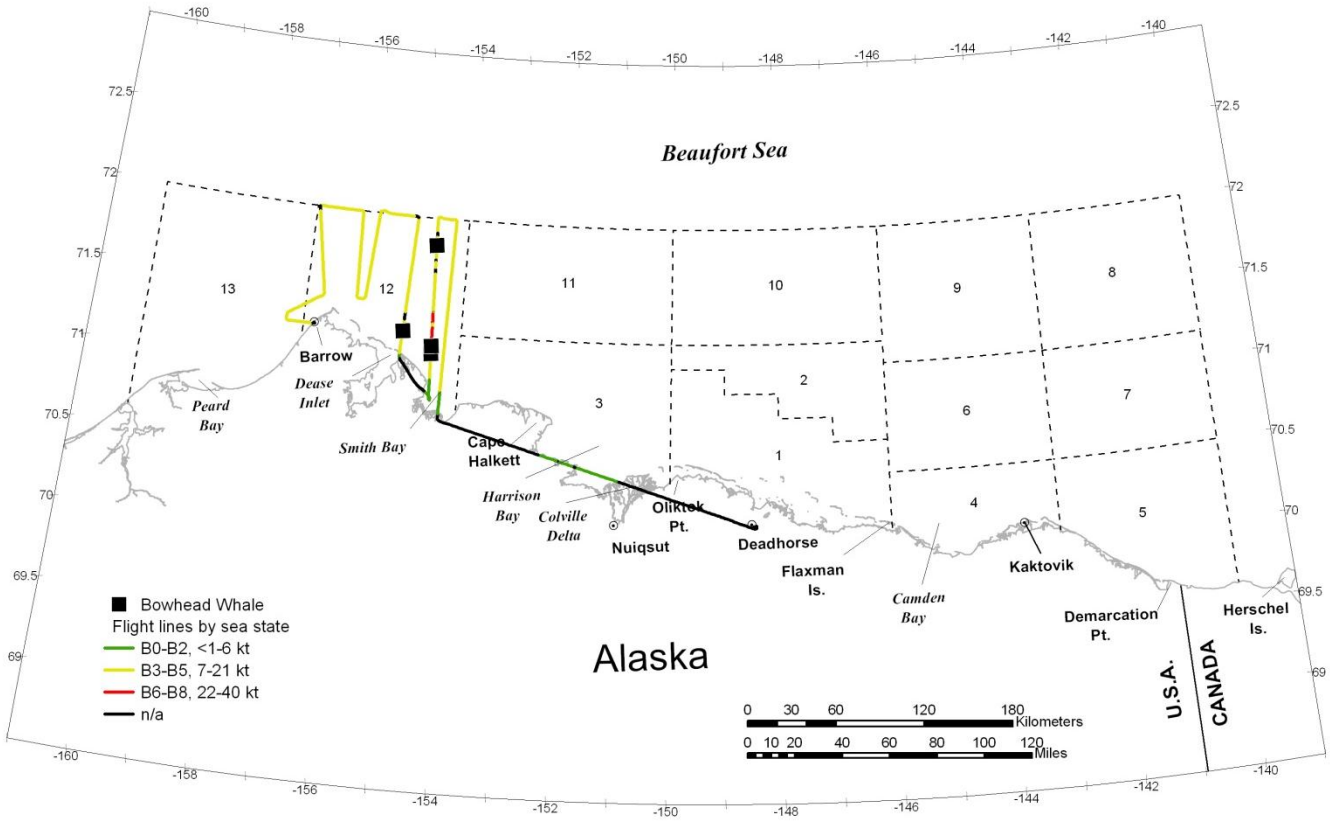

Figure C-19. -- Flight 17 survey track, depicted by sea state, and all sightings.

11 October 2010, Flight 18

Flight was a transect survey of Blocks 3 and 11. Survey conditions were good, with partly cloudy or overcast skies. Sea state was Beaufort 0 nearshore and inside the barrier islands where new ice was forming and Beaufort 1-6 offshore, with visibility ranging from 1-10 km. New ice was present nearshore, from 0-90%. Belugas were seen in the northwest corner of Block 11.

Cetacean Sightings, all effort

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
18	10/11/10 11:25	71.877	-153.899	beluga	swim	1	0	11
18	10/11/10 11:26	71.881	-153.899	beluga	swim	2	0	11
18	10/11/10 11:26	71.885	-153.900	beluga	swim	1	0	11
18	10/11/10 11:26	71.892	-153.902	beluga	swim	2	0	11
18	10/11/10 11:26	71.899	-153.903	beluga	swim	1	0	11
18	10/11/10 11:26	71.900	-153.904	beluga	swim	3	0	11
18	10/11/10 11:27	71.911	-153.905	beluga	mill	5	0	11
18	10/11/10 11:27	71.916	-153.906	beluga	swim	4	0	11
18	10/11/10 11:27	71.917	-153.906	beluga	swim	1	0	11
18	10/11/10 11:27	71.923	-153.906	beluga	swim	2	0	11
18	10/11/10 11:27	71.931	-153.908	beluga	swim	2	0	11
18	10/11/10 11:27	71.941	-153.910	beluga	swim	1	0	11
18	10/11/10 11:28	71.950	-153.911	beluga	swim	2	0	11
18	10/11/10 11:28	71.955	-153.912	beluga	swim	1	0	11
18	10/11/10 11:28	71.971	-153.914	beluga	swim	1	0	11
18	10/11/10 11:29	71.999	-153.906	beluga	swim	1	0	11
18	10/11/10 11:30	72.002	-153.885	beluga	swim	1	0	11
18	10/11/10 11:38	71.908	-153.294	beluga	swim	1	0	11
18	10/11/10 11:39	71.885	-153.288	beluga	swim	1	0	11
18	10/11/10 11:41	71.810	-153.265	beluga	swim	3	0	11

Flight No.	Date and Time	Latitude °N	Longitude °W	Species	Behavior	Total No.	Calf No.	Block
18	10/11/10 11:42	71.792	-153.260	beluga	swim	1	0	11
18	10/11/10 11:42	71.784	-153.257	beluga	swim	2	1	11
18	10/11/10 11:42	71.784	-153.257	beluga	swim	1	0	11
18	10/11/10 11:43	71.768	-153.252	beluga	swim	1	0	11
18	10/11/10 12:49	71.929	-152.849	beluga	swim	5	1	11

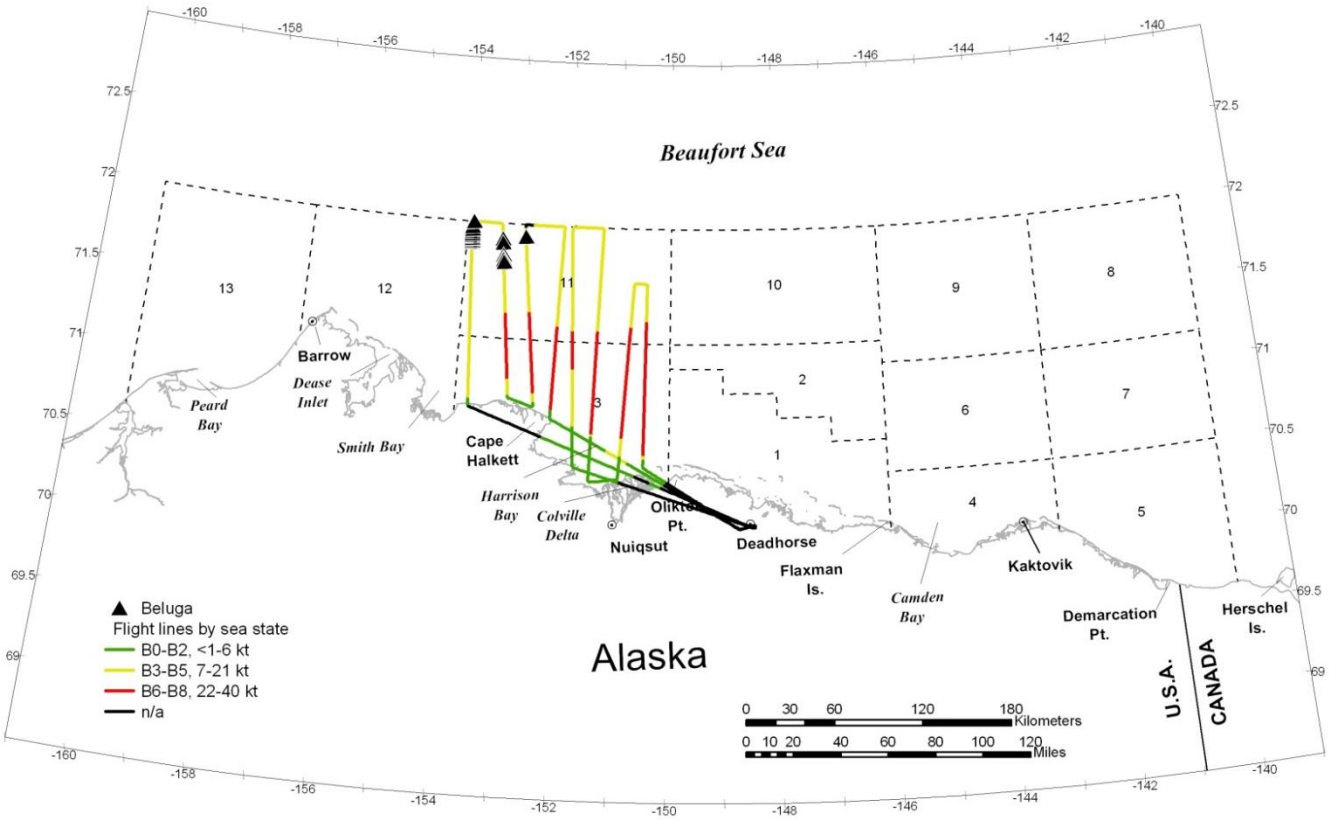

Figure C-20. -- Flight 18 survey track, depicted by sea state, and all sightings.

15 October 2010, Flight 19

Flight was a search and deadhead survey of Blocks 1 and 2 in an attempt to find an area suitable for transects. Survey conditions were very poor, with low ceilings and very high sea states (Beaufort 8). Visibility ranged from 0 to <1 km. There were no sightings.

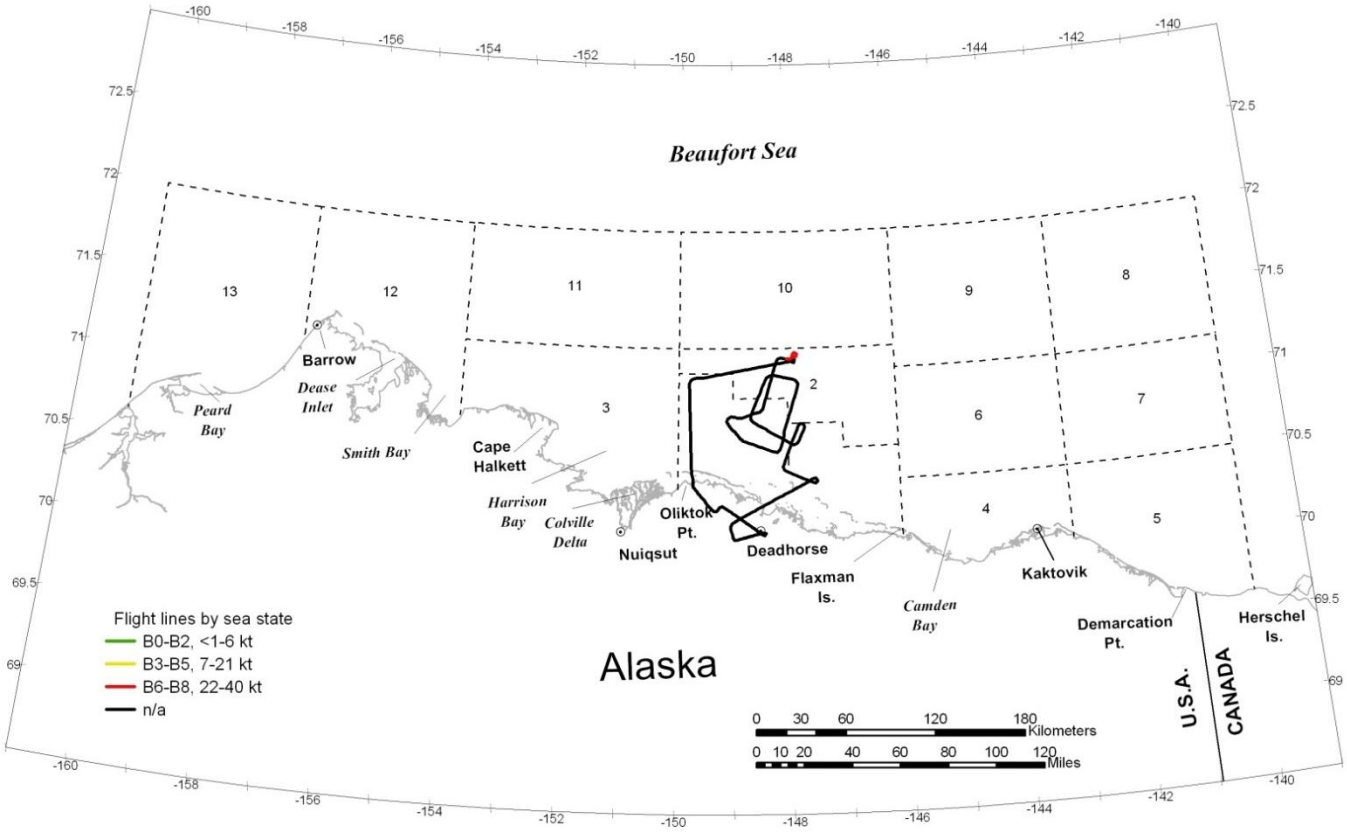

Figure C-21. -- Flight 19 survey track, depicted by sea state.

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APPENDIX D: GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND INITIALISMS

AEWC	Alaska Eskimo Whaling Commission
AFSC	Alaska Fisheries Science Center
ANOVA	analysis of variance
BLM	Bureau of Land Management
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
BWASP	Bowhead Whale Aerial Survey Project
CI	confidence interval
e.g.	for example
ESA	Endangered Species Act
FR	Federal Register
GPS	Global Positioning System
hr	hour
i.e.	that is
IBCAO	International Bathymetric Chart of the Arctic Ocean
km	kilometer
m	meter
Max	maximum
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
Min	minimum
n	sample size
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NOS	Notice of Sale
NMFS	National Marine Fisheries Service
nm	nautical mile
NSB	North Slope Borough
OAS	Office of Aircraft Services
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
P	probability
RDI	Resource Data Incorporated
s	second
SAIC	Science Applications International Corporation
SD	standard deviation
SPUE	sightings per unit effort (sighting rate)
TrSi	transect sightings
USC	U.S. Code
USDOC	U.S. Department of Commerce
USDOD	U.S. Department of Defense
USDOI	U.S. Department of the Interior
WPUE	whales per unit effort (index of relative abundance or occurrence)

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The Department of the Interior Mission

Protecting America's Great Outdoors and Powering Our Future

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.