OCS Study
BOEMRE 2010-033

Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 2006-2008

Final Report

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Funding Agency:
Bureau of Ocean Energy Management, Regulation, and Enforcement
Alaska OCS Region
3801 Centerpoint Drive, Suite 500, Anchorage, AK 99503
Contract No. M07RG13260

February 2011

Cover Photo Credit:
Cynthia Christman
National Marine Mammal Laboratory/Alaska Fisheries Science Center
Bowhead Whales
Chukchi Sea, Alaska
July 11, 2009
NMFS Permit No. 782-1719

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Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 2006-2008

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This study was funded by the U.S. Department of the Interior, Minerals Management Service (MMS), Alaska Outer Continental Shelf Region, Anchorage, Alaska, through an Inter-agency Agreement between MMS and the National Marine Mammal Laboratory (M07RG13260), as part of the MMS Alaska Environmental Studies Program.

February 2011

REPORT AVAILABILITY

This document is available to the public through:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161
FAX: (703) 605 6900
www.ntis.gov

CITATION

May be cited as: Clarke, J.T., Christman, C.L., Ferguson, M.C., and Grassia, S.L. 2011. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 2006-2008. Final Report, OCS Study BOEMRE 2010-033. National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way NE, F/AKC3, Seattle, WA 98115-6349.

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ABSTRACT

This report describes field activities and data analyses for aerial surveys of bowhead whales (*Balaena mysticetus*) conducted during fall 2006 (2 September – 16 October), fall 2007 (3 September – 10 October), and fall 2008 (5 September – 18 October) in the Beaufort Sea, between 140°W and 158°W, south of 72°N and north of the Alaskan coastline.

During September and October 2006-2008, ice cover was extremely light, with historic minimum summer sea ice retreat observed in 2007 and 2008.

In 2006, a total of 27 survey flights were attempted. There were 124 sightings of 406 bowhead whales. Additionally, 22 gray whales (*Eschrichtius robustus*), 525 belugas (*Delphinapterus leucas*), 59 bearded seals (*Erignathus barbatus*), 407 ringed seals (*Pusa hispida*), and 77 polar bears (*Ursus maritimus*) were observed. Total flight time was 90 hours, which included 56 hours of on transect survey effort.

Median distance from locations of sightings of bowhead whales in 2006 to a normalized shoreline was 34.3 km (range = 4-92 km) in the East Region, and 39.2 km (range = 3-74 km) in the West Region. Median depth at sightings was 44 m (range = 8-1,868 m) in the East Region, and 32 m (range = 7-204 m) in the West Region. Compared with other light ice years, sightings were significantly farther from shore and in deeper water in both the East and West Regions. The more seaward locations of bowhead whales may have been due to the presence of grounded ice in the East Region in September. Sightings in September 2006 in the East Region were significantly farther from shore and in deeper water than sightings in October. There was no statistically significant difference in the West Region between September and October.

In 2007, a total of 21 survey flights were attempted. There were 144 sightings of 409 bowhead whales. Additionally, 20 gray whales, 117 belugas, 106 bearded seals, 56 Pacific walruses (*Odobenus rosmarus*), 1,732 ringed seals, and 83 polar bears were observed. Total flight time was 93 hours, which included 36 hours of on transect survey effort.

Median distance from locations of sightings of bowhead whales in 2007 to a normalized shoreline was 21.8 km (range 1-74 km) in the East Region and 25.7 km (range 15-35 km) in the West Region. Median depth at sightings was 34 m (range 14-403 m) in the East Region and 22.5 m (range 12-35 m) in the West Region. Compared to other light ice years, sightings were significantly closer to shore and in shallower water in the East Region, but there was no significant difference in the West Region (sample size was very small in 2007 in the West Region). When non-migrating whales (feeding, milling, or resting whales) were removed from the central tendency analysis for all light ice years, bowhead whale sightings in the East Region were in significantly shallower water in 2007 than in previous light ice years, although distance from shore was not significantly different.

In 2008, a total of 20 survey flights were attempted. There were 127 sightings of 276 bowhead whales. Additionally, 2 gray whales, 15 belugas, 52 bearded seals, 285 unidentified pinnipeds,

and 103 polar bears were observed. Total flight time was 107 hours, which included 53 hours of on transect survey effort.

Median distance from locations of sightings of bowhead whales in 2008 to a normalized shoreline was 21.3 km (range 6-38 km) in the East Region and 18.4 km (range 3-57 km) in the West Region. Median depth at sightings was 29 m (range 12-40 m) in the East Region, and 15 m (range 3-33 m) in the West Region. Compared with other light ice years, sightings were significantly closer to shore and in shallower water in both the East and West Regions.

CONTENTS

Page

Abstract v

List of Figures ix
List of Tables xi
List of Appendices xiii

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 Analysis 14

Results 15
- Fall 2006 15
  - Environmental Conditions 15
  - Survey Effort 15
  - Bowhead Whale Observations 15
    - Sighting Summary 15
    - Sighting Rates 26
    - Habitat Associations 28
    - Behaviors 28
    - Distance from Shore 30
    - Depth at Sighting 30
    - Distribution of Migrating Bowhead Whales, 2006, Relative to Previous Light Ice Years 35
  - Other Marine Mammal Observations 35
- Fall 2007 43
  - Environmental Conditions 43
  - Survey Effort 43

Bowhead Whale Observations 43
Sighting Summary 43
Sighting Rates 53
Habitat Associations 55
Behaviors 55
Distance from Shore 55
Depth at Sighting 56
Distribution of Migrating Bowhead Whales, 2007, Relative to Previous Light Ice Years 56
Other Marine Mammal Observations 62
Fall 2008 71
Environmental Conditions 71
Survey Effort 71
Bowhead Whale Observations 71
Sighting Summary 71
Sighting Rates 82
Habitat Associations 84
Behaviors 84
Distance from Shore 86
Depth at Sighting 86
Distribution of Migrating Bowhead Whales, 2008, Relative to Previous Light Ice Years 86
Other Marine Mammal Observations 91

Discussion 99
Conclusions 99
Management Use of Real-Time Field Information 101
Management Use of Interannual Monitoring 101

Acknowledgments 101

Literature Cited 103

LIST OF FIGURES

Page

Figure 1. Study area showing Survey Blocks 4
Figure 2. East and West Regions showing a normalized shoreline and selected IBCAO isobaths 12
Figure 3. Combined flight tracks, 2–15 September 2006 17
Figure 4. Combined flight tracks, 16-30 September 2006 18
Figure 5. Combined flight tracks, 1–15 October 2006 19
Figure 6. Combined flight tracks, 16 October 2006 20
Figure 7. Bowhead whale sightings, fall 2006 22
Figure 8. Bowhead whale sightings, 2-15 September 2006 23
Figure 9. Bowhead whale sightings, 16-30 September 2006 24
Figure 10. Bowhead whale sightings, 1-15 October 2006 25
Figure 11. Sighting rates of bowhead whales, fall 2006 (transect whales/transect km surveyed). .. 27
Figure 12. Sighting rates of feeding and milling bowhead whales, fall 2006 (transect whales/transect km surveyed) 29
Figure 13. Bowhead whale sightings on transect, fall 2006, showing mean distance from a normalized shoreline 33
Figure 14. Bowhead whale sightings on transect, excluding feeding, milling and resting whales, fall 2006, showing mean distance from a normalized shoreline 34
Figure 15. Gray whale sightings, fall 2006 36
Figure 16. Beluga sightings, fall 2006 37
Figure 17. Bearded seal sightings, fall 2006 38
Figure 18. Pacific walrus sightings, fall 2006 39
Figure 19. Ringed seal sightings, fall 2006 40
Figure 20. Polar bear sightings, fall 2006 42
Figure 21. Combined flight tracks, 3–15 September 2007 45
Figure 22. Combined flight tracks, 16-30 September 2007 46
Figure 23. Combined flight tracks, 1–10 October 2007 47
Figure 24. Bowhead whale sightings, fall 2007 49
Figure 25. Bowhead whale sightings, 3-15 September 2007 50
Figure 26. Bowhead whale sightings, 16-30 September 2007 51
Figure 27. Bowhead whale sightings, 1-10 October 2007 52
Figure 28. Sighting rates of bowhead whales, fall 2007 (transect whales/transect km surveyed). 54
Figure 29. Sighting rates of feeding and milling bowhead whales, fall 2007 (transect whales/transect km surveyed) 57
Figure 30. Bowhead whale sightings on transect, fall 2007, showing mean distance from a normalized shoreline 60
Figure 31. Bowhead whale sightings on transect, excluding feeding, milling and resting whales, fall 2007, showing mean distance from a normalized shoreline 61

Figure 32. Gray whale sightings, fall 2007 63
Figure 33. Beluga sightings, fall 2007 64
Figure 34. Number of belugas and annual effort (hour), total and transect only, 1989-2007 65
Figure 35. Bearded seal sightings, fall 2007 66
Figure 36. Pacific walrus sightings, fall 2007 67
Figure 37. Ringed seal sightings, fall 2007 68
Figure 38. Polar bear sightings, fall 2007 69
Figure 39. Combined flight tracks, 5–15 September 2008 73
Figure 40. Combined flight tracks, 16-30 September 2008 74
Figure 41. Combined flight tracks, 1–15 October 2008 75
Figure 42. Combined flight tracks, 16-18 October 2008 76
Figure 43. Bowhead whale sightings, fall 2008 78
Figure 44. Bowhead whale sightings, 5-15 September 2008 79
Figure 45. Bowhead whale sightings, 16-30 September 2008 80
Figure 46. Bowhead whale sightings, 1-15 October 2008 81
Figure 47. Sighting rates of bowhead whales, fall 2008 (transect whales/transect km surveyed) 83
Figure 48. Sighting rates of feeding and milling bowhead whales, fall 2008 (transect whales/transect km surveyed). 85
Figure 49. Bowhead whale sightings on transect, fall 2008, showing mean distance from a normalized shoreline 89
Figure 50. Bowhead whale sightings on transect, excluding feeding, milling and resting whales, fall 2008, showing mean distance from a normalized shoreline 90
Figure 51. Gray whale sightings, fall 2008 92
Figure 52. Beluga sightings, fall 2008 93
Figure 53. Number of belugas and annual effort (hour), total and transect only, 1982-2008 94
Figure 54. Bearded seal sightings, fall 2008 95
Figure 55. Unidentified pinniped sightings, fall 2008 96
Figure 56. Polar bear sightings, fall 2008 97
Figure 57. Comparison of bowhead whale transect sightings, September-October 2006, to bowhead whale transect sightings, September-October of previous light ice years (1982, 1986-87, 1989-90, 1993-2005) 100

LIST OF TABLES

Page

Table 1. Operational definitions of observed whale behaviors 9
Table 2. Daily and semimonthly aerial survey effort in the Beaufort Sea, 2 September-16 October 2006 16
Table 3. Daily and semimonthly marine mammal sightings, 2 September-16 October 2006, showing number of sightings and number of individuals (i.e., no. sightings/no. individuals) 21
Table 4. Survey effort, number of bowhead whales per Survey Block, and sighting rate (WPUE; whales per km surveyed) per Survey Block for bowhead whales on transect, fall 2006 26
Table 5. Semimonthly summary of bowhead whales observed by percent ice cover at sighting location, fall 2006 28
Table 6. Semimonthly summary of bowhead whales observed by behavioral category, fall 2006 30
Table 7. Central-tendency statistics for distance from shore (km) and depth (m) at transect sightings of bowhead whales (September-October), by year and region, 1982-2006 31
Table 8. Survey effort, number of belugas per Survey Block, and sighting rate (WPUE; whales per km surveyed) per Survey Block for belugas on transect, fall 2006 41
Table 9. Daily and semimonthly aerial survey effort in the Beaufort Sea, 3 September-10 October 2007 44
Table 10. Daily and semimonthly summary of marine mammal sightings, 3 September-10 October 2007, showing number of sightings and number of individuals (i.e., no. of sightings/no. of individuals) 48
Table 11. Survey effort, number of bowhead whales per Survey Block, and sighting rate (WPUE; whales per km surveyed) per Survey Block for bowhead whales on transect, fall 2007 53
Table 12. Semimonthly summary of bowhead whales observed by percent ice cover at sighting location, fall 2007 55
Table 13. Semimonthly summary of bowhead whales observed by behavioral category, fall 2007. 56
Table 14. Central-tendency statistics for distance from shore (km) and depth (m) at transect sightings of bowhead whales (September-October), by year and region, 1982-2007 58
Table 15. Daily and semimonthly aerial survey effort in the Beaufort Sea, 5 September-18 October 2008 72
Table 16. Daily and semimonthly summary of marine mammal sightings, 5 September-18 October 2008, showing number of sightings and number of individuals (i.e., no. of sightings/no. of individuals) 77
Table 17. Survey effort, number of bowhead whales per Survey Block, and sighting rate (WPUE; whales per km surveyed) by Survey Block for bowhead whales on transect, fall 2008 82
Table 18. Semimonthly summary of bowhead whales observed by percent ice cover at sighting location, fall 2008 84

Table 19. Semimonthly summary of bowhead whales observed by behavioral category, fall 2008 84
Table 20. Central-tendency statistics for distance from shore (km) and depth (m) at transect sightings of bowhead whales (September-October), by year and region, 1982-2008..... 87

LIST OF APPENDICES

Page

Appendix A: Fall 2006 Ice Concentration Maps – Alaskan Beaufort Sea 109
Appendix B: Fall 2006 Bowhead Whale Sighting Data 119
Appendix C: Fall 2006 Daily Flight Summaries 125
Appendix D: Fall 2007 Ice Concentration Maps – Alaskan Beaufort Sea 153
Appendix E: Fall 2007 Bowhead Whale Sighting Data 161
Appendix F: Fall 2007 Daily Flight Summaries 167
Appendix G: Fall 2008 Ice Concentration Maps – Alaskan Beaufort Sea 189
Appendix H: Fall 2008 Bowhead Whale Sighting Data 199
Appendix I: Fall 2008 Daily Flight Summaries 205
Appendix J: Glossary of Abbreviations, Acronyms, and Initialisms 227

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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 of 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 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 Oil and Gas Lease 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, 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 recommends that whale distribution studies during the fall migration continue, along with acoustic monitoring studies to describe the impact of exploration 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 (NOS) (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 NOS for each contained an Information to Lessees clause that "MMS intends to continue its area wide endangered whale monitoring program in the Beaufort Sea during exploration activities" (USDOI, MMS 1988, 1991, 1996, 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 field work and reporting activities for the Beaufort Sea on an annual basis (Treacy 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2000, 2002a, 2002b; Monnett and Treacy 2005; USDOI, MMS 2008). In 2007, an Interagency Agreement between the 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, full responsibility for all aspects of the BWASP surveys and related tasks was adopted by NMML. 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 the 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 the MMS.

METHODS AND MATERIALS

Study Area

The annual survey program has been based on a design of north/south transects distributed randomly within established geographic blocks overlapping or near Beaufort and Chukchi 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 Alaskan coastline, with occasional surveys west of 157°W in the Chukchi Sea (Survey Block 13).

A large-scale Beaufort Gyre moves waters clockwise from the Canadian Basin westward in the deeper offshore regions. Nearshore surface currents tend to follow local wind patterns and bathymetry, moving from the east in winter, with an onshore component, and to the west in summer, with an offshore component (Brower et al. 1988). There is recent evidence for the existence of two regimes or climate states for arctic atmospheric-ice-ocean circulation. 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 for 5-7 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 fast 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 totally 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 summer ice pack has been shrinking, setting records for new minimums in several years including 2006, 2007, and 2008 (National Snow and Ice Data Center 2006, 2007, 2008). The open water season has lengthened and the southern edge of the ice pack has been farther from Alaskan shorelines.

Local weather patterns affect the frequency and effectiveness of all marine aerial surveys. The present study area is in the arctic climate zone, with mean temperatures at the Alaskan Beaufort Sea coast locations of Barrow, Lonely (west of Cape Halkett), Oliktok, and Barter Island (near Kaktovik) 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

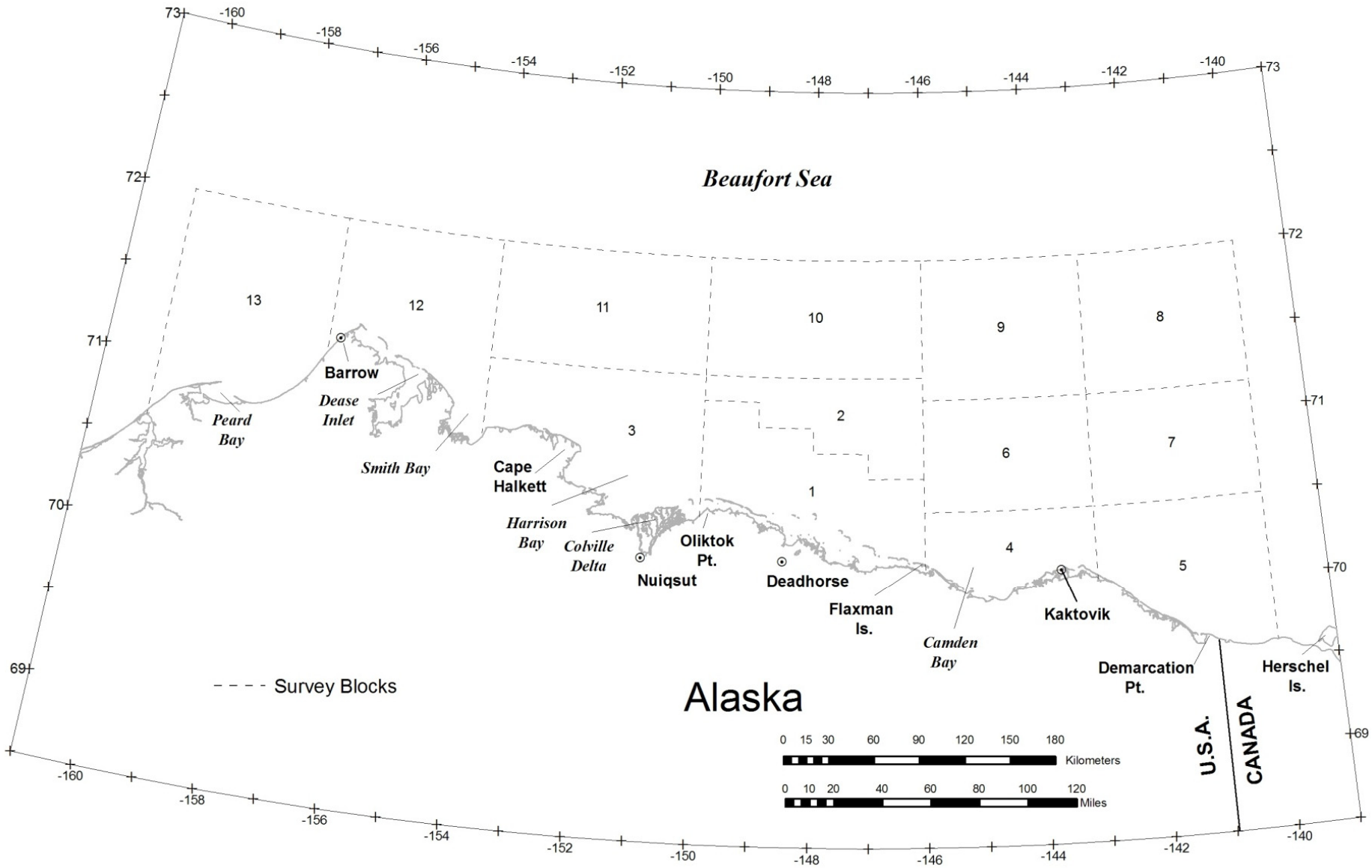

Figure 1. -- Study area showing Survey Blocks.

latitudes) or increased infrared back-radiation due to increased cloudiness, water vapor, or CO_2 (Wendler et al. 2009). Precipitation across the North Slope occurs an average of 10-34% of the time during September (snow with some rain) and 13-43% during October (almost all snow), with the heaviest precipitation at Barrow and Barter Island during both months (Brower et al. 1988). Fog (without precipitation) reduces visibility approximately 11-19% of the time during September and 6-8% of the time during October. Mean wind speed in the same communities is from 5-6 m/s during September and 5-7 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 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 westerly. The occurrence of storms (at least one hourly reading of wind speed >15 m/s which equals approximately Beaufort Wind Force 7 or a moderate gale) has also increased since 1972 (Wendler et al. 2009). Highest annual mean wind speeds at Barrow were recorded in the early 1990s; mean annual wind speed in 2006 was approximately 5.2 m/s (Fig. 3, 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

The project aircraft was a de Havilland Twin Otter Series 300 equipped for arctic operation and aerial surveys of whales. Onboard equipment, data collection, and post-field analyses replicated equipment and standard procedures developed and used in past years (1979-2005). These methodologies are described in detail elsewhere (Treacy 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2000, 2002a, 2002b; Monnett and Treacy 2005; USDOI, MMS, 2008).

Aircraft were equipped with two medium-sized bubble windows behind the cabin bulkhead and two larger bubble windows forward of the aft bulkhead 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 to a common communication system. The aircraft's maximum time aloft under normal survey load was extended to approximately 7 hours through the use of a supplemental onboard fuel tank.

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. An onboard printer provided a hard-copy backup of data as they were collected in 2006; data were backed up to an onboard external hard drive in lieu of an onboard printer in 2007-2008. A custom mapping program developed by MMS project personnel in Visual Basic permitted observers to view the aircraft's trackline in real time.

Onboard safety equipment included an impact-triggered emergency locator transmitter installed in the aircraft, a 6-person Switlik search and rescue life raft equipped with a portable personal locator beacon and desalination pump, a portable ICOM A3 Sport aircraft-band transceiver, an emergency Magellan 3000 GPS, and dry suits.

The U.S. Department of the Interior, National Business Center, Aviation Management "Automated Flight Following" (AFF) system was used by Anchorage-based Aviation Management personnel for "satellite-tracking" the project aircraft over the Alaskan Beaufort Sea. Aviation Management obtained current flight information in the form of maps for visual tracking of the survey aircraft. As a backup, an Iridium satellite phone was used when needed for communicating the aircraft's position to Aviation Management. 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.

Aerial Survey Design

Aerial surveys were based out of Deadhorse, Alaska, from 1 September through 20 October. Field schedules were designed to monitor the progress of the fall bowhead whale migration across the Alaskan Beaufort Sea. All bowhead whale observations were recorded along with incidental sightings of other marine mammals.

Daily flight patterns were based on sets of unique transect grids computer-generated for each Survey Block. Transect grids were derived by dividing each Survey Block into sections 30 minutes of longitude across. A minute mark along the northern edge of each section was selected at random then connected by a straight line to a similarly selected endpoint along the southern edge of that same section. This procedure was followed for all sections of that Survey Block. 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 the Survey Blocks to be flown on a given day was nonrandom, based primarily on criteria such as reported or observed weather conditions over the study area. 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, 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) since 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 (n) 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 random transect legs joined together by connect legs were flown, followed by a search leg back to Deadhorse. Surveys generally were flown at a target altitude of 458 m. Weather permitting, this altitude was maintained in order to maximize visibility and to minimize potential disturbance to marine mammals. When cloud ceilings were less than 305 m or the wind force was at or 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 or wind force requirements.

Primary observers were stationed on either side of the aircraft at large bubble windows which permitted a 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, and was stationed at an aft bubble window, although some aircraft configurations had a flat window at the data recorder position. A clinometer was used to measure the angle of inclination to each sighting when the initial sighting location was abeam of the aircraft.

When bowhead whales were encountered while surveying a transect line, the aircraft sometimes diverted from transect for brief (< 10 minute) periods and circled the whales to observe behavior, obtain better estimates of their numbers, and determine whether calves were present. Any new sightings of whales made while circling were recorded as on search rather than as on transect. Likewise, sightings made while en route to transect grids were recorded as on search.

In 2007 and 2008, survey effort over land or in areas where visibility was zero was designated as deadhead and not incorporated into further analyses.

Data Entry

Customized, menu-driven data entry software developed by MMS and Resource Data Incorporated (RDI) project personnel was used to record all data in database format (MS-Access 97). 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, reason for entry, species, total number, observer, swim direction (magnetic), clinometer angle, calf number, 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.

The behavior, swim speed, and swim direction for 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. Swimming 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). Likewise, whale size was estimated relatively as calf (length less than half of accompanying adult), immature, adult, or large adult. In 2006, swim direction was recorded in magnetic degrees using the aircraft's compass. Starting in 2007, swim direction was recorded relative to the aircraft's heading, 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 over a 1-2 km lateral distance 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 legs, connect legs, and general search portions of the flight. The program provided options for editing the data file, calculating summary values, and printing various flight synopses.

Tables listing the number of survey hours flown for individual days, half-months, months, or Survey Blocks were subject to decimal-rounding errors and may or may not add up to the grand total shown for the entire field season.

The water depth at each bowhead whale sighting in the 1982-2008 database was derived from the International Bathymetric Chart of the Arctic Ocean (IBCAO) containing grid cells 2.5 km square (http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/arctic.html).

Maps were prepared with application software (ArcGIS) based on Universal Transverse Mercator Zone 6 (central meridian = long. 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.

Sea ice concentrations were derived from the Beaufort Sea Ice Analysis provided by the National Ice Center in Suitland, Maryland. The Beaufort Sea Ice Analysis shows average ice concentrations over the prior 2-to 3-day period based on visual, infrared, and synthetic-aperture-radar satellite imagery combined with reconnaissance, ship, and shore observations, including

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 general 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 about in association with a floating log.
Mating	Ventral-ventral orienting 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 pushes.
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.

sea-ice observations made during the project. Polygons of ice concentrations in the Beaufort Sea that bracket the field season were downloaded from the National Ice Center web site for the western Arctic (http://www.natice.noaa.gov) and imported into ArcGIS. Total sea ice concentrations, regardless of ice type, were edited from these polygons and specially coded to distinguish 0%, 1 to 19%, 20 to 39%, 40 to 59%, 60 to 79%, 80 to 94%, or 95 to 100% ice cover.

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 connect) being conducted or the prevailing environmental conditions (sea state, ice cover, etc.) when the sightings were made. As with previous reports in this series (Treacy 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2000, 2002a, 2002b; Monnett and Treacy 2005; USDOI, MMS 2008), 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 and the median depth at sighting for 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 statistical analyses of distance from shore and depth at sighting used median values and the nonparametric Mann-Whitney U-test. The 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 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 from 2006 to 2008, all of which were light ice years, were compared with combined data from previous years having "light ice coverage" (i.e., 1982, 1986, 1987, 1989, 1990, and 1993-2005).

All bowhead whale sightings made while on transect, regardless of distance from the transect line, were used. 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. Selected isobaths (10 m, 20 m, 30 m, 40 m, 50 m, 60 m,

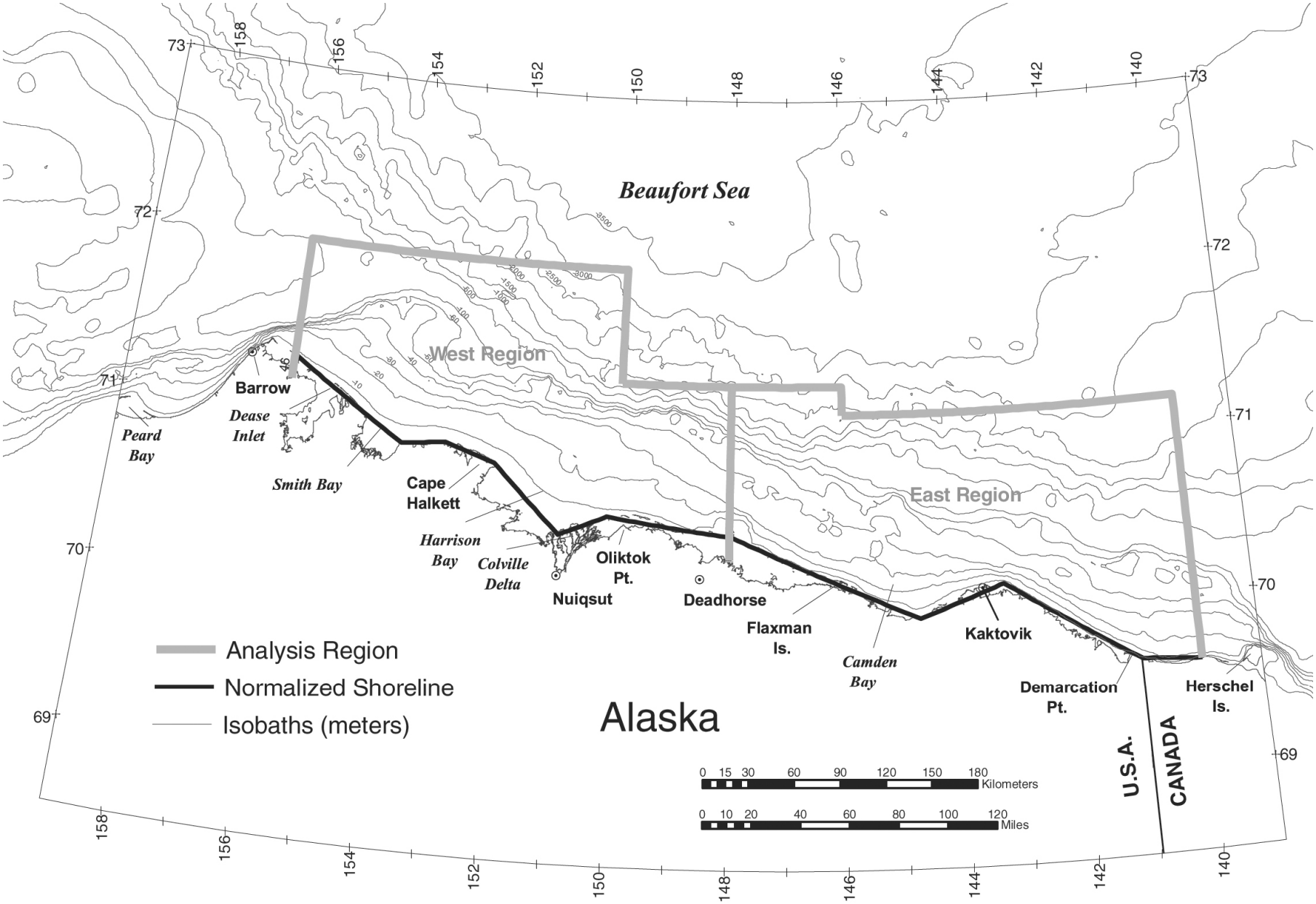

Figure 2. -- East and West Regions showing a normalized shoreline and selected IBCAO isobaths.

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°W-148°W). Therefore, the delineation between East-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 from the shore north 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 from shore north 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

The following data subsets from BWASP 2006 were analyzed:

- 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 en route 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 can be considered "non-migratory" and may influence, at least temporarily, the migratory path.

Analyzing the bowhead whale migration corridor based on sighting data only may be biased because survey effort is often variable both within and across years. For example, there may be more sightings in areas with greater transect effort and fewer sightings in areas with less transect effort, which biases the analysis. Analysis developments are currently underway that will base future migration corridor statistics on encounter rates, which will factor in variable survey effort and thereby remove the potential for bias.

Sighting Rate and Relative Occurrence Analysis

Sighting rate (whales per unit effort = WPUE) calculations are a means of assessing relative occurrence that accounts for inconsistencies in survey effort across the study area. Sighting rates were derived on two different scales. Estimated total effort (transect, search, and connect, in kilometers) and transect effort only (in kilometers) per Survey Block were calculated to determine annual sighting rates for bowhead whales and belugas. Effort over land and between barrier islands and the mainland was not included in this sighting rate analysis, as neither bowhead whales nor belugas are seen in those regions. Although Survey Blocks are arbitrary geographic areas, they provide a basis for inter-annual cross-comparisons. Sighting rate on a finer scale (5' latitude by 15' longitude), using a grid matrix consisting of approximately equilateral grid cells, was superimposed across the study area using ArcGIS. 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 was calculated for the finer scale as the number of individual whales on transect per unit of transect effort. The finer scale grid includes areas within the barrier islands.

RESULTS

Fall 2006

Environmental Conditions

Sea ice coverage in the Alaskan Beaufort Sea (Appendix A) was light overall during the 2006 BWASP survey period. By 4 September most of the study area was either ice-free or had less than 30% ice. The nearshore central Alaskan Beaufort coast, from eastern Camden Bay to Harrison Bay, remained covered with 10-40% ice throughout the study season. The remainder of the study area was essentially ice-free from 25 September through the end of the study season. Ice percentages and sea states at each bowhead whale sighting are shown in Appendix B. For purposes of inter-year comparisons of bowhead whale and other marine mammal distribution and occurrence, 2006 is considered a "light ice year".

Survey Effort

The fall field season was from 2 September through 16 October 2006. There were 27 flights, of which 18 were in September and 9 were in October. Daily totals of kilometers and hours flown per survey flight during this period are shown in Table 2. On 5 days, two survey flights per day were completed to take maximum advantage of good survey conditions. Over 19,600 km of trackline were flown in 90 hours in the study area. The average survey flight was 728 km. A total of 12,393 km of transect lines were flown in 56 hours. Transect effort constituted 63% of the total kilometers flown and 62% of the total flight hours. During early September and early October, coverage was scattered across the entire study area, but inclement weather in late September limited survey effort to the central Alaskan Beaufort Sea. Survey coverage was highest in Blocks 1, 2, 3, 4 and 12, and lowest in Block 7. In early September two flights were conducted adjacent to Block 12 in the Chukchi Sea. There was no effort in Survey Blocks 8, 9, and 10. Survey flight lines are summarized by semimonthly period in Figures 3 through 6. Flight lines and associated sea states are shown for individual flights in Appendix C.

Bowhead Whale Observations

Sighting Summary -- During fall 2006 surveys 124 sightings of 406 bowhead whales were collected in the study area (Table 3). Bowhead whales were distributed throughout the survey area between 140°W and 158°W (Fig. 7). Out of the 406 whales, 16 were identified as calves (Appendix B), resulting in a seasonal calf ratio (number calves/total whales) of 0.039. Locations of bowhead whale sightings are shown by semimonthly period in Figures 8 through 10. Bowhead whale sightings and associated sea states are shown for individual flights in Appendix C.

Table 2. -- Daily and semimonthly aerial survey effort in the Beaufort Sea, 2 September-16 October 2006. Distance measurements and time calculations are rounded.

Day	Flight no.	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect (hr)	Total (hr)
2 Sep	1	546	72	14	632	2.5	3.1
3 Sep	2	235	35	328	599	1.1	2.8
3 Sep	3	621	77	41	739	2.8	3.3
4 Sep	4	569	70	61	701	2.8	3.5
5 Sep	5	903	135	269	1,307	3.9	5.7
5 Sep	6	0	0	243	243	0.0	1.1
6 Sep	7	558	39	129	726	2.6	3.4
7 Sep	8	865	85	102	1,051	3.8	5.2
12 Sep	9	0	0	325	325	0.0	1.5
13 Sep	10	723	83	389	1,195	3.1	5.2
14 Sep	11	653	53	161	867	3.0	4.4
14 Sep	12	489	56	11	555	2.2	2.6
15 Sep	13	684	109	177	970	2.9	4.1
16 Sep	14	955	119	135	1,208	4.0	5.2
18 Sep	15	325	63	224	612	1.4	2.5
21 Sep	16	13	0	209	222	0.1	1.0
24 Sep	17	0	0	127	127	0.0	0.5
25 Sep	18	290	128	130	548	1.3	2.5
1 Oct	19	224	56	216	496	1.0	2.3
6 Oct	20	299	84	563	946	1.3	4.3
10 Oct	21	426	85	591	1,103	1.8	5.0
11 Oct	22	359	48	279	685	1.6	3.2
11 Oct	23	596	79	23	698	2.7	3.3
13 Oct	24	646	168	343	1,157	2.8	5.2
13 Oct	25	506	50	10	566	2.2	2.6
15 Oct	26	908	185	117	1,210	4.1	5.5
16 Oct	27	0	0	181	181	0.0	1.0
Semimonthly Effort Summary							
2-15 Sep		6,846	814	2,250	9,910	30.7	46.0
16-30 Sep		1,583	310	825	2,717	6.8	11.7
1-15 Oct		3,964	755	2,142	6,861	17.5	31.3
16 Oct		0	0	181	181	0.0	1.0
Total		12,393	1,879	5,398	19,669	55.0	90.0

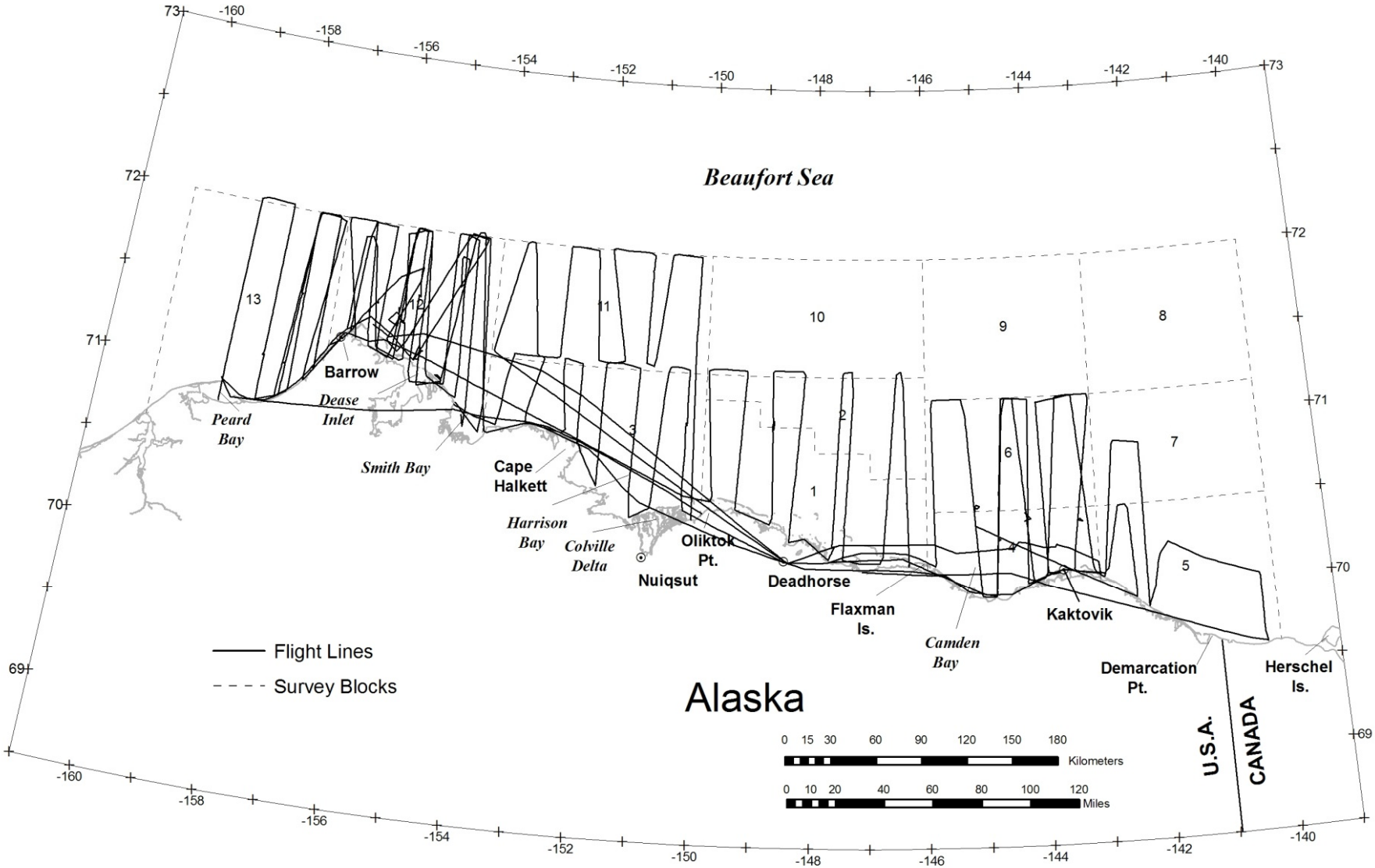

Figure 3. -- Combined flight tracks, 2–15 September 2006.

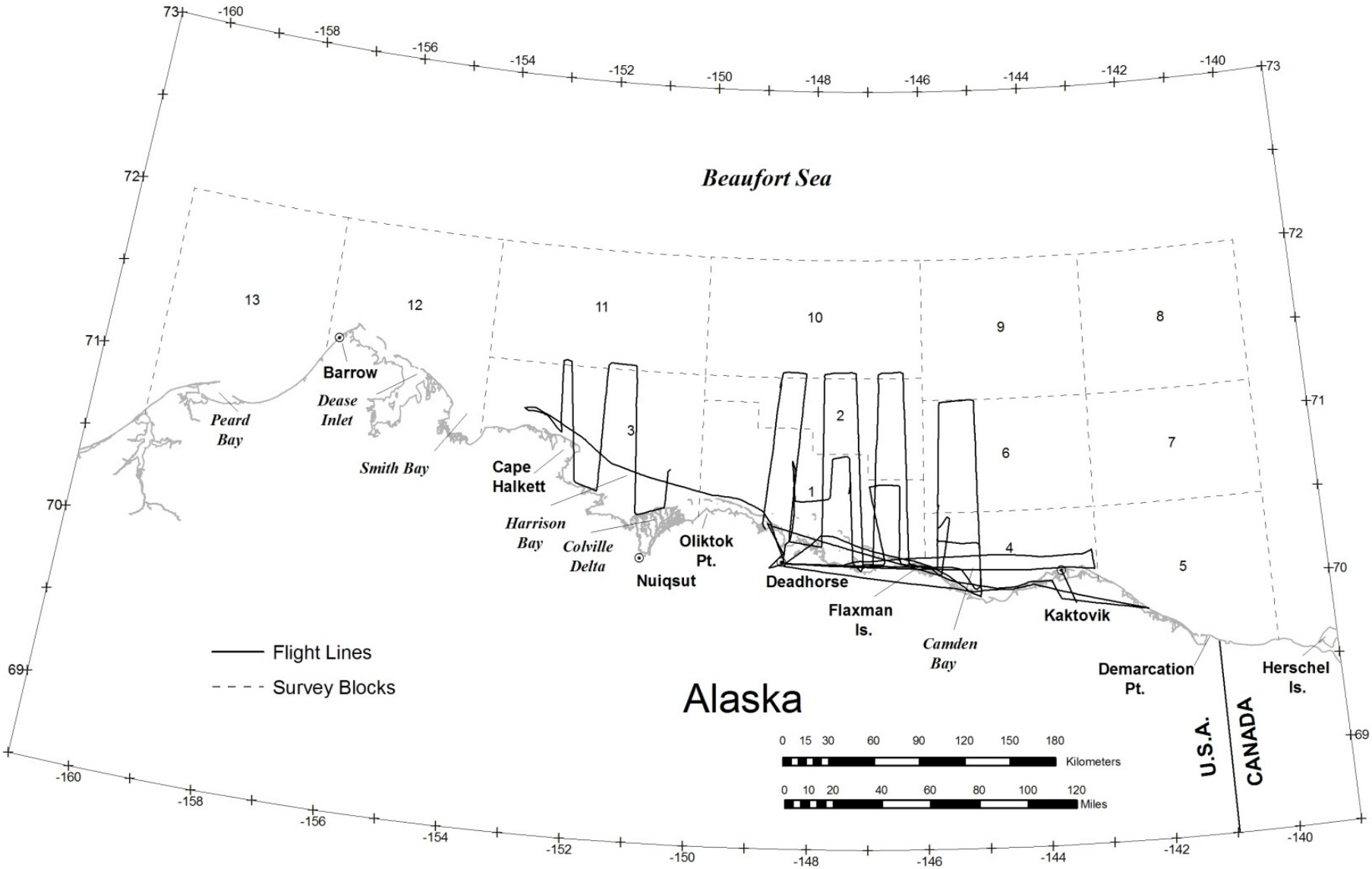

Figure 4. -- Combined flight tracks, 16-30 September 2006.

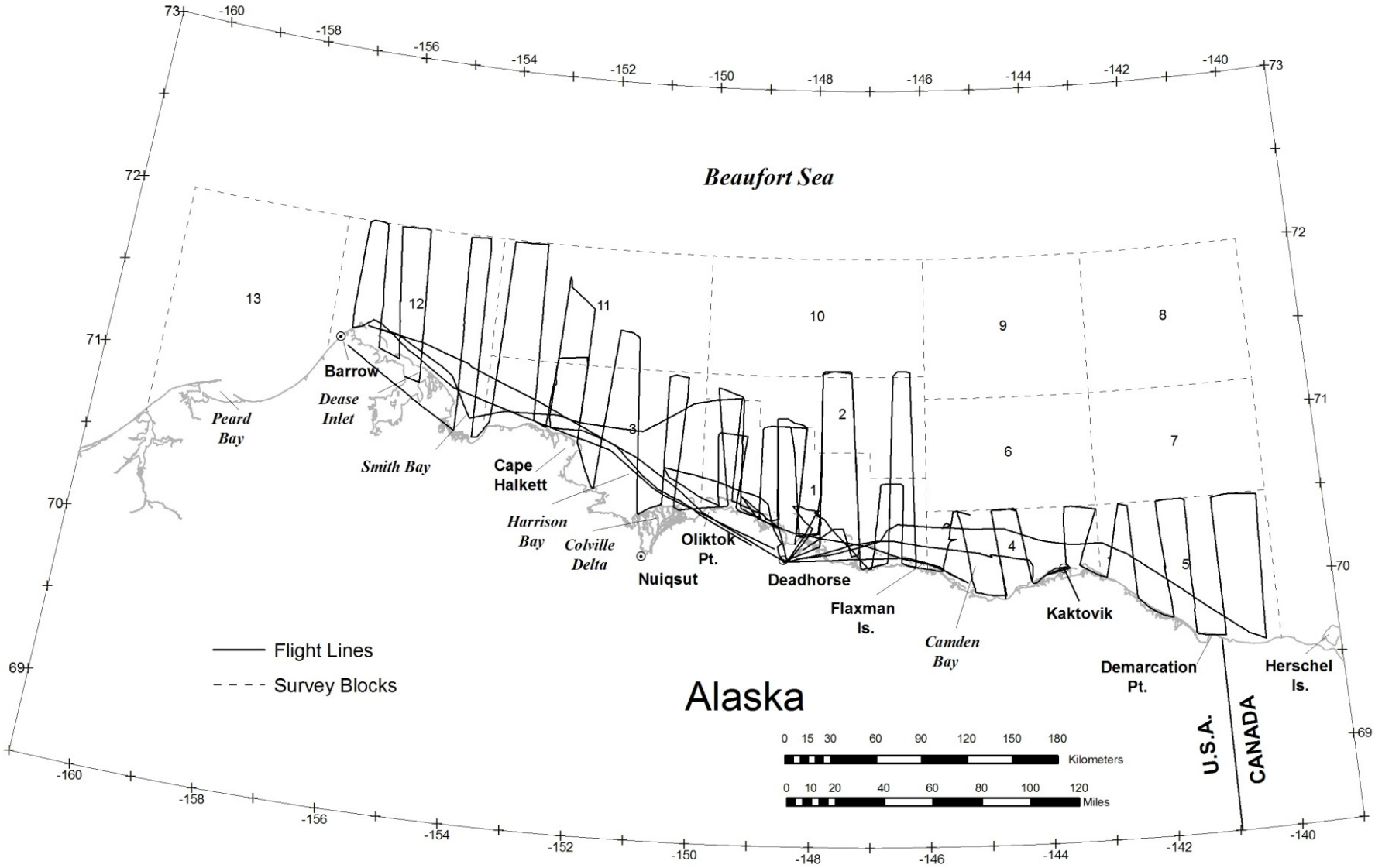

Figure 5. -- Combined flight tracks, 1–15 October 2006.

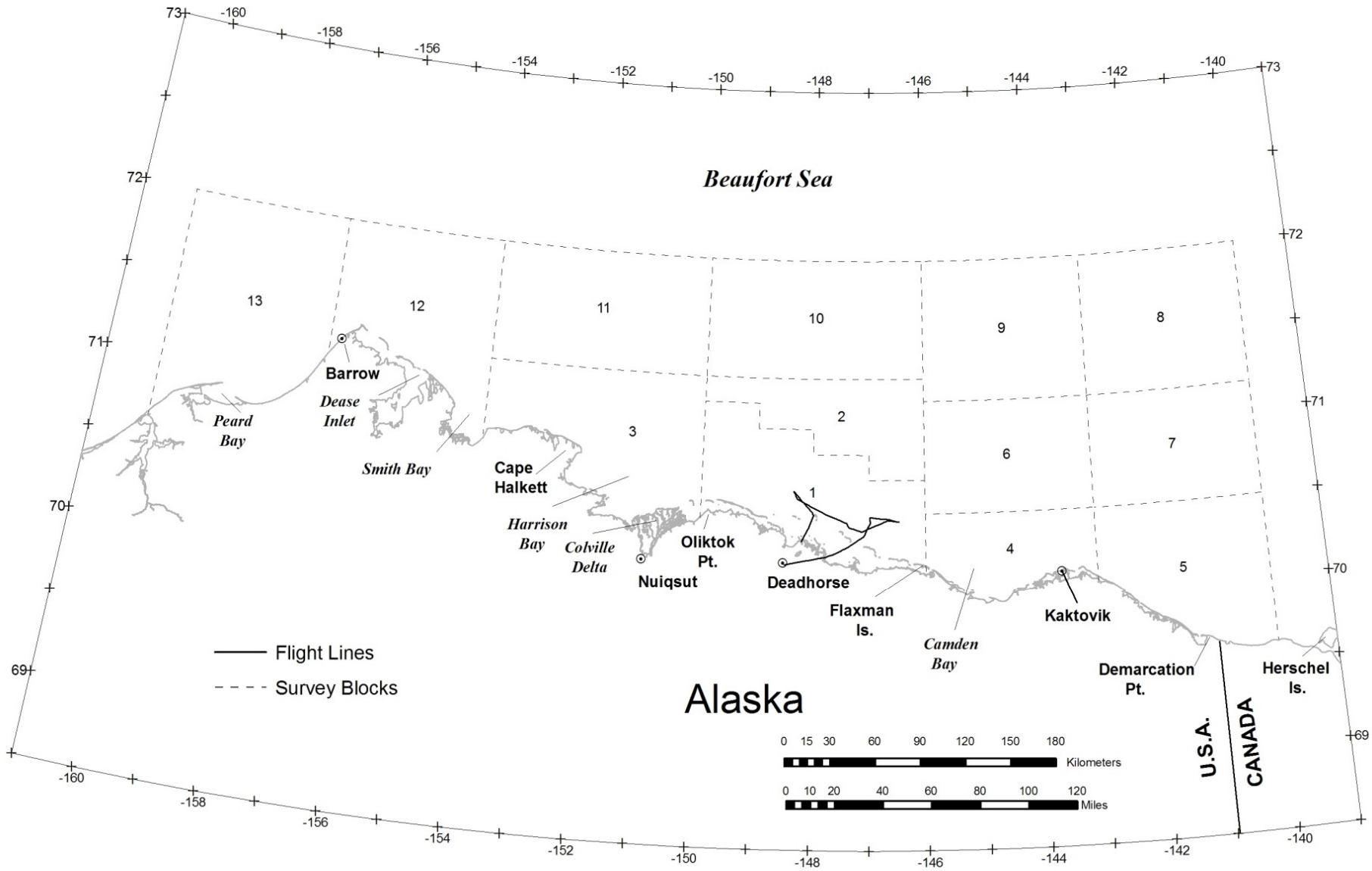

Figure 6. -- Combined flight tracks, 16 October 2006.

Table 3. -- Daily and semimonthly marine mammal sightings, 2 September-16 October 2006, showing number of sightings and number of individuals (i.e., no. sightings/no. individuals).

Day	Flight no.	Bowhead whale	Gray whale	Beluga	Unidentified cetacean	Bearded seal	Ringed seal	Walrus	Unidentified pinniped	Polar bear	Polar bear tracks
2 Sep	1	1/2	0	9/90	0	4/4	13/15	2/150	0	0	0
3 Sep	2	0	2/3	0	0	2/2	1/1	0	2/2	0	0
3 Sep	3	5/5	0	1/3	0	0	2/2	0	0	0	0
4 Sep	4	8/28	2/2	8/102	0	1/1	19/33	1/2	3/12	0	0
5 Sep	5	12/14	1/1	1/7	0	1/1	30/34	0	0	1/1	0
5 Sep	6	2/9	0	0	0	0	1/1	0	0	0	0
6 Sep	7	8/11	0	5/30	2/2	2/2	4/4	0	1/1	0	0
7 Sep	8	19/48	0	25/154	0	3/3	22/23	0	1/1	0	0
12 Sep	9	0	0	0	0	0	0	0	0	0	0
13 Sep	10	4/4	0	1/1	0	2/3	11/19	0	1/2	2/3	0
14 Sep	11	17/164	0	10/33	0	7/7	20/24	2/72	0	0	0
14 Sep	12	1/1	1/16	0	0	23/25	35/57	1/1	0	2/2	0
15 Sep	13	4/4	0	5/12	0	2/2	43/111	0	0	2/2	0
16 Sep	14	2/3	0	9/28	0	5/5	25/33	0	0	1/1	0
18 Sep	15	0	0	0	0	0	0	0	0	0	0
21 Sep	16	0	0	0	0	1/1	1/1	0	0	1/1	0
24 Sep	17	0	0	0	0	0	1/1	0	0	0	0
25 Sep	18	3/7	0	0	0	0	11/28	0	0	0	0
1 Oct	19	2/3	0	0	0	1/1	4/5	0	0	2/4	0
6 Oct	20	6/28	0	0	0	1/1	1/2	0	0	0	0
10 Oct	21	1/1	0	0	0	0	1/1	0	0	4/16	2
11 Oct	22	4/6	0	3/26	0	0	0	0	0	0	0
11 Oct	23	5/13	0	2/6	0	0	0	0	0	0	0
13 Oct	24	9/13	0	2/2	1/1	0	0	0	0	3/24	0
13 Oct	25	6/19	0	4/9	0	0	1/1	0	0	0	0
15 Oct	26	5/23	0	5/22	0	1/1	10/11	0	0	0	1
16 Oct	27	0	0	0	0	0	0	0	0	2/23	0
					Semimonthly Sighting Summary						
2-15 Sep		81/290	6/22	65/432	2/2	47/50	201/324	6/225	8/18	7/8	0
16-30 Sep		5/10	0	9/28	0	6/6	38/63	0	0	2/2	0
1-15 Oct		38/106	0	16/65	1/1	3/3	17/20	0	0	9/44	3
16 Oct		0	0	0	0	0	0	0	0	2/23	0
Total		124/406	6/22	90/525	3/3	56/59	256/407	6/225	8/18	20/77	3

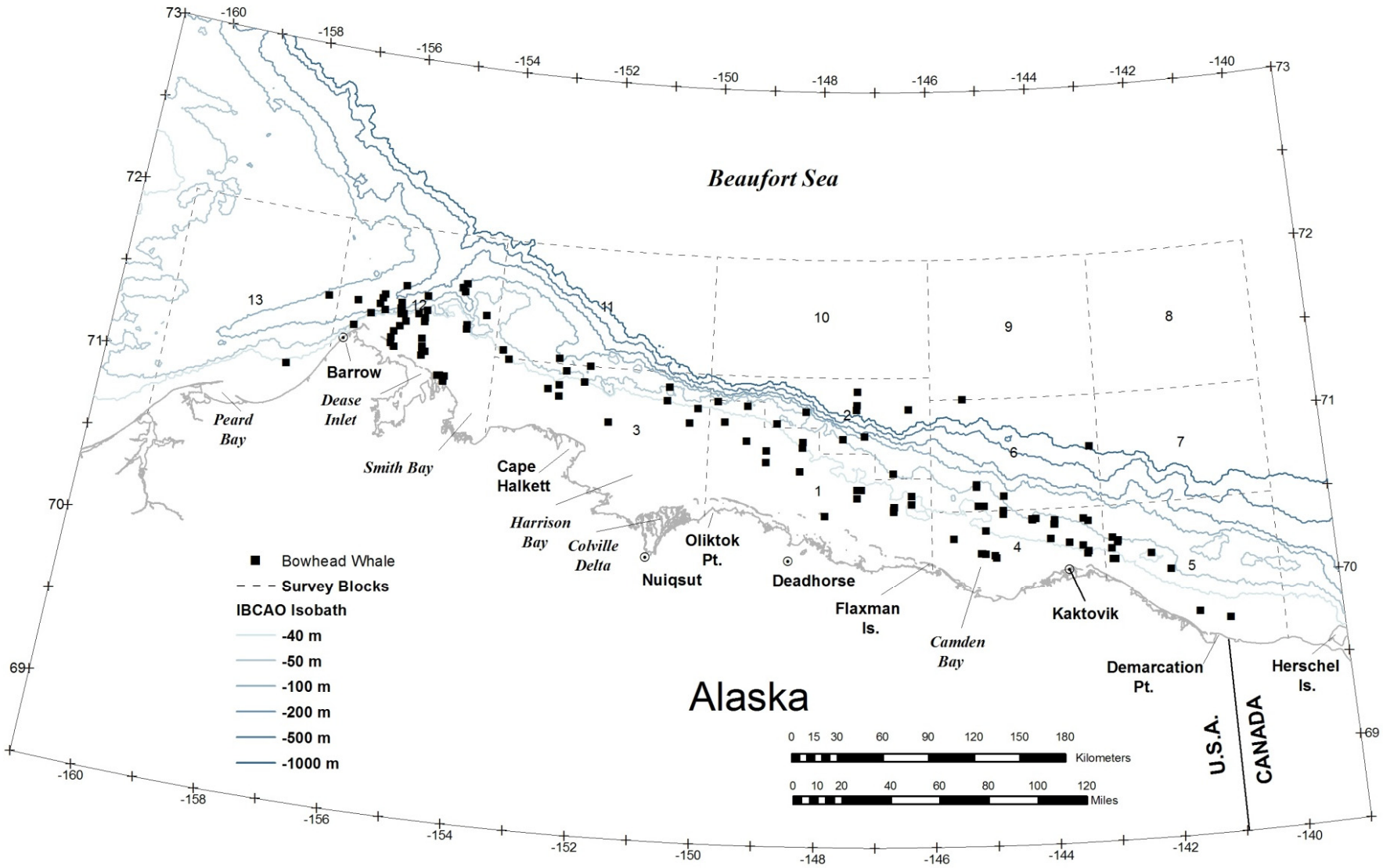

Figure 7. -- Bowhead whale sightings, fall 2006.

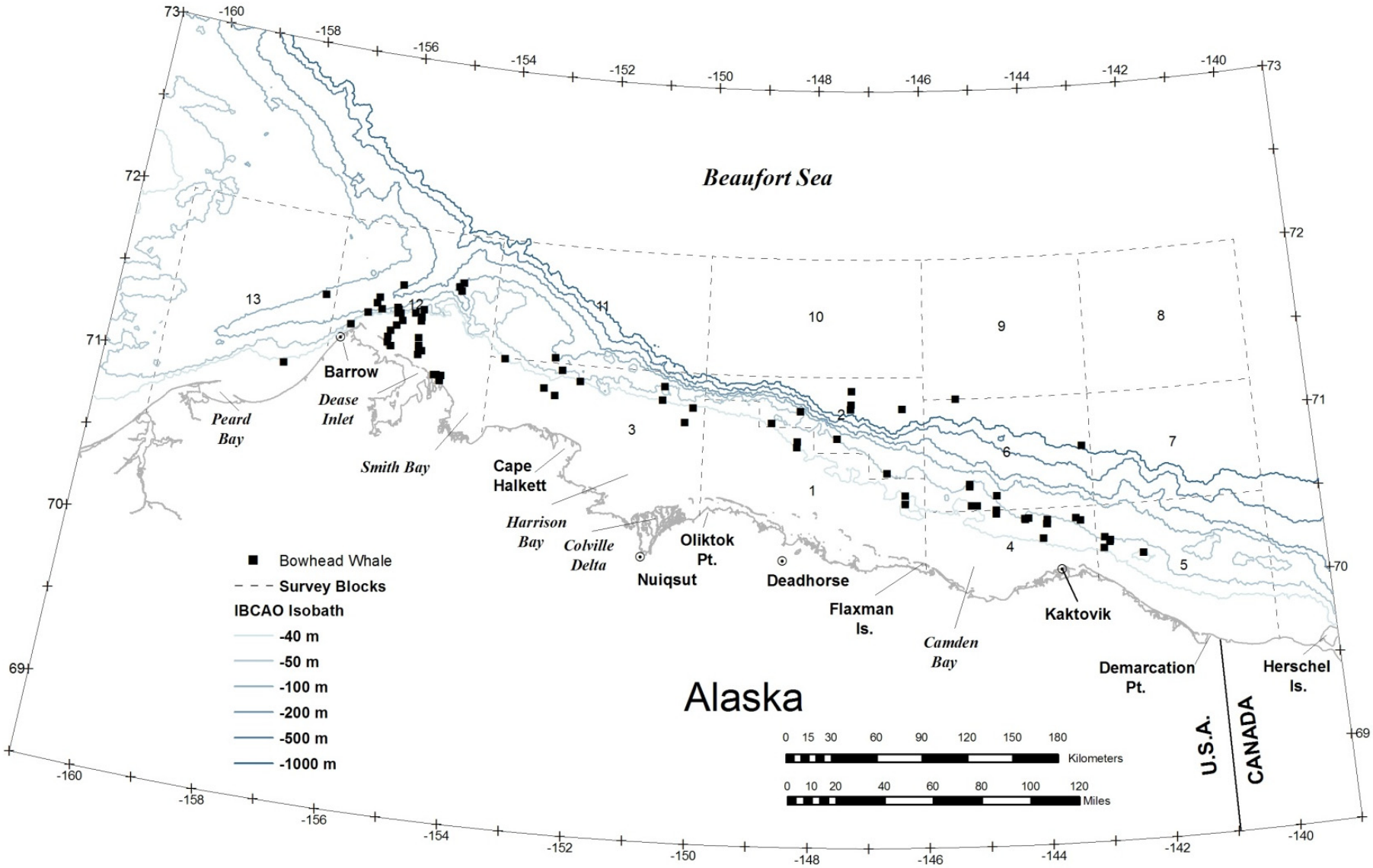

Figure 8. -- Bowhead whale sightings, 2-15 September 2006.

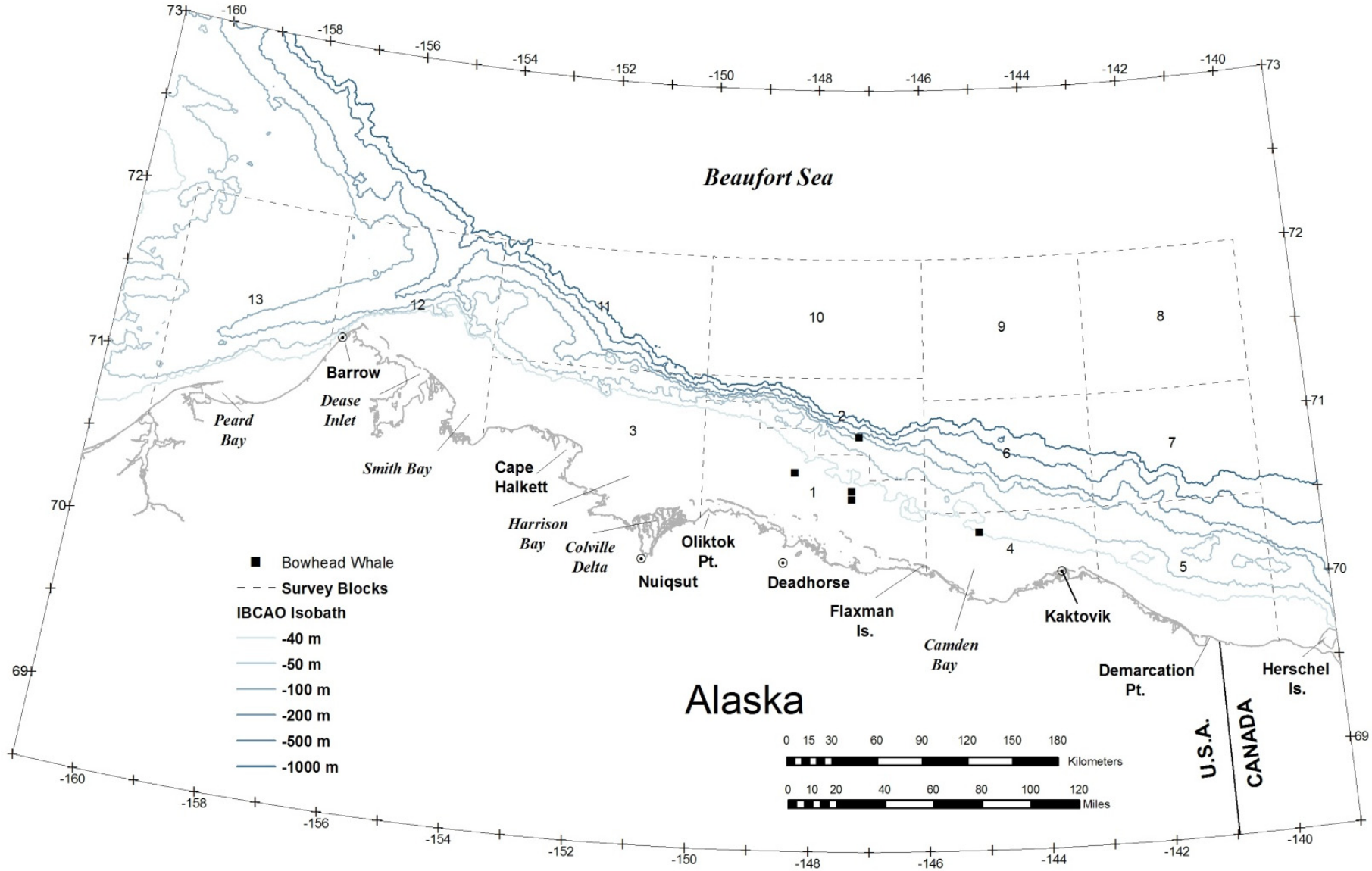

Figure 9. -- Bowhead whale sightings, 16-30 September 2006.

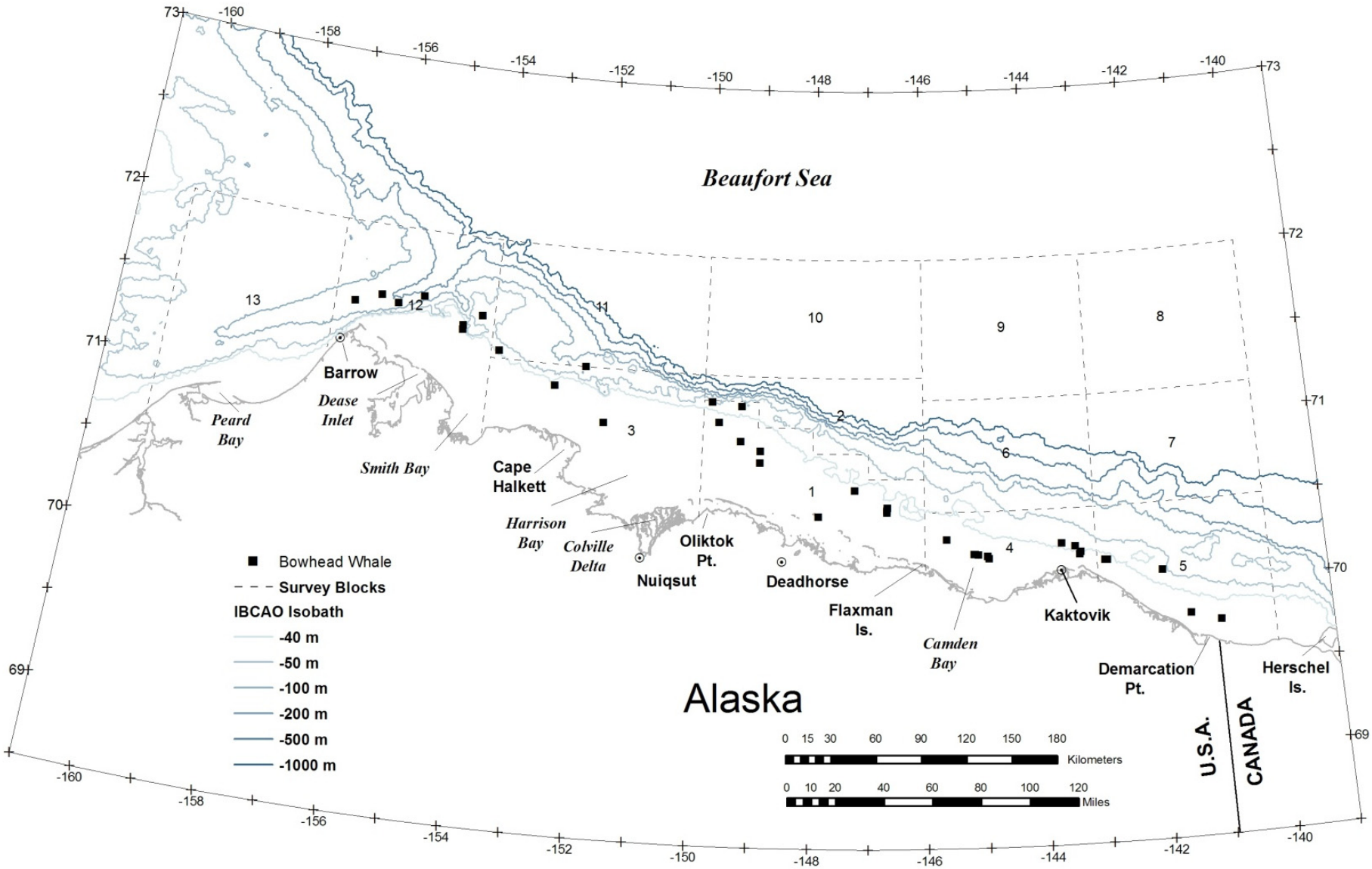

Figure 10. -- Bowhead whale sightings, 1-15 October 2006.

Table 4. -- Survey effort, number of bowhead whales per Survey Block, and sighting rate (WPUE; whales per km surveyed) per Survey Block for bowhead whales on transect, fall 2006.

Block	Total effort (km)*	Total bowhead (no. animals)	Transect effort (km)*	Transect bowhead (no. animals)	Transect WPUE
1	3,083	55	2,121	54	0.025
2	1,273	10	1,047	10	0.010
3	3,324	16	1,580	12	0.008
4	2,365	64	1,050	34	0.032
5	1,183	14	733	12	0.016
6	1,006	16	886	13	0.015
7	99	0	81	0	0.000
8	0	0	0	0	0
9	0	0	0	0	0
10	0	0	0	0	0
11	1,205	1	904	1	0.001
12	3,527	227	2,572	198	0.077
13	1,200	3	967	3	0.003
Total	18,267	406	11,942	337	0.028

* Total and Transect Effort (km) do not match values in Table 2 because effort between barrier islands and the mainland was not included in the sighting rate analysis by block.

Sighting Rates -- In fall 2006, bowhead whales were seen from west of Barrow to Canada. Several large groups of bowhead whales were recorded as transect sightings and the fine-scale sighting rate analysis reflects this. Areas of greatest sighting rates were between Point Barrow and Smith Bay, north of Deadhorse, and north of Camden Bay and Kaktovik (Fig. 11). The largest groups were observed on 4 September north of Smith Bay (one group of 20 feeding whales), 14 September nearshore north of Smith Bay (groups of 17, 25 and 70 whales) and offshore north of Dease Inlet (groups of 10 and 13 whales), and 15 October northeast of Deadhorse (one group of 17 whales). Sighting rates were low in the nearshore areas of the central Alaskan Beaufort Sea where ice persisted for most of the study period.

Highest sighting rates by Survey Block were in Block 12 (0.077 bowhead whales on transect/transect km flown), Block 4 (0.032 bowhead whales on transect/transect km flown) and Block 1 (0.025 bowhead whales on transect/transect km flown) (Table 4). Sighting rates using all bowhead whale sightings by Survey Block were similar to sighting rates using bowhead whales seen on transect only. Previous Survey Block sighting rate analyses for light ice years (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

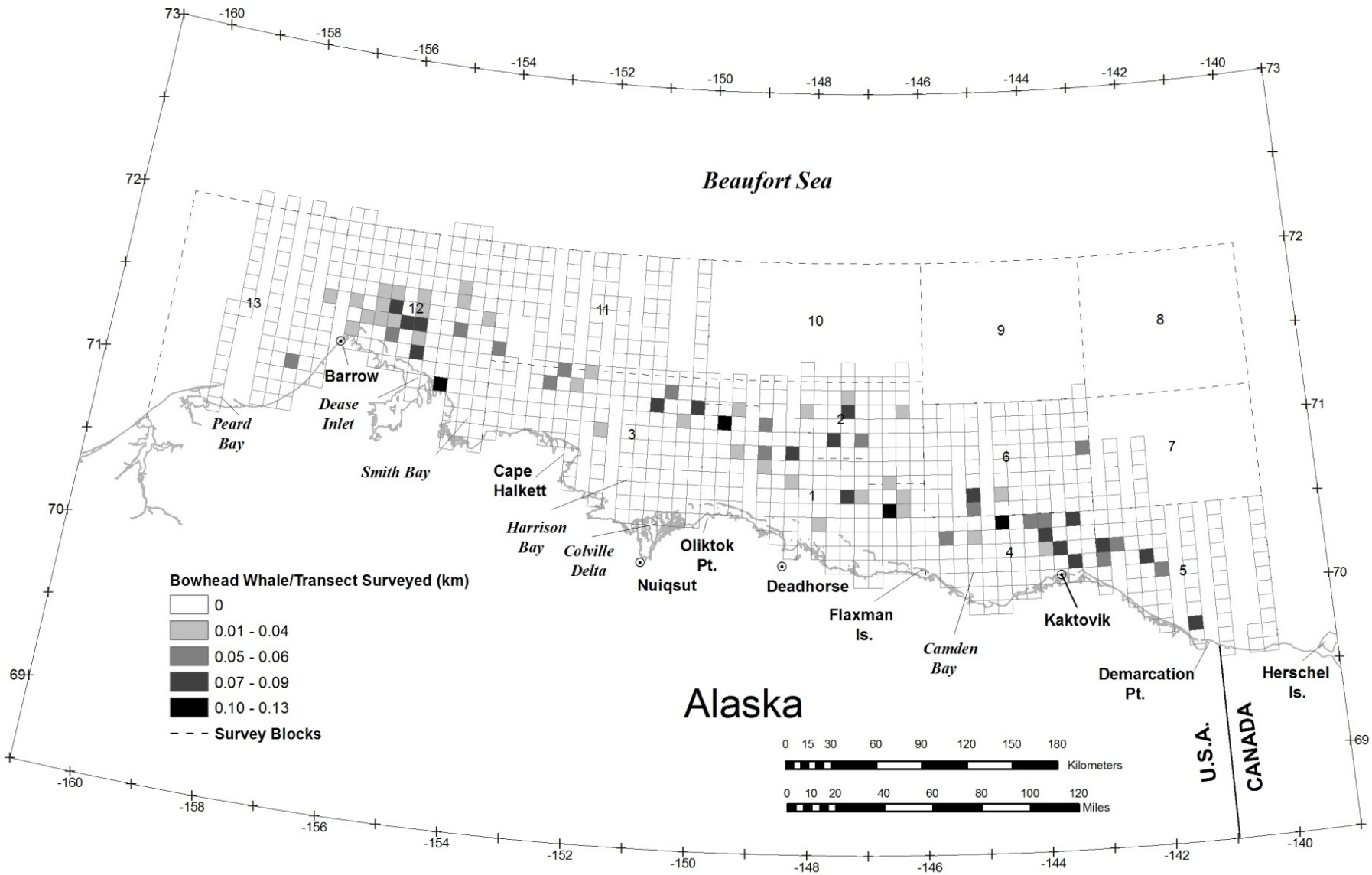

Figure 11. -- Sighting rates of bowhead whales, fall 2006 (transect whales/transect km surveyed).

Table 5. -- Semimonthly summary of bowhead whales observed by percent ice cover at sighting location, fall 2006.

Percent Ice cover	2-15 Sep	16-30 Sep	1-15 Oct	Total
0	225 (77%)	8 (80%)	96 (90%)	329 (81%)
1-5	49 (16%)	1 (10%)	0	50 (12%)
6-10	7 (2%)	1 (10%)	3 (2%)	11 (2%)
11-20	2 (< 1%)	0	0	2 (< 1%)
21-30	2 (< 1%)	0	0	2 (< 1%)
31-40	1 (< 1%)	0	0	1 (< 1%)
41-50	4 (1%)	0	5 (4%)	9 (2%)
91-100	0	0	2 (1%)	2 (< 1%)
Total	290	10	106	406

periods (due to lack of suitable visibility) or time spent surveying inside the barrier islands. Nonetheless, the pattern of highest sighting rates per year is similar across all years. In light ice years, highest sighting rates are generally in coastal Survey Blocks (1, 3, 4, 5, and 12), and are usually correlated with large groups of bowhead whales in feeding or milling aggregations.

Habitat Associations -- The percentage of ice cover visible from the aircraft at each bowhead whale sighting is included in Appendix B. Of the 406 bowhead whales counted over the field season, 329 whales (81%) were sighted in open water, 50 (12%) whales were observed in 1-5% sea ice, 11 (2%) were observed in 6-10% sea ice, 2 (0.5%) were in 11-20% sea ice, 2 (0.5%) were in 21-30% sea ice, 10 (2.5%) were in 31-50% sea ice, and 2 (0.5%) were in 90-100% sea ice coverage (Table 5). For comparison purposes, approximately 60% of total survey time was flown over completely open water (< 1% ice coverage; see Appendix A for weekly ice concentrations).

Behaviors -- Behaviors of the 406 bowhead whales observed during fall 2006 are summarized in Table 6. The behavior most often recorded was swimming (44%). Feeding was seen in 136 whales. Sighting rates of feeding and milling whales are shown in Figure 12. Feeding was most commonly observed in Block 12 between Smith Bay and Point Barrow. Milling, which may be indicative of feeding, was observed across the study area. Feeding behavior is not always detectable during aerial surveys and is likely underestimated in the database. A single adult whale was observed playing with a log.

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 which may indicate a response to the survey aircraft; no responses were observed.

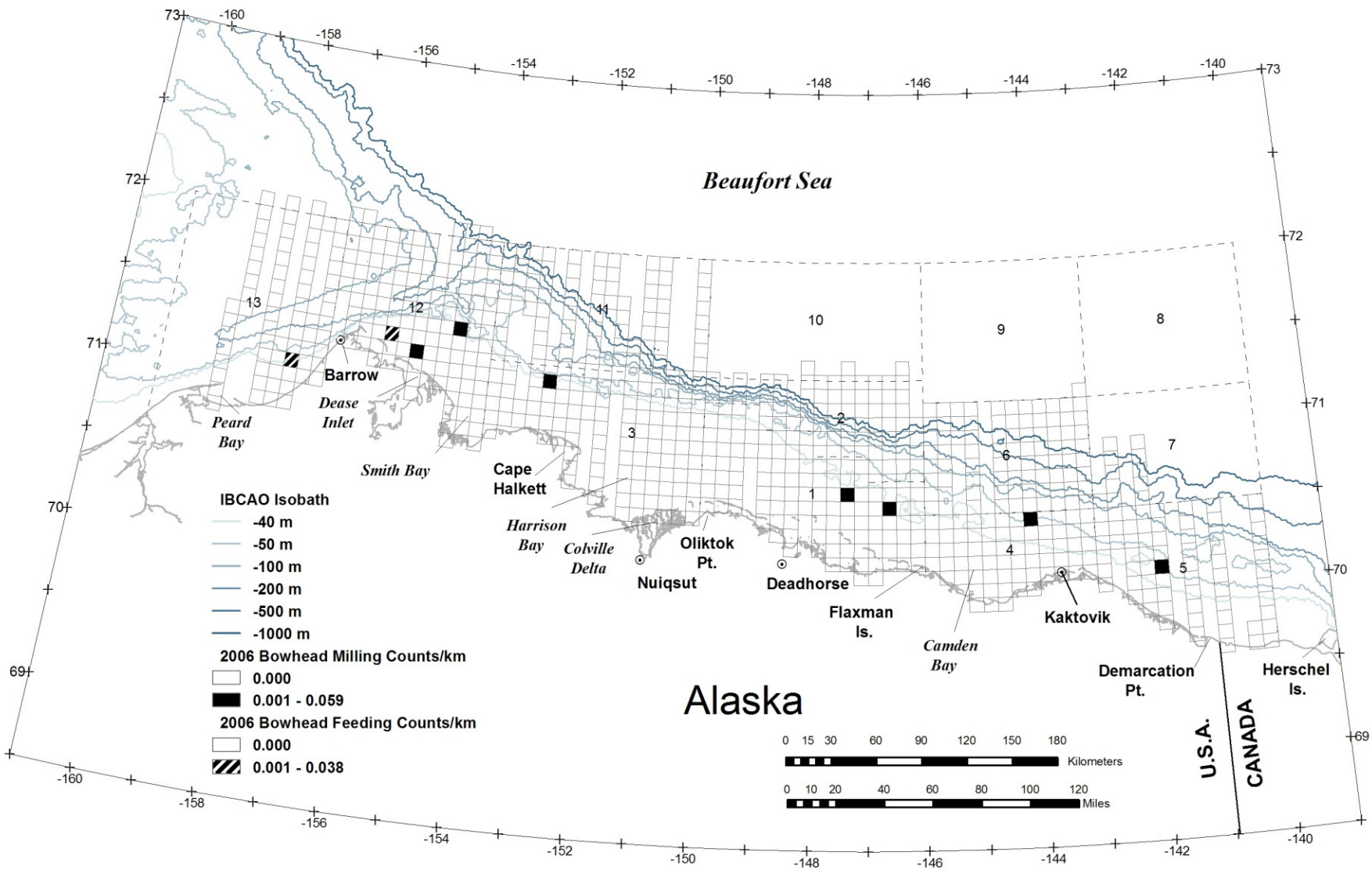

Figure 12. -- Sighting rates of feeding and milling bowhead whales, fall 2006 (transect whales/transect km surveyed).

Table 6. -- Semimonthly summary of bowhead whales observed by behavioral category, fall 2006.

Behavior	2-15 Sep	16-30 Sep	1-15 Oct	Total
breach	1 (< 1%)	0	2 (1%)	3 (< 1%)
dive	2 (< 1%)	0	0	2 (< 1%)
feed	136 (46%)	0	0	136 (33%)
log play	1 (< 1%)	0	0	1 (< 1%)
mill	24 (8%)	2 (20%)	45 (42%)	71 (17%)
rest	11 (3%)	0	0	11 (2%)
swim	115 (39%)	8 (80%)	59 (55%)	182 (44%)
Total	290	10	106	406

Distance From Shore -- Distances from shore of fall 2006 bowhead whale sightings made on transect were measured using ArcGIS as the distance due north of a normalized shoreline. Mean distance from locations of all bowhead whale sightings on transect to a normalized shoreline in 2006 was 39.3 km (SD = 22.4) in the East Region and 37.2 km (SD = 19.6) in the West Region (Fig. 13, Table 7). Mean distance from locations of "migrating" bowhead whales on transect (i.e., excluding sightings of feeding, milling, or resting whales) was 38.6 km (SD = 22.4) in the East Region and 39.8 km (SD = 19.4) in the West Region (Fig. 14). A Mann-Whitney U-test of significant difference of the median distance from shore indicated no difference between distances of all whales versus distances of only those whales considered "migrating" in either the East (Z = 0.137, P = 0.8910) or West (Z = -0.578, P = 0.5635) regions.

Bowhead whale sightings were significantly farther from shore in the East Region during September (median 43.5 km) than during October (median 24.1 km, Z = 4.182, P = 0.00003). There was no significant difference between September and October distance from shore in the West Region.

Depth at Sighting -- Mean depth at sightings of all bowhead whales on transect was 196 m (SD = 446.0, range 8-1,868 m) in the East Region, and 40 m (SD = 34.1, range 7-204 m) in the West Region (Table 7). Mean depth of "migrating" bowhead whales on transect (i.e., excluding sightings of feeding, milling, or resting whales), was 182 m (SD = 422.8, range 8-1,868 m) in the East Region, and 43 m (SD = 35.9, range 7-204 m) in the West Region. A Mann-Whitney U-test of significant difference of median depths indicates no difference between depths of all whales versus depths of those whales considered "migrating" in either the East (Z = 0.256, P = 0.7980) or West (Z = -0.520, P = 0.6028) Regions. Bowhead whale sightings were significantly deeper in the East Region during September (median 48 m) than during October (median 38 m, Z = 4.094, P= 0.00004). There was no significant difference between September and October depths at bowhead whale sightings in the West Region.

Table 7. -- Central-tendency statistics for distance from shore (km) and depth (m) at transect sightings of bowhead whales (September-October), by year and region, 1982-2006.

			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
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

			Distance from shore (km)				Depth (m)			
Year	Region	TrSi	Median	Mean	SD	Min-Max	Median	Mean	SD	Min-Max
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

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

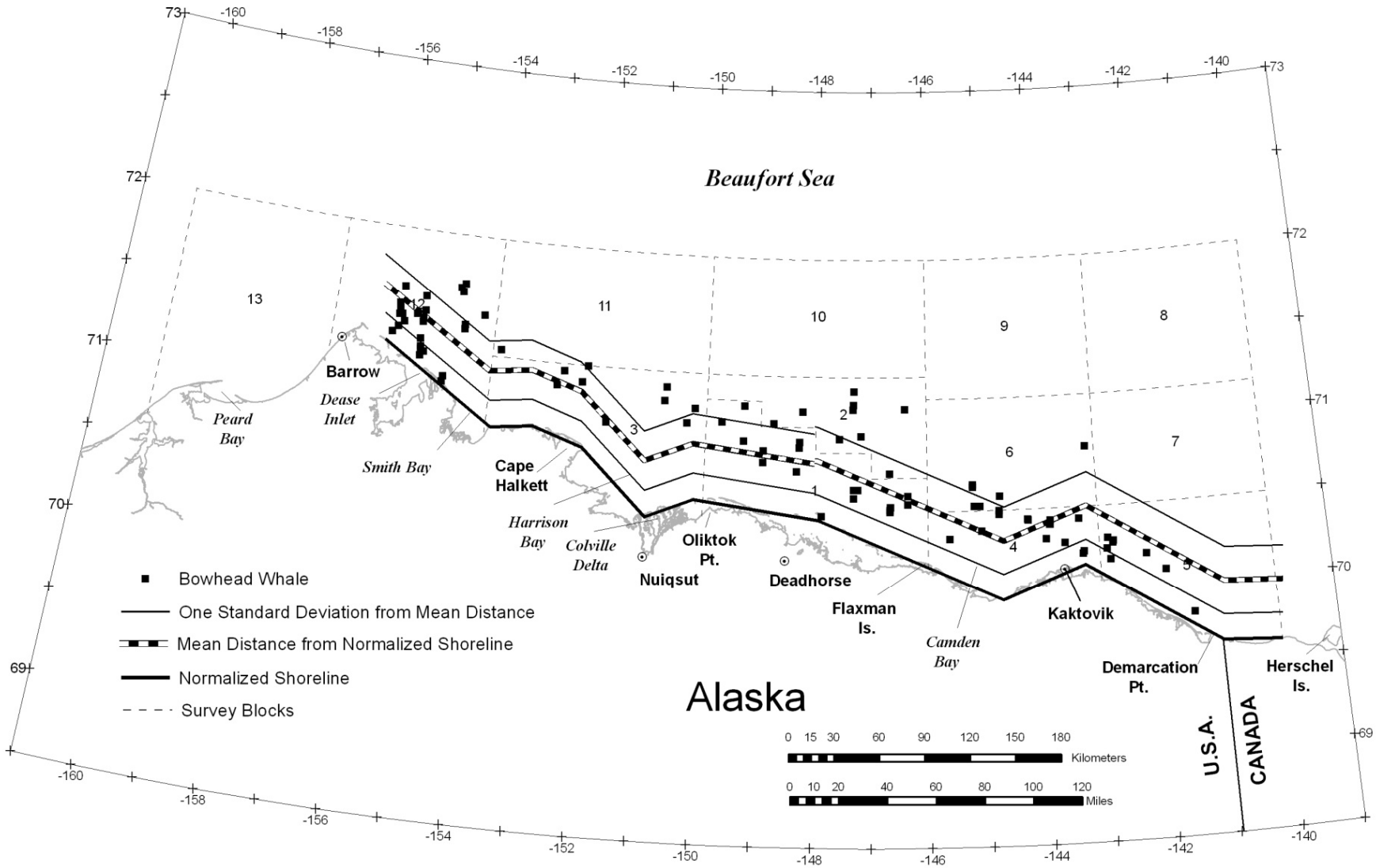

Figure 13. -- Bowhead whale sightings on transect, fall 2006, showing mean distance from a normalized shoreline.

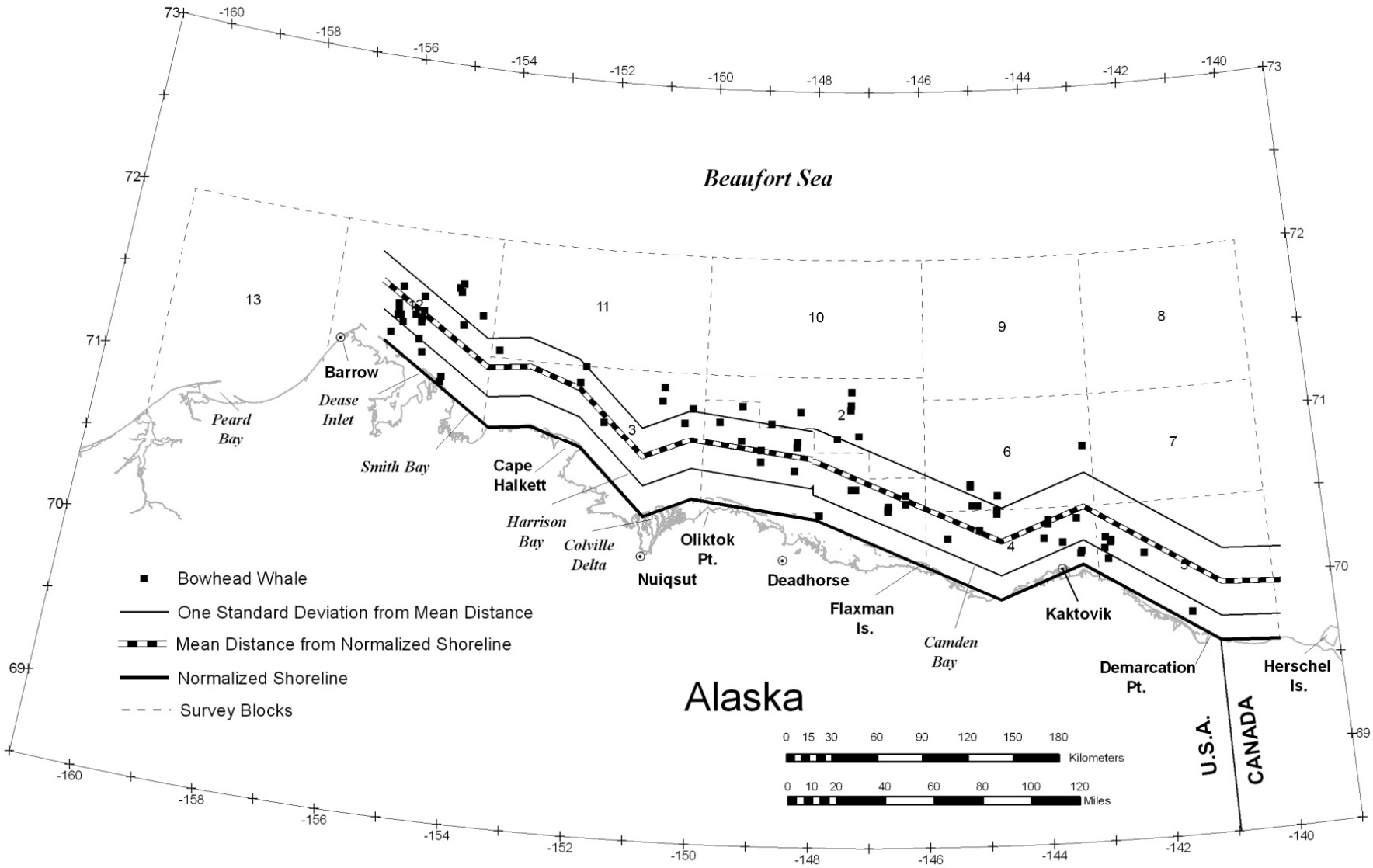

Figure 14. -- Bowhead whale sightings on transect, excluding feeding, milling and resting whales, fall 2006, showing mean distance from a normalized shoreline.

Based on the lack of significant difference between all transect bowhead whale sightings in 2006 and sightings limited to those whales considered "migrating" (excluding feeding, milling, or resting animals), additional analyses of the bowhead whale migration corridor incorporated all sightings and were not limited to only those animals considered actively "migrating".

Distribution of Migrating Bowhead Whales, 2006, Relative to Previous Light Ice Years -- In order to evaluate whether significant displacements occurred in the bowhead whale migratory corridor during 2006, estimates of median depth at sighting and distance of sighting from a normalized shoreline were compared with data from previous years having "light ice" coverage (i.e., 1982, 1986, 1987, 1989, 1990, and 1993-2005). Median distance from shore in the East Region in 2006 was 34.3 km (n = 45), which was significantly (Z = -3.038, P = 0.0024) farther than the median distance from shore in the East Region during previous "light ice" years of 27.0 km (n = 769). Median depth at sightings in the East Region in 2006 was 44 m, which was significantly (Z = -2.378, P = 0.0174) deeper than depths for bowhead whales in the East Region during previous "light ice" years, which was 40 m.

Median distance from shore in the West Region in 2006 was 39.2 km (n = 46), which was significantly (Z = -2.684, P = 0.0072) farther than the median distance from shore in the West Region during previous "light ice" years of 26.7 km (n = 672). Median depth at sightings in the West Region in 2006 was 32 m, which was significantly (Z = -3.416, P = 0.0006) deeper than depths for bowhead whales in the West Region during previous "light ice" years, which was 22 m.

Other Marine Mammal Observations

There were six sightings of 22 gray whales (Fig. 15) during the 2006 BWASP surveys. Gray whales were seen east and west of Point Barrow. Most gray whales were feeding, as evidenced by mud plumes.

During fall 2006 surveys, 525 belugas were observed (Fig. 16) along the shelf break and slope. The distribution of belugas sighted in 2006 overlapped the distributions recorded during previous surveys. Although belugas are often associated with ice (Moore et al. 2000), most belugas (82%) were seen in < 10% ice cover. Beluga sighting rate was highest in Blocks 6 (0.159 belugas on transect/transect km surveyed) and 12 (0.105 belugas on transect/transect km surveyed) (Table 8), where the largest groups of belugas were seen.

Bearded seals (56 sightings of 59 seals), small pinnipeds identified as ringed seals (256 sightings of 407 seals) and Pacific walruses (6 sightings of 225 walruses) were seen during fall 2006. Bearded and ringed seals were distributed across the Alaskan Beaufort Sea and into the Chukchi Sea (Figs. 17 and 19), while Pacific walrus distribution was limited to north and east of Point Barrow (Fig. 18).

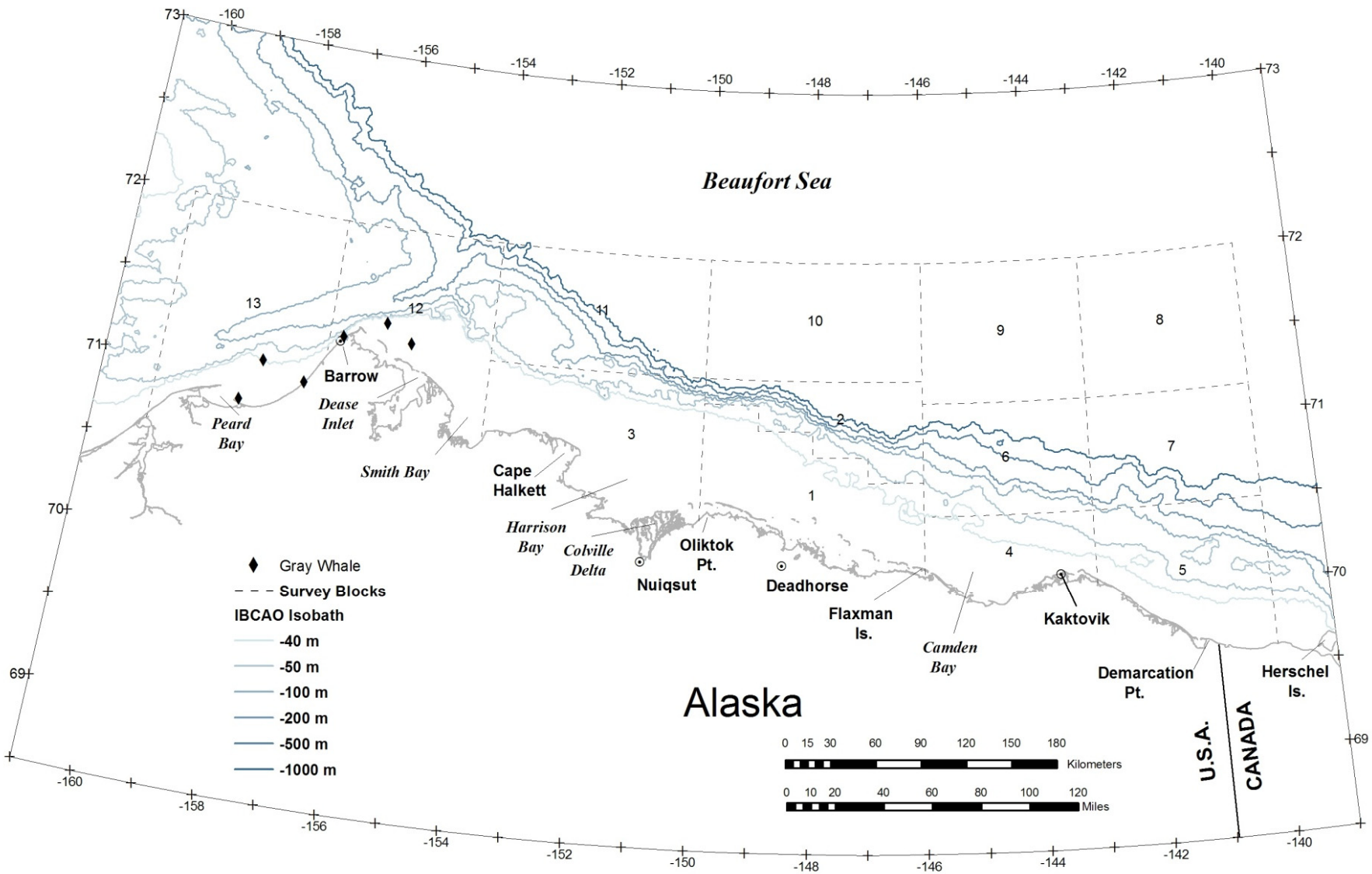

Figure 15. -- Gray whale sightings, fall 2006.

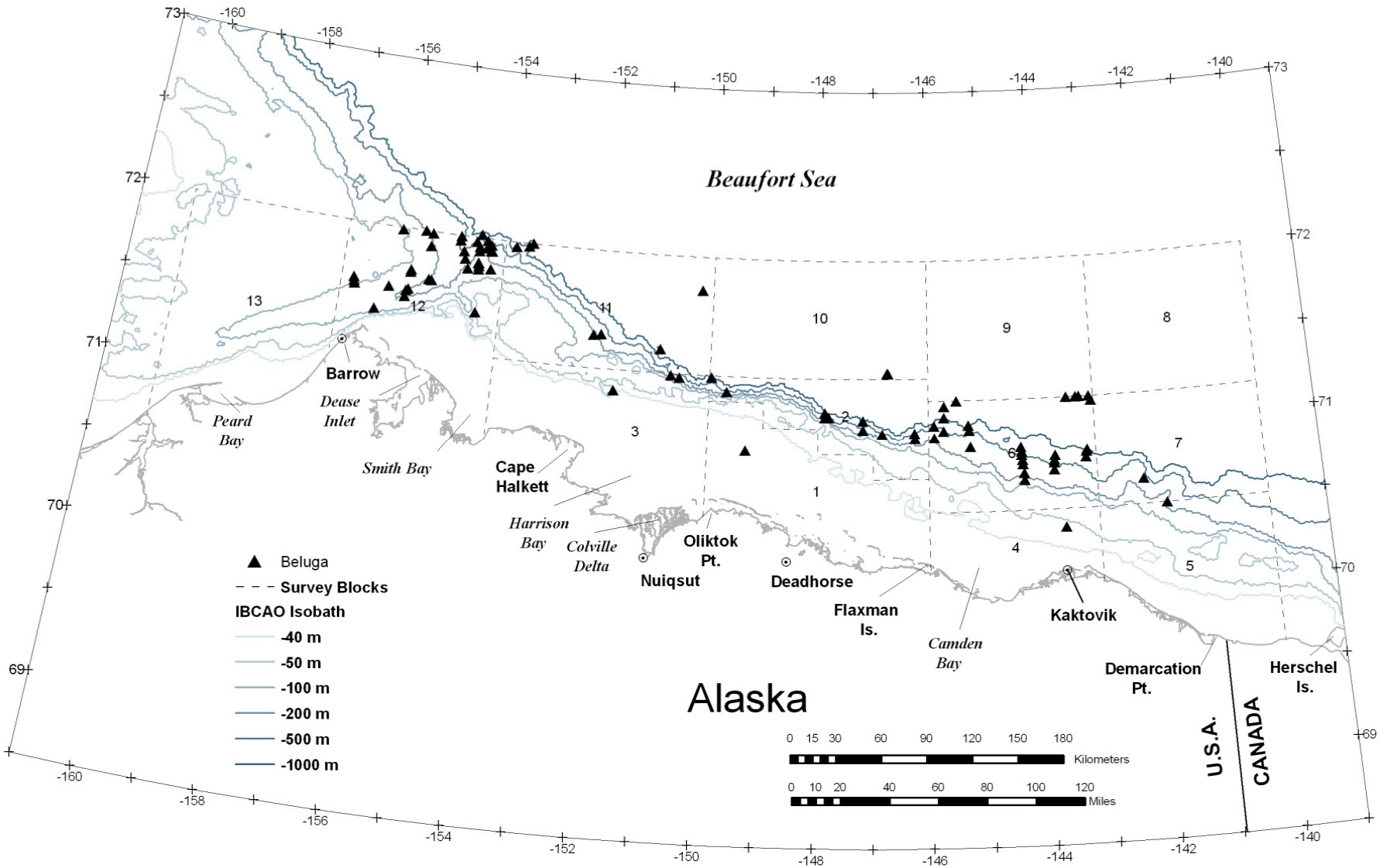

Figure 16. -- Beluga sightings, fall 2006.

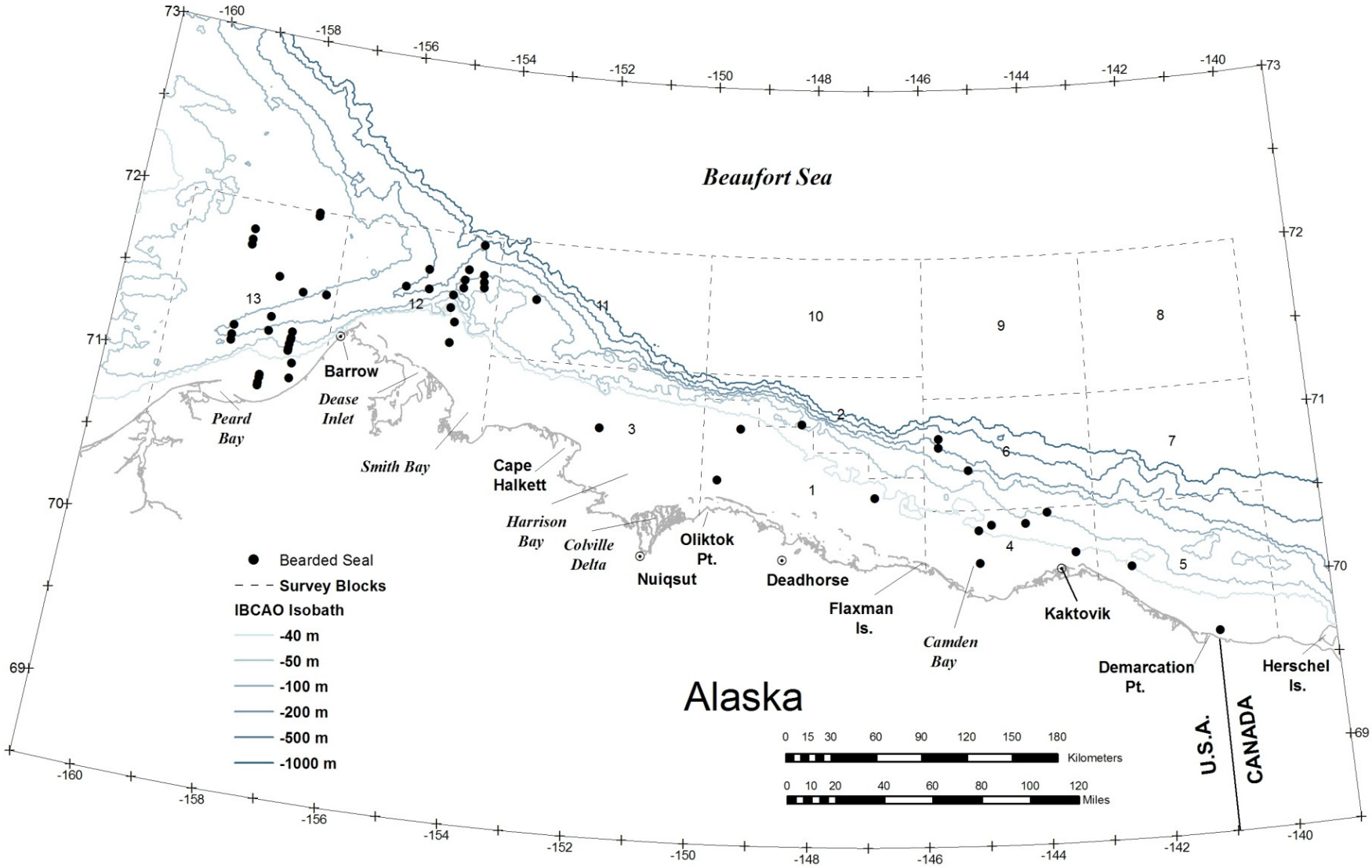

Figure 17. -- Bearded seal sightings, fall 2006.

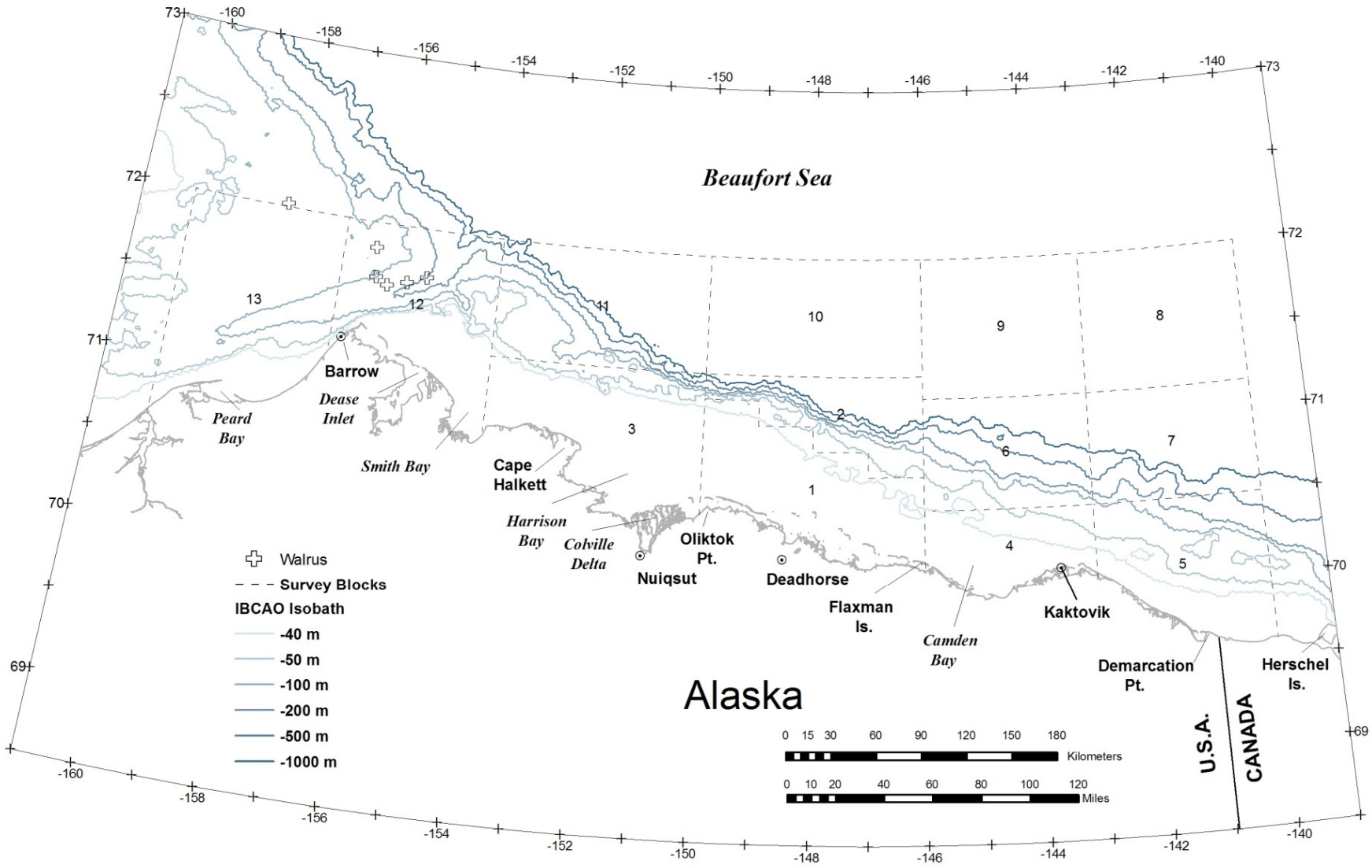

Figure 18. -- Pacific walrus sightings, fall 2006.

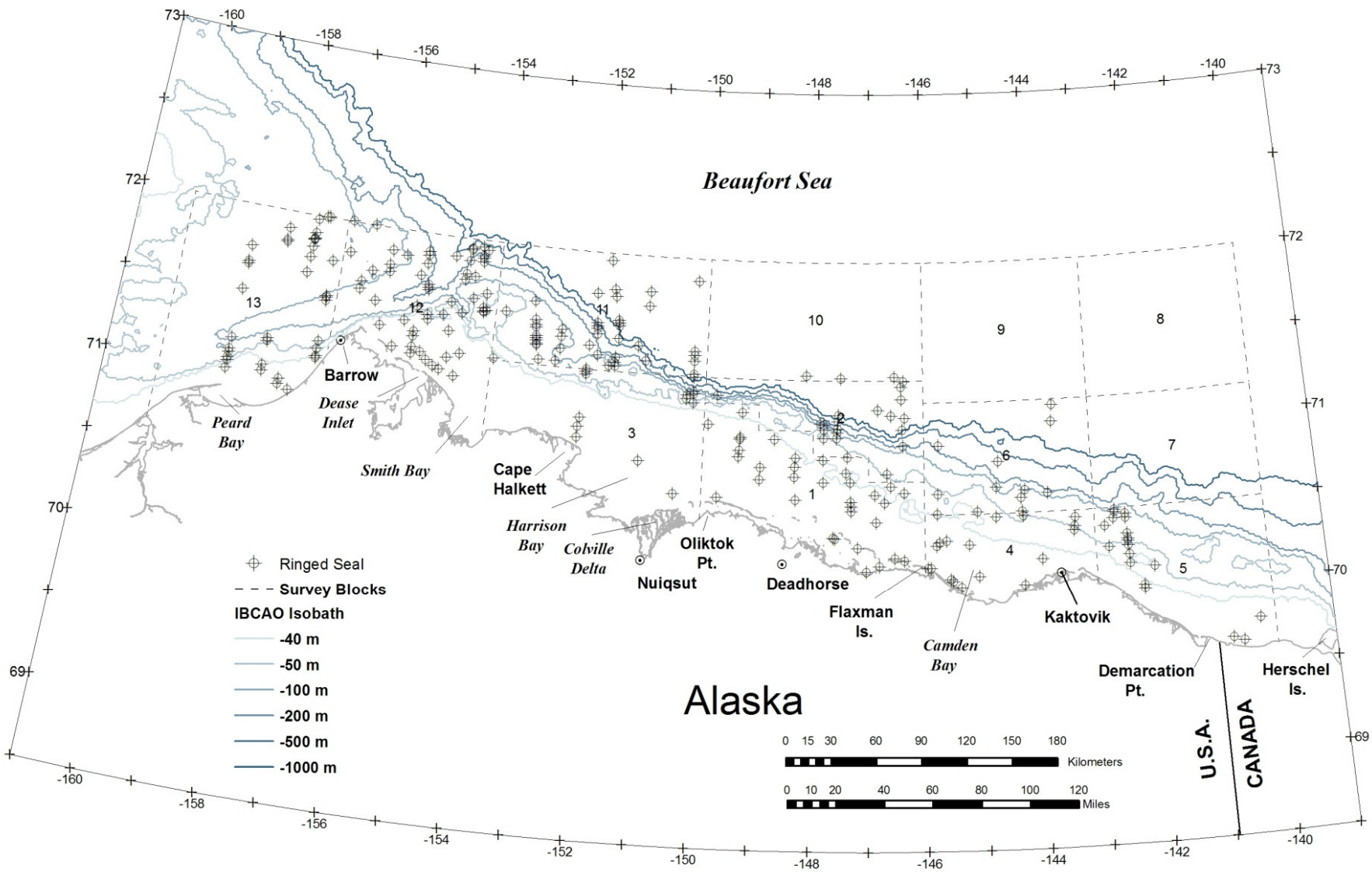

Figure 19. -- Ringed seal sightings, fall 2006.

Table 8. -- Survey effort, number of belugas per Survey Block, and sighting rate (WPUE; whales per km surveyed) per Survey Block for belugas on transect, fall 2006.

Block	Total effort (km)*	Total belugas (# animals)	Transect effort (km)*	Transect belugas (# animals)	Transect WPUE
1	3,083	6	2,121	6	0.003
2	1,273	36	1,047	31	0.030
3	3,324	7	1,580	4	0.003
4	2,365	1	1,050	1	0.001
5	1,183	0	733	0	0.000
6	1,006	165	886	141	0.159
7	99	2	81	1	0.012
11	1,205	18	904	18	0.020
12	3,527	290	2,572	271	0.105
13	1,200	0	967	0	0.000
Total	18,267	525	11,942	473	0.040

*Total and Transect Effort (km) do not match values in Table 2 because effort between barrier islands and the mainland was not included in the sighting rate analysis by block.

In 2006, 77 polar bears were sighted, although some of the bears may have been counted twice (Fig. 20). On 10 October, 16 bears were observed on Cross Island (site of the Nuiqsut fall whaling camp) and 23 bears were seen there on 16 October. On 13 October, 24 bears were counted near Kaktovik on Barter Island. Other polar bears were seen alone or in small groups.

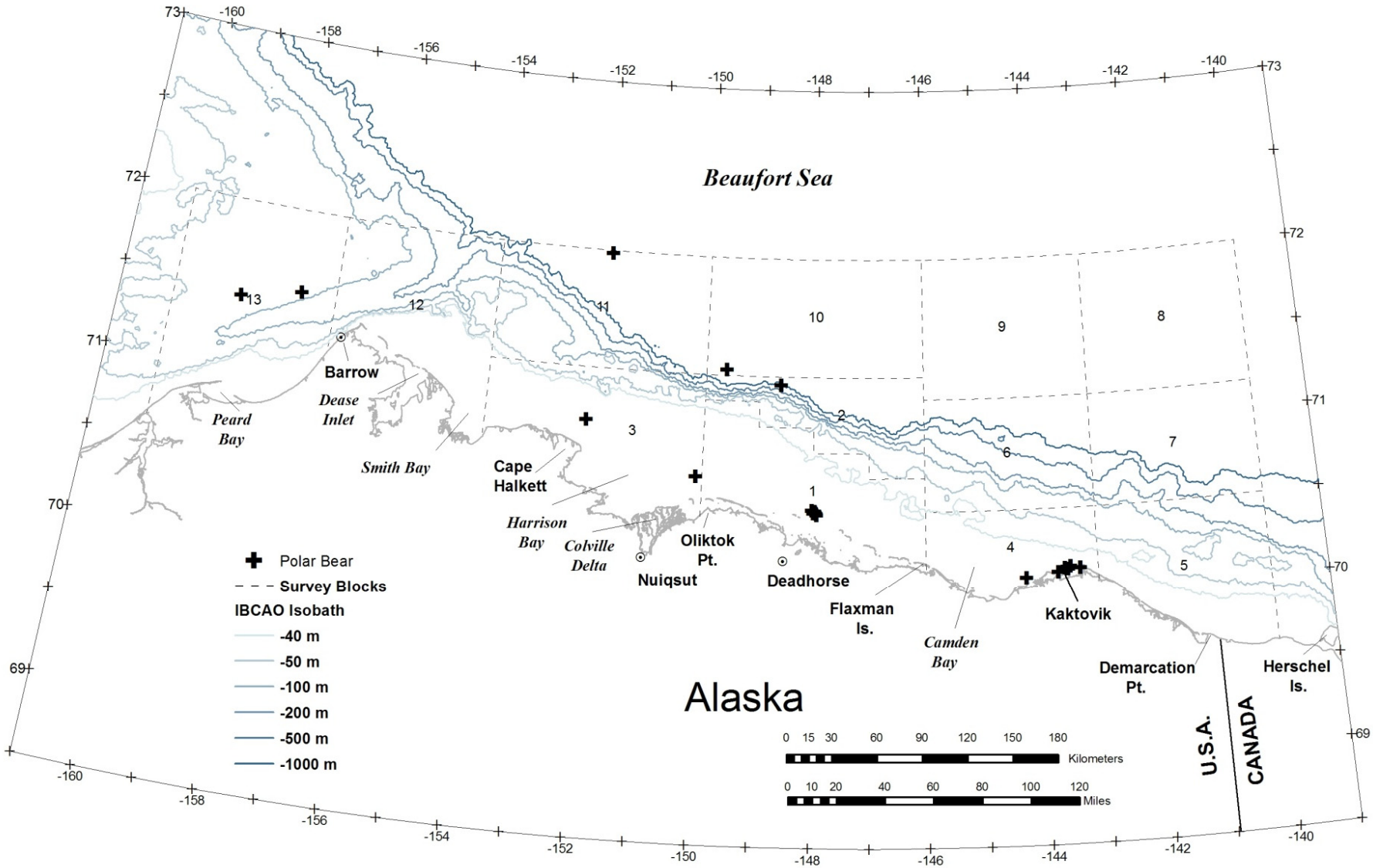

Figure 20. -- Polar bear sightings, fall 2006.

Fall 2007

Environmental Conditions

Sea ice coverage in the Alaskan Beaufort Sea was extremely light during the 2007 BWASP survey period. Sea ice in 2007 receded to historical minimums (National Snow and Ice Data Center 2007). By 3 September, nearly the entire study area was ice-free; ice existed in only the northeastern corner of Block 7 (Fig. D-2). The study area remained largely ice-free through the last BWASP survey on 10 October; by 12 October, new/grease ice was forming east of Deadhorse. Ice percentage and sea state at each bowhead whale sighting are shown in Appendix E. For purposes of inter-year comparisons of bowhead whale and other marine mammal distribution and occurrence, 2007 was considered a "light ice year".

Survey Effort

The fall field season was from 3 September through 10 October 2007 (Table 9). There were 21 flights, of which 13 were in September and 8 were in October. Surveys were not conducted after 10 October due to sustained high winds and overall unsuitable survey conditions. Daily totals of kilometers and hours flown per survey flight during this period are shown in Table 9. On two days, two survey flights per day were completed to take maximum advantage of good survey conditions. Over 17,000 km of trackline were flown in 93 hours in the study area; 15.5% of total survey effort was on deadhead (non-useable survey time). The average survey flight was 811 km. A total of 6,529 km of transect lines were flown in 36 hours. These transects constituted 38% of the total kilometers flown and 39% of the total flight hours. Survey flight lines are summarized by semimonthly period in Figures 21 through 23. Survey coverage was uneven in the study area. Lower than normal transect coverage was flown in Blocks 3, 7, 11, and the westernmost part of Block 1. There was no effort in Survey Blocks 8, 9, and 10. Flight lines and associated seas states are shown for individual flights in Appendix F.

Bowhead Whale Observations

Sighting Summary -- During 2007 surveys, 144 sightings of 409 bowhead whales were observed in the study area (Table 10). Bowhead whales were distributed throughout the survey area (Fig. 24). The greater number of sightings in the eastern half of the study area is likely related to the greater amount of survey effort in that area, and the relative lack of sightings between 148°W and 154°W is likely due to the relative lack of survey effort in that area. Of the 409 bowhead whales, 14 were identified as calves (Appendix E), resulting in a seasonal calf ratio (number of calves/total whales) of 0.034. Locations of bowhead whale sightings are shown by semimonthly period in Figures 25 through 27.

Table 9. -- Daily and semimonthly aerial survey effort in the Beaufort Sea, 3 September-10 October 2007. Distance measurements and time calculations are rounded.

Day	Flight no.	Transect (km)	Connect (km)	Search (km)	Deadhead (km)	Total (km)	Transect (hr)	Total (hr)
3 Sep	1	169	11	588	28	796	1.0	4.5
4 Sep	2	0	0	233	286	519	0.0	2.1
7 Sep	3	401	64	256	70	791	2.2	4.1
10 Sep	4	811	63	525	56	1,455	4.2	7.8
11 Sep	5	471	80	380	20	951	2.6	5.0
11 Sep	6	207	0	330	18	555	1.1	3.1
14 Sep	7	0	0	53	174	227	0.0	1.0
17 Sep	8	955	155	301	31	1,442	6.2	7.8
18 Sep	9	807	68	277	83	1,235	4.9	7.4
20 Sep	10	0	18	539	23	580	0.0	3.4
21 Sep	11	595	93	415	54	1,157	3.1	6.6
26 Sep	12	0	0	181	518	699	0.0	6.9
30 Sep	13	54	0	672	77	803	0.3	4.2
2 Oct	14	0	0	490	20	510	0.0	2.4
3 Oct	15	337	27	529	31	924	2.2	4.9
3 Oct	16	166	17	148	245	576	0.9	3.2
4 Oct	17	0	0	93	268	361	0.0	1.7
7 Oct	18	0	0	422	111	533	0.0	2.7
8 Oct	19	0	0	433	317	750	0.0	3.4
9 Oct	20	878	134	81	170	1,263	4.3	6.8
10 Oct	21	678	75	110	48	911	3.4	4.6
Semimonthly Effort Summary								
3-15 Sep		2,059	218	2,365	652	5,294	11.1	27.5
16-30 Sep		2,411	334	2,385	786	5,916	14.5	36.2
1-10 Oct		2,059	253	2,306	1,210	5,828	10.8	29.5
Total		6,529	805	7,056	2,648	17,038	36.4	93.2

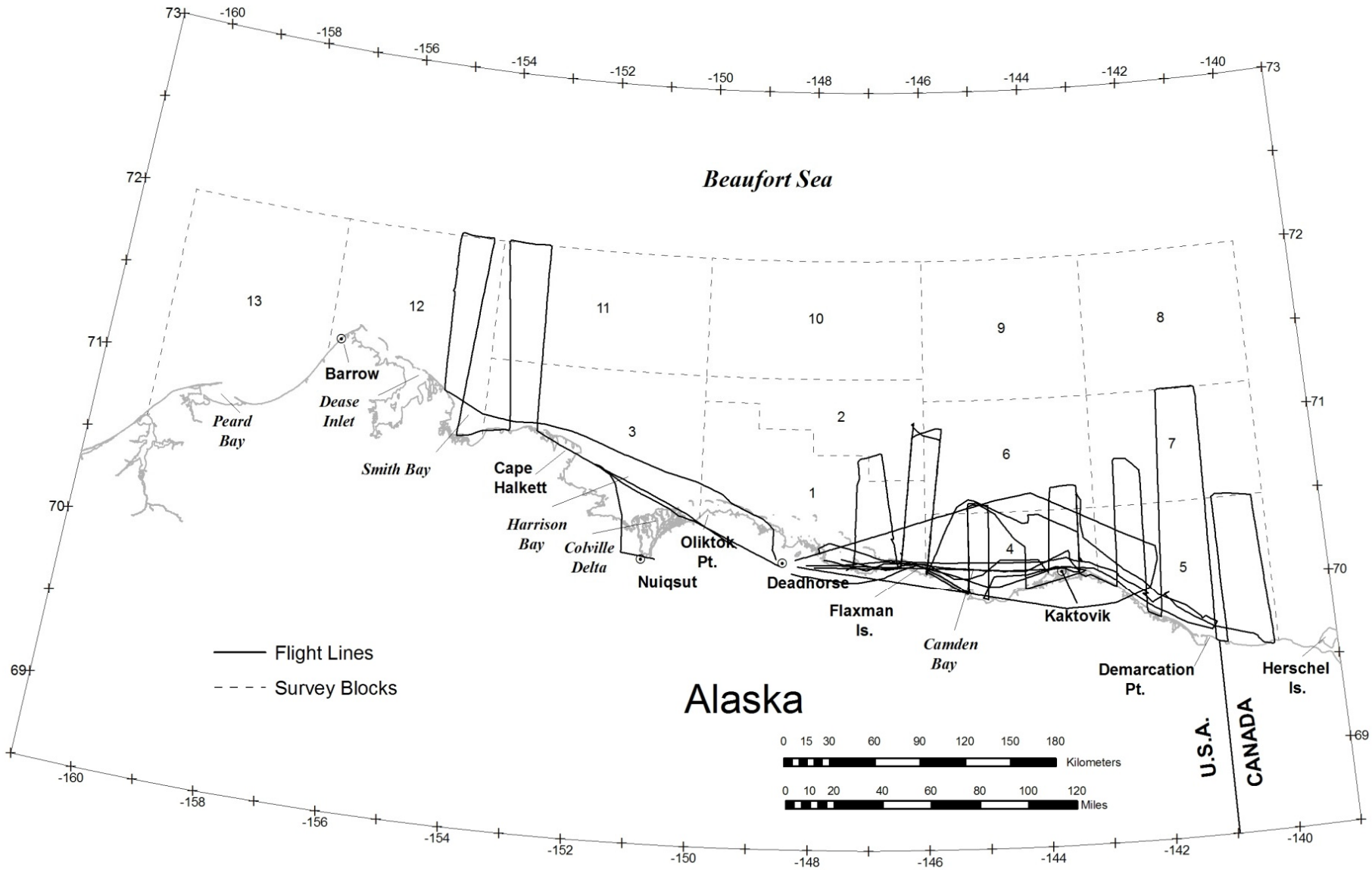

Figure 21. -- Combined flight tracks, 3–15 September 2007.

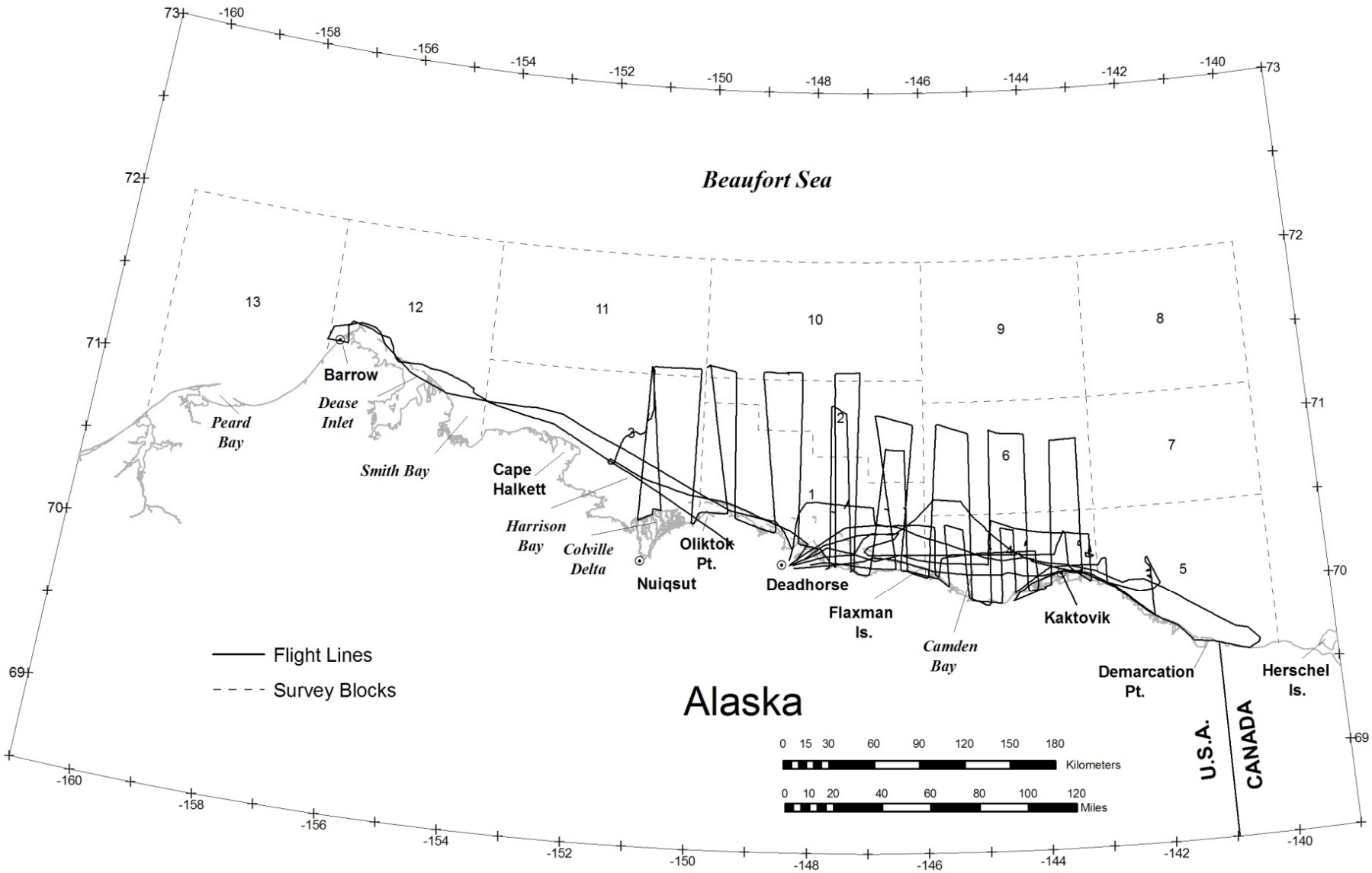

Figure 22. -- Combined flight tracks, 16-30 September 2007.

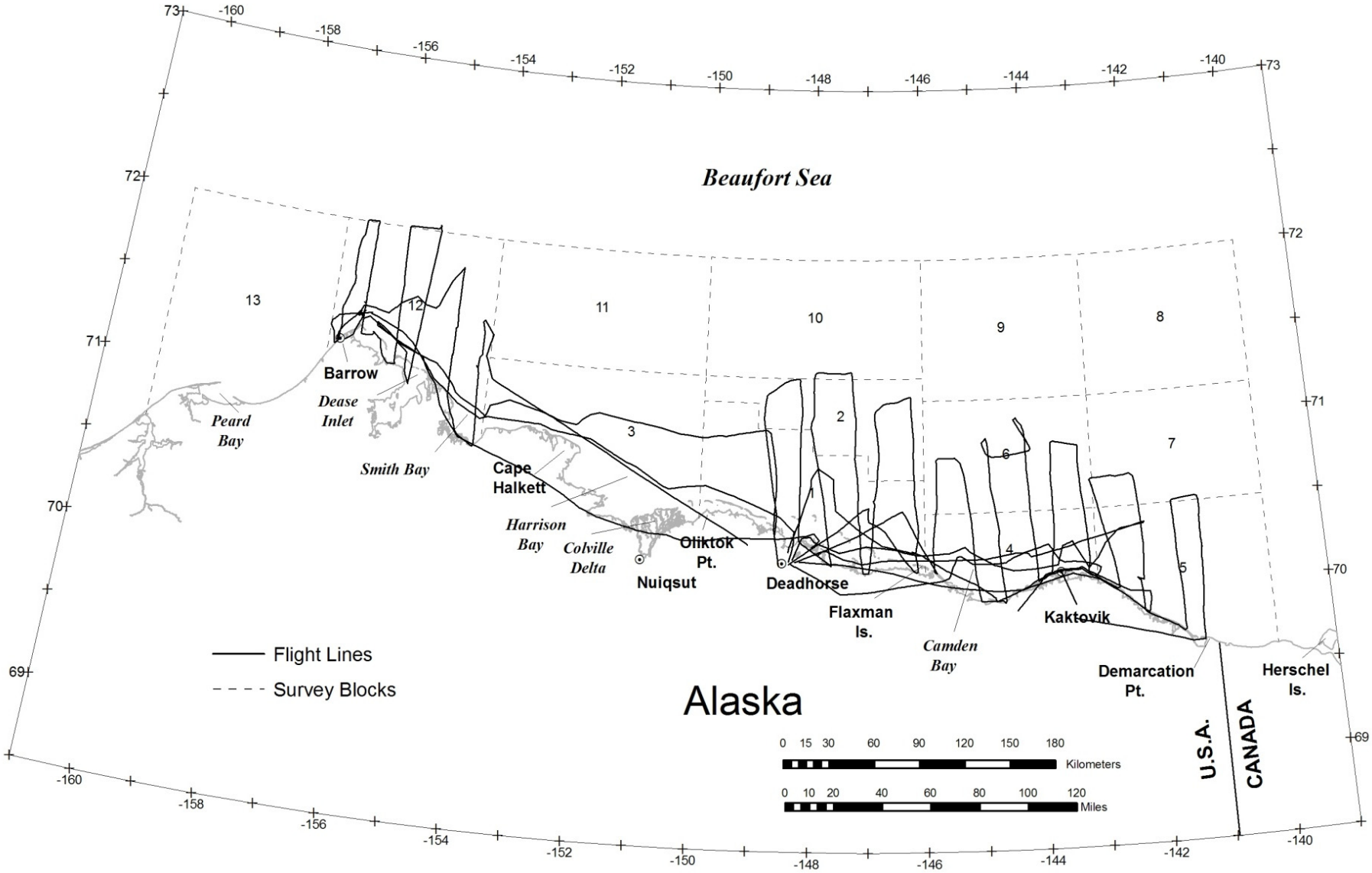

Figure 23. -- Combined flight tracks, 1–10 October 2007.

Table 10. -- Daily and semimonthly summary of marine mammal sightings, 3 September-10 October 2007, showing number of sightings and number of individuals (i.e., no. of sightings/no. of individuals).

Day	Flight no.	Bowhead whale	Gray whale	Beluga	Unidentified cetacean	Bearded seal	Ringed seal	Walrus	Unidentified pinniped	Polar bear	Polar bear tracks
3 Sep	1	25/81	0	1/1	1/1	6/6	23/46	0	3/3	6/14	0
4 Sep	2	1/1	0	0	0	0	0	0	0	0	0
7 Sep	3	5/16	0	1/3	0	8/8	115/532	0	0	1/1	0
10 Sep	4	29/81	0	2/26	0	20/22	22/70	0	1/1	3/7	0
11 Sep	5	0	0	2/23	0	5/6	73/135	8/31	1/1	3/6	0
11 Sep	6	7/20	0	0	0	7/8	65/230	0	0	3/4	0
14 Sep	7	0	0	0	0	0	0	0	0	0	0
17 Sep	8	4/22	0	1/2	0	15/21	93/226	2/2	1/1	6/6	0
18 Sep	9	22/53	0	3/9	1/1	7/8	103/407	0	13/15	3/9	0
20 Sep	10	12/27	0	0	0	0	2/3	0	0	0	0
21 Sep	11	14/64	0	0	0	3/4	7/7	0	0	1/3	0
26 Sep	12	0	0	0	0	0	1/1	0	0	0	0
30 Sep	13	2/4	0	0	0	0	1/1	0	0	3/18	1
2 Oct	14	3/3	0	0	0	1/1	1/6	0	0	0	0
3 Oct	15	2/4	3/14	4/45	1/1	15/18	21/37	11/20	4/10	1/1	0
3 Oct	16	4/17	3/6	0	0	3/4	6/13	2/3	1/1	0	0
4 Oct	17	1/1	0	0	0	0	0	0	0	2/5	0
7 Oct	18	2/2	0	0	0	0	0	0	0	7/9	0
8 Oct	19	3/3	0	0	0	0	0	0	0	0	0
9 Oct	20	5/5	0	1/4	0	0	10/10	0	6/9	0	0
10 Oct	21	3/5	0	1/4	0	0	6/8	0	2/2	0	0
Semimonthly Sightings Summary											
3-15 Sep		67/199	0	6/53	1/1	46/50	298/1013	8/31	5/5	16/32	0
16-30 Sep		54/170	0	4/11	1/1	25/33	207/645	2/2	14/16	13/36	1
1-10 Oct		23/40	6/20	6/53	1/1	19/23	44/74	13/23	13/22	10/15	0
Total		144/409	6/20	16/117	3/3	90/106	549/1732	23/56	32/43	39/83	1

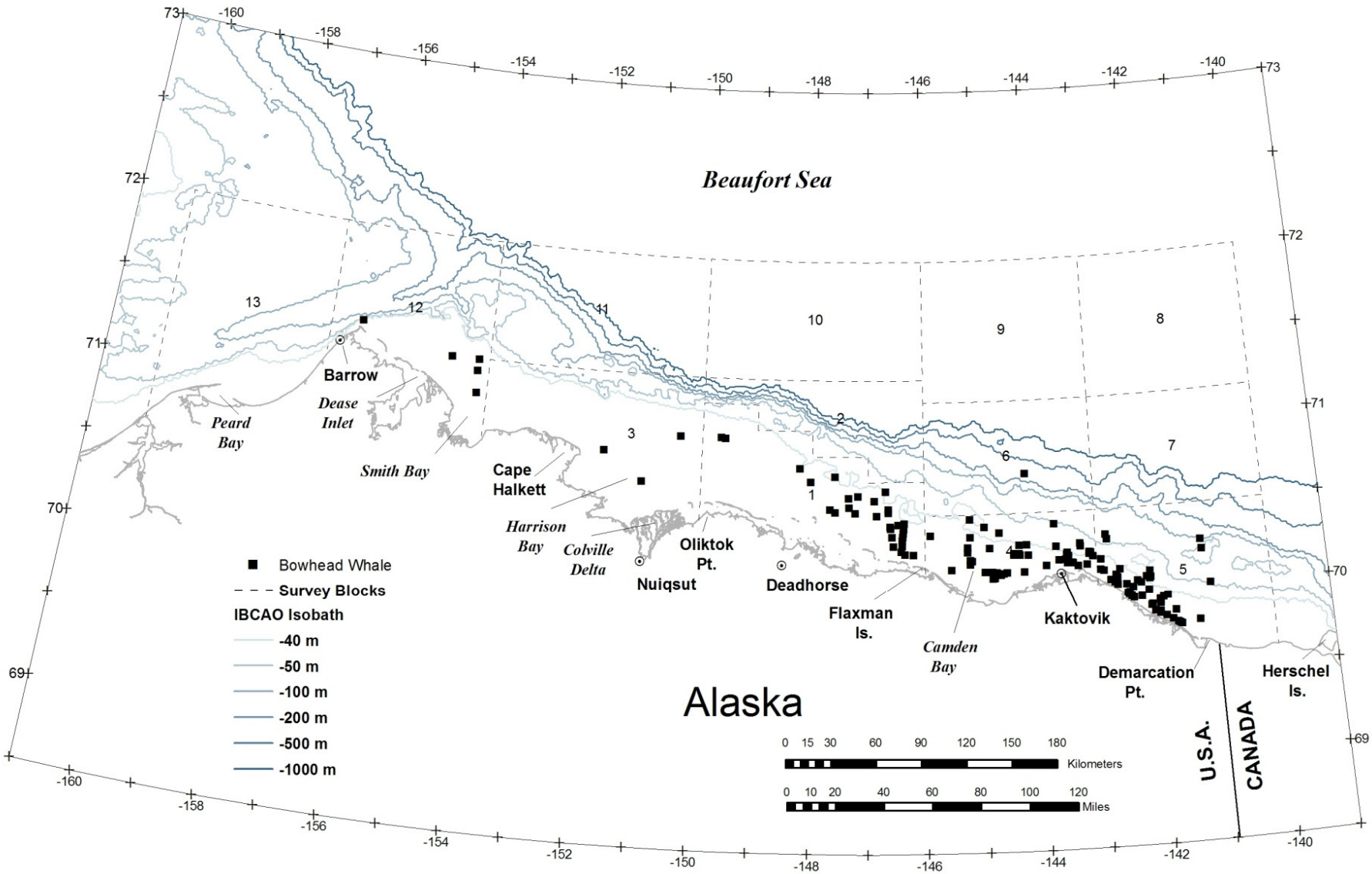

Figure 24. -- Bowhead whale sightings, fall 2007.

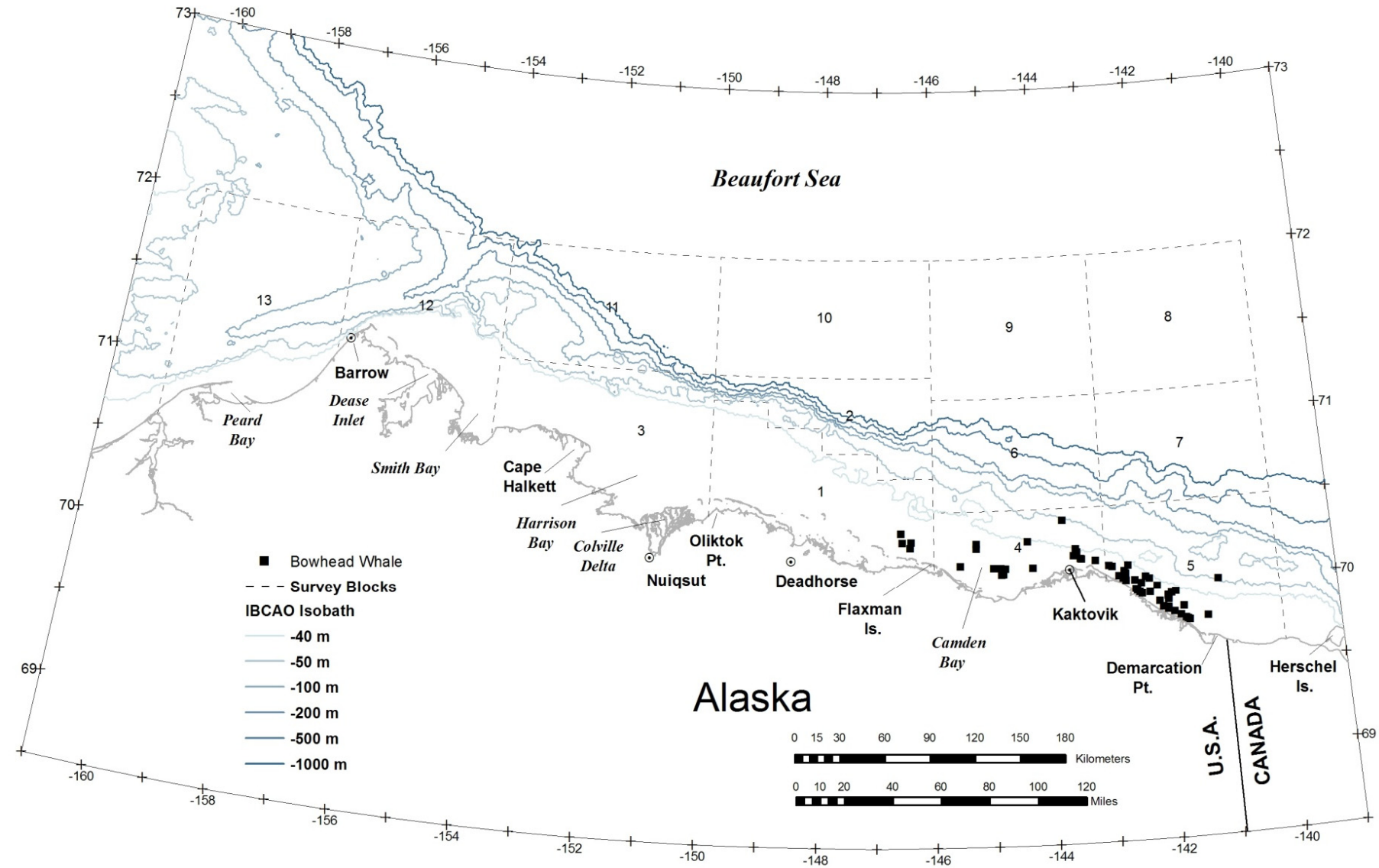

Figure 25. -- Bowhead whale sightings, 3-15 September 2007.

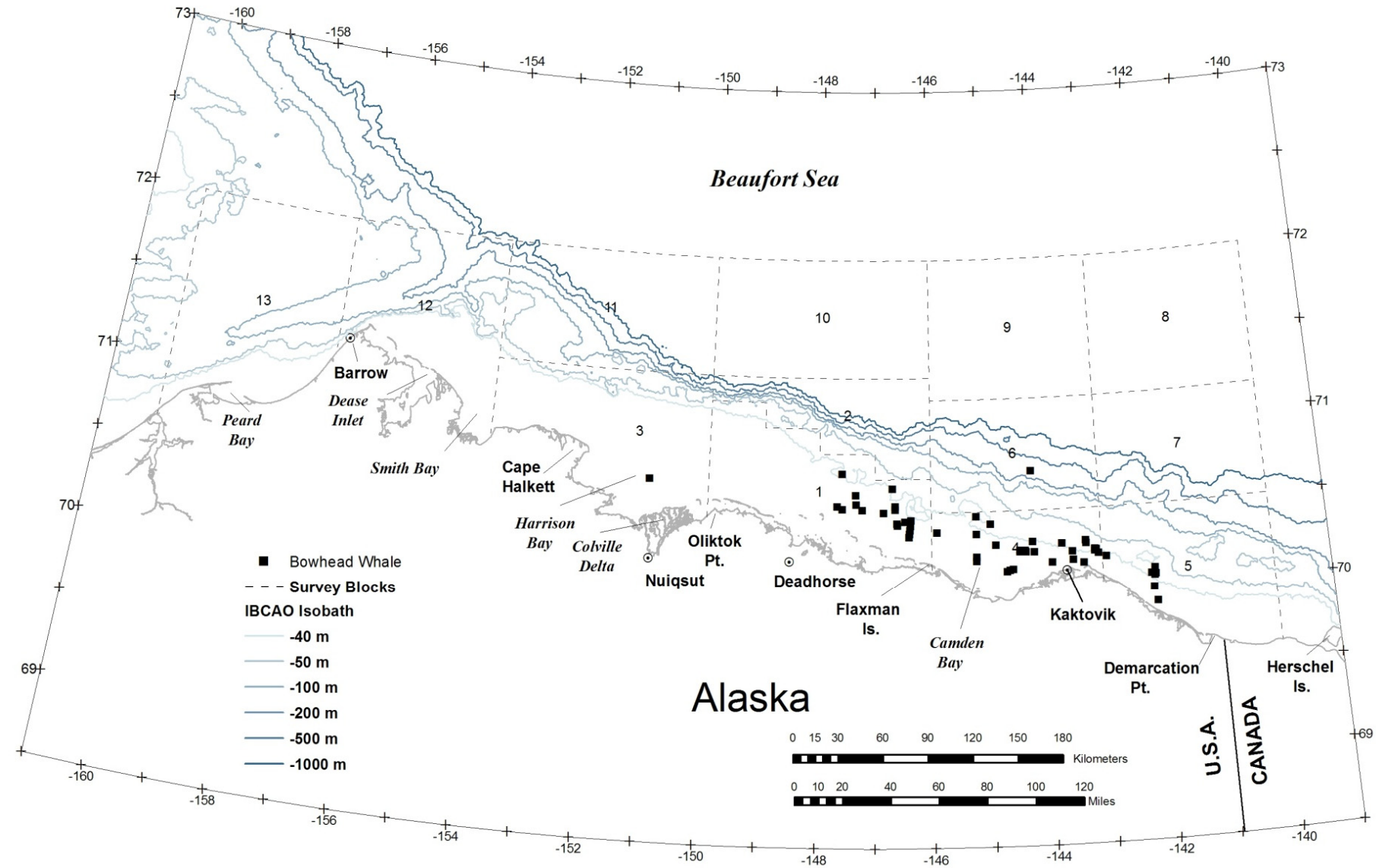

Figure 26. -- Bowhead whale sightings, 16-30 September 2007.

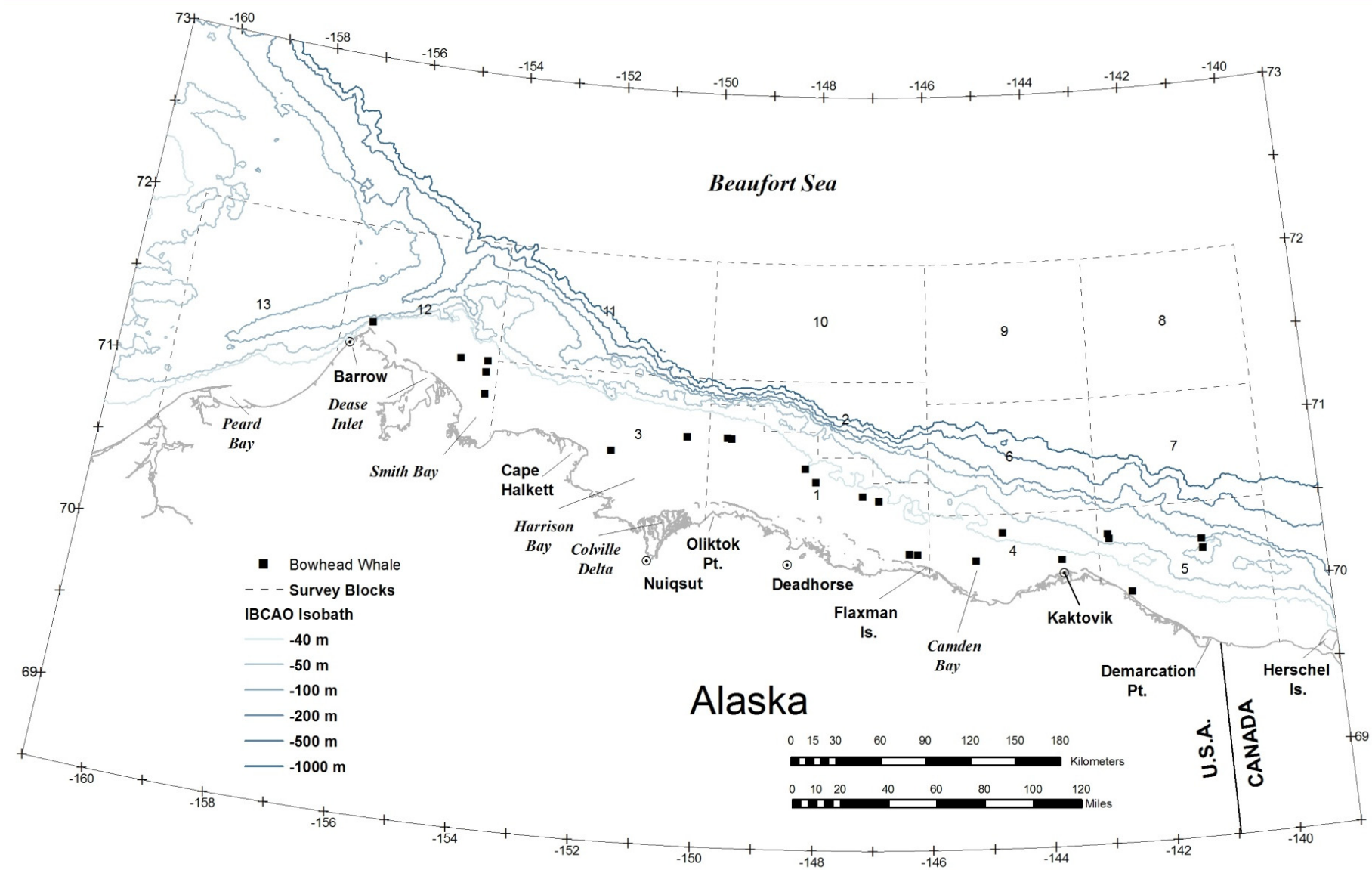

Figure 27. -- Bowhead whale sightings, 1-10 October 2007.

Table 11. -- Survey effort, number of bowhead whales per Survey Block, and sighting rate (WPUE; whales per km surveyed) per Survey Block for bowhead whales on transect, fall 2007.

Block	Total effort (km)*	Total bowhead (no. animals)	Transect effort (km)*	Transect bowhead (no. animals)	Transect WPUE
1	2,414	118	1,250	109	0.087
2	984	0	760	0	0.000
3	1,179	3	369	1	0.003
4	3,691	96	1,239	19	0.015
5	1,862	166	847	39	0.046
6	967	6	718	6	0.008
7	322	0	228	0	0.000
8	0	0	0	0	0
9	0	0	0	0	0
10	0	0	0	0	0
11	230	0	167	0	0.000
12	1,454	20	716	17	0.024
13	4	0	0	0	0
Total	13,107	409	6,294	191	0.030

* Total and Transect Effort (km) do not match values in Table 9 because effort between barrier islands and the mainland was not included in the sighting rate analysis by block.

Sighting Rates -- In fall 2007, bowhead whales were seen from Point Barrow to Canada. Several large groups of bowhead whales were recorded as "on transect" sightings and the fine-scale sighting rate analysis reflects this. Areas of greatest sighting rates (transect whales/transect km surveyed) were north of Smith Bay, northeast of Deadhorse, and east of Kaktovik (Fig. 28). The largest groups were observed on 21 September east of Kaktovik (group of 22 whales), and 7, 17, 18, and 21 September northeast of Deadhorse (10, 19, 13, and 27 whales, respectively).

Highest sighting rates by Survey Block were in Block 1 (0.087 bowhead whales on transect/transect km flown) and Block 5 (0.046 bowhead whales on transect/transect km flown) (Table 11). Sighting rates using all bowhead whale sightings by Survey Block were similar to sighting rates using bowhead whales seen on transect only. Previous Survey Block sighting rate analyses for light ice years (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. Nonetheless, the pattern of highest sighting rates per year is similar across all years. In light ice years, highest sighting rates are generally in coastal Survey Blocks (1, 3, 4, 5, and 12), and are usually correlated with large groups of bowhead whales in feeding or milling aggregations.

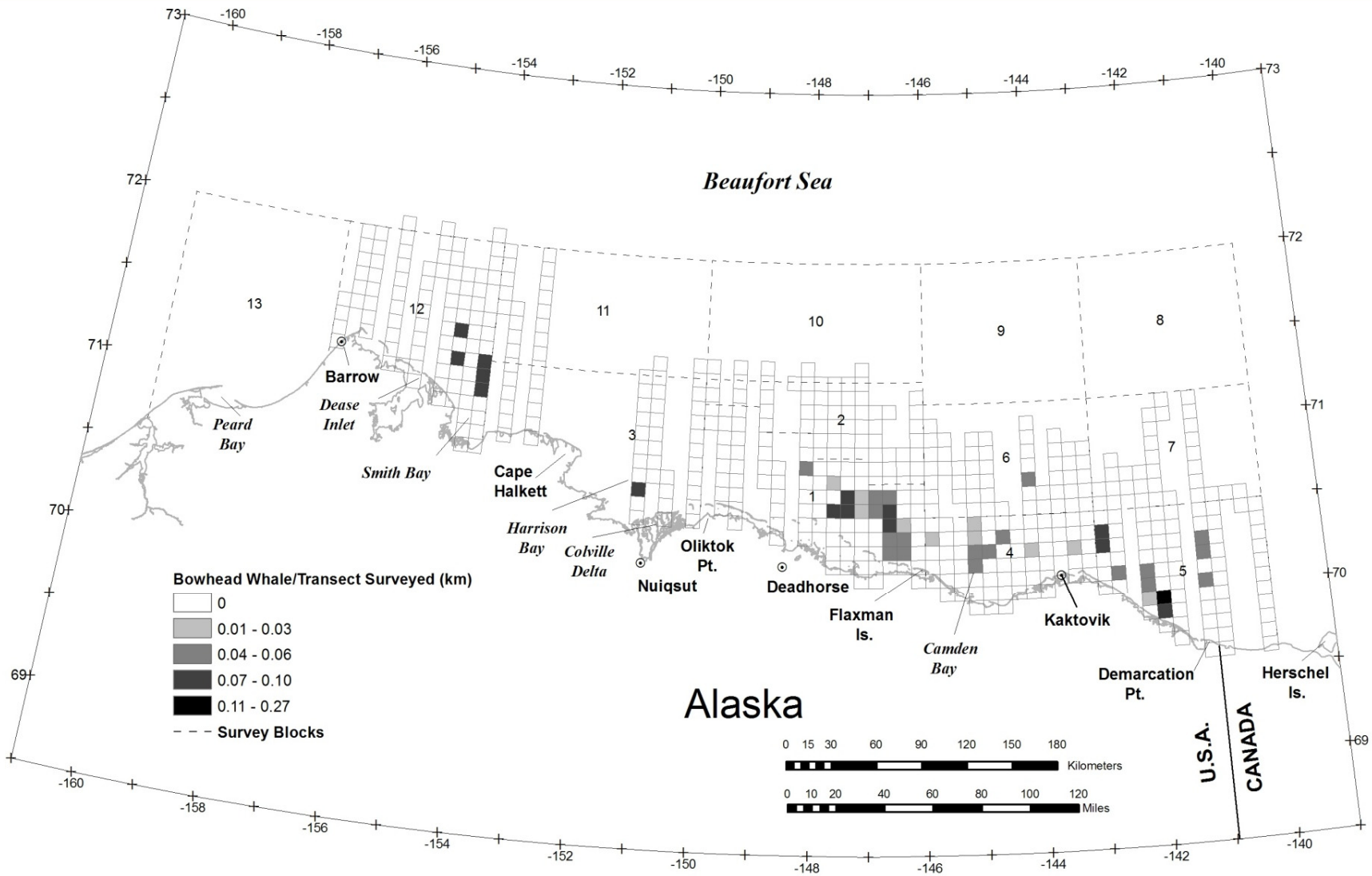

Figure 28. -- Sighting rates of bowhead whales, fall 2007 (transect whales/transect km surveyed).

Table 12. -- Semimonthly summary of bowhead whales observed by percent ice cover at sighting location, fall 2007.

Percent Ice cover	3-15 Sep	16-30 Sep	1-10 Oct	Total
0	199 (100%)	169 (99%)	35 (87%)	403 (98%)
1-5	0	1 (< 1%)	3 (7%)	4 (< 1%)
6-10	0	0	1 (2%)	1 (< 1%)
81-90	0	0	1 (2%)	1 (< 1%)
Total	199	170	40	409

Habitat Associations -- Weekly ice coverage for the Alaskan Beaufort Sea during fall 2007 is included in Appendix D, and the percentage of ice cover visible from the aircraft at each bowhead whale sighting is included in Appendix E. Of the 409 bowhead whales counted over the field season, 403 whales (98%) were sighted in open water, 5 (1%) whales were observed in 1-10% sea ice, and 1 (< 1%) whale was observed in 81-90% sea ice coverage (Table 12). As noted previously, the BWASP study area was essentially ice-free during September and early October 2007.

Behaviors -- Behaviors of 403 bowhead whales observed during fall 2007 are summarized in Table 13. The behaviors most often recorded were milling (44%) and swimming (40%). Feeding was recorded for 19 whales (4%). Sighting rates of feeding and milling whales are shown in Figure 29. Feeding was infrequently observed in 2007, compared with past years. Milling, which may be indicative of feeding, was observed more frequently and across the study area. Feeding behavior is not always detectable during aerial surveys and is likely underestimated in the database. A single dead bowhead whale was seen on 3 October north of Smith Bay.

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 which may indicate a response to the aircraft; no responses were observed.

Distance from Shore -- Distances from shore of fall 2007 bowhead whale sightings made on transect were measured using ArcGIS as the distance due north of a normalized shoreline. Mean distance from locations of all bowhead whale sightings on transect to a normalized shoreline in 2007 was 23.2 km (SD = 14.4) in the East Region, and 25.7 km (SD = 8.0) in the West Region (Fig. 30, Table 14). Note there were very few sightings on transect in the West Region. Mean distance from locations of "migrating" bowhead whales on transect (i.e., excluding sightings of feeding, milling or resting whales), was 27.0 km (SD = 15.5) in the East Region, and 26.1 km (SD = 8.9) in the West Region (Fig. 31). A Mann-Whitney U-test of significant difference of the median distance from shore indicated no difference between distances of all whales versus

Table 13. -- Semimonthly summary of bowhead whales observed by behavioral category, fall 2007. Behavior was not recorded for all sightings.

Behavior	3-15 Sep	16-30 Sep	1-10 Oct	Total
breach	0	0	2 (5%)	2 (< 1%)
dive	22 (11%)	3 (1%)	1 (2%)	26 (6%)
feed	11 (5%)	5 (3%)	3 (7%)	19 (4%)
mill	101 (50%)	70 (42%)	9 (22%)	180 (44%)
rest	1 (< 1%)	6 (3%)	3 (7%)	10 (2%)
swim	61 (30%)	80 (48%)	22 (55%)	163 (40%)
tail slap	3 (1%)	0	0	3 (< 1%)
Total	199	164	40	403

distances of only those whales considered "migrating" in either the East (Z = -1.261, P = 0.2074) or West (Z = -0.091, P = 0.9273) Regions.

Depth at Sighting -- Mean depth at sightings of all bowhead whales on transect was 43 m (SD = 54.2, range 14-403 m) in the East Region, and 23 m (SD = 8.6, range 12-35 m) in the West Region
(Table 14). Mean depth of "migrating" bowhead whales on transect (i.e., excluding sightings of feeding, milling, or resting whales), was 48 m (SD = 66.4, range 14-403 m) in the East Region, and 23 m (SD = 9.5, range 12-35 m) in the West Region. A Mann-Whitney U-test of significant difference of median depths indicates no difference between depths of all whales versus depths of only those whales considered "migrating" in either the East (Z = -0.720, P = 0.4717) or West (Z = -0.091, P = 0.9273) Regions.

Based on the lack of significant difference between all bowhead whale sightings in 2007 and sightings limited to those whales considered "migrating" (excluding feeding, milling, or resting animals), additional analyses of the bowhead whale migration corridor incorporated all sightings and were not limited to only those animals considered actively "migrating".

Distribution of Migrating Bowhead Whales, 2007, Relative to Previous Light Ice Years -- In order to evaluate whether significant displacements occurred in the bowhead whale migratory corridor during 2007, estimates of median depth at sighting and distance of sightings from a normalized shoreline were compared with data from previous years having "light ice" coverage (i.e., 1982, 1986, 1987, 1989, 1990, and 1993-2006). Median distance from shore during previous "light ice" years was 27.3 km in the East Region, and 27.0 km in the West Region; the median water depth at sightings was 40 m in the East Region and 23 m in the West Region.

During 2007, bowhead whales in the East Region were significantly closer to shore (21.8 km vs. 27.3 km, n = 49, Z = 2.854, P = 0.0043) and in shallower water (34 m vs. 40 m, Z = 3.497, P =

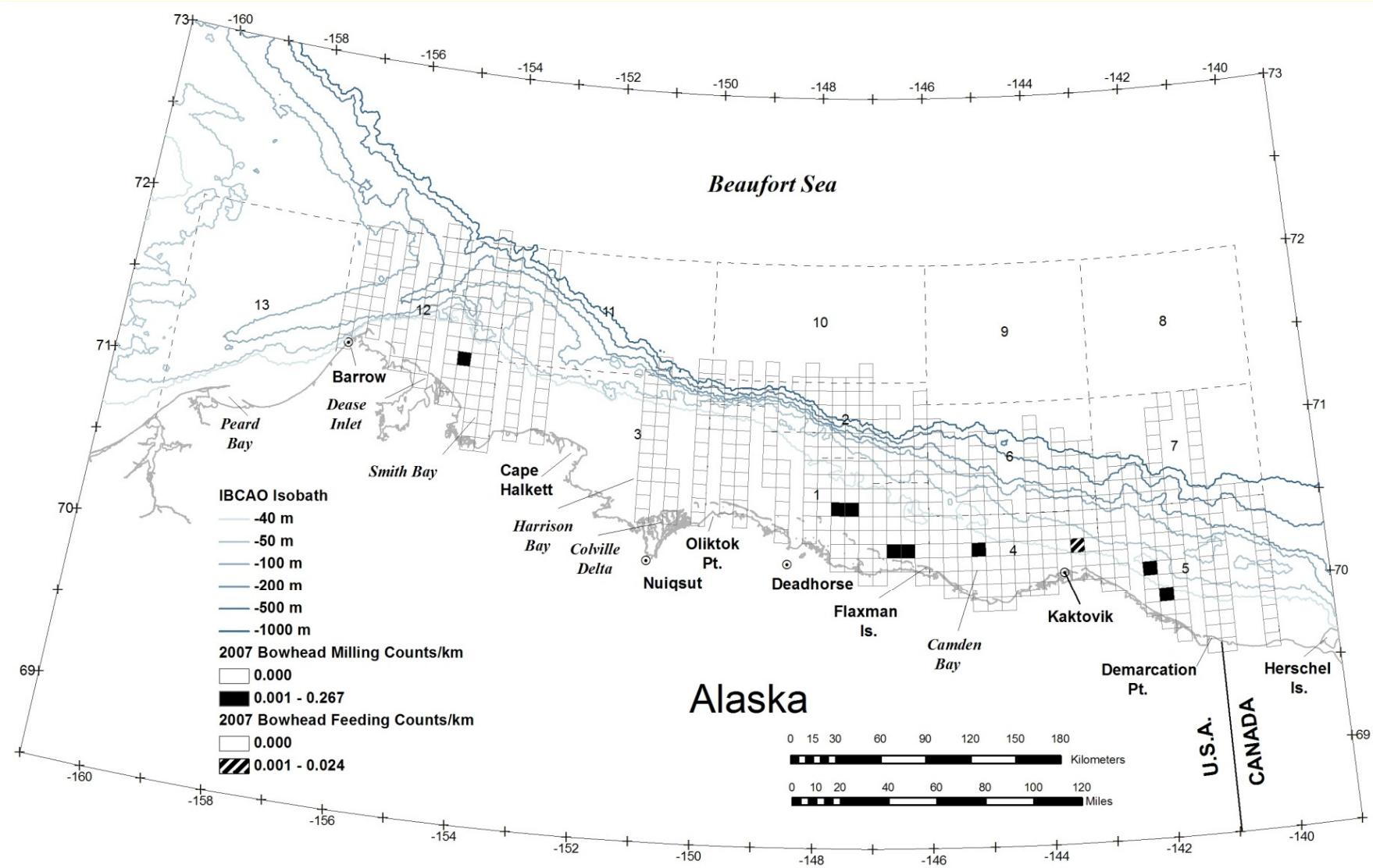

Figure 29. -- Sighting rates of feeding and milling bowhead whales, fall 2007 (transect whales/transect km surveyed).

Table 14. -- Central-tendency statistics for distance from shore (km) and depth (m) at transect sightings of bowhead whales (September-October), by year and region, 1982-2007.

			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
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

Table 14. -- Continued.

			Distance from shore (km)				Depth (m)			
Year	Region	TrSi	Median	Mean	SD	Min-Max	Median	Mean	SD	Min-Max
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	8.05	15-35	23	23	8.55	12-35

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

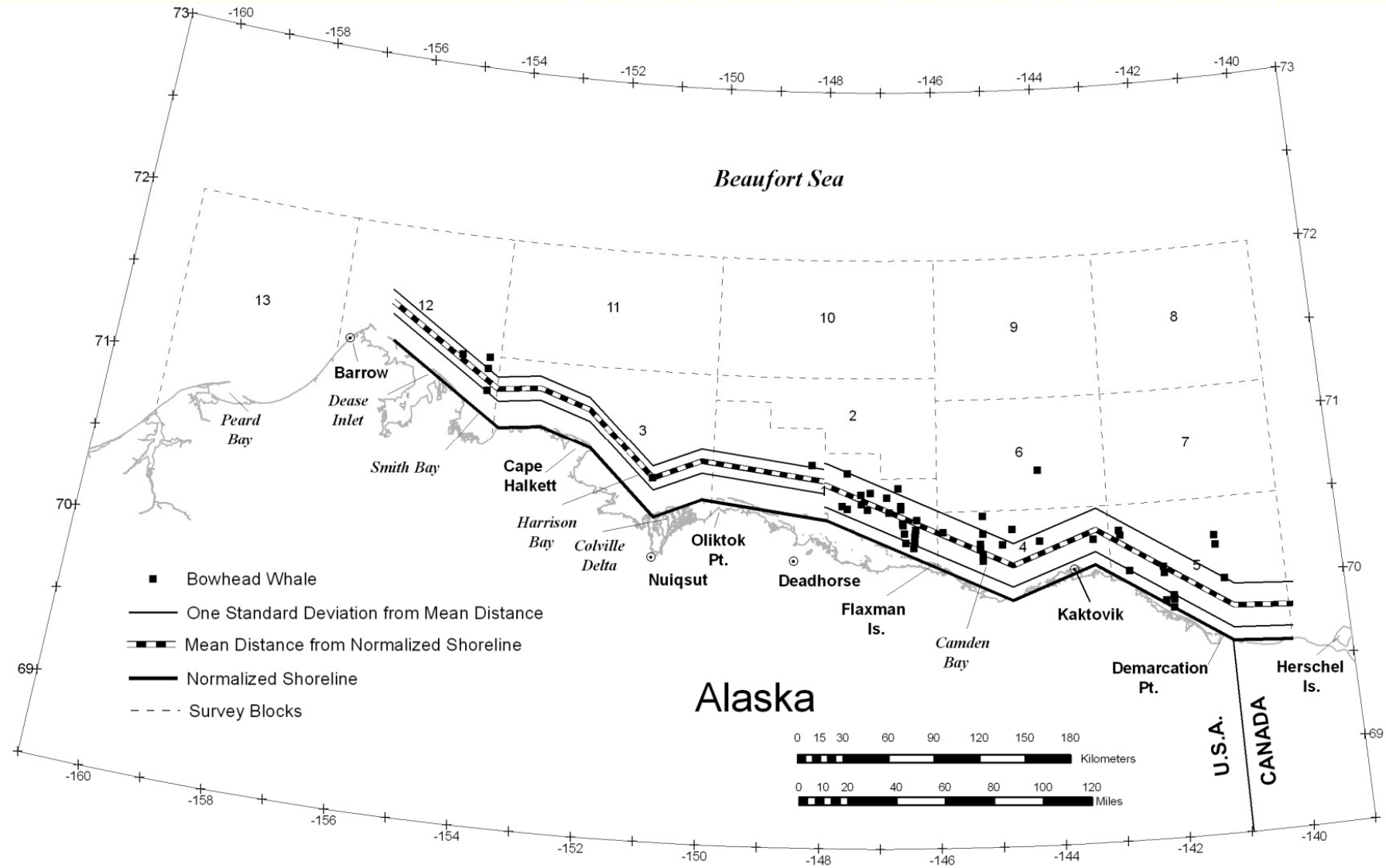

Figure 30. -- Bowhead whale sightings on transect, fall 2007, showing mean distance from a normalized shoreline.

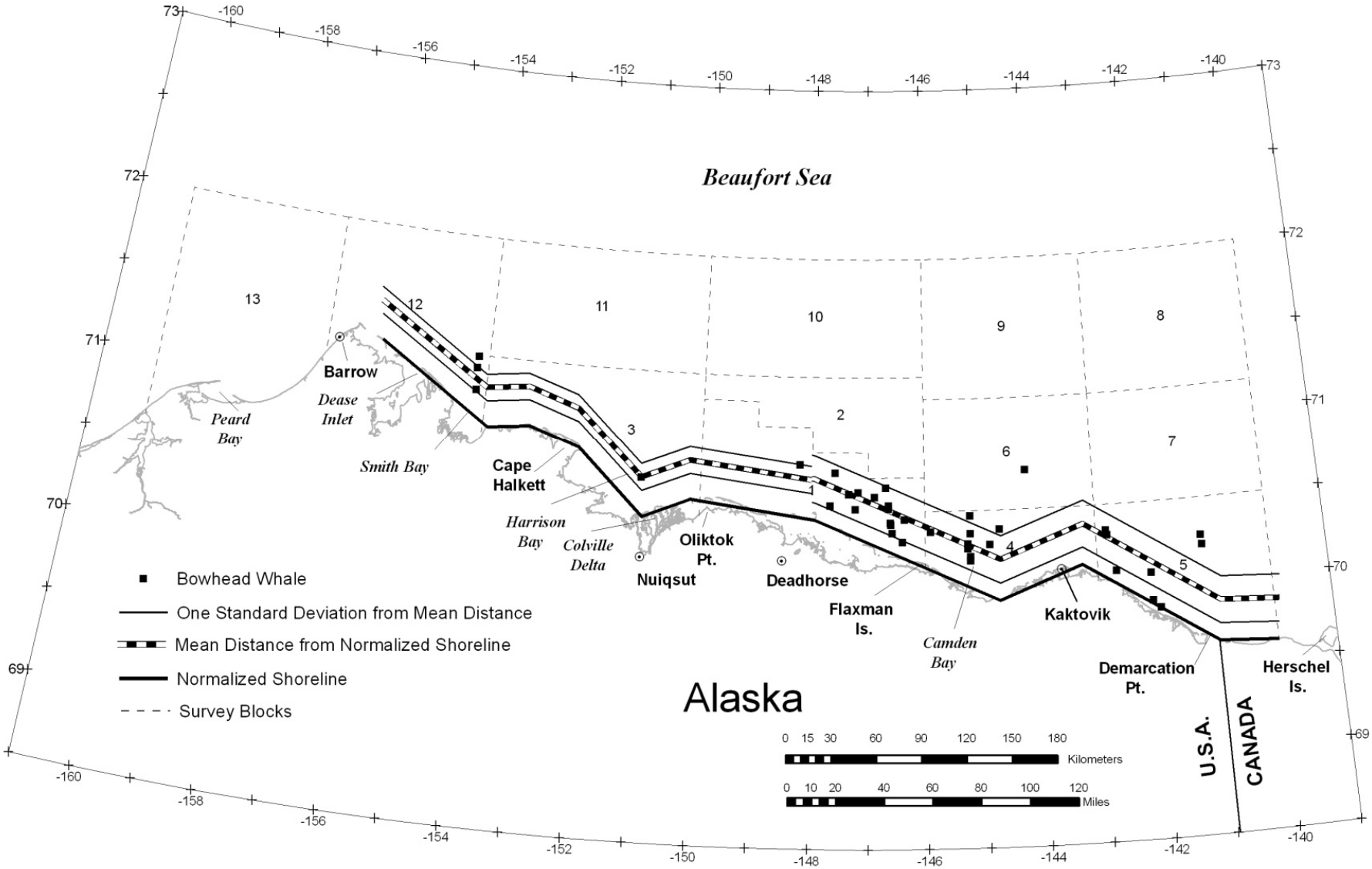

Figure 31. -- Bowhead whale sightings on transect, excluding feeding, milling and resting whales, fall 2007, showing mean distance from a normalized shoreline.

0.0005) than in previous "light ice" years (n = 814). This trend remained consistent even when "non-migrating" bowhead whale sightings were removed from the multiyear analysis.

Bowhead whales in 2007 were closer to shore (25.8 km in 2007, n = 32 vs. 27.2 km for previous "light ice" years, n = 718) and in shallower water (36 m in 2007 vs. 40 m in previous "light ice" years), although this difference was statistically significant only for water depth (Z = 2.199, P = 0.0278). In the West Region, sample size was too small (n = 6) to allow any statistical comparisons with previous light ice years.

Other Marine Mammal Observations

There were six sightings of 20 gray whales (Fig. 32) during the 2007 BWASP surveys. Gray whales were seen north and west of Point Barrow on 3 October only. Most gray whales were feeding, as evidenced by mud plumes.

During fall 2007 surveys, 117 belugas were observed (Fig. 33), mainly along the shelf break and slope. Far fewer belugas were seen in 2007 than in any year since 1990 (Fig. 34), perhaps due to the lack of ice cover (belugas may have been farther offshore in heavier ice) or due to the relative lack of survey effort in the deeper, offshore areas of the study area (Figs. 21-23, Table 11). Belugas, with group sizes ranging from 1 to 20, were also seen very close to shore in September. Belugas are usually associated with ice (Moore et al. 2000); however, all belugas seen in 2007 were in ice-free water as there was no ice cover in the study area during the survey period.

Bearded seals (90 sightings of 106 seals), small pinnipeds identified as ringed seals (549 sightings of 1,732 seals) and Pacific walruses (23 sightings of 56 walruses) were seen during fall 2007. Ringed and bearded seals were distributed across the Alaskan Beaufort Sea and into the northeasternmost Chukchi Sea (Figs. 35 and 37), while Pacific walrus distribution was mostly limited to north and east of Point Barrow (Fig. 36).

In 2007, 83 polar bears were sighted, although some of the bears may have been counted twice (Fig. 38). No bears were seen on Cross Island, as they have in past years, but all polar bears were found on shore along the coast. Bear sightings were clustered west of Deadhorse, east of Flaxman Island (West Camden Bay) and near Kaktovik. Bears were seen on 12 of 18 flights, from 3 September to 7 October. The largest bear group (13 animals) was seen near Kaktovik on Barter Island; other polar bears were seen alone or in small groups of two to seven animals.

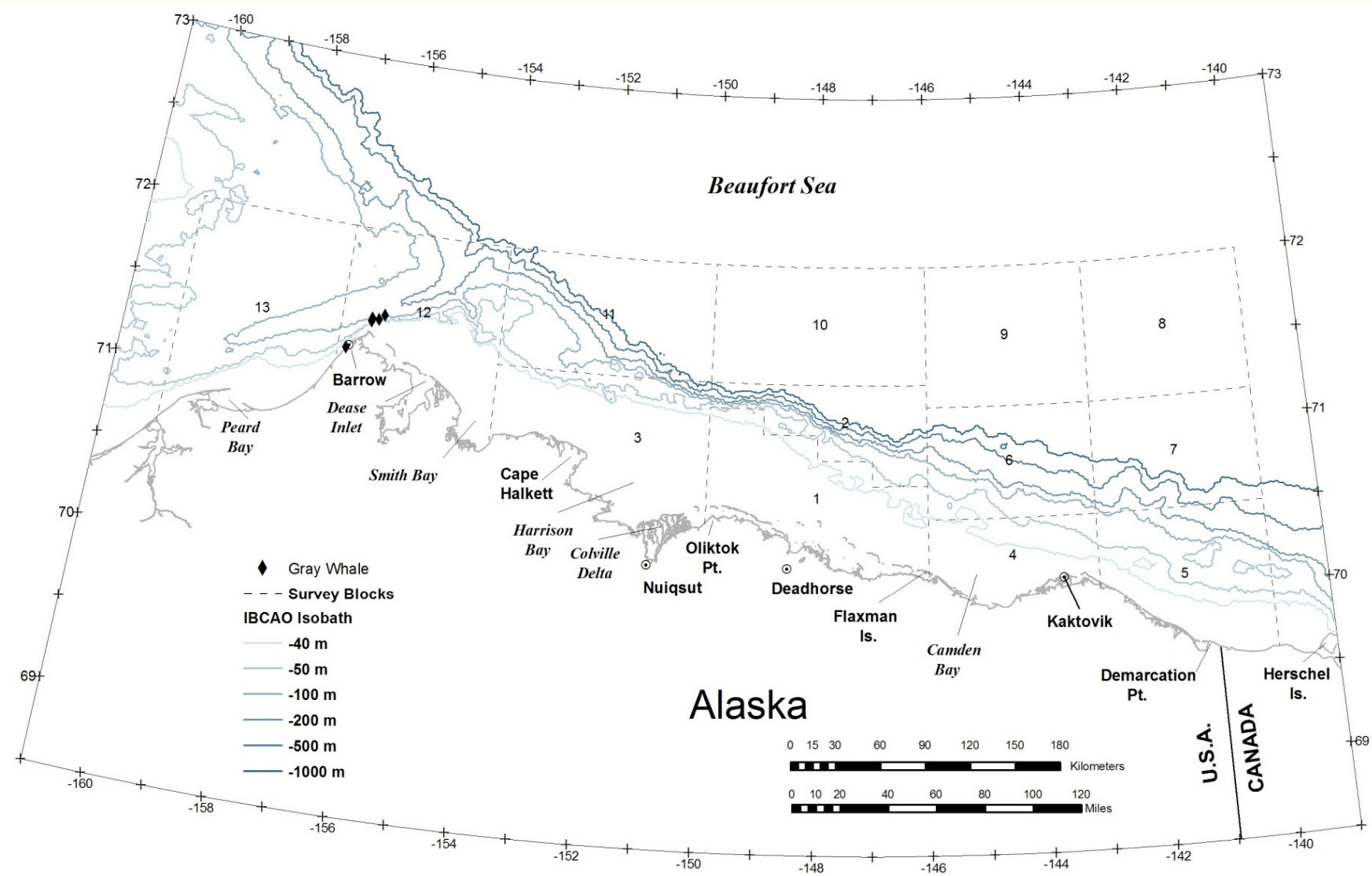

Figure 32. -- Gray whale sightings, fall 2007.

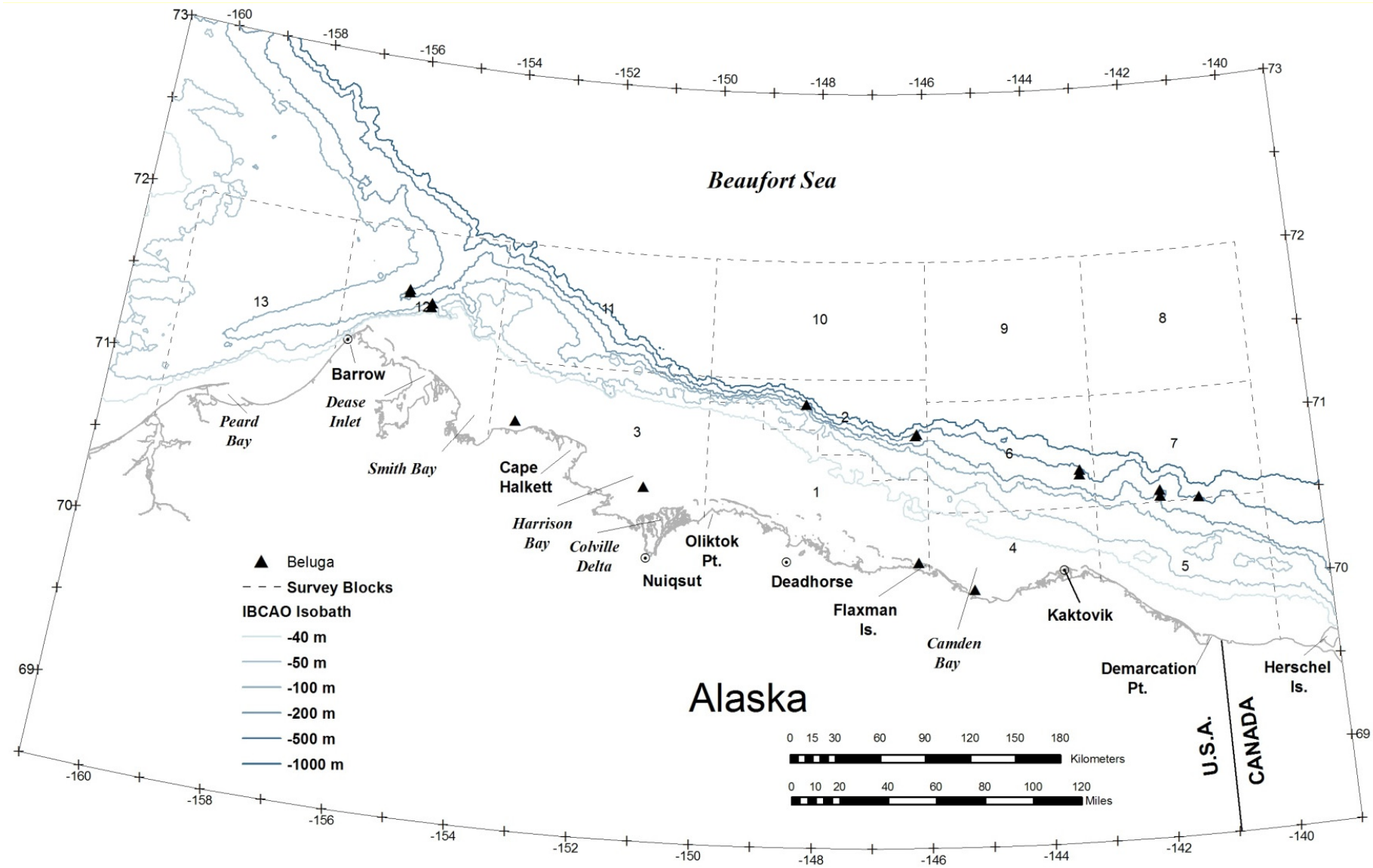

Figure 33. -- Beluga sightings, fall 2007.

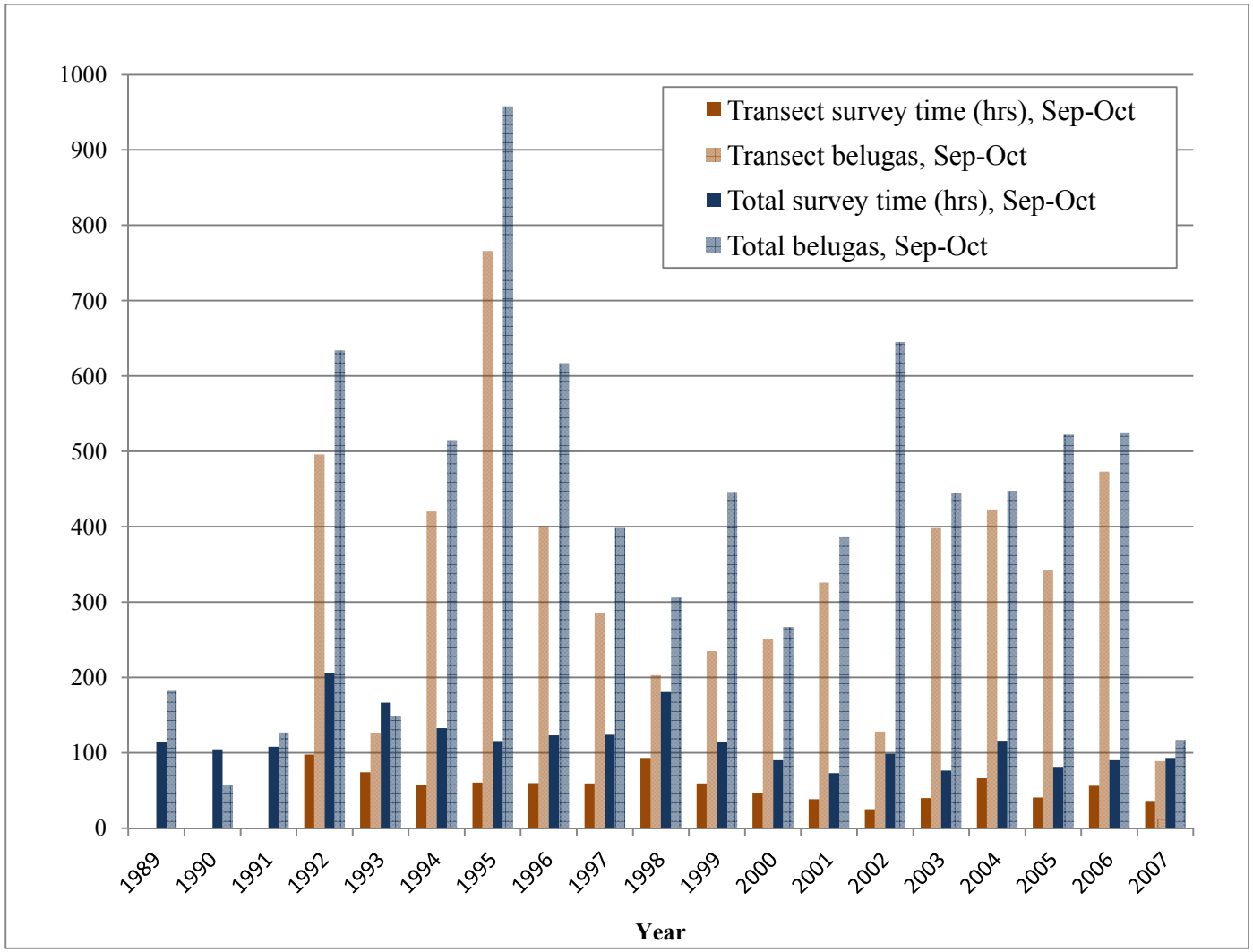

Figure 34. -- Number of belugas and annual effort (hour), total and transect only, 1989-2007. Transect data not available for 1989-1991.

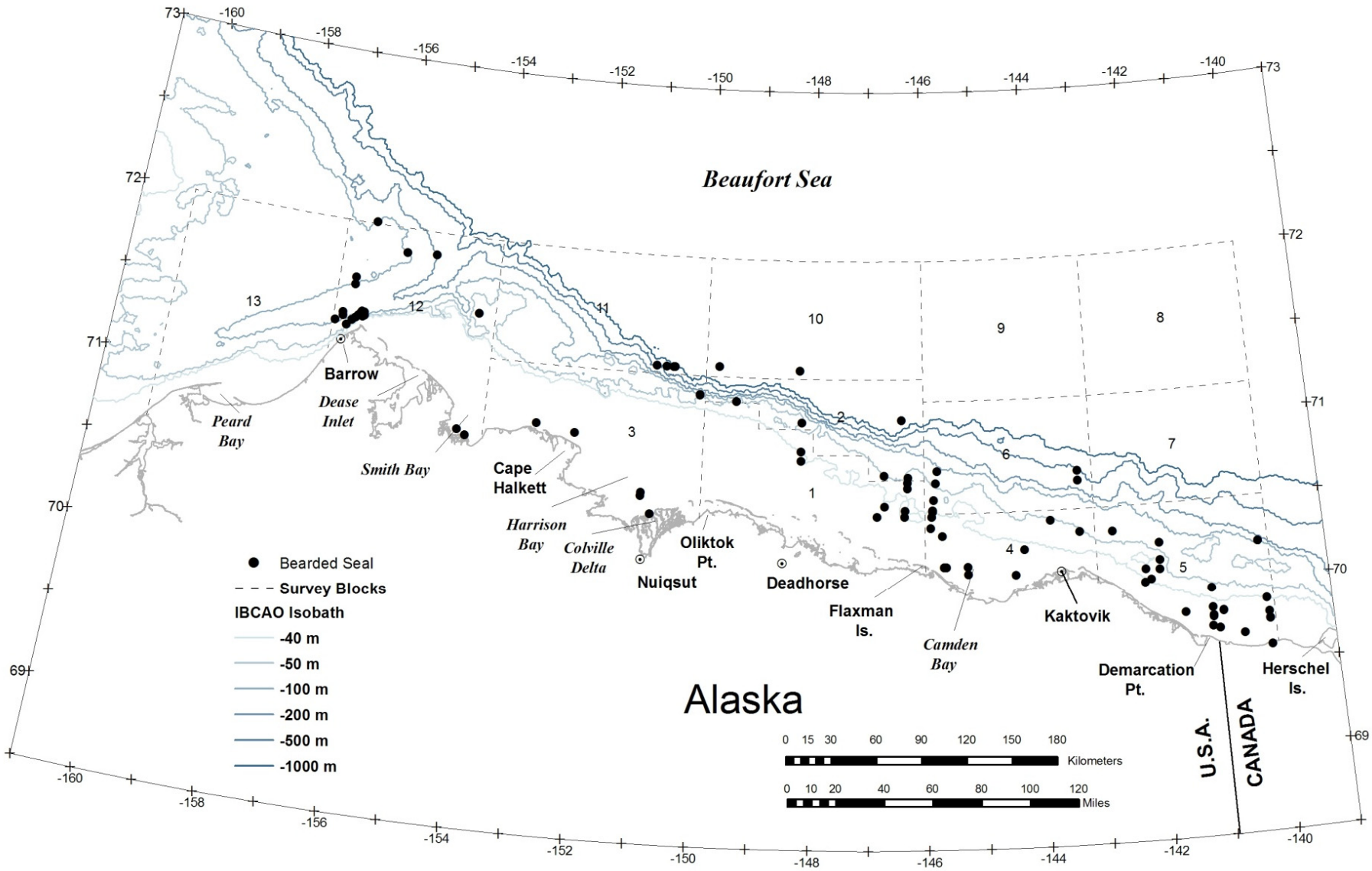

Figure 35. -- Bearded seal sightings, fall 2007.

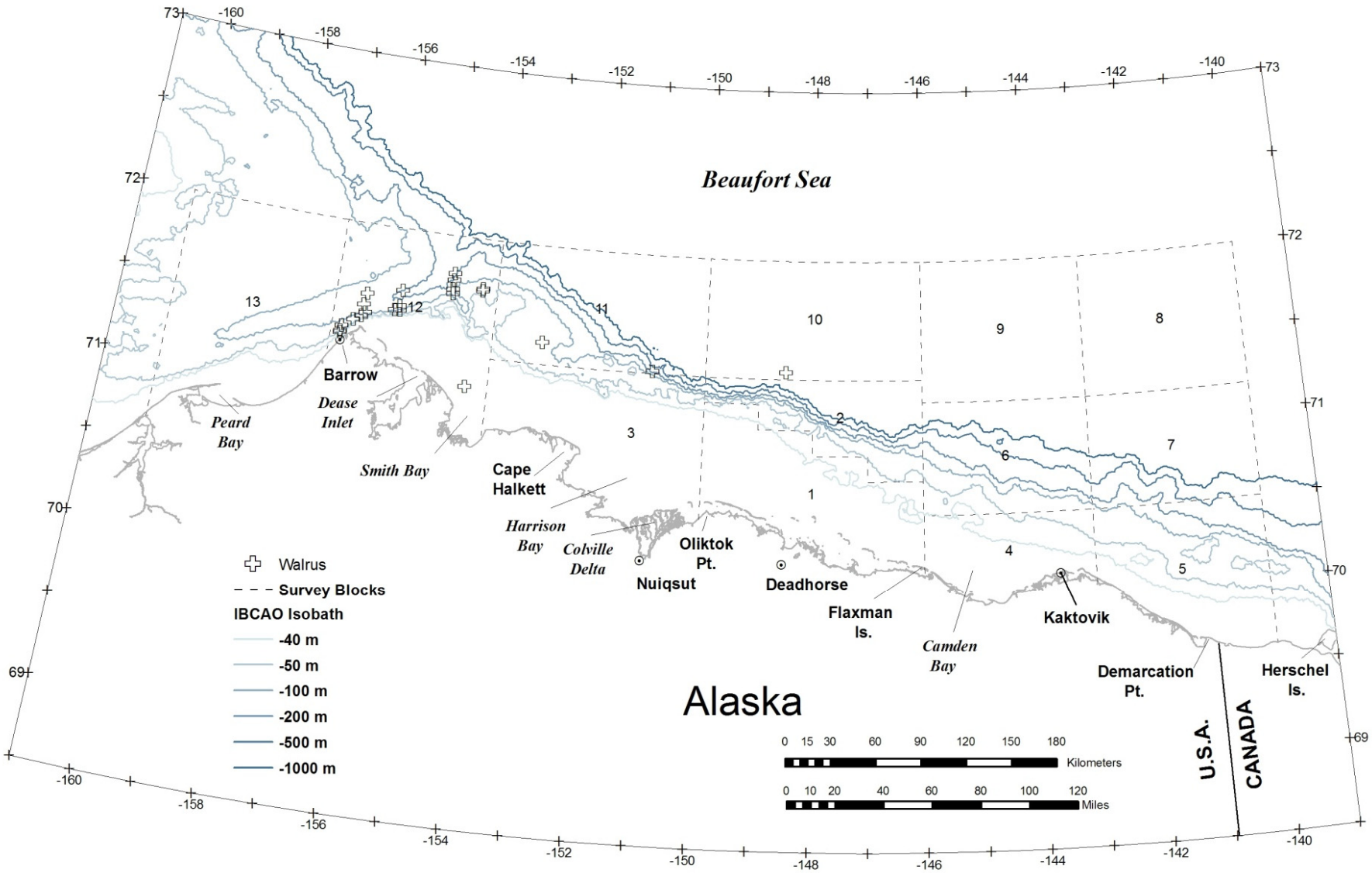

Figure 36. -- Pacific walrus sightings, fall 2007.

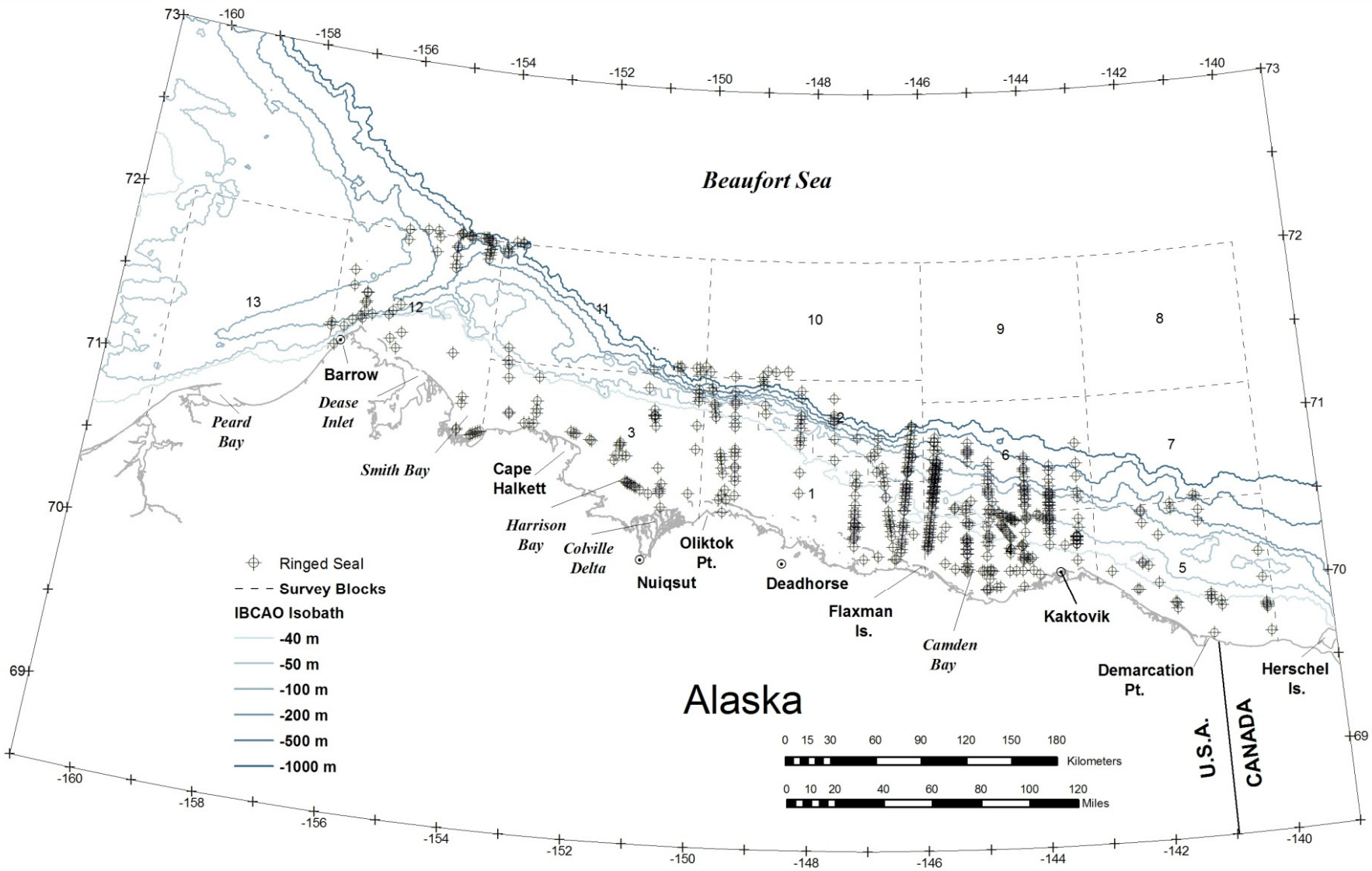

Figure 37. -- Ringed seal sightings, fall 2007.

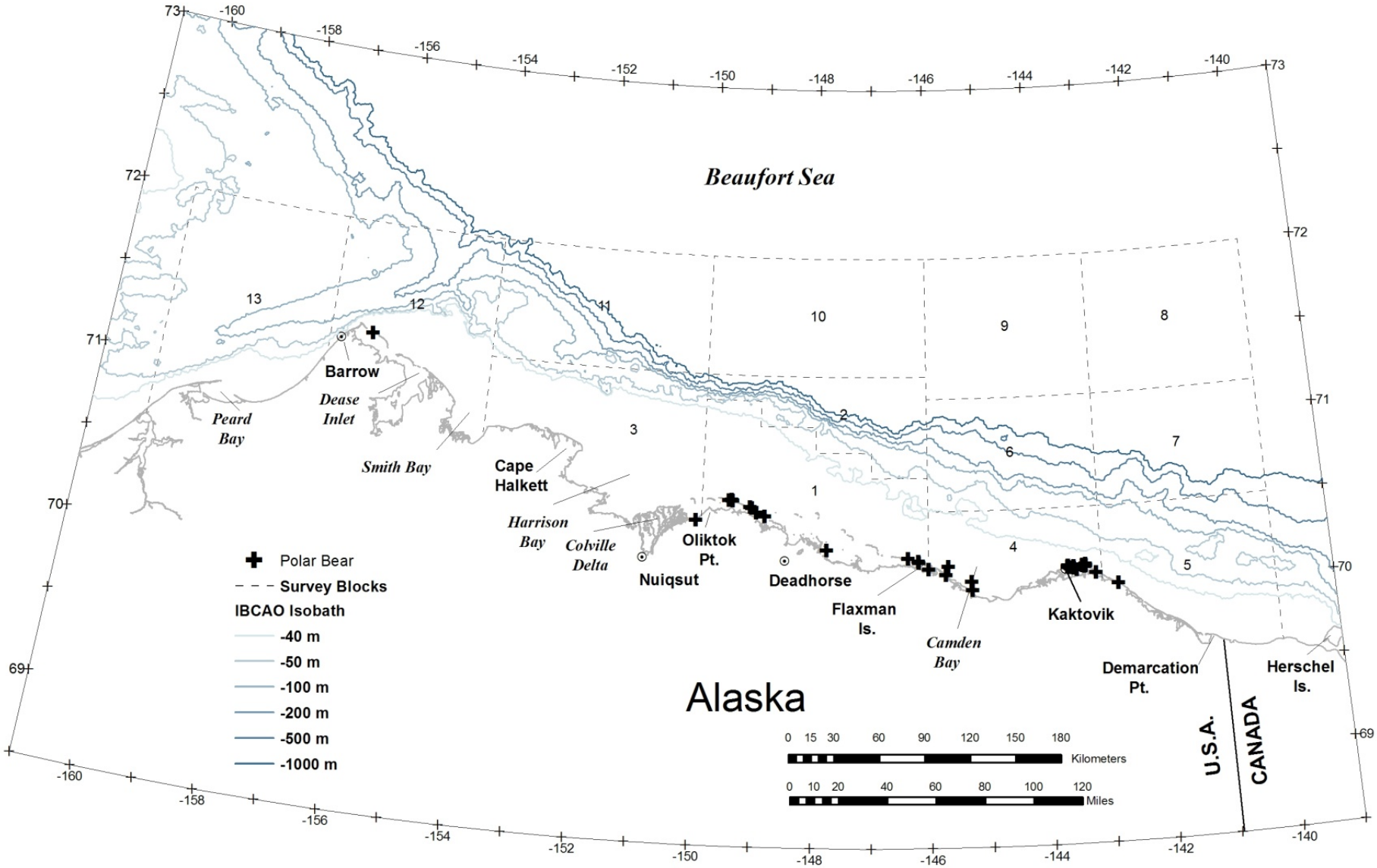

Figure 38. -- Polar bear sightings, fall 2007.

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Fall 2008

Environmental Conditions

Sea ice coverage in the Alaskan Beaufort Sea was extremely light during the BWASP 2008 survey period. Sea ice extent in 2008 receded to the second lowest level since satellite measurements began in 1979, and second only to 2007 (National Snow and Ice Data Center 2008). For most of the survey season, ice persisted only in the far eastern offshore Survey Blocks (Blocks 7 and 8) (Figs. G-1 to G-5). New/grease ice started to form in early October in the offshore areas and, by mid-October, much of the eastern half of the study area was covered with new ice. Ice percentage and sea state at each bowhead whale sighting are shown in Appendix H. The absence of sea ice in most of the study area in 2008 led to higher than preferred sea state conditions on many potential survey days. For purposes of inter-year comparisons of bowhead whales and other marine mammal distribution and occurrence, 2008 is considered a "light ice year".

Survey Effort

The fall field season was from 5 September through 18 October 2008 (Table 15). There were 20 flights, of which 13 were in September and 7 were in October (flight numbering started at 20 because BWASP effort was preceded by aerial surveys in the Chukchi Sea in summer 2008). Over 21,000 km of trackline were flown during 107 hours in the study area; 22% of total survey effort was on deadhead (non-useable survey time). The average survey flight was 1,092 km. A total of 11,039 km of random-transect lines were flown in 54 hours. These random transects constituted 51% of the total kilometers flown and 50% of the total flight hours. Survey flight lines are summarized by semimonthly period in Figures 39 through 42. During most semimonthly periods, coverage was scattered across the entire study area. Survey coverage was highest in Blocks 1, 2, and 4, and lowest in Blocks 6 and 7. There was no effort in Survey Blocks 8, 9, and 10. Flight lines and associated sea states are shown for individual flights in Appendix I.

Bowhead Whale Observations

Sighting Summary -- During fall 2008 surveys, 127 sightings of 276 bowhead whales were observed in the study area (Table 16). Bowhead whales were distributed throughout the survey area (Fig. 43). There were few sightings of bowhead whales east of Kaktovik (Block 5), and the greatest number of sightings occurred in the central Alaskan Beaufort Sea and east of Point Barrow. Of the 276 bowhead whales, 16 were identified as calves, including 8 calves observed on 18 September northeast of Deadhorse (Appendix H). The resulting seasonal calf ratio (number of calves/total whales) was 0.058. Locations of bowhead whale sightings are shown by semimonthly period in Figures 44 through 46.

Table 15. -- Daily and semimonthly aerial survey effort in the Beaufort Sea, 5 September-18 October 2008. Distance measurements and time calculations are rounded.

Day	Flight no.	Transect (km)	Connect (km)	Search (km)	Deadhead (km)	Total (km)	Transect (hr)	Total (hr)
5 Sep	20	188	60	373	349	970	0.9	4.4
7 Sep	21	0	0	190	371	561	0.0	3.0
10 Sep	22	769	195	251	88	1,303	3.7	6.9
12 Sep	23	1,054	117	180	113	1,464	5.3	7.7
14 Sep	24	629	88	265	105	1,087	3.1	5.1
18 Sep	25	589	138	188	284	1,199	3.0	6.0
19 Sep	26	832	163	170	239	1,404	4.1	7.6
23 Sep	27	320	39	219	433	1,011	1.6	4.9
24 Sep	28	575	51	198	214	1,038	2.9	5.7
25 Sep	29	529	63	108	73	773	2.6	3.9
26 Sep	30	985	166	56	222	1,429	4.8	7.2
27 Sep	31	13	0	226	415	654	0.1	2.6
28 Sep	32	448	78	440	124	1,090	2.2	5.3
1 Oct	33	294	26	206	584	1,110	1.5	4.7
8 Oct	34	759	101	328	204	1,392	3.6	6.6
9 Oct	35	872	186	149	244	1,451	4.2	7.2
11 Oct	36	121	18	146	232	517	0.6	2.2
13 Oct	37	715	80	157	41	993	3.5	5.1
17 Oct	38	823	131	164	140	1,258	3.9	6.2
18 Oct	39	524	125	116	362	1,127	2.5	5.1
			Semimonthly Effort Summary					
5-15 Sep		2,640	460	1,259	1,026	5,385	12.9	27.0
16-30 Sep		4,291	698	1,605	2,004	8,598	21.2	43.0
1-15 Oct		2,761	411	986	1,305	5,463	13.3	25.8
16-18 Oct		1,347	256	280	502	2,385	6.3	11.3
Total		11,039	1,825	4,130	4,837	21,831	53.7	107.0

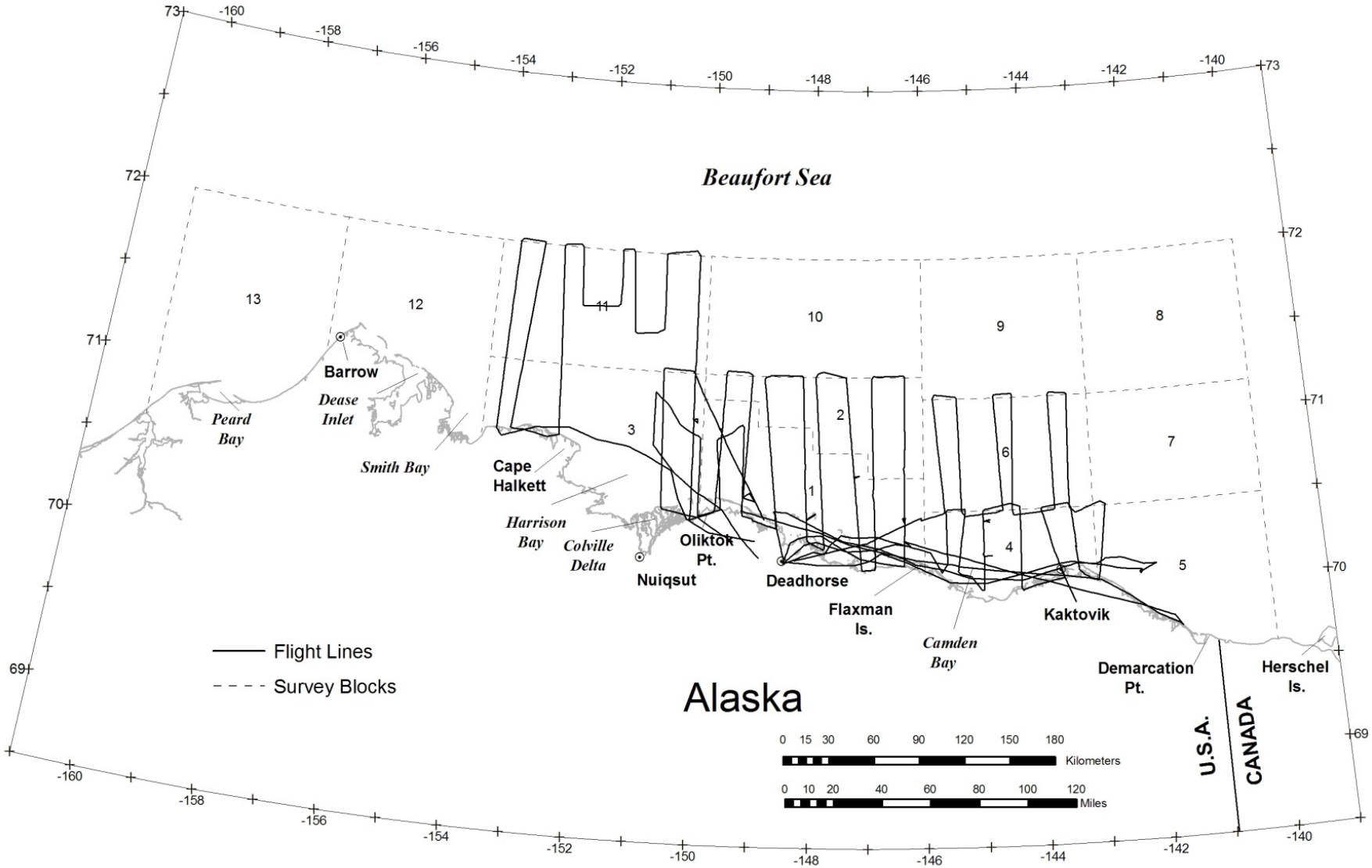

Figure 39. -- Combined flight tracks, 5–15 September 2008.

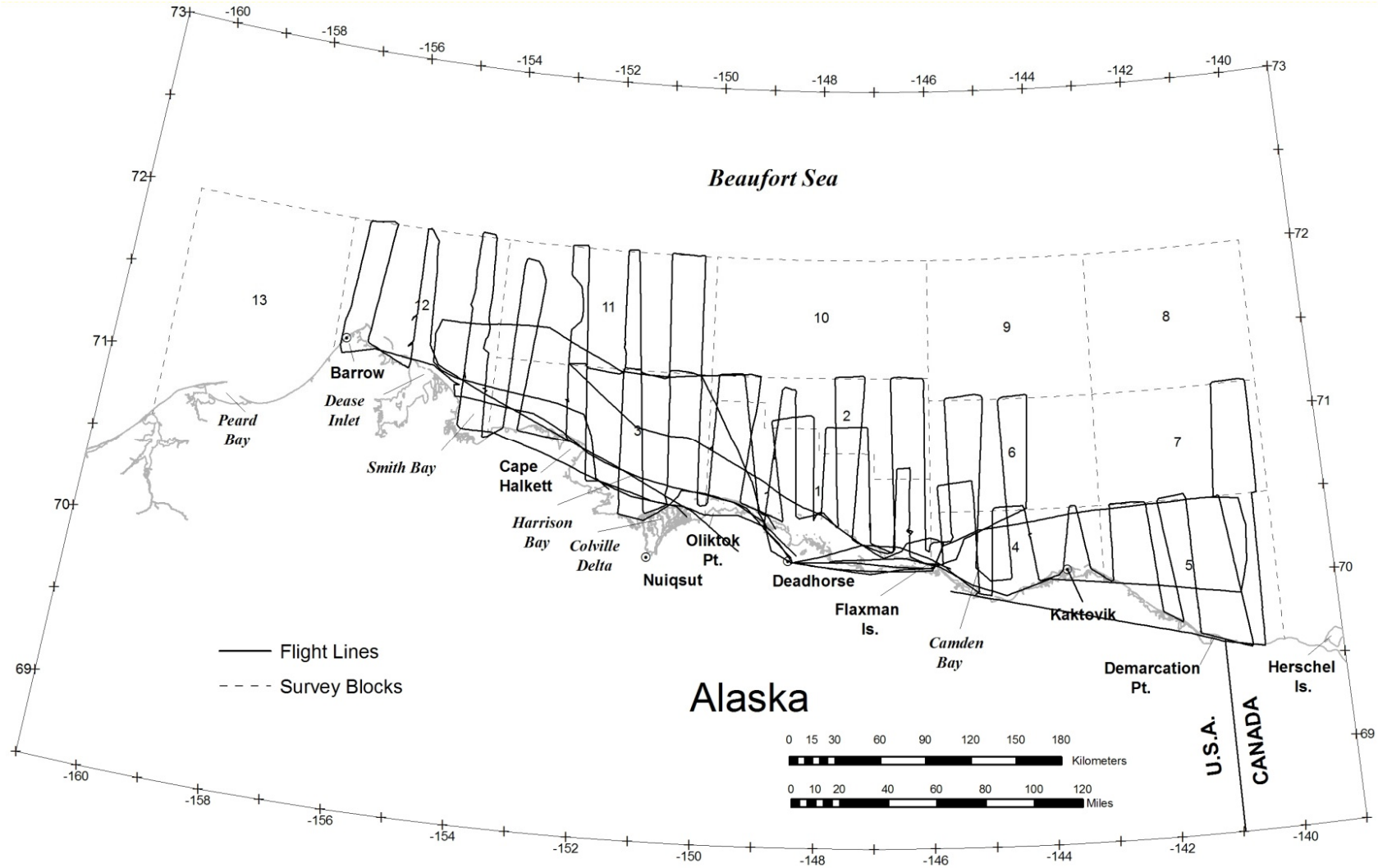

Figure 40. -- Combined flight tracks, 16-30 September 2008.

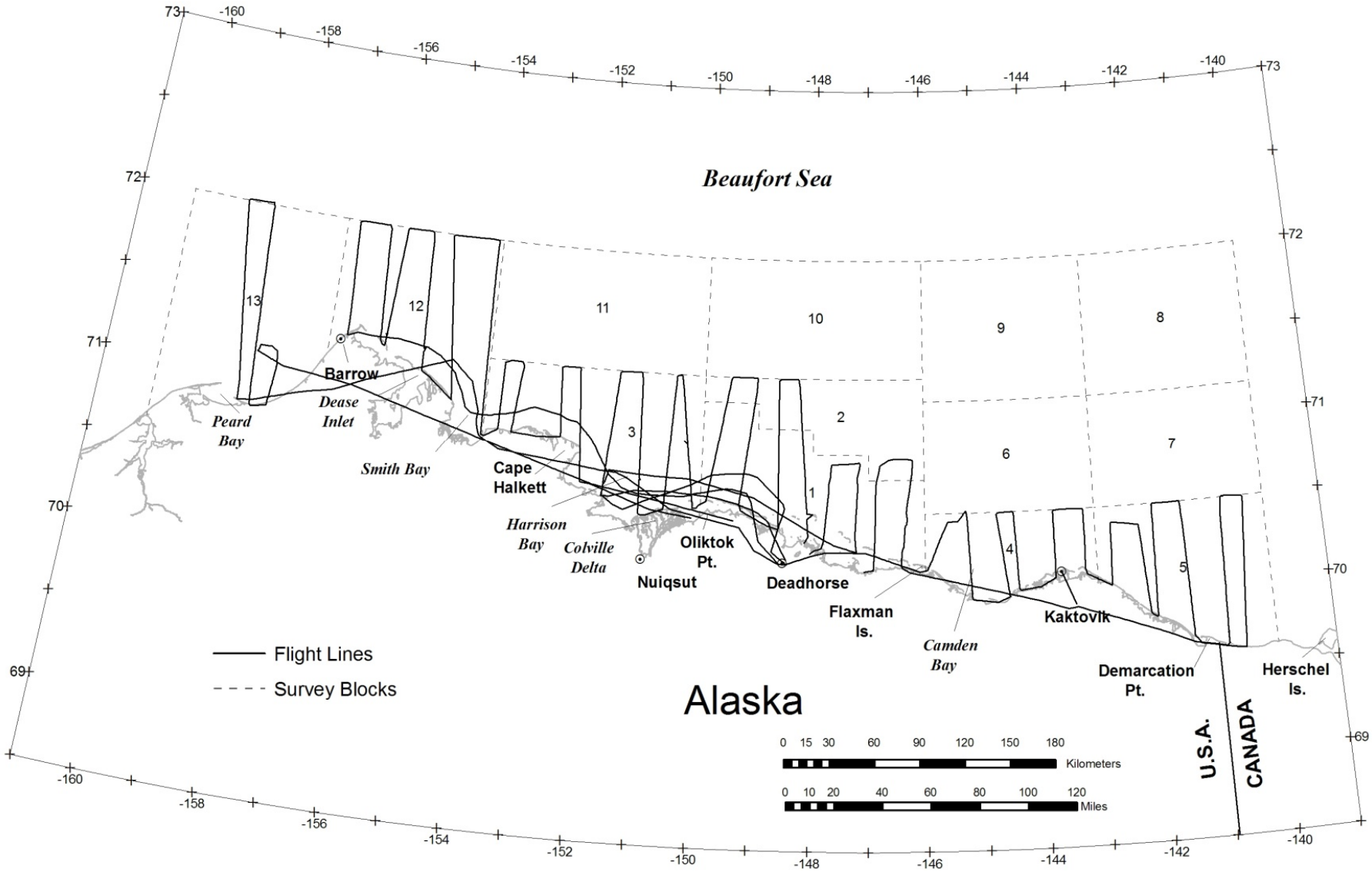

Figure 41. -- Combined flight tracks, 1–15 October 2008.

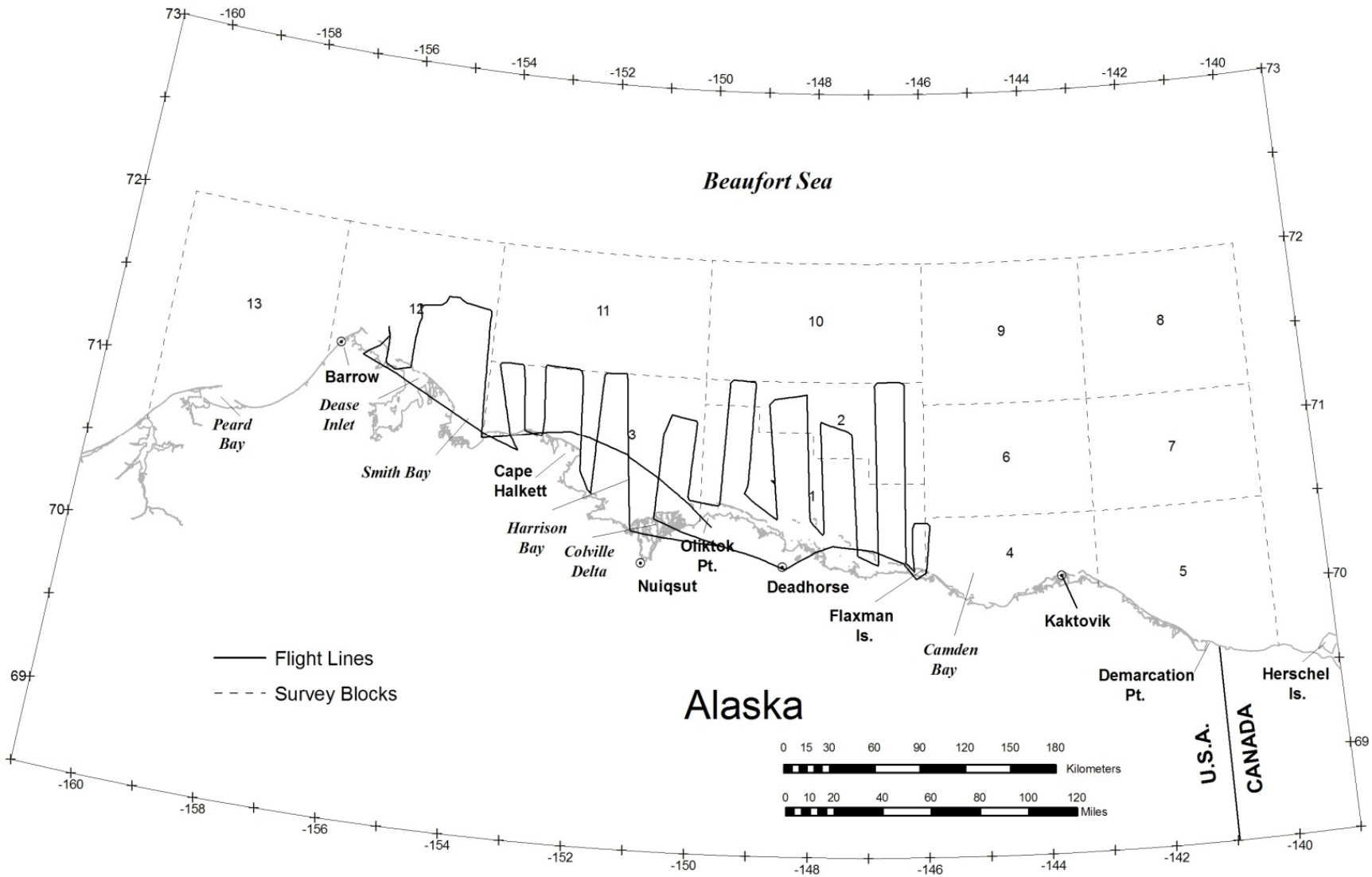

Figure 42. -- Combined flight tracks, 16-18 October 2008.

Table 16. -- Daily and semimonthly summary of marine mammal sightings, 5 September-18 October 2008, showing number of sightings and number of individuals (i.e., no. of sightings/no. of individuals).

Day	Flight no.	Bowhead whale	Gray whale	Beluga	Unidentified cetacean	Bearded seal	Ringed seal	Walrus	Unidentified pinniped	Polar bear	Polar bear tracks
5 Sep	20	5/8	0	0	3/3	0	0	0	1/1	1/1	0
7 Sep	21	4/5	0	0	0	4/5	0	0	3/3	1/1	0
10 Sep	22	13/19	0	0	2/3	0	0	0	1/1	1/1	0
12 Sep	23	11/14	0	0	0	8/8	0	0	7/7	3/14	0
14 Sep	24	0	0	0	0	2/2	0	0	8/14	0	0
18 Sep	25	19/45	0	0	0	0	0	0	1/1	4/19	0
19 Sep	26	6/7	0	1/1	2/2	3/4	0	0	39/109	0	0
23 Sep	27	19/44	1/1	1/2	0	7/8	0	0	12/48	1/1	0
24 Sep	28	19/46	0	1/1	0	1/1	0	0	5/19	2/2	0
25 Sep	29	2/2	0	0	1/1	4/4	0	0	5/6	2/2	0
26 Sep	30	6/11	0	0	0	5/7	0	0	5/8	2/15	0
27 Sep	31	0	0	0	0	0	0	0	1/1	0	0
28 Sep	32	4/6	0	2/11	0	5/10	0	0	20/65	2/17	0
1 Oct	33	0	1/1	0	1/2	0	0	0	0	0	0
8 Oct	34	16/66	0	0	1/1	0	0	0	0	1/1	0
9 Oct	35	1/1	0	0	0	1/1	0	0	0	0	0
11 Oct	36	0	0	0	0	0	0	0	0	0	0
13 Oct	37	2/2	0	0	0	2/2	0	0	1/1	1/22	0
17 Oct	38	0	0	0	0	0	0	0	1/1	1/7	0
18 Oct	39	0	0	0	0	0	0	0	0	0	0
Semimonthly Sightings Summary											
5-15 Sep		33/46	0	0	5/6	14/15	0	0	20/26	6/17	0
16-30 Sep		75/161	1/1	5/15	3/3	25/34	0	0	88/257	13/56	0
1-15 Oct		19/69	1/1	0	2/3	3/3	0	0	1/1	2/23	0
16-18 Oct		0	0	0	0	0	0	0	1/1	1/7	0
Total		127/276	2/2	5/15	10/12	42/52	0	0	110/285	22/103	0

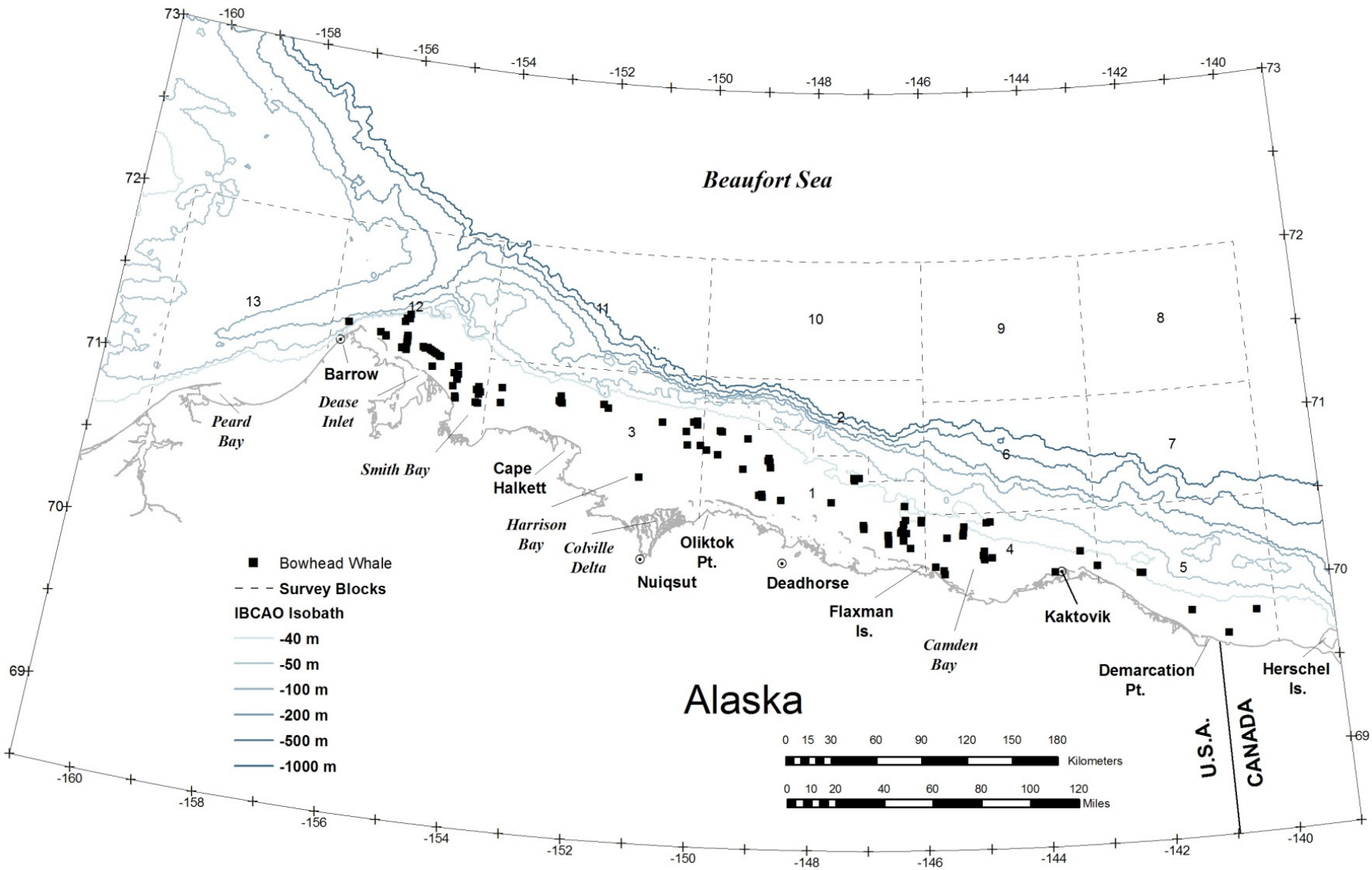

Figure 43. -- Bowhead whale sightings, fall 2008.

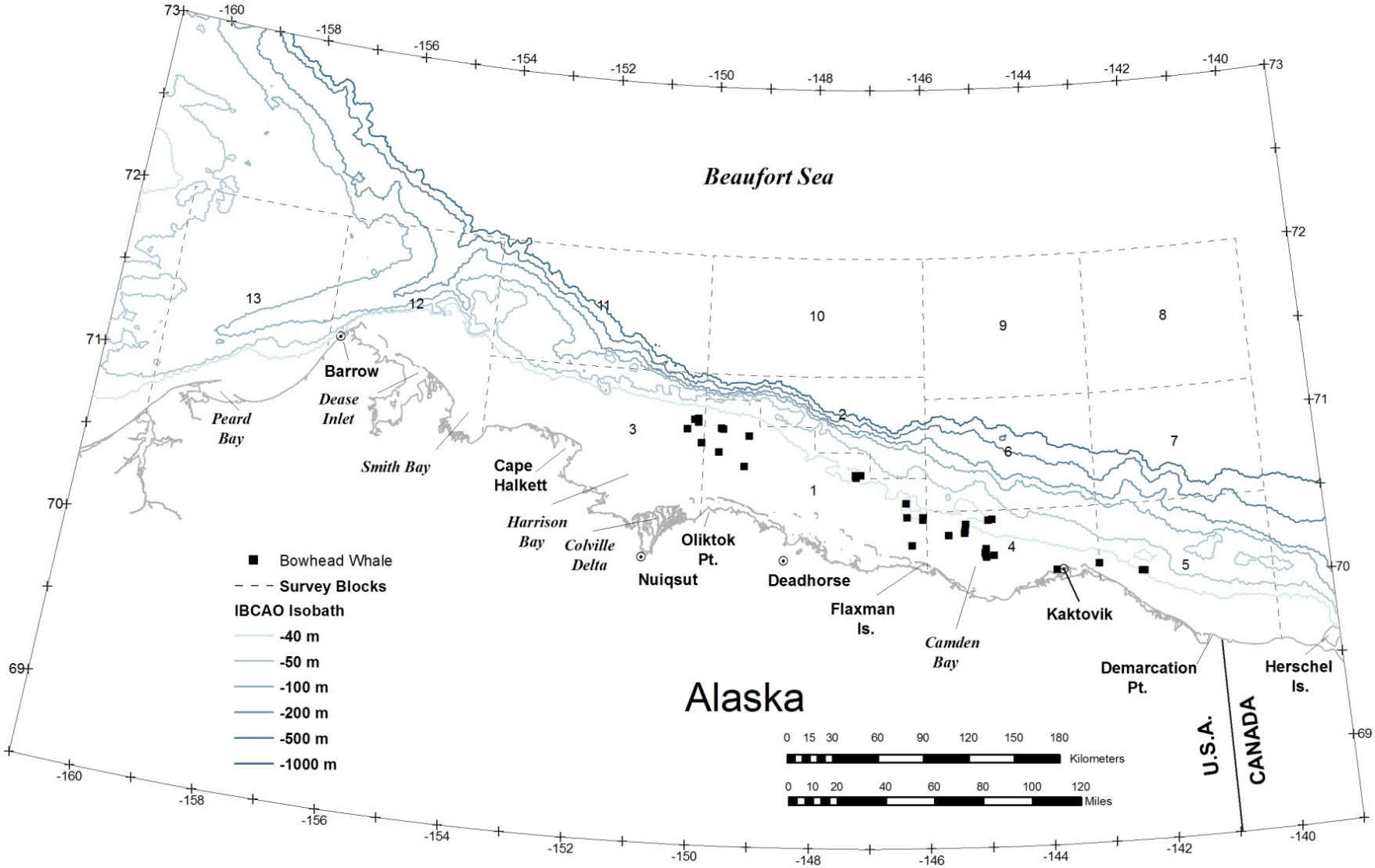

Figure 44. -- Bowhead whale sightings, 5-15 September 2008.

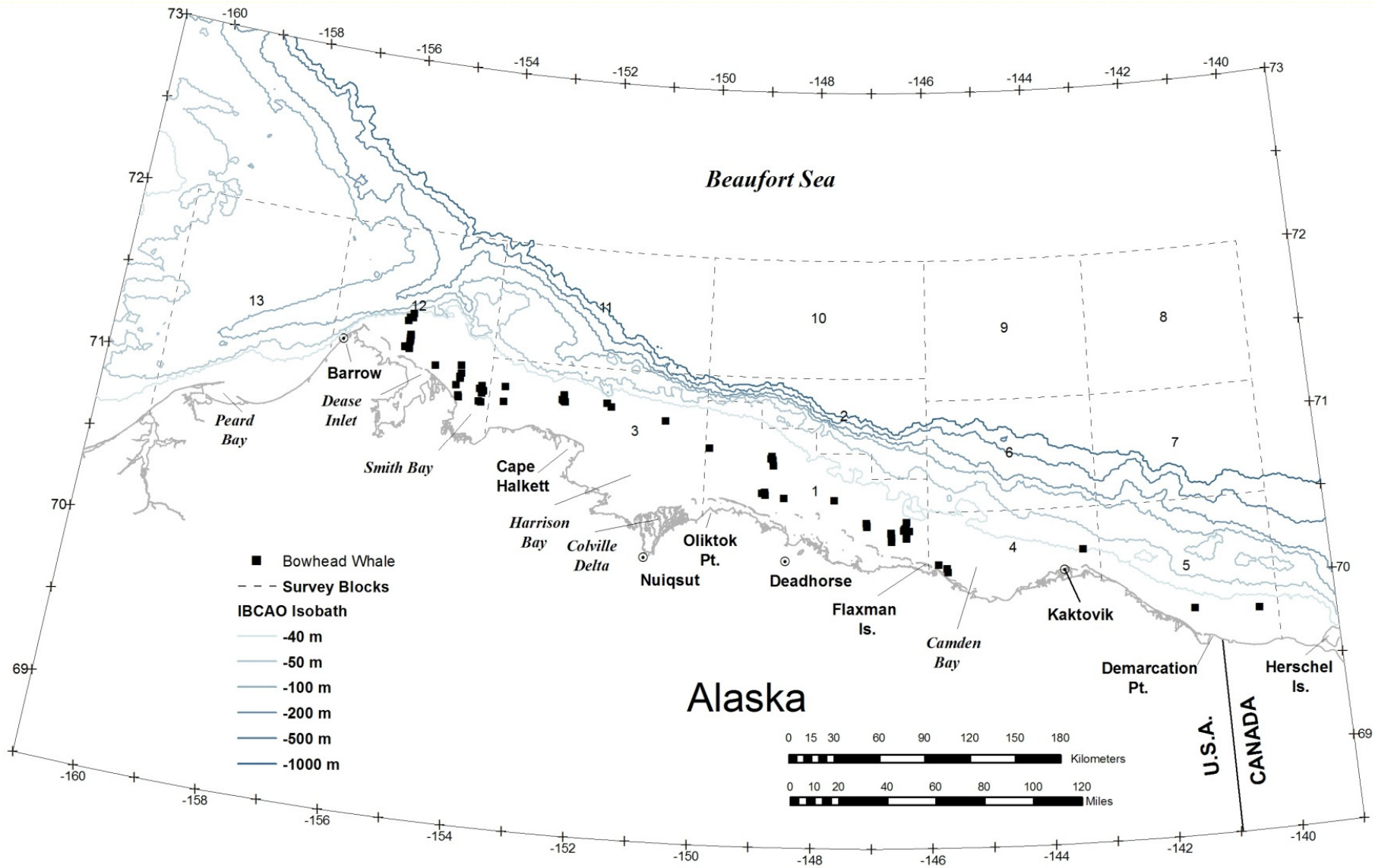

Figure 45. -- Bowhead whale sightings, 16-30 September 2008.

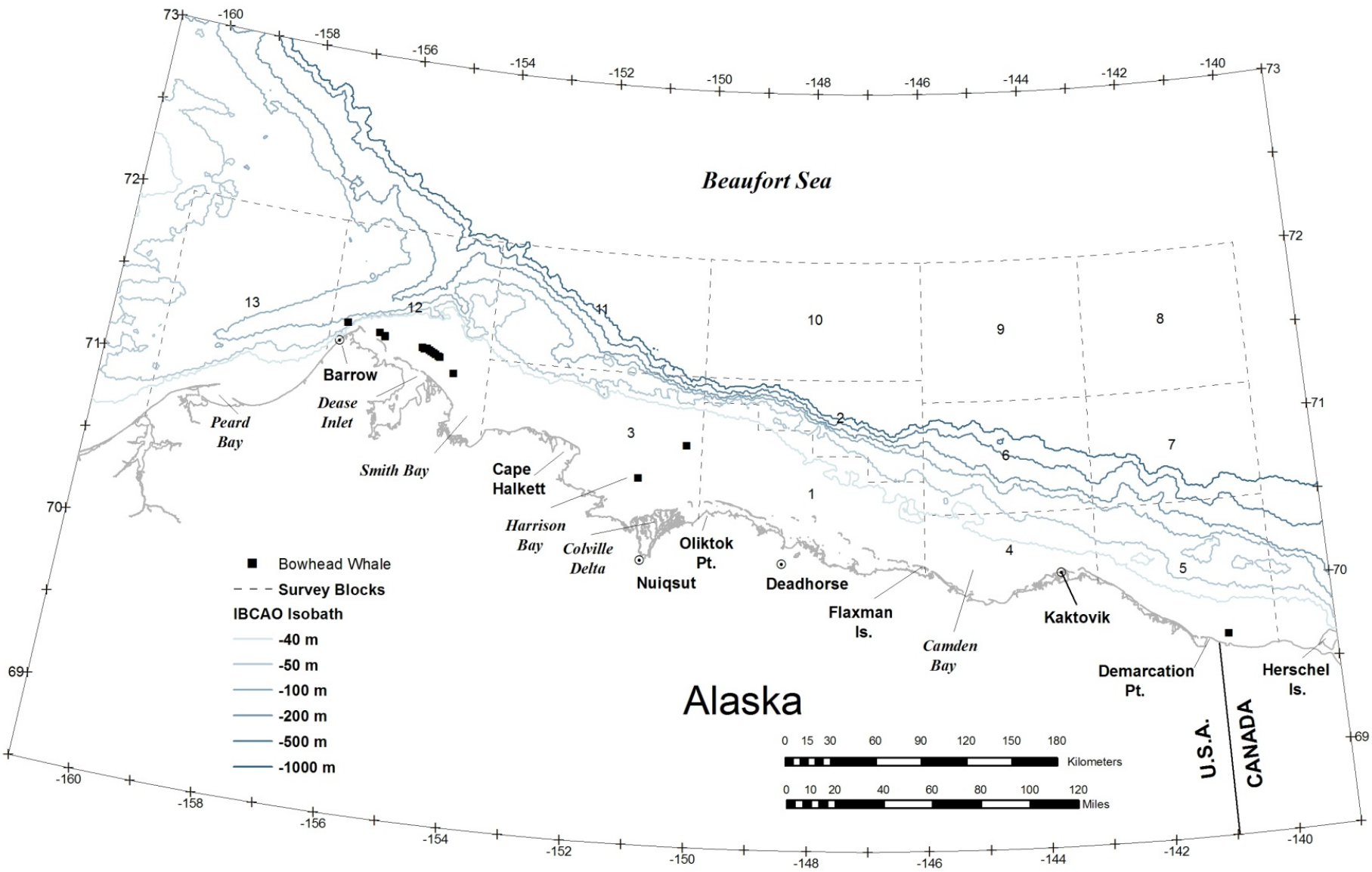

Figure 46. -- Bowhead whale sightings, 1-15 October 2008.

Table 17. -- Survey effort, number of bowhead whales per Survey Block, and sighting rate (WPUE; whales per km surveyed) by Survey Block for bowhead whales on transect, fall 2008.

Block	Total effort (km)*	Total bowhead (no. animals)	Transect effort (km)*	Transect bowhead (no. animals)	Transect WPUE
1	3,518	78	2,288	29	0.013
2	1,474	0	1,082	0	0.000
3	3,409	24	2,026	12	0.006
4	1,668	20	966	12	0.012
5	1,335	7	998	3	0.003
6	992	0	780	0	0.000
7	229	0	149	0	0.000
8	0	0	0	0	0
9	0	0	0	0	0
10	0	0	0	0	0
11	1,231	0	1,033	0	0.000
12	1,790	147	1,240	58	0.047
13	363	0	294	0	0.000
Total	16,009	276	10,856	114	0.011

*Total and Transect Effort (km) do not match values in Table 15 because effort between barrier islands and the mainland were not included in the sighting rate analysis by block.

Sighting Rates -- In fall 2008, bowhead whales were seen from Point Barrow to Canada. Areas of greatest fine-scale sighting rates (transect whales/transect km surveyed) were northwest of Smith Bay and northeast of Deadhorse (Fig. 47). The largest group of bowhead whales on transect (12 animals) was observed on 8 October northeast of Smith Bay. Fewer large groups were recorded on transect than in previous years, likely due to conservative recording of initial group size observed while on transect (on effort), compared with sightings that were made after diverting from the transect line, which were consequently categorized as sightings made while on search (off effort).

Highest sighting rates by Survey Block were in Block 12 (0.047 bowhead whales on transect/transect km flown), Block 1 (0.013 bowhead whales on transect/transect km flown) and Block 4 (0.012 bowhead whales on transect/transect km flown) (Table 17). Sighting rates using all bowhead whale sightings by Survey Block were similar to sighting rates using bowhead whales seen on transect only. Previous Survey Block sighting rate analyses for light ice years (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. Nonetheless, the pattern of highest sighting rates per year is similar across all years. In light ice

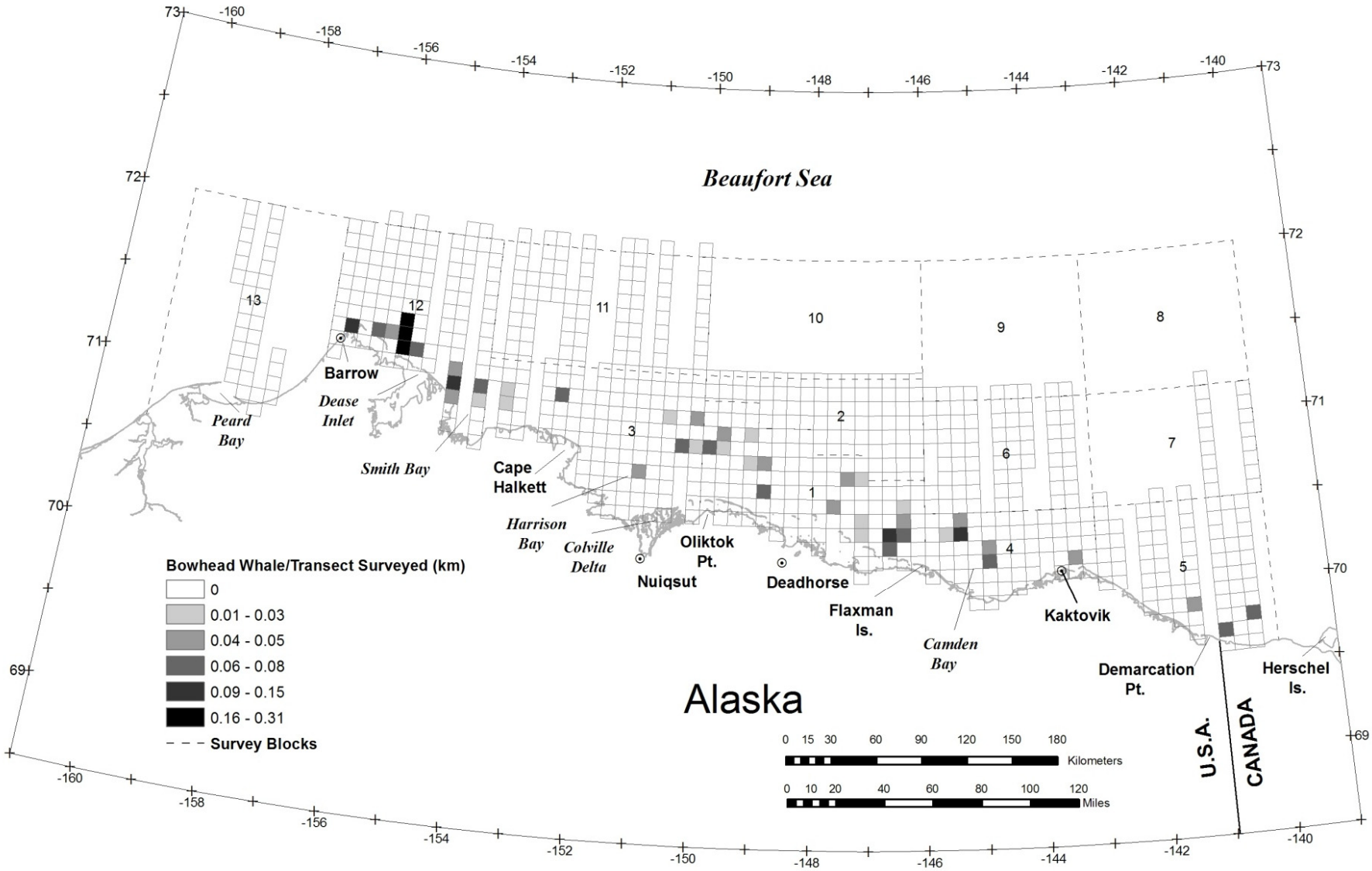

Figure 47. -- Sighting rates of bowhead whales, fall 2008 (transect whales/transect km surveyed).

Table 18. -- Semimonthly summary of bowhead whales observed by percent ice cover at sighting location, fall 2008.

Percent Ice cover	5-15 Sep	16-30 Sep	1-15 Oct	Total
0	46 (100%)	161 (100%)	66 (95%)	273 (98%)
1-5	0	0	1 (1%)	1 (< 1%)
11-20	0	0	1 (1%)	1 (< 1%)
41-50	0	0	1 (1%)	1 (< 1%)
Total	46	161	69	276

Table 19. -- Semimonthly summary of bowhead whales observed by behavioral category, fall 2008. Behavior was not recorded for all sightings.

Behavior	5-15 Sep	16-30 Sep	1-15 Oct	Total
breach	0	5 (3%)	0	5 (2%)
cow with calf	4 (8%)	27 (17%)	0	31 (12%)
dive	1 (2%)	3 (1%)	0	4 (1%)
feed	0	8 (5%)	22 (46%)	30 (12%)
mate	0	4 (2%)	0	4 (1%)
mill	0	15 (9%)	2 (4%)	17 (6%)
rest	2 (4%)	1 (< 1%)	1 (2%)	4 (1%)
swim	39 (84%)	88 (58%)	22 (46%)	149 (61%)
Total	46	151	47	244

years, highest sighting rates are generally in coastal Survey Blocks (1, 3, 4, 5, and 12) and are usually correlated with large groups of bowhead whales in feeding or milling aggregations.

Habitat Associations -- Weekly ice coverage for the Alaskan Beaufort Sea during fall 2008 is included in Appendix G, and the percentage of ice cover visible from the aircraft at each bowhead whale sighting is included in Appendix H. Of the 276 bowhead whales counted over the field season, 273 whales (98%) were sighted in open water, 2 (1%) whales were observed in 1-20% sea ice, and 1 (< 1%) whale was observed in 41-50% sea ice coverage (Table 18).

Behaviors -- Behaviors of 244 bowhead whales observed during fall 2008 are summarized in Table 19. The behavior most often recorded was swimming (61%). Feeding was observed in 30 whales (12%). Sighting rates of feeding and milling whales are shown in Figure 48. Feeding and milling were infrequently observed in 2008, compared with previous years. Feeding behavior is not always detectable during aerial surveys and is likely underestimated in the database.

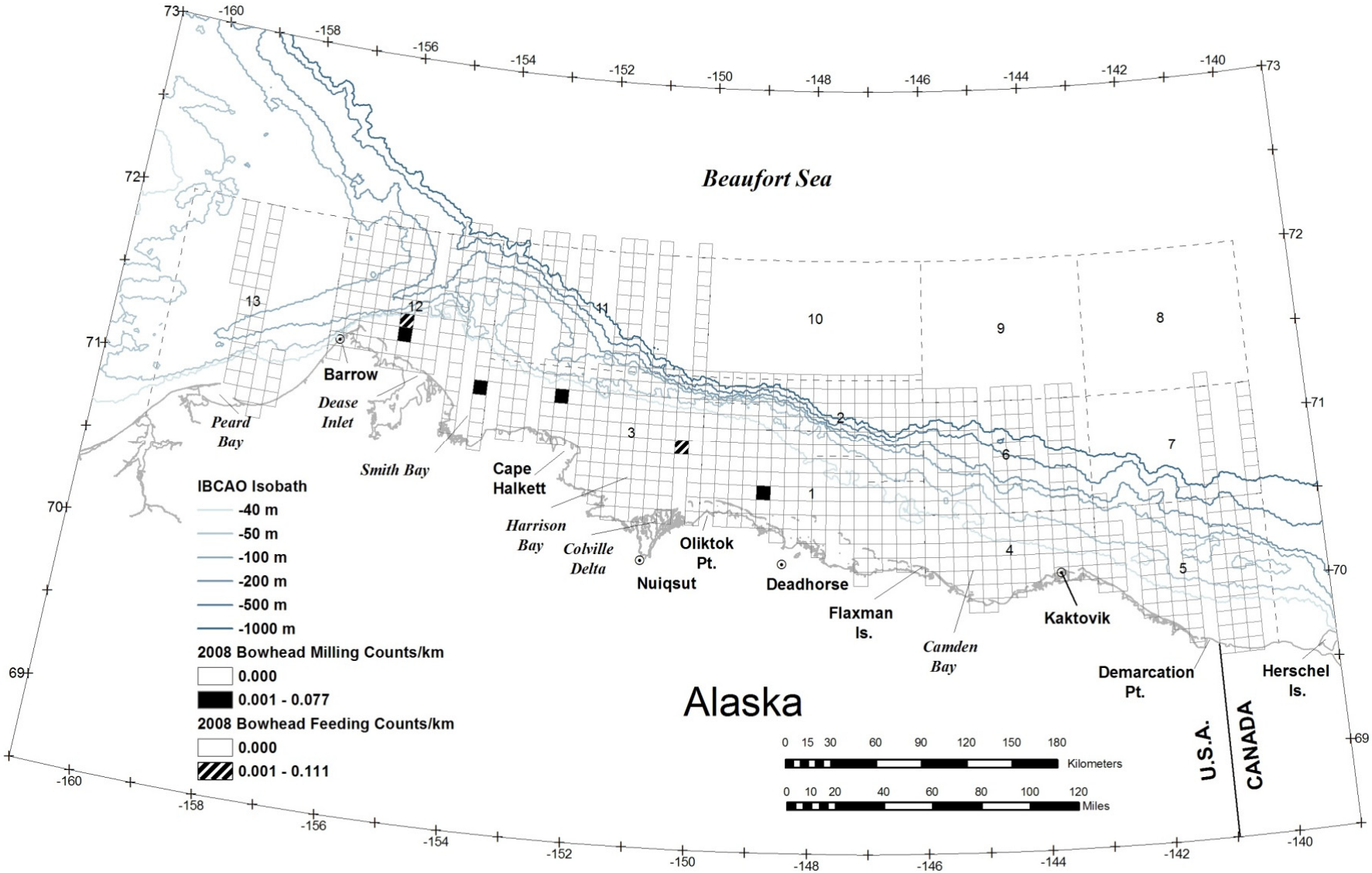

Figure 48. -- Sighting rates of feeding and milling bowhead whales, fall 2008 (transect whales/transect km surveyed).

Marine mammal observers and the flight crew watched for sudden overt changes (e.g., an abrupt dive, course diversion, or cessation of initial behavior observed) in whale behavior which may indicate a response to the survey aircraft; no responses were observed.

Distance from Shore -- Distances from shore of fall 2008 bowhead whale sightings made on transect were measured using ArcGIS, as the distance due north of a normalized shoreline. Mean distance from locations of all bowhead whale sightings on transect to a normalized shoreline in 2008 was 20.5 km (SD = 10.7) in the East Region and 22.6 km (SD = 13.9) in the West Region (Fig. 49, Table 20). Mean distance from locations of "migrating" bowhead whales on transect (i.e., excluding sightings of feeding, milling or resting whales), was 23.1 km (SD = 14.9) in the West Region (Fig. 50). A Mann-Whitney U-test of significant difference of the median distance from shore indicated no difference between distances of all whales versus distances of only those whales considered "migrating" in the West Region ($Z = -0.088$, $P = 0.9297$). Comparison of migrating bowhead whales with all bowhead whales in the East Region was not necessary because no feeding, milling, or resting whales were recorded in that region.

Depth at Sighting -- Mean depth for sightings of all bowhead whales on transect was 28 m (SD = 7.7, range 12-40 m) in the East Region and 17 m (SD = 6.9, range 3-33 m) in the West Region (Table 20). Mean depth of "migrating" bowhead whales on transect (i.e., excluding sightings of feeding, milling, or resting whales) was 17 m (SD = 7.4, range 3-33 m) in the West Region. A Mann-Whitney U-test of significant difference of medians indicates no difference between depths of all whales versus depths of only those whales considered "migrating" in the West Region ($Z = 0.013$, $P = 0.9899$). As with distance from shore, comparison of migrating bowhead whales with all bowhead whales in the East Region was not necessary because no feeding, milling, or resting whales were recorded in that region.

Based on the lack of significant difference between all bowhead whale sightings in 2008 and sightings limited to those whales considered "migrating" (excluding feeding, milling, or resting animals), additional analyses of the bowhead whale migration corridor incorporated all sightings and were not limited to only those animals considered actively "migrating".

Distribution of Migrating Bowhead Whales, 2008, Relative to Previous Light Ice Years -- In order to evaluate whether significant displacements occurred in the bowhead whale migratory corridor during 2008, estimates of median depth at sighting and distance of sightings from a normalized shoreline were compared with comparable data from previous years having "light ice" coverage (i.e., 1982, 1986, 1987, 1989, 1990, and 1993-2007). Median distance from shore for bowhead whale sightings during previous years with "light ice" coverage was 26.9 km in the East Region ($n = 863$) and 27.0 km in the West Region ($n = 724$); the median water depth at sightings was 40 m in the East Region and 23 m in the West Region.

During 2008, bowhead whales in the East Region were significantly closer to shore (21.3 km vs 26.9 km; $Z = 2.733$, $P = 0.0063$) and in shallower water (29 m vs. 40 m; $Z = 5.148$, $P < 0.00001$) than in previous "light ice" coverage" years.

Table 20. -- Central-tendency statistics for distance from shore (km) and depth (m) at transect sightings of bowhead whales (September-October), by year and region, 1982-2008.

			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
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

Table 20. -- Continued.

			Distance from shore (km)				Depth (m)			
Year	Region	TrSi	Median	Mean	SD	Min-Max	Median	Mean	SD	Min-Max
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	8.05	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

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

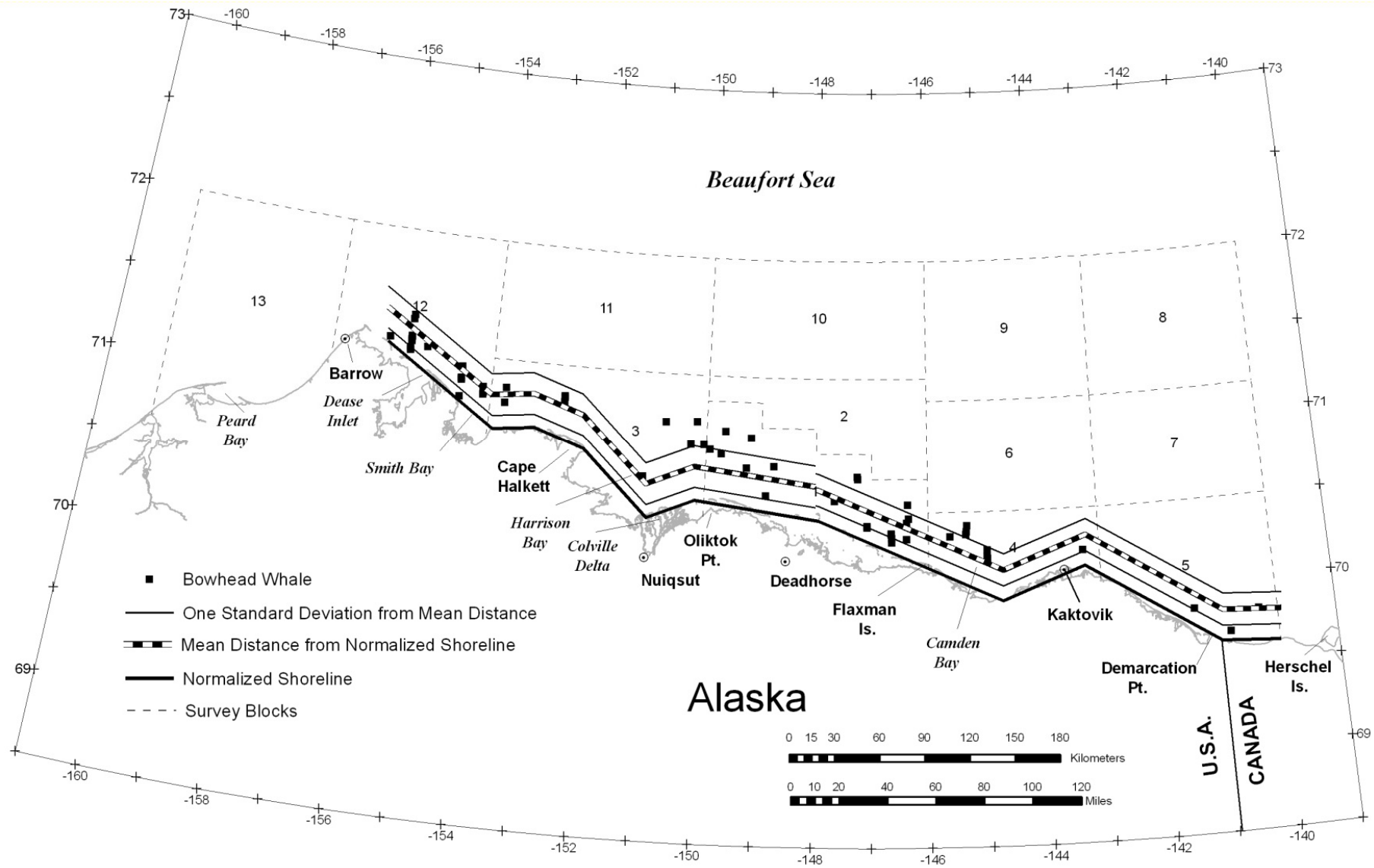

Figure 49. -- Bowhead whale sightings on transect, fall 2008, showing mean distance from a normalized shoreline.

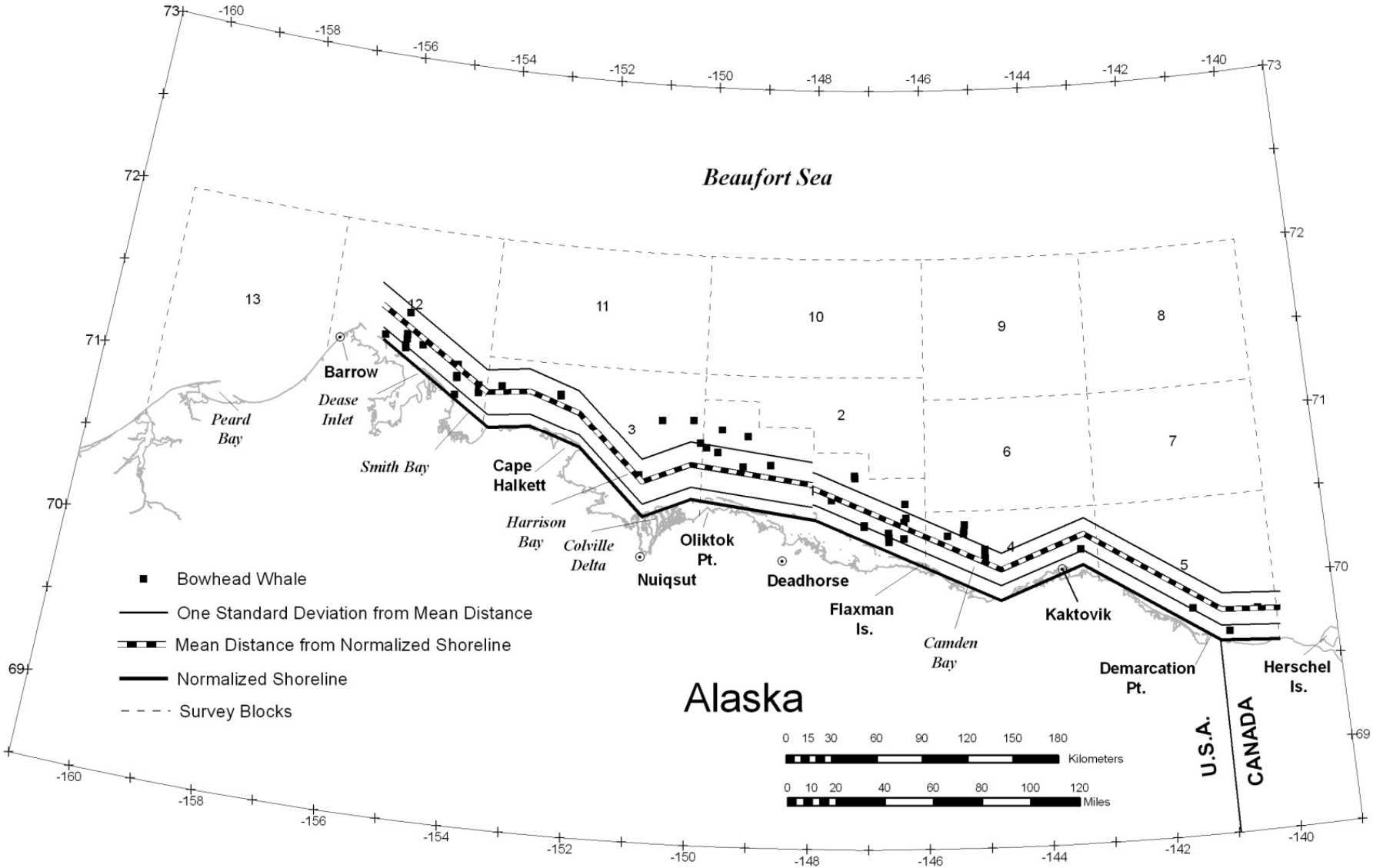

Figure 50. -- Bowhead whale sightings on transect, excluding feeding, milling and resting whales, fall 2008, showing mean distance from a normalized shoreline.

Likewise in the West Region, bowhead whales were significantly closer to shore (18.4 km vs. 27.0 km; Z = 2.866, P = 0.0042) and in shallower water (15 m vs. 23 m, Z = 4.508, P = 0.000007) in 2008 compared with historical "light ice" years.

Other Marine Mammal Observations

There were two sightings of gray whales (Fig. 51) during the 2008 BWASP surveys: single gray whales were seen west of Point Barrow on 23 September and 1 October.

In fall 2008, 15 belugas were observed (Fig. 52). Far fewer belugas were seen in 2008 than in any year since 1982 (Fig. 53), perhaps due to the lack of ice cover (belugas may have been farther offshore in heavier ice) or due to the relative lack of survey effort in deeper, offshore areas of the study area (Figs. 39-42). In particular, survey effort in Blocks 6 and 7, areas that are normally sampled frequently, was particularly light (Table 17). Belugas are usually associated with ice (Moore et al. 2000); however, all belugas seen in 2008 were in ice-free water as there was no ice cover in the study area during the survey period.

Bearded seals (42 sightings of 52 seals) and unidentified pinnipeds (110 sightings of 285 seals) were seen during fall 2008 and were distributed across the Alaskan Beaufort Sea and into the northeastern Chukchi Sea (Figs. 54 and 55). Unidentified pinnipeds include sightings of small pinnipeds that in previous years were recorded as ringed seals. The distributions of spotted (*Phoca largha*) and ringed (*Pusa hispida*) seals overlap in the Alaskan Beaufort Sea (Boveng et al. 2009, Angliss and Allen 2009), and behaviors that would be observable from survey altitude (> 1,000') are not distinct enough to allow positive species identification (D. Rugh and D. Withrow, AFSC-NMML. Pers. commun., 8 December 2009). Therefore, confidence in identifying small pinnipeds to species was considered low, and they were reported as unidentified pinnipeds.

In 2008, 103 polar bears were sighted, although some of the bears may have been seen repeatedly (Fig. 56). All polar bear sightings were along the shore, from due east of Point Barrow to Kaktovik. Bears were seen on Cross Island on multiple days: 13 bears on 12 September, 15 bears on 18 September, 14 bears on 26 September, 16 bears on 28 September, 22 bears on 13 October, and 7 bears on 17 October. Other bear sightings were of single animals or pairs. Bears were seen on 13 of 19 flights, from 5 September to 17 October.

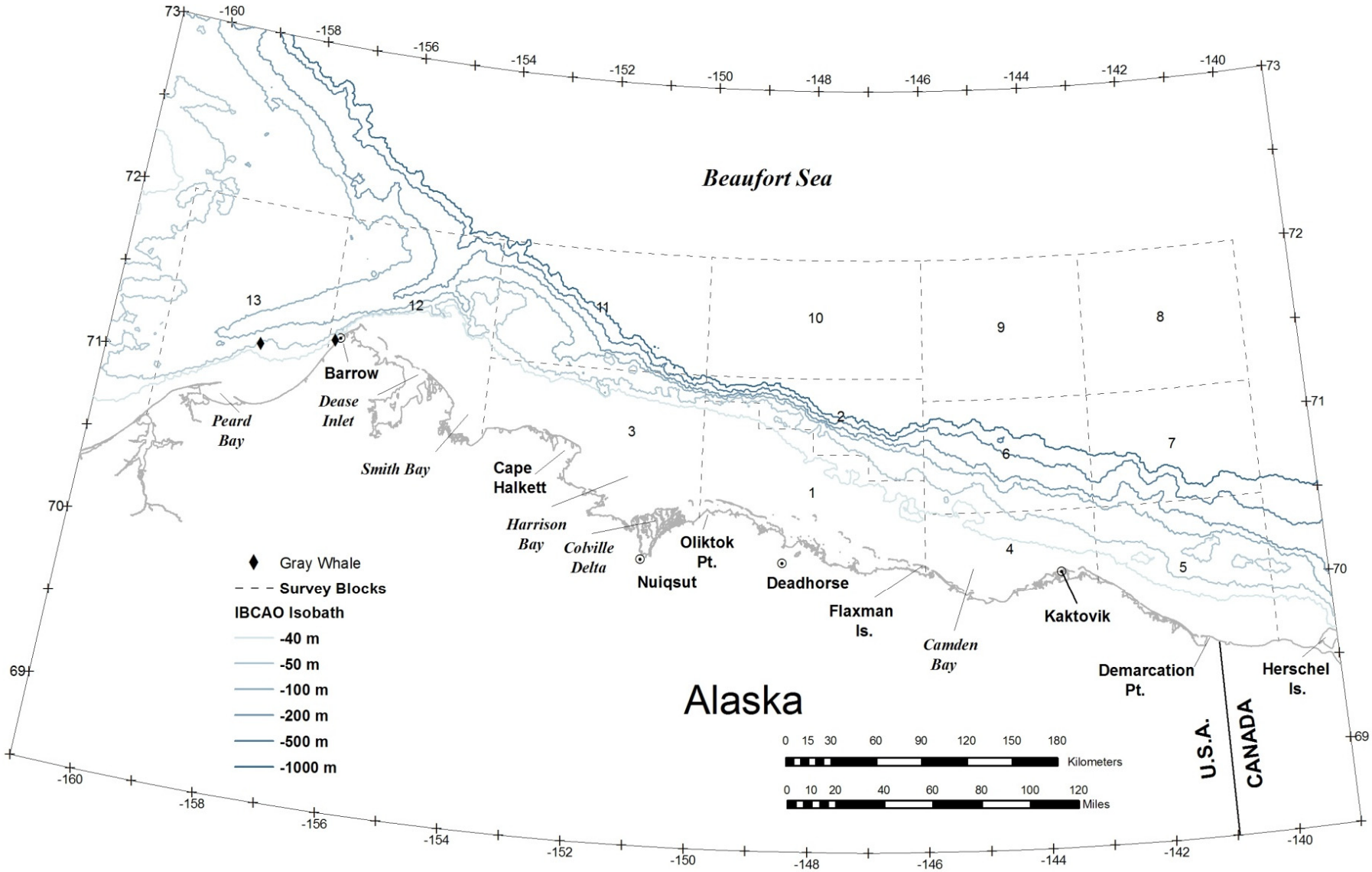

Figure 51. -- Gray whale sightings, fall 2008.

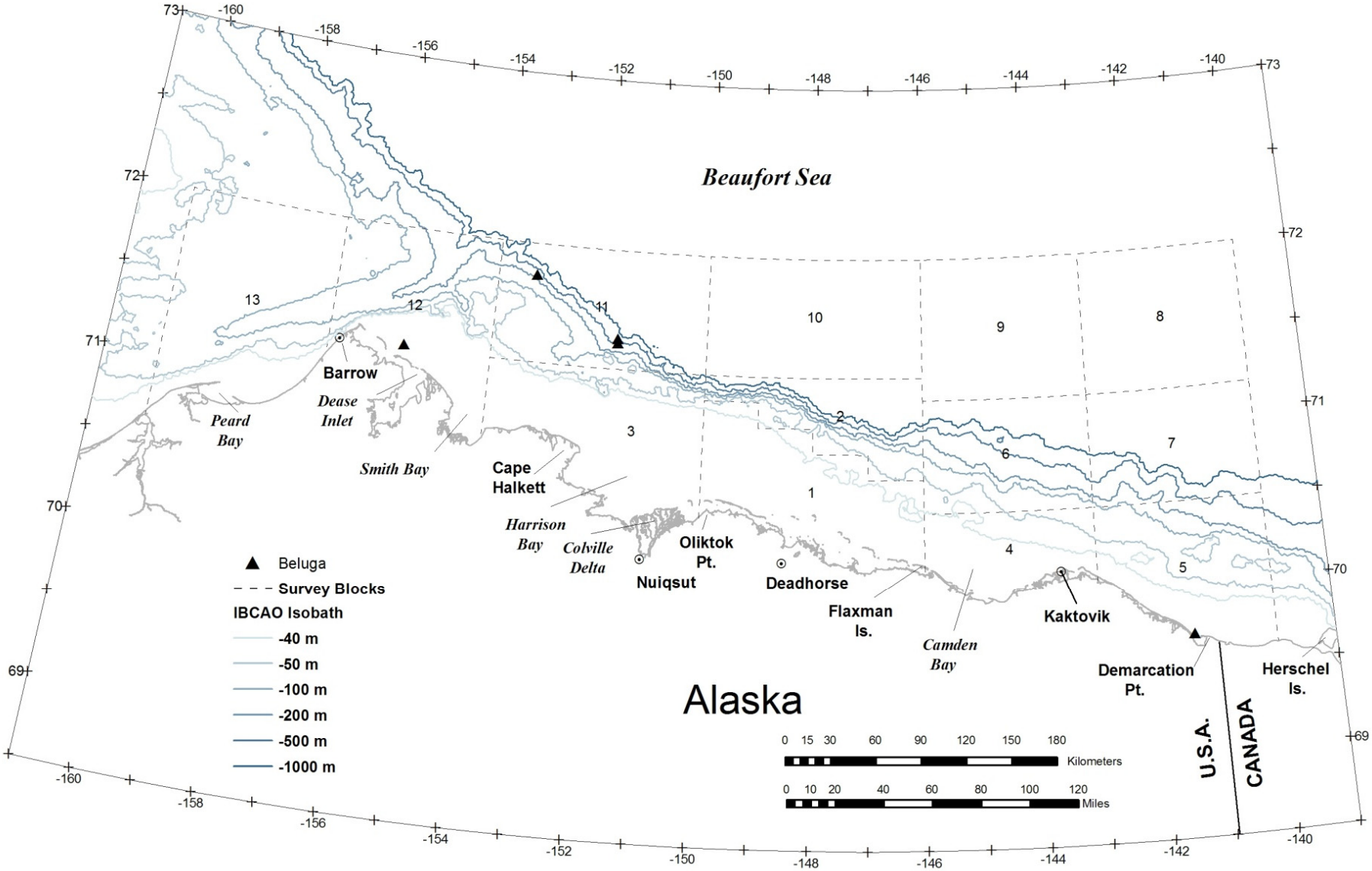

Figure 52. -- Beluga sightings, fall 2008.

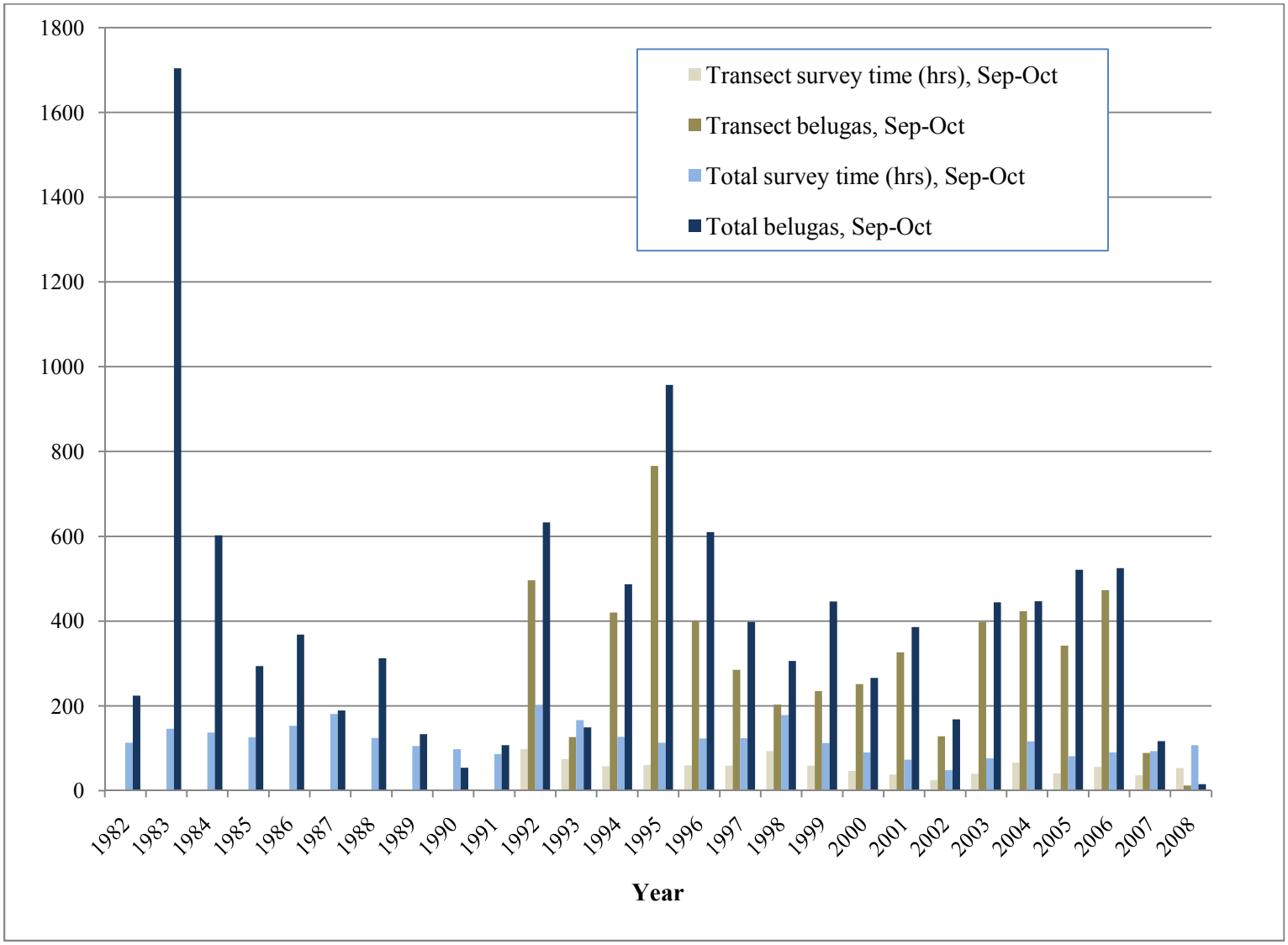

Figure 53. -- Number of belugas and annual effort (hour), total and transect only, 1982-2008. Transect data not available for 1982-1991.

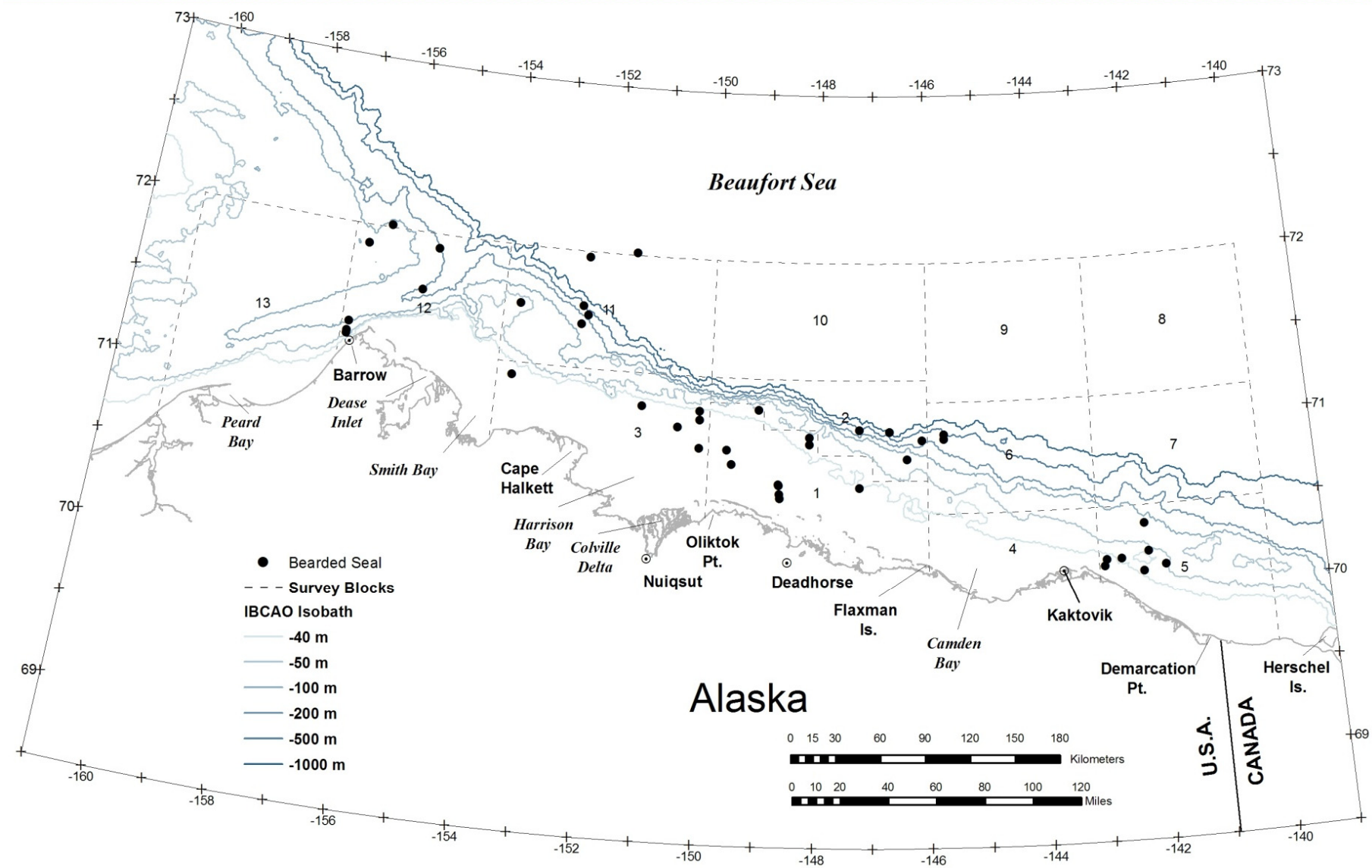

Figure 54. -- Bearded seal sightings, fall 2008.

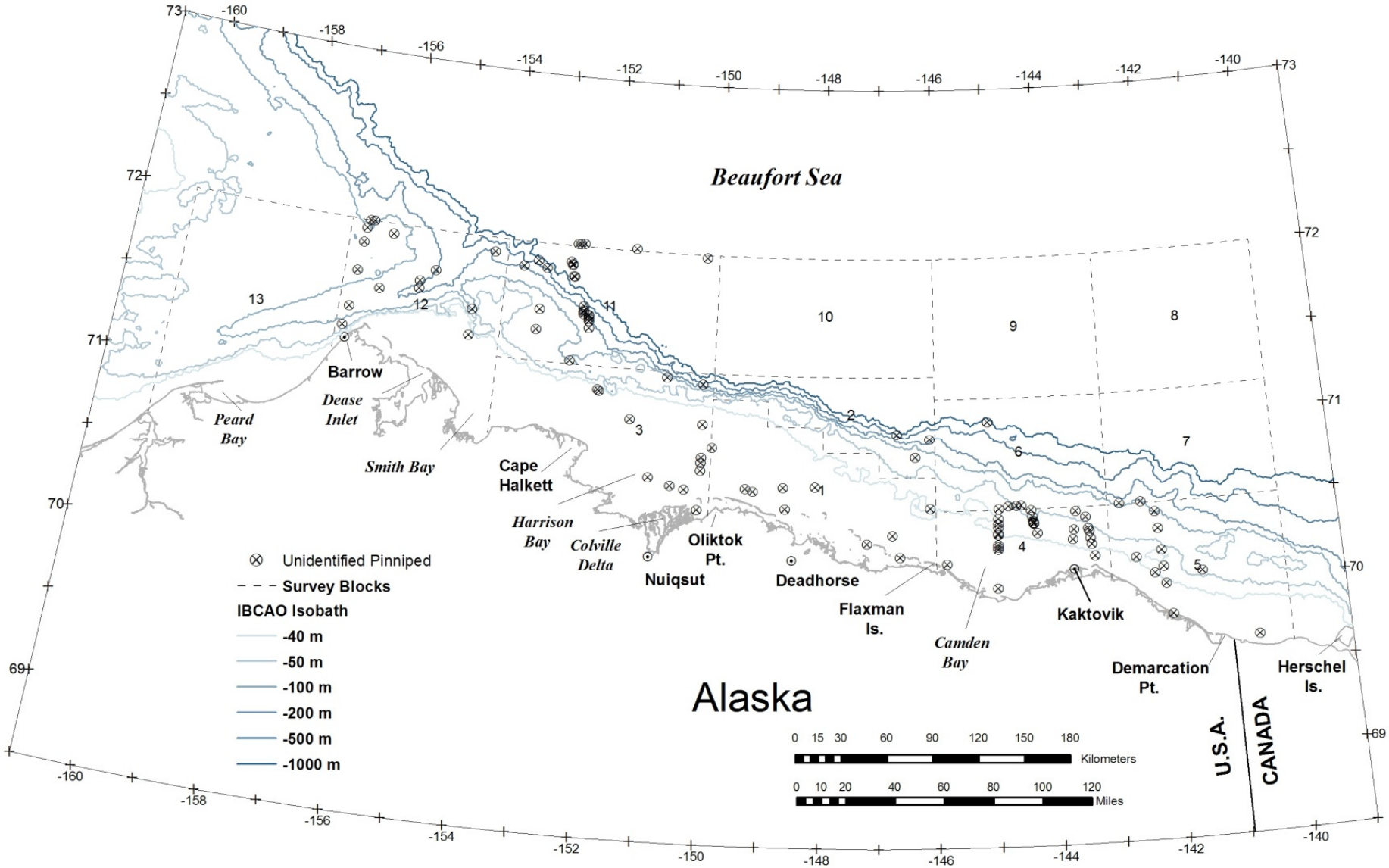

Figure 55. -- Unidentified pinniped sightings, fall 2008.

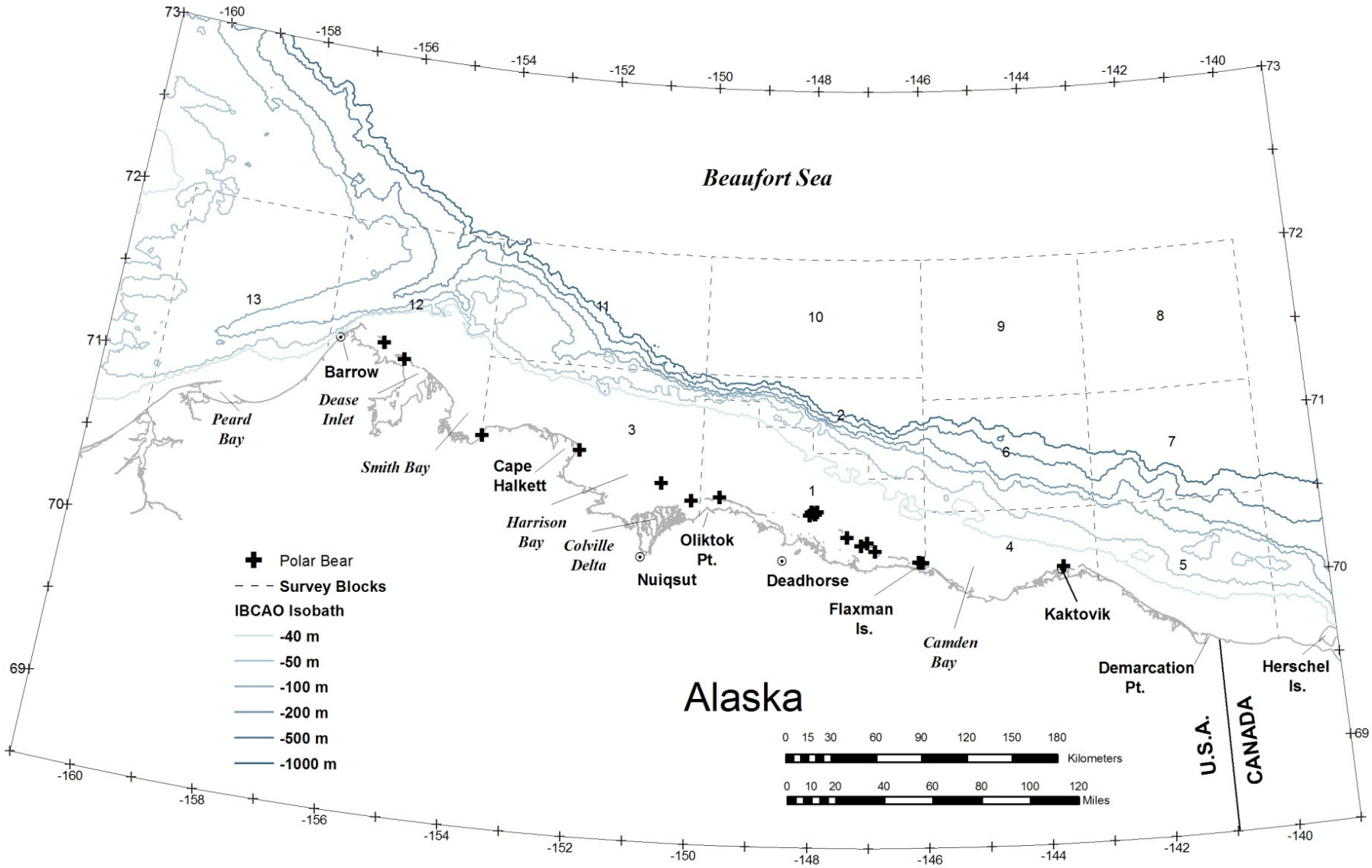

Figure 56. -- Polar bear sightings, fall 2008.

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DISCUSSION

Conclusions

In 2006, bowhead whale sightings were significantly farther from shore and in deeper water throughout the Alaskan Beaufort Sea compared to previous light ice years, as shown via central tendency statistics and visual comparison (Fig. 57). The statistical trend for more seaward locations of bowhead whales could be explained by lower concentrations of bowhead whale prey near the coastline (compared to past years) leading to a reduced density of feeding whales, by persistence of sea ice near the coastline between Kaktovik and Oliktok Point throughout most of September (see Appendix A), by the presence of shallow hazard seismic work nearshore, or by other factors not identified.

In 2007, bowhead whale sightings were significantly closer to shore and in shallower water in the East Region compared to previous light ice years. The statistical trend for more coastal locations of bowhead whales in the East Region could be explained by higher concentrations of bowhead whale prey near the coastline (compared to past years) leading to an increased density of feeding whales. Relatively few whales were identified as feeding in 2007, but a relatively high percentage was identified as milling, which may be indicative of feeding behavior. Analyses in the West Region were compromised by low sample sizes.

Survey effort in 2007 was uneven, with the majority of effort in the nearshore areas east of Deadhorse and, to a lesser extent, near Barrow. Survey effort in Blocks 3, 6, 7, and 11 was particularly lacking compared to previous years. The lack of survey effort west of Deadhorse (Survey Blocks 3 and 11) impacted the central tendency analyses, because there were only six transect bowhead whale sightings for the entire season. The lack of survey effort in offshore blocks east of Deadhorse (Survey Blocks 6 and 7) likely impacted the observed distribution of marine mammals, particularly belugas. While survey effort is highly dependent on weather in any given year, the uneven effort in 2007 underscores the importance of inter-year consistency to allow for continued multi-year analyses.

In 2008, bowhead whale sightings were significantly closer to shore and in shallower water in both the East and West Regions than in previous light ice years. The statistical trend for more coastal locations of bowhead whales could be due to higher concentrations of bowhead whale prey near the coastline (compared to past years), although the percentage of bowhead whale behaviors listed as feeding or milling in 2008 (18%) was considerably lower than those recorded in 2006 (50%) or 2007 (48%). Survey effort in 2008 was fairly evenly distributed, with less effort in offshore Blocks 6 and 7.

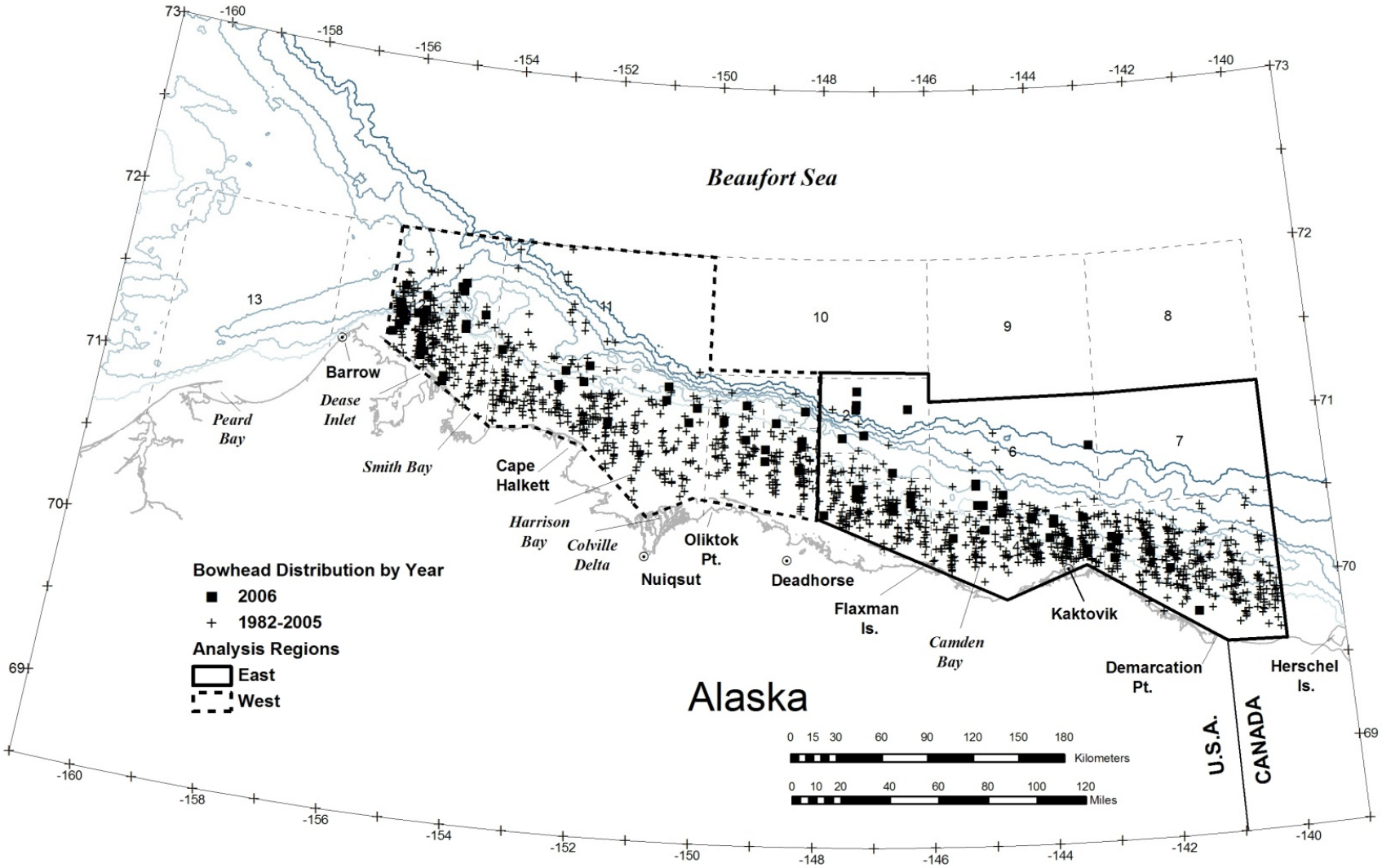

Figure 57. -- Comparison of bowhead whale transect sightings, September-October 2006, to bowhead whale transect sightings, September-October of previous light ice years (1982, 1986-87, 1989-90, 1993-2005).

Management Use of Real-Time Field Information

The MMS issues various types of 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. During fall 2006, there was limited offshore oil and gas exploration. During fall 2007 and 2008, there were several ongoing offshore oil and gas exploration activities (Rodrigues et al. 2009a, b). BWASP aerial survey data were made available to representatives of oil companies, the NSB Department of Wildlife Management and other private and government entities on a near real-time basis to encourage data transfer and enhance management via a website maintained by NMML (http://www.afsc.noaa.gov/nmml/cetacean/bwasp/index.php).

Management Use of Interannual Monitoring

The MMS 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 from time to time, the data recorded have remained remarkably consistent (especially data from 1982 to 2008), thus permitting many direct comparisons across years. Such continuous, long-term, area-wide, aerial monitoring of a large whale migration is indeed unique. The BWASP historical dataset has been used by industry, government, and academic entities. Most recently, oceanographers from the Woods Hole Oceanographic Institution and University of Alaska Fairbanks used data from BWASP (1984-2008) to assist with analysis of the relationship between ocean circulation and bowhead whale feeding hotspots near Barrow, as part of the MMS-funded Bowhead Whale Feeding Ecology Study (BOWFEST) (Ashjian et al. 2010).

Results from the 2008 BWASP field season were presented by NMFS personnel at several venues, including the 2009 Open Water Stakeholders Meeting (April 2009, Anchorage), MMS Information Transfer Meeting (October 2008, Anchorage), and BOWFEST workshop at the Alaska Marine Science Symposium (January 2009, Anchorage).

ACKNOWLEDGMENTS

This study was funded by the U.S. Department of the Interior, Minerals Management Service (MMS), Alaska Outer Continental Shelf Region, Anchorage, Alaska, as part of the MMS Alaska Environmental Studies Program (currently the Bureau of Ocean Energy Management, Regulation and Enforcement). We particularly appreciate the support, guidance and encouragement of Charles Monnett.

In 2006, responsibility for BWASP surveys and management remained completely within MMS. The study benefited from the efforts of numerous MMS staff that assumed various roles on the

survey team or assisted with technical, administrative or logistical aspects of the study, including Cleve Cowles, Deborah Epperson, Jeffrey Gleason, Charles Monnett, Tom Murrell, Carol Rodin, Lisa Rotterman, Mike Salyer, Caryn Smith, and Ruthie Way. Sue Moore and Julie Mocklin (NMFS) kindly assisted with surveys conducted from Barrow during early September.

Personnel of the U.S. Department of the Interior, National Business Center (NBC), Aviation Management (formerly OAS) were extremely helpful in making all 2006 aircraft arrangements, including administering the contract with ERA Aviation (Alf Aanensen, Carol Peterson, Joe Bussard, Anita Roberts, Bud Walters) and monitoring satellite tracking of survey flights (Jan Bennett, Lark Wuerth). Don Fry, Tommy McWilliams, Jane Tuomi, and Roger Warren (ERA Aviation) piloted the Twin Otter in 2006. Amber Babcock (ERA Aviation) provided much appreciated help with equipment and logistics.

In 2007, BWASP surveys and management transitioned from MMS Alaska OCS Region to NMFS via Interagency Agreement M07RG13260 between MMS and NMFS. BWASP benefited from the combined expertise of MMS and NMFS personnel who provided support to the survey team or assisted with technical, administrative or logistical aspects of the study. Observers included Charles Monnett and Lisa Rotterman (MMS), Laura Morse, Stephen Claussen, and Kim Goetz (NMFS), and Janet Clarke of Science Applications International Corporation (SAIC).

In 2008, management and implementation of BWASP was solely the responsibility of NMFS. Numerous NMFS personnel provided support to the survey team or assisted with technical, administrative, or logistical aspects of the study. Dave Rugh and Kim Shelden (NMFS) were the NMML Program Coordinators and Janet Clarke (SAIC) was the Program Manager. Observers included Jeff Childs, Gary Friedrichsen, and Laura Morse (NMFS), and Janet Clarke (SAIC).

In 2007 and 2008, survey aircraft were provided by the National Oceanic and Atmospheric Administration (NOAA) Aircraft Operations Center (AOC), Tampa, FL, via Interagency Agreement M07RG13263. Jeff Hagen and the AOC Programs Office were instrumental in assisting with aircraft arrangements and preparations. Surveys were capably and safely flown by Phil Eastman, Jason Mansour, Doug MacIntyre, Wally Pierce, Scott Sandorf, and Kristie Twining. On-site aircraft mechanical support was provided by Sean Campbell, Mike Merek, and Ron Pauley; Evergreen (2007) and ERA Helicopter (2008) provided a hangar at the Deadhorse airport. Real-time monitoring via satellite tracking of the aircraft was provided by Jan Bennett and Lark Wuerth of the U.S. Department of the Interior, National Business Center, Aviation Management Division.

Mike Hay of Resource Data Incorporated (RDI) provided much needed assistance with data analyses, mapping, and report preparation. The National Ice Center provided draft sea-ice-severity rankings and sea-ice concentrations in ARC/INFO format (www.natice.noaa.gov). Phil Clapham, Dave Rugh, and Kim Shelden (NMFS) reviewed the report. The Alaska Fisheries Science Center's (AFSC) Publications Unit was instrumental in formatting and preparing this report for publication.

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APPENDIX A: FALL 2006 ICE CONCENTRATION MAPS – ALASKAN BEAUFORT SEA

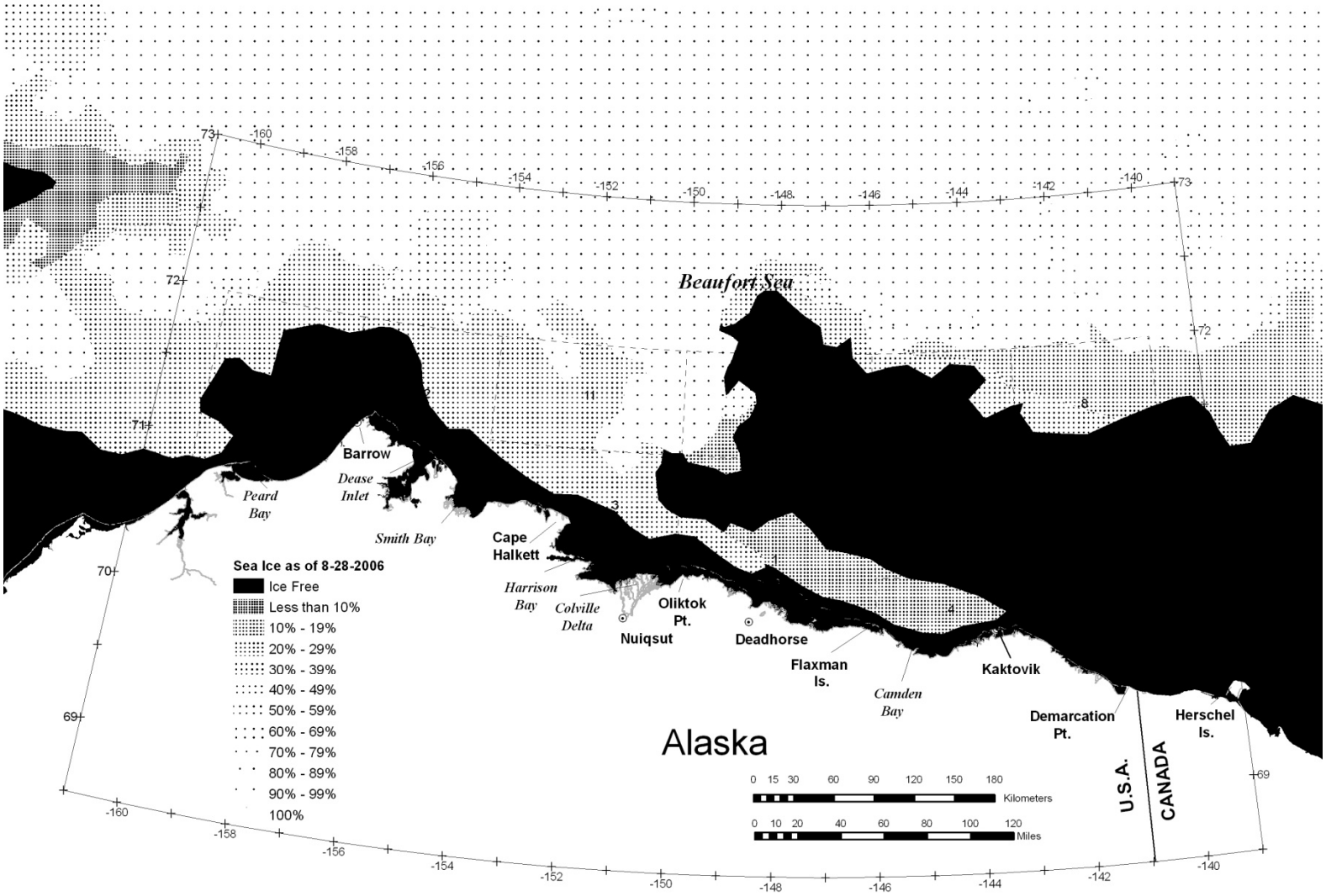

Figure A-1 – Ice concentrations in the Alaskan Beaufort Sea, 28 August 2006.

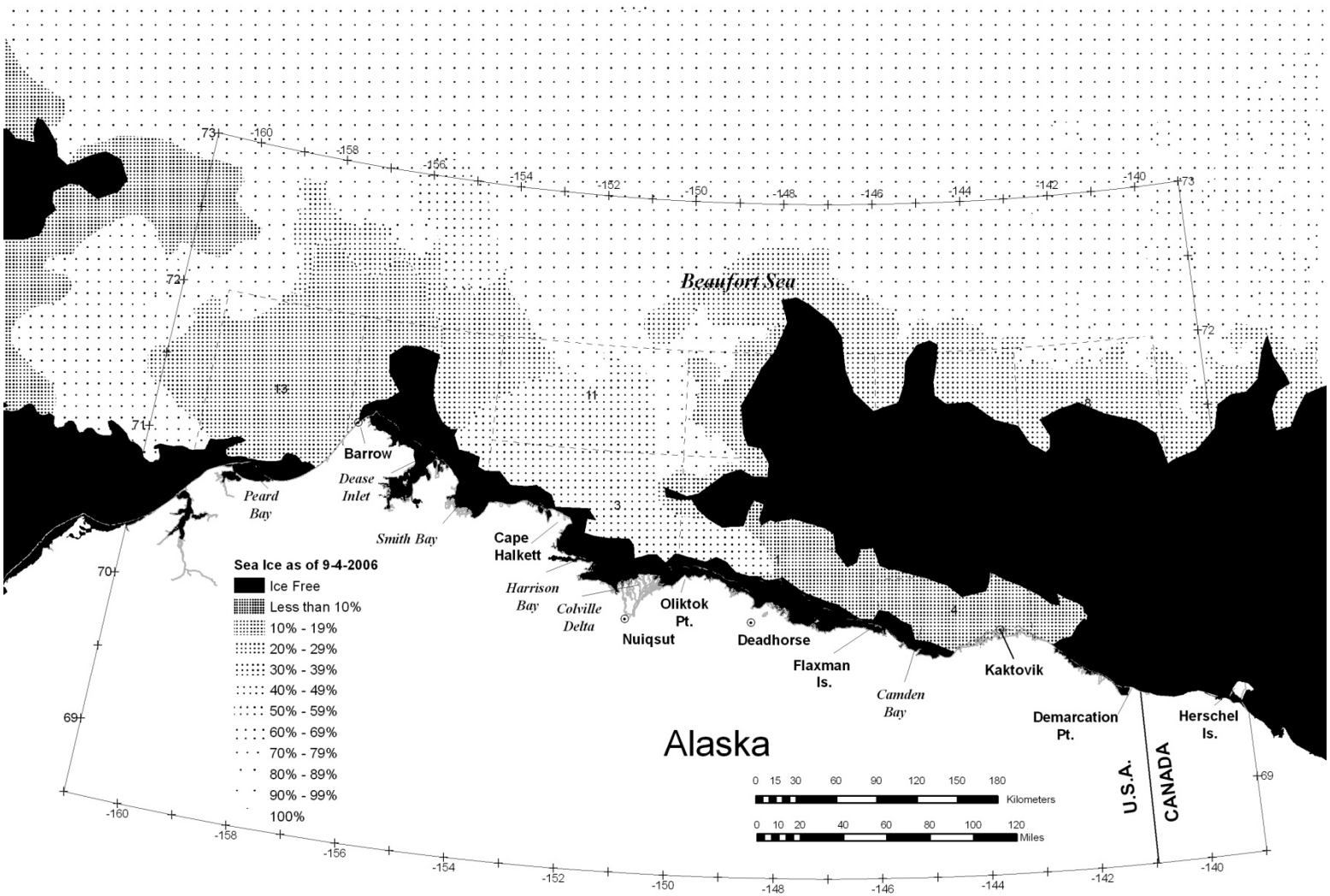

Figure A-2 – Ice concentrations in the Alaskan Beaufort Sea, 4 September 2006.

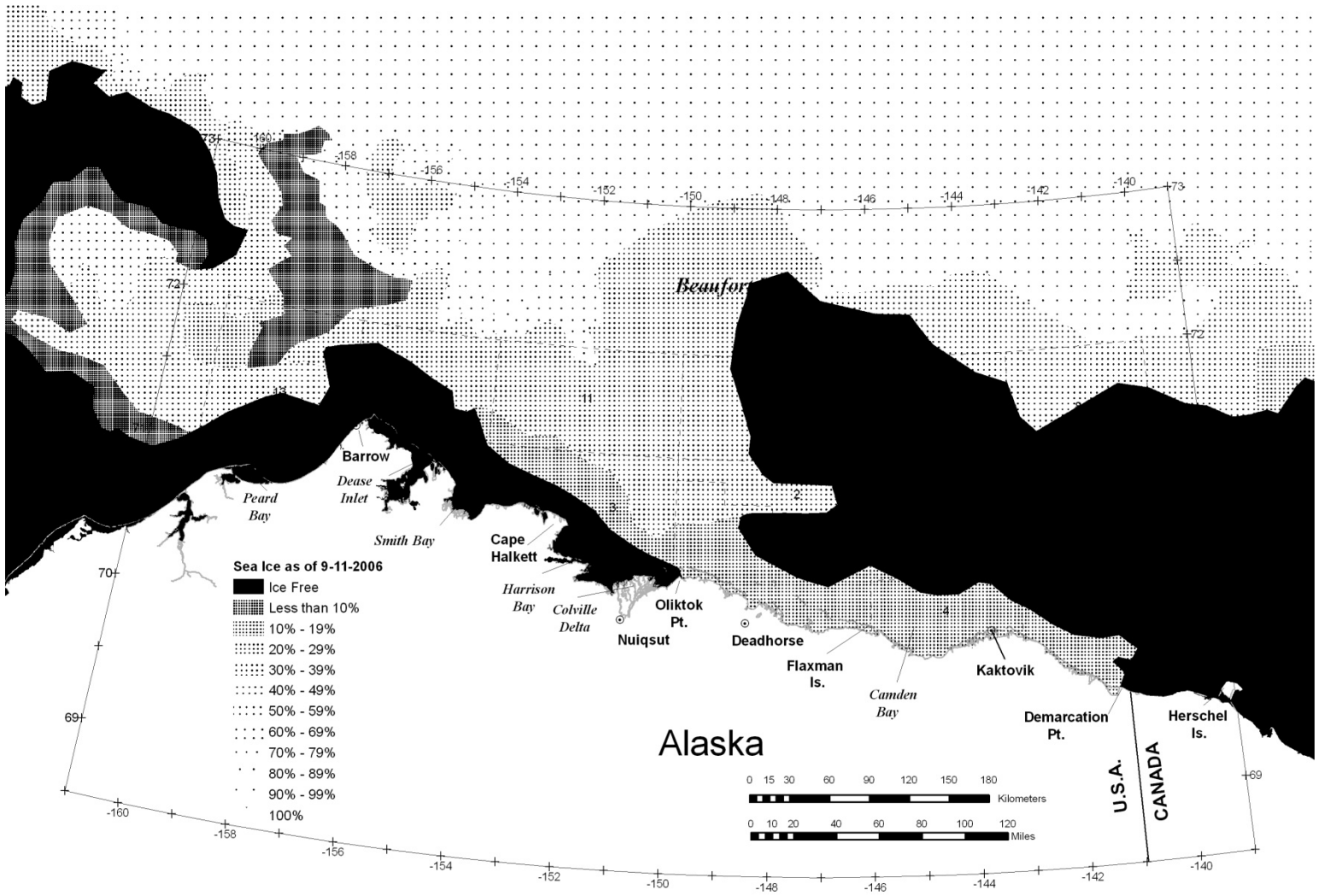

Figure A-3 – Ice concentrations in the Alaskan Beaufort Sea, 11 September 2006.

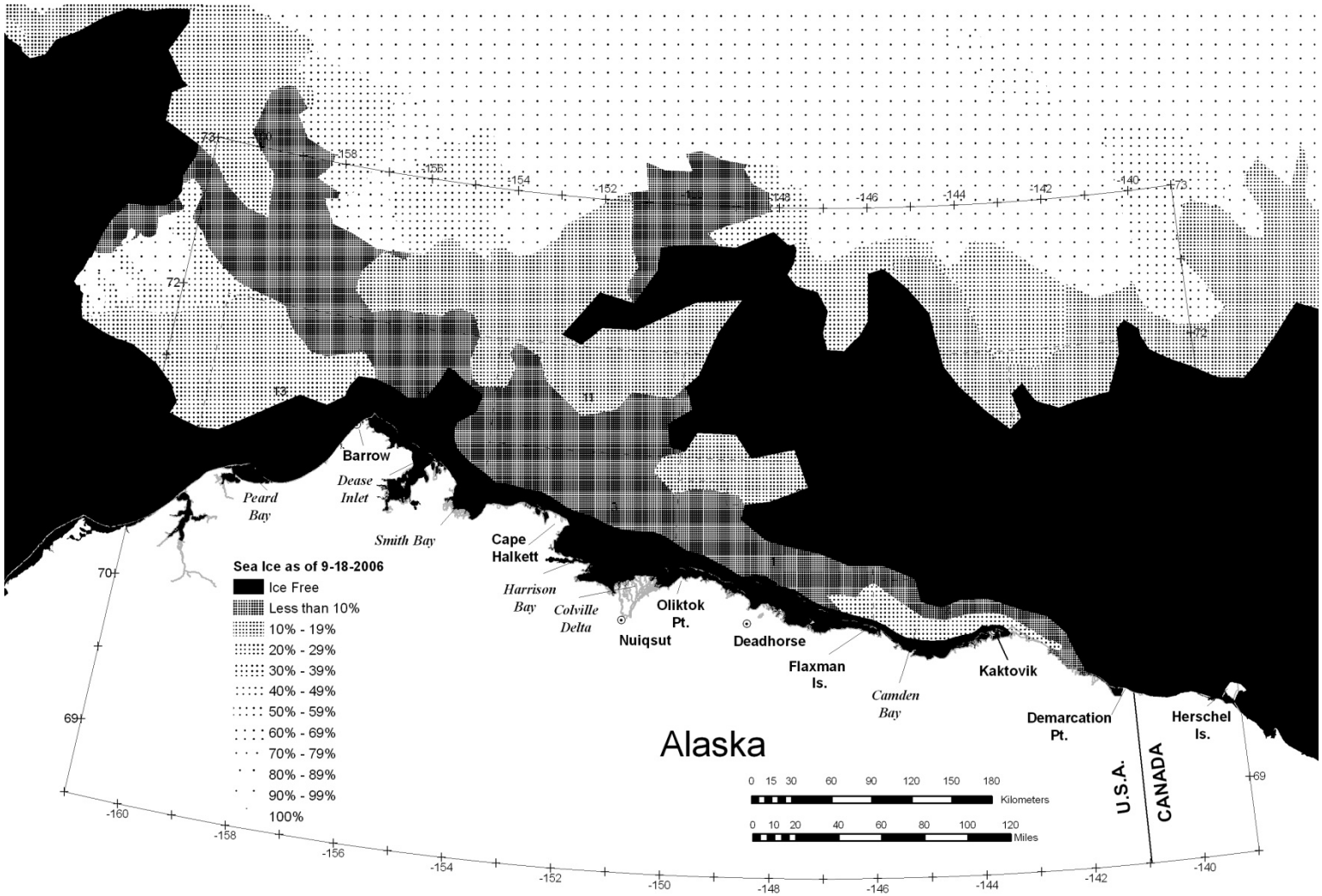

Figure A-4 – Ice concentrations in the Alaskan Beaufort Sea, 18 September 2006.

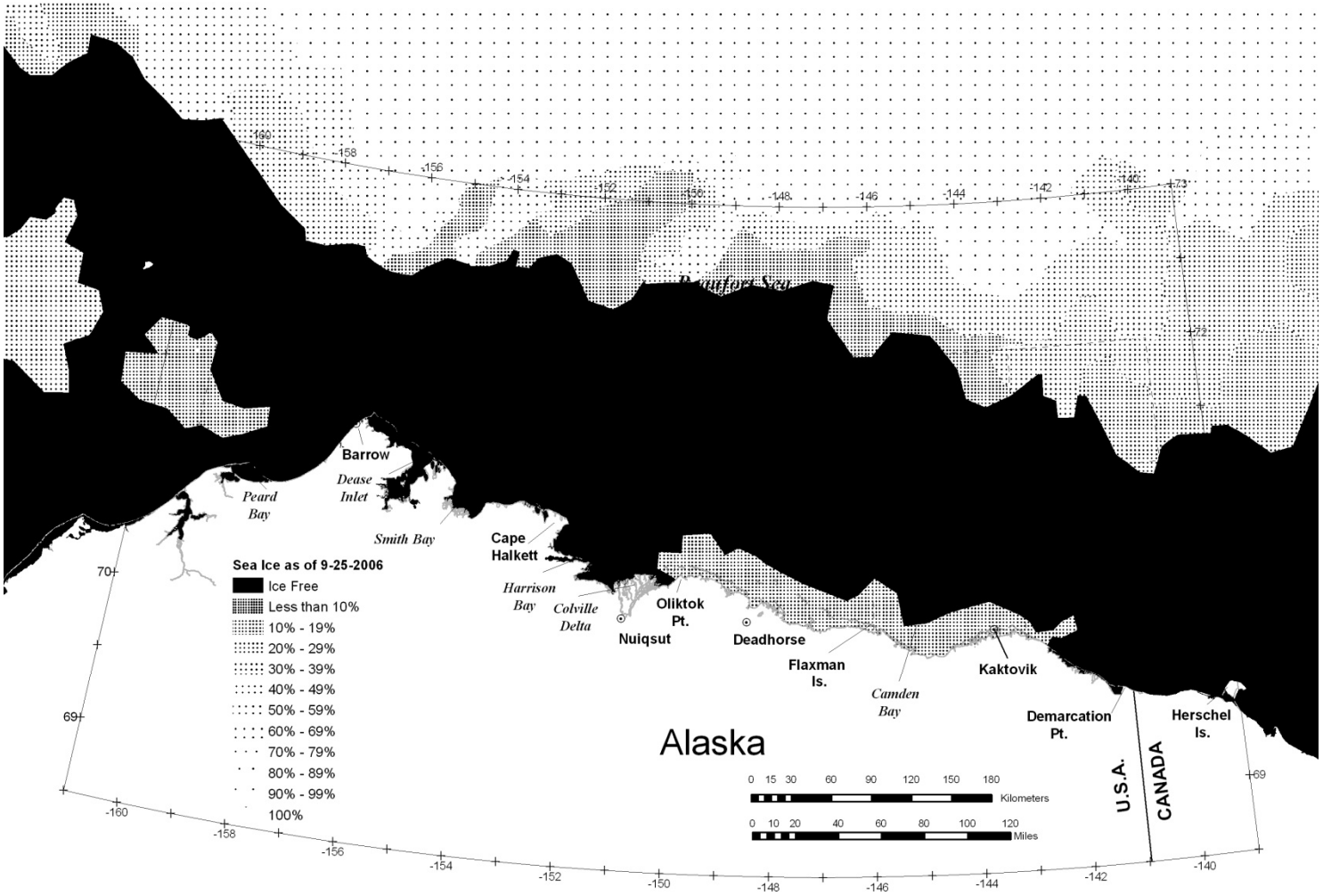

Figure A-5 – Ice concentrations in the Alaskan Beaufort Sea, 25 September 2006.

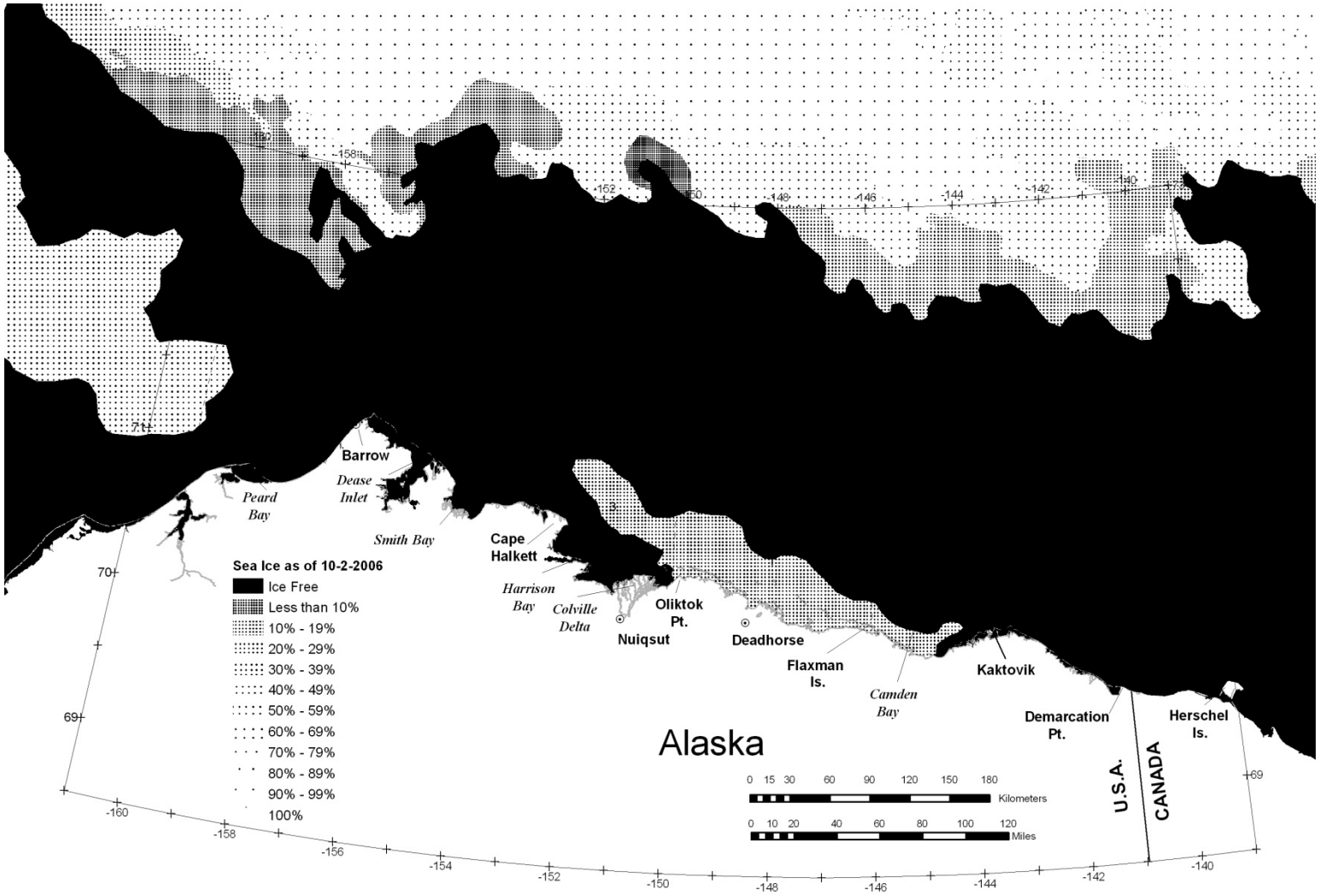

Figure A-6 – Ice concentrations in the Alaskan Beaufort Sea, 2 October 2006.

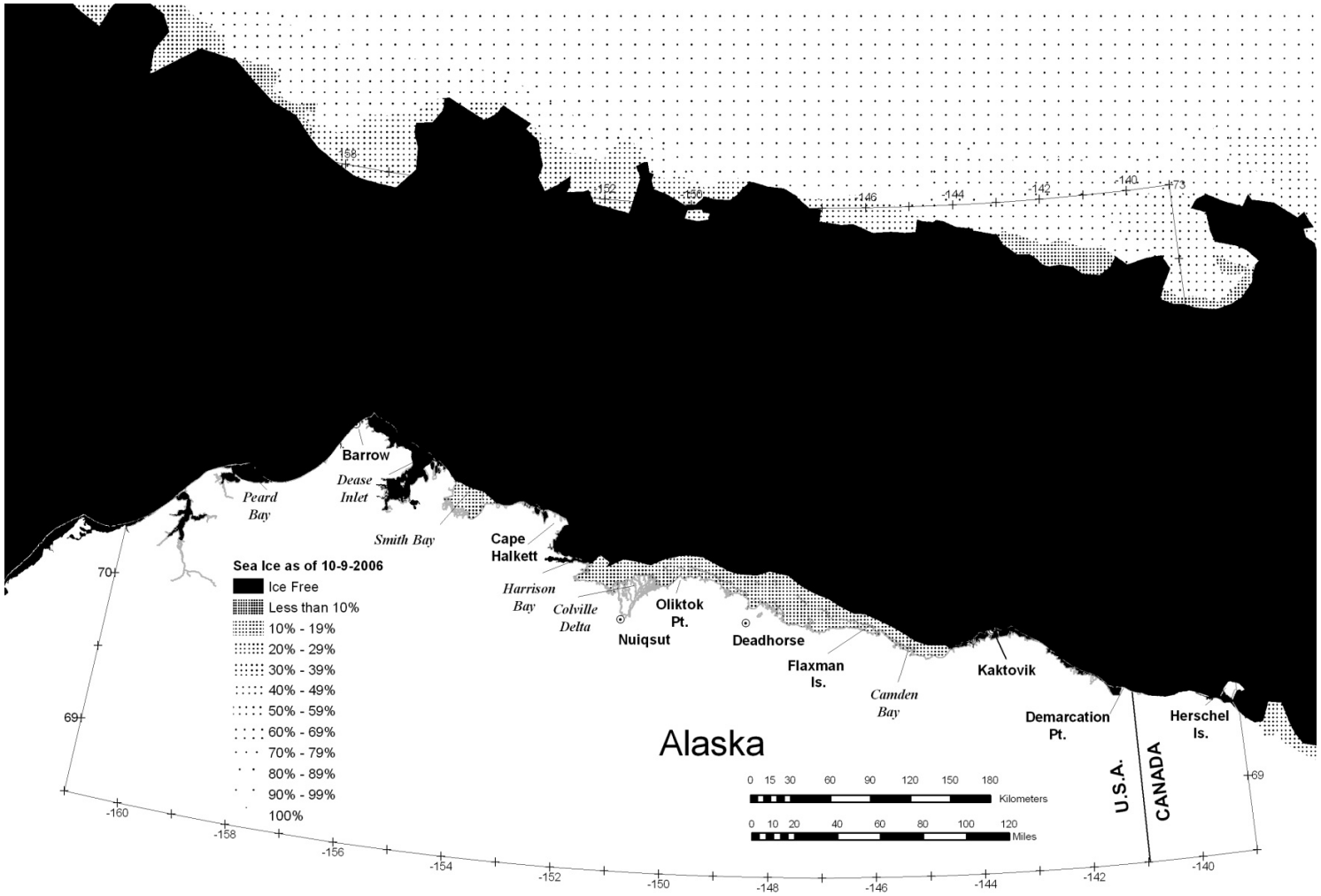

Figure A-7 – Ice concentrations in the Alaskan Beaufort Sea, 9 October 2006.

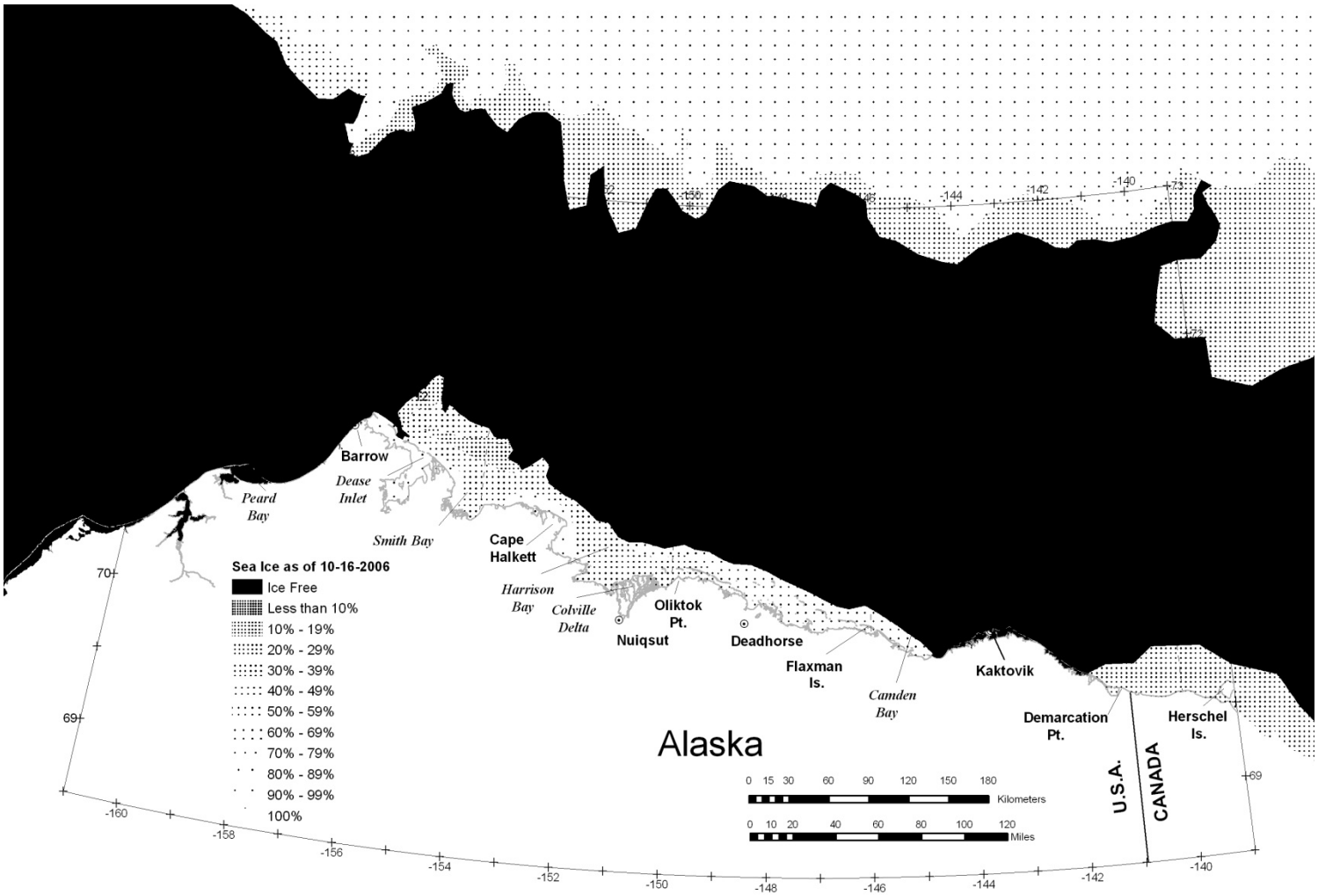

Figure A-8 – Ice concentrations in the Alaskan Beaufort Sea, 16 October 2006.

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APPENDIX B: FALL 2006 BOWHEAD WHALE SIGHTING DATA

Table B-1
Selected data for bowhead whale sightings, fall 2006
([1]not recorded)

Flight No	Date	Total Whales	No of Calves	Latitude (N)	Longitude (W)	Behavior	Compass Heading, True	Ice (%)	Wind Force
1	2 Sep	2	0	71º26.5'	155º41.5'	swim	262º	0	0
3	3 Sep	1	0	71º00.2'	150º20.9'	swim	294º	1	1
3	3 Sep	1	0	71º12.7'	150º44.6'	swim	324º	40	1
3	3 Sep	1	0	71º07.8'	150º46.1'	swim	284º	20	1
3	3 Sep	1	0	71º12.3'	152º18.0'	swim	263º	25	1
3	3 Sep	1	0	71º15.7'	152º38.5'	rest	283º	30	0
4	4 Sep	1	0	71º29.9'	155º28.5'	swim	342º	5	1
4	4 Sep	1	0	71º39.1'	155º45.6'	swim	[1]	10	1
4	4 Sep	1	0	71º30.3'	155º47.4'	swim	192º	5	1
4	4 Sep	1	0	71º29.0'	155º47.7'	swim	342º	0	1
4	4 Sep	20	0	71º24.6'	155º47.7'	feed	[1]	0	1
4	4 Sep	1	0	71º30.9'	155º49.0'	swim	202º	10	1
4	4 Sep	2	0	71º29.6'	156º06.3'	swim	231º	10	1
4	4 Sep	1	0	71º22.6'	156º37.9'	swim	221º	5	1
5	5 Sep	1	0	71º01.3'	148º45.8'	dive	295º	0	1
5	5 Sep	1	0	71º05.6'	148º14.4'	swim	326º	5	1
5	5 Sep	2	0	70º54.8'	148º17.4'	swim	325º	0	1
5	5 Sep	1	0	70º52.8'	148º17.7'	swim	310º	0	1
5	5 Sep	1	0	70º56.0'	147º34.2'	swim	326º	0	1
5	5 Sep	1	0	71º13.0'	147º18.3'	swim	326º	0	1
5	5 Sep	1	0	71º08.2'	147º19.2'	swim	286º	0	1
5	5 Sep	1	0	71º06.5'	147º19.7'	swim	356º	0	1
5	5 Sep	1	0	70º43.7'	146º39.7'	rest	[1]	0	1
5	5 Sep	1	0	71º06.6'	146º23.0'	rest	[1]	0	2
5	5 Sep	1	0	70º35.8'	146º20.6'	swim	116º	0	1
5	5 Sep	2	0	70º32.7'	146º20.5'	swim	286º	0	1
6	5 Sep	1	0	71º17.6'	153º43.3'	swim	283º	5	0
6	5 Sep	8	0	71º20.2'	155º55.2'	feed	[1]	0	0
7	6 Sep	1	0	71º27.7'	156º21.0'	rest	[1]	50	1
7	6 Sep	2	0	71º31.5'	156º12.3'	swim	261º	50	1
7	6 Sep	1	0	71º33.7'	156º10.4'	swim	261º	50	1
7	6 Sep	2	0	71º22.5'	155º53.4'	swim	296º	1	1
7	6 Sep	1	0	71º18.3'	155º55.2'	swim	181º	1	3
7	6 Sep	1	0	71º17.1'	155º51.0'	swim	161º	1	3
7	6 Sep	1	0	71º31.5'	155º19.3'	swim	162º	20	1

Flight No	Date	Total Whales	No of Calves	Latitude (N)	Longitude (W)	Behavior	Compass Heading, True	Ice (%)	Wind Force
7	6 Sep	2	0	71º31.6'	157º10.5'	swim	261º	1	3
8	7 Sep	3	1	71º10.0'	145º24.5'	rest	[1]	0	2
8	7 Sep	1	0	70º39.4'	145º11.3'	log play	[1]	0	1
8	7 Sep	1	0	70º38.6'	145º11.1'	swim	287º	0	1
8	7 Sep	1	0	70º31.7'	145º09.6'	swim	267º	1	1
8	7 Sep	8	1	70º31.6'	145º04.0'	swim	267º	0	1
8	7 Sep	3	0	70º28.7'	144º43.6'	swim	267º	0	0
8	7 Sep	1	0	70º29.9'	144º43.4'	swim	297º	0	0
8	7 Sep	1	0	70º35.1'	144º42.5'	swim	267º	0	1
8	7 Sep	7	2	70º26.6'	144º13.6'	mill	27º	0	1
8	7 Sep	4	0	70º26.2'	144º13.5'	rest	[1]	0	1
8	7 Sep	1	2	70º26.6'	144º09.6'	swim	267º	0	1
8	7 Sep	2	0	70º24.3'	143º50.6'	swim	237º	0	1
8	7 Sep	3	1	70º25.9'	143º50.0'	swim	237º	0	0
8	7 Sep	1	0	70º24.4'	143º50.4'	swim	97º	0	0
8	7 Sep	1	0	70º51.6'	143º08.9'	swim	298º	0	2
8	7 Sep	5	0	70º25.9'	143º19.7'	swim	268º	0	1
8	7 Sep	2	0	70º25.1'	143º14.7'	swim	248º	1	1
8	7 Sep	1	0	70º16.7'	142º45.1'	swim	268º	0	1
8	7 Sep	2	0	70º17.4'	142º44.8'	swim	288º	0	1
10	13 Sep	1	0	70º12.0'	142º10.8'	swim	273º	1	2
10	13 Sep	1	0	70º18.5'	142º50.3'	swim	308º	0	3
10	13 Sep	1	0	70º14.7'	142º51.5'	swim	308º	5	3
10	13 Sep	1	0	70º19.3'	143º54.8'	dive	57º	5	1
11	14 Sep	10	0	71º42.7'	154º38.8'	swim	322º	1	2
11	14 Sep	13	0	71º41.1'	154º42.8'	swim	262º	1	2
11	14 Sep	3	0	71º41.3'	154º42.6'	swim	52º	1	2
11	14 Sep	1	0	71º39.8'	154º40.1'	swim	282º	0	2
11	14 Sep	1	0	71º09.0'	154º51.5'	swim	262º	0	2
11	14 Sep	9	0	71º08.1'	154º52.8'	feed	[1]	0	2
11	14 Sep	3	0	71º09.2'	154º56.8'	feed	[1]	0	2
11	14 Sep	1	0	71º09.0'	154º59.5'	swim	82º	0	2
11	14 Sep	1	0	71º07.1'	154º52.3'	swim	312º	0	2
11	14 Sep	25	1	71º15.3'	155º19.8'	feed	[1]	0	2
11	14 Sep	70	1	71º17.7'	155º19.9'	feed	[1]	0	2
11	14 Sep	6	0	71º16.9'	155º16.2'	swim	332º	0	2
11	14 Sep	17	0	71º18.4'	155º20.1'	mill	[1]	0	2
11	14 Sep	1	0	71º21.3'	155º21.2'	swim	52º	0	2
11	14 Sep	1	0	71º27.3'	155º20.7'	breach	322º	5	2

Flight No	Date	Total Whales	No of Calves	Latitude (N)	Longitude (W)	Behavior	Compass Heading, True	Ice (%)	Wind Force
11	14 Sep	1	0	71º28.8'	155º20.8'	swim	172º	5	2
11	14 Sep	1	0	71º29.1'	155º44.8'	swim	352º	10	0
12	14 Sep	1	0	71º05.2'	157º44.1'	feed	335º	1	1
13	15 Sep	1	0	71º06.4'	152º44.9'	swim	233º	10	1
13	15 Sep	1	0	71º08.7'	152º57.4'	swim	173º	10	1
13	15 Sep	1	0	71º20.0'	152º47.5'	swim	248º	5	1
13	15 Sep	1	0	71º05.6'	150º12.3'	swim	115º	1	1
14	16 Sep	1	0	70º22.9'	145º02.6'	swim	177º	10	0
14	16 Sep	2	0	70º57.1'	147º10.5'	swim	266º	0	2
18	25 Sep	2	0	70º35.0'	147º18.3'	mill	[1]	0	2
18	25 Sep	4	0	70º38.0'	147º18.5'	swim	266º	0	2
18	25 Sep	1	0	70º44.4'	148º20.2'	swim	325º	1	0
19	1 Oct	2	1	70º47.3'	148º56.7'	swim	275º	10	1
19	1 Oct	1	0	70º51.4'	148º56.5'	swim	[1]	10	4
20	6 Oct	10	1	70º14.8'	145º08.1'	mill	[1]	0	2
20	6 Oct	7	0	70º14.5'	145º03.6'	mill	[1]	0	2
20	6 Oct	2	0	70º14.7'	145º06.9'	mill	[1]	0	2
20	6 Oct	6	1	70º13.1'	144º52.2'	mill	[1]	0	2
20	6 Oct	1	0	70º14.0'	144º53.8'	swim	267º	0	2
20	6 Oct	2	0	70º20.3'	145º36.7'	swim	296º	0	2
21	10 Oct	1	0	71º08.5'	149º50.6'	swim	235º	0	4
22	11 Oct	2	1	71º31.6'	156º37.2'	swim	261º	0	3
22	11 Oct	1	0	71º35.0'	156º08.3'	swim	271º	0	3
22	11 Oct	2	0	71º32.9'	155º48.5'	breach	262º	0	3
22	11 Oct	1	0	71º36.5'	155º20.6'	swim	262º	0	3
23	11 Oct	3	1	71º26.7'	154º33.8'	mill	[1]	0	3
23	11 Oct	6	1	71º28.1'	154º34.0'	swim	262º	0	3
23	11 Oct	1	0	71º32.4'	154º13.4'	swim	262º	0	3
23	11 Oct	1	0	71º20.8'	153º50.7'	swim	293º	0	3
23	11 Oct	2	1	71º18.1'	152º12.6'	swim	234º	0	3
24	13 Oct	1	0	70º16.4'	143º21.4'	swim	267º	0	2
24	13 Oct	1	0	69º46.4'	140º55.3'	swim	328º	0	1
24	13 Oct	1	0	69º49.6'	141º25.7'	swim	198º	0	1
24	13 Oct	4	0	70º05.8'	141º51.7'	mill	[1]	0	2
24	13 Oct	1	0	70º10.8'	142º48.6'	swim	358º	0	2
24	13 Oct	1	0	70º10.9'	142º50.9'	swim	188º	0	2
24	13 Oct	2	0	70º13.4'	143º16.7'	swim	337º	0	2
24	13 Oct	1	0	70º14.2'	143º15.7'	swim	237º	0	2
24	13 Oct	1	0	70º17.6'	143º35.2'	swim	277º	0	2

Flight No	Date	Total Whales	No of Calves	Latitude (N)	Longitude (W)	Behavior	Compass Heading, True	Ice (%)	Wind Force
25	13 Oct	1	0	70º28.6'	147º52.8'	swim	265º	100	1
25	13 Oct	3	0	70º38.0'	147º13.9'	swim	266º	0	2
25	13 Oct	2	0	70º30.2'	146º39.4'	swim	96º	50	1
25	13 Oct	1	0	70º30.8'	146º39.4'	swim	96º	50	1
25	13 Oct	2	0	70º31.9'	146º39.2'	swim	26º	50	1
25	13 Oct	10	0	70º31.9'	146º39.1'	mill	[1]	0	1
26	15 Oct	3	0	71º10.4'	152º45.2'	mill	[1]	0	1
26	15 Oct	1	0	70º58.7'	151º49.0'	swim	269º	100	1
26	15 Oct	1	0	71º01.2'	149º42.3'	swim	25º	0	2
26	15 Oct	1	0	71º07.2'	149º18.1'	swim	285º	0	2
26	15 Oct	17	0	70º54.7'	149º18.1'	swim	25º	0	2

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APPENDIX C: FALL 2006 DAILY FLIGHT SUMMARIES

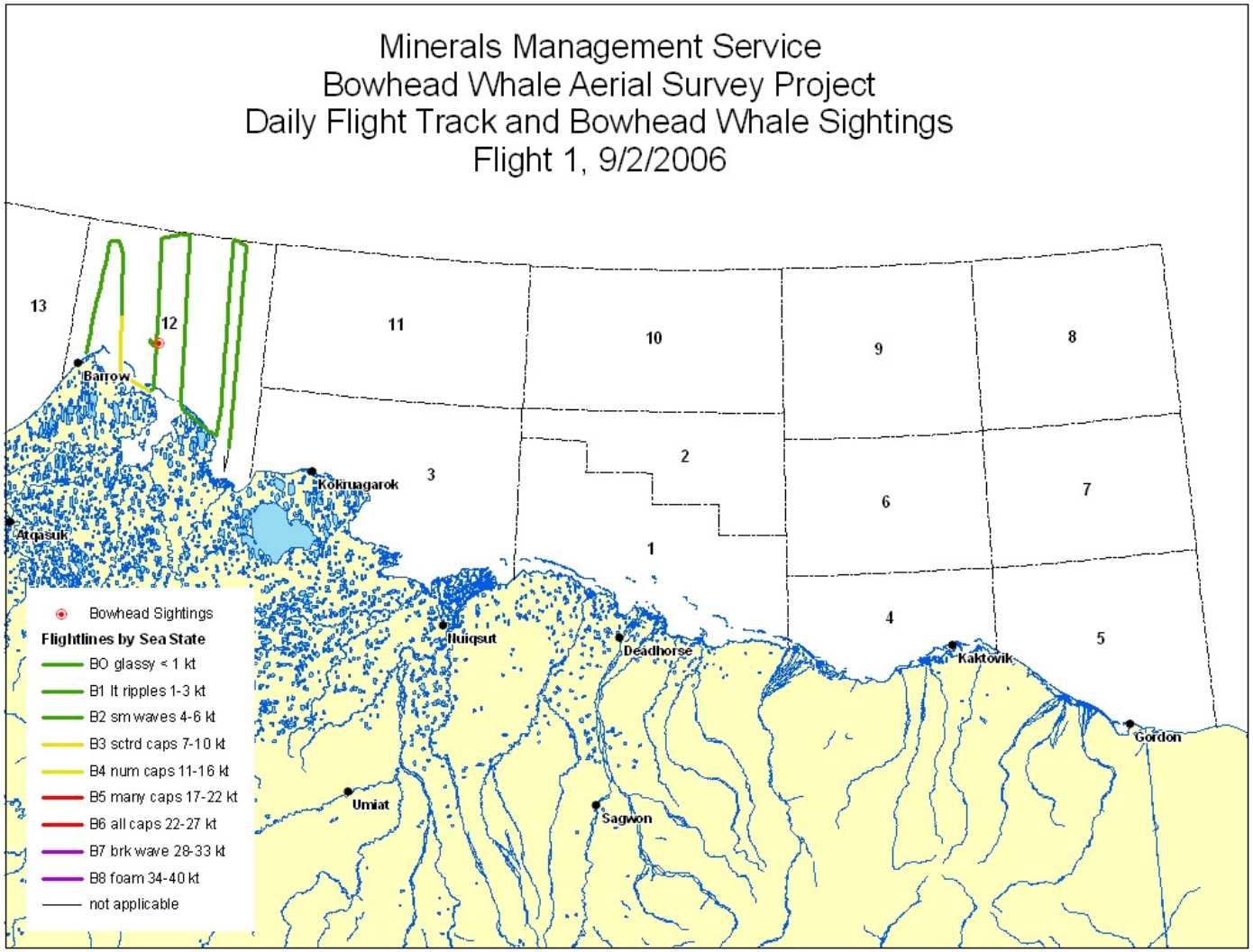

Figure C-1 – Aerial survey flight track, 2 September 2006.

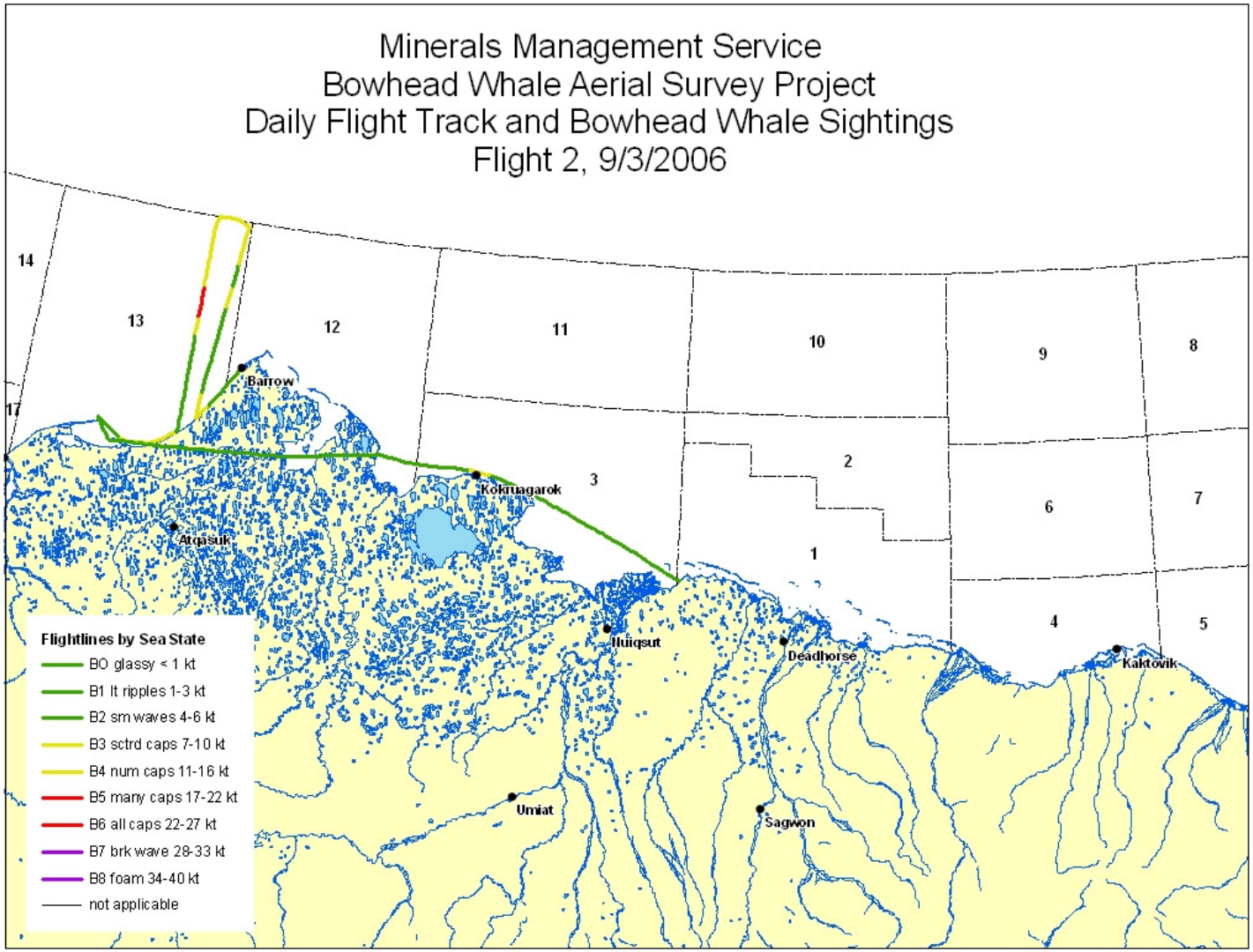

Figure C-2 – Aerial survey flight track, 3 September 2006.

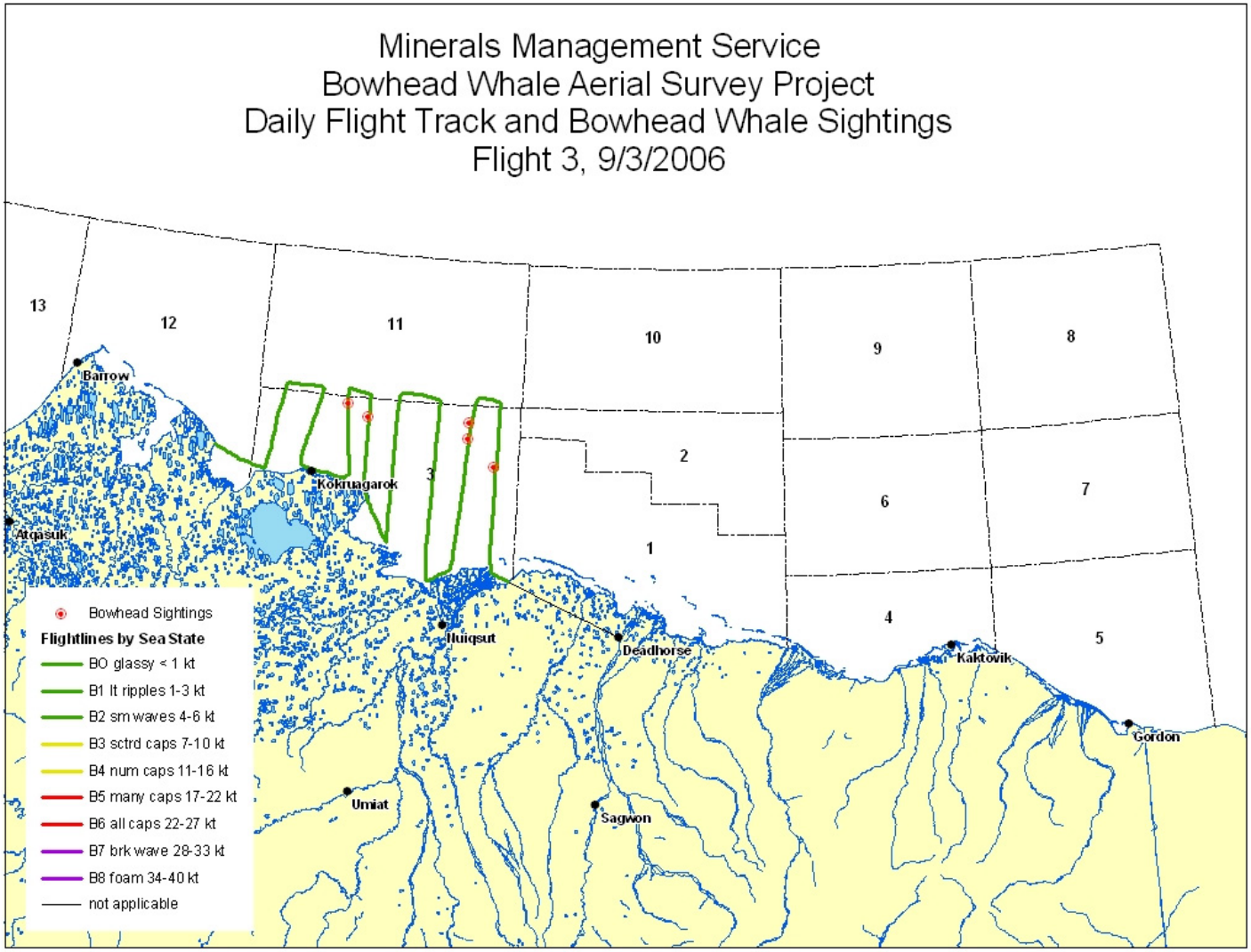

Figure C-3 – Aerial survey flight track, 3 September 2006.

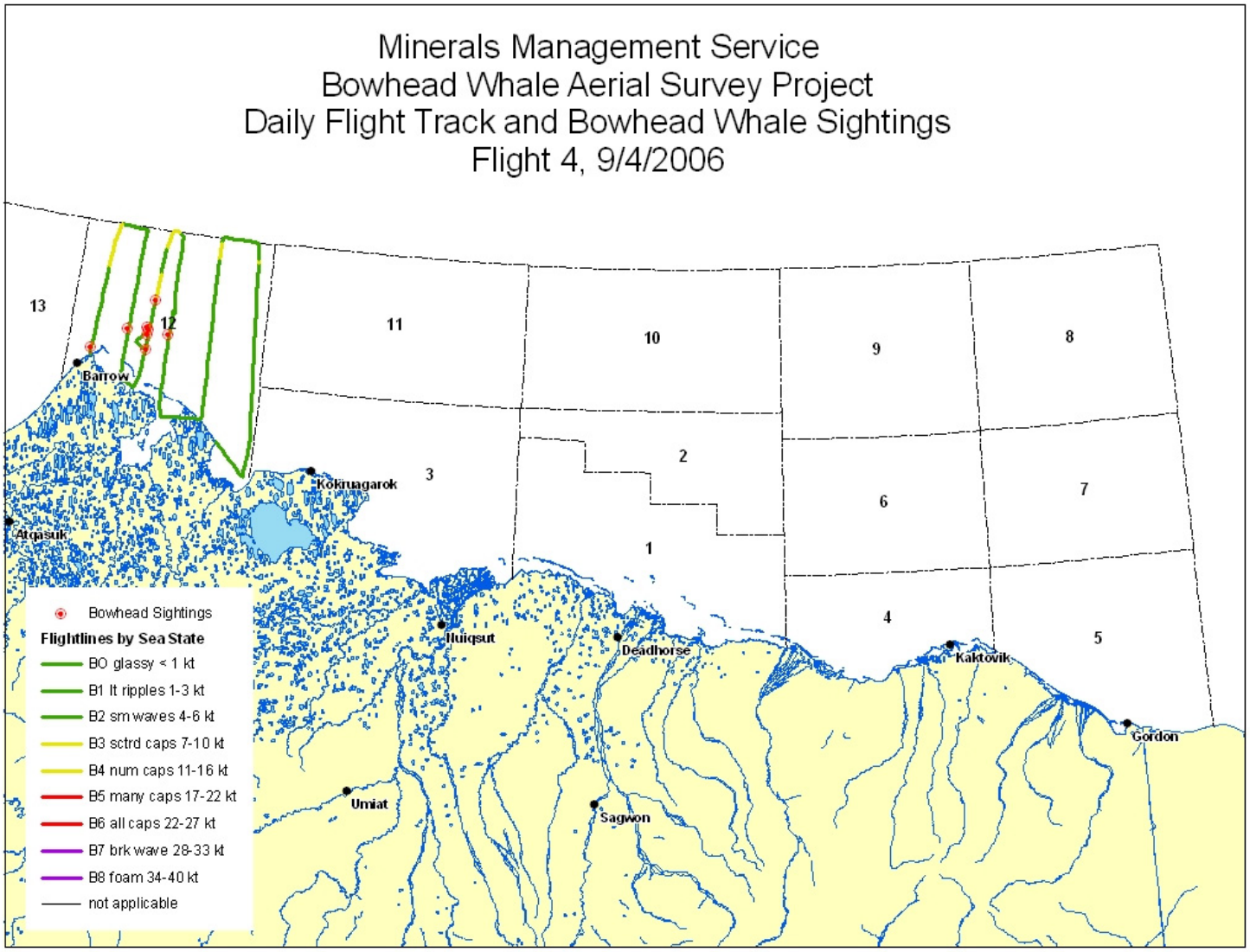

Figure C-4 – Aerial survey flight track, 4 September 2006.

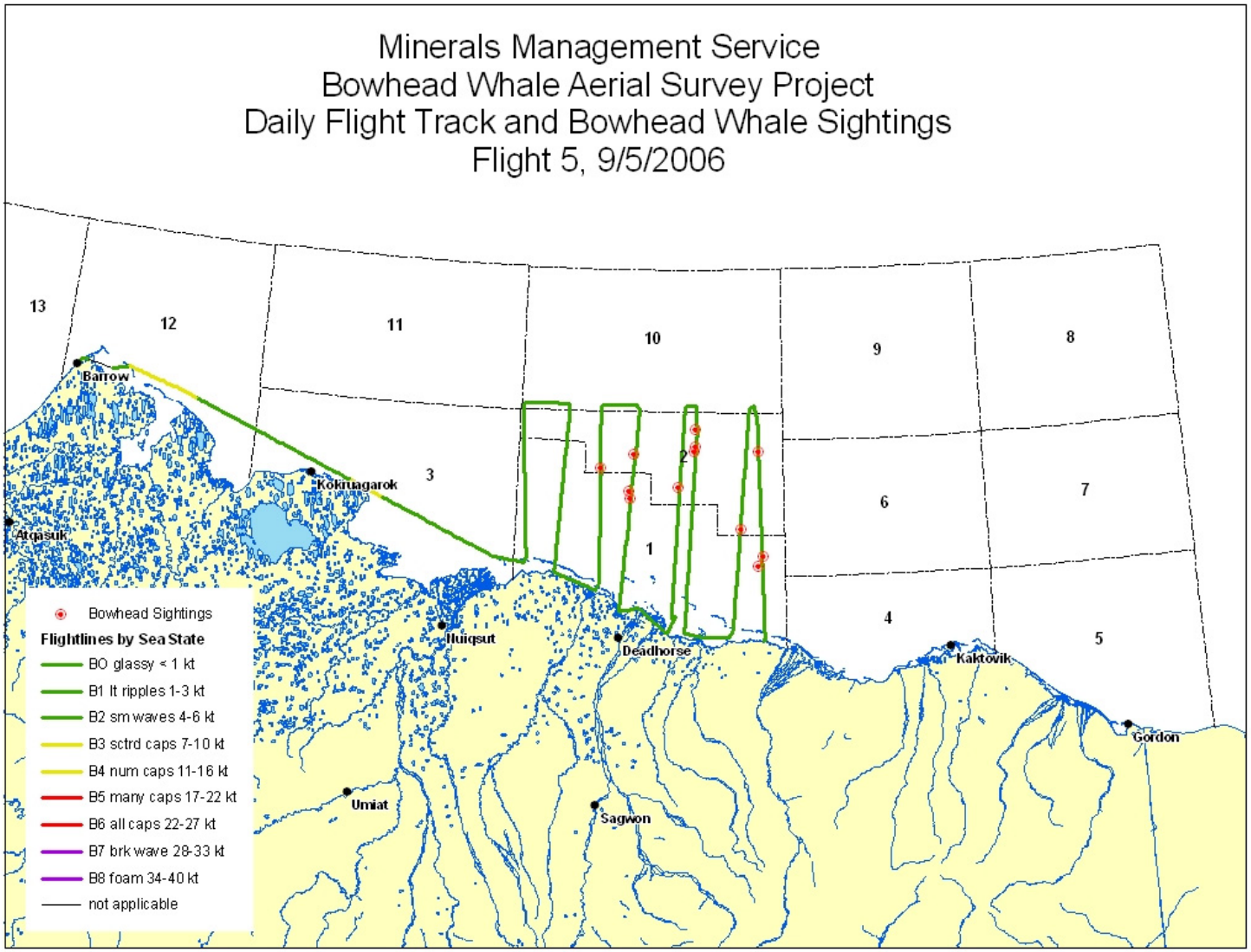

Figure C-5 – Aerial survey flight track, 5 September 2006.

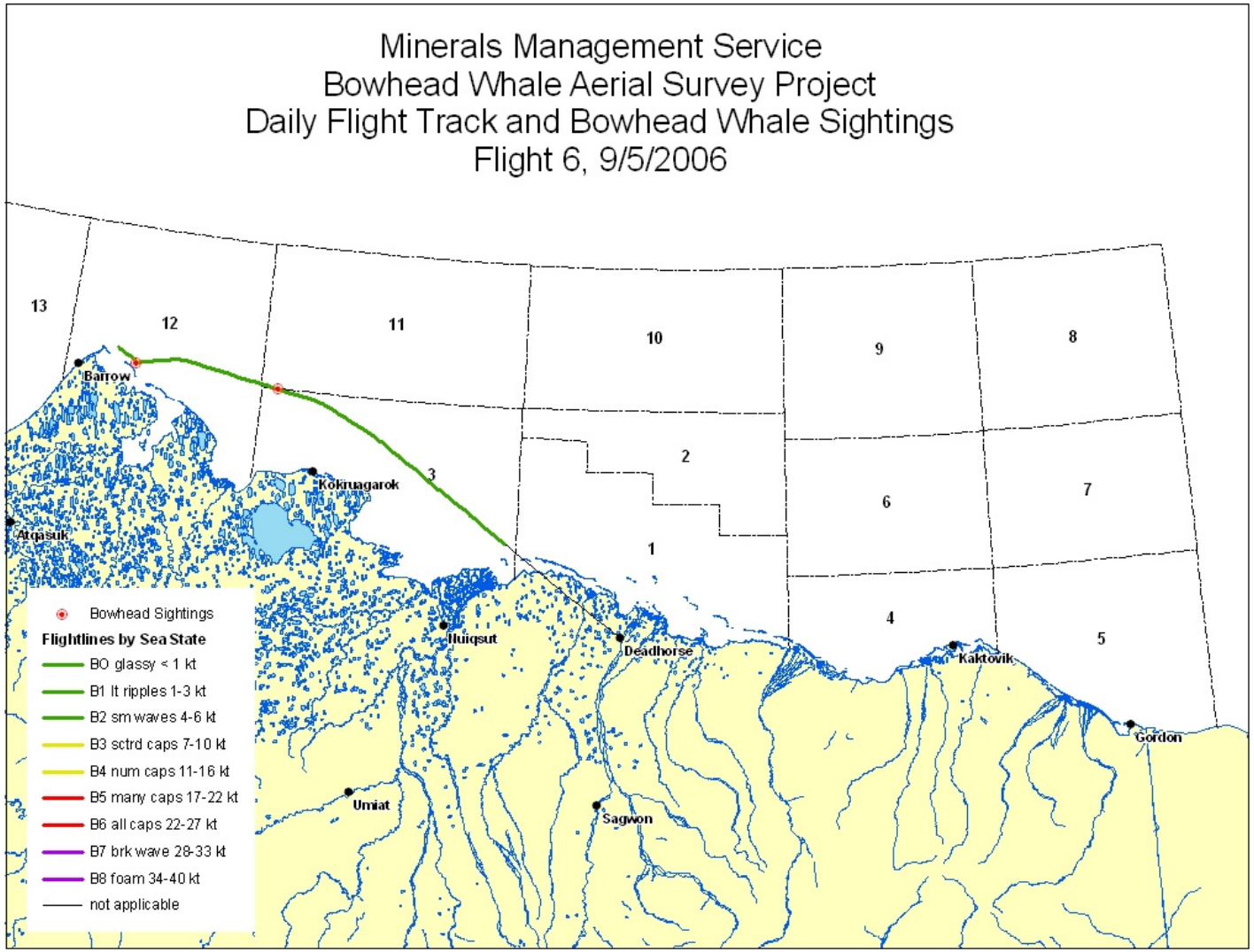

Figure C-6 – Aerial survey flight track, 5 September 2006.

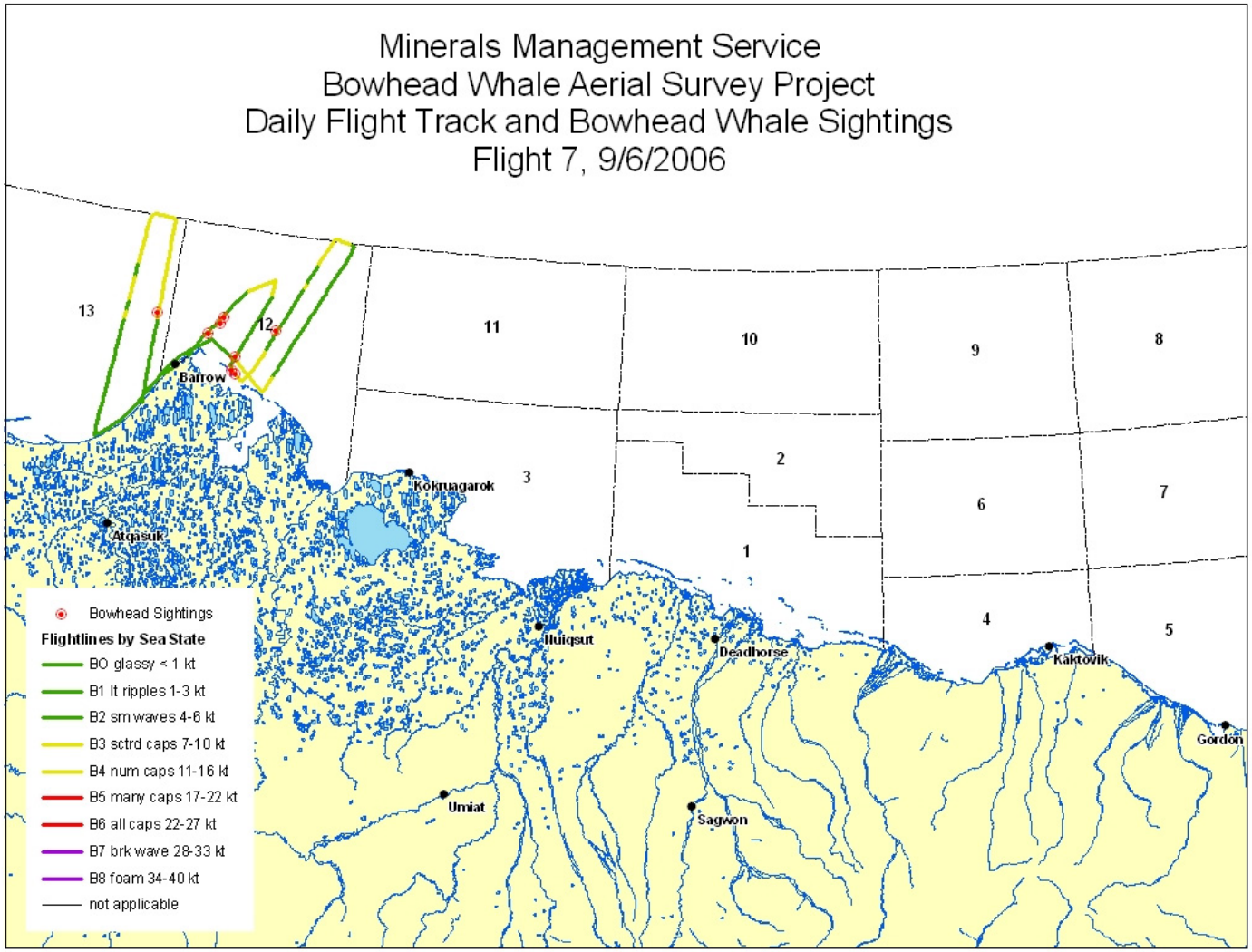

Figure C-7 – Aerial survey flight track, 6 September 2006.

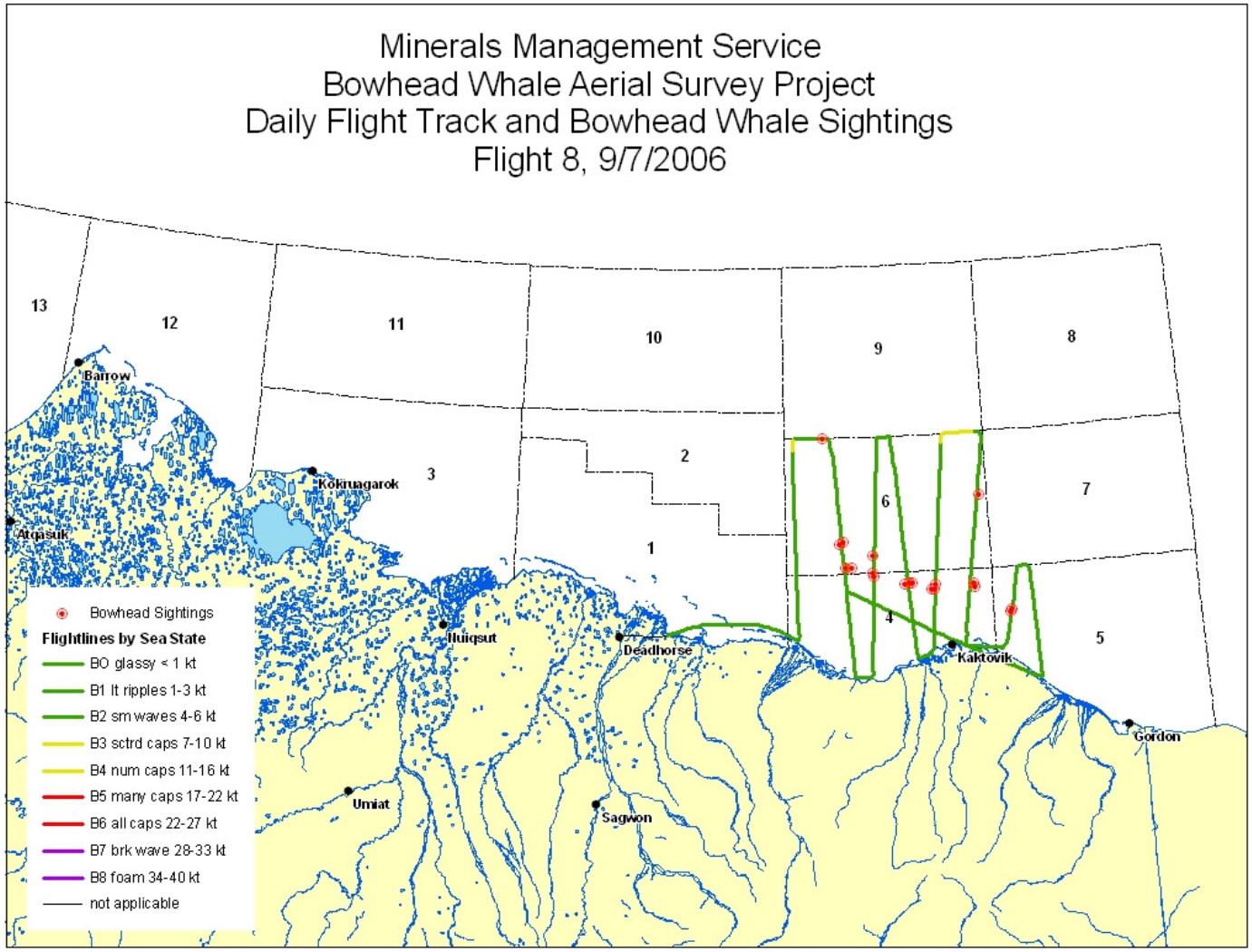

Figure C-8 – Aerial survey flight track, 7 September 2006.

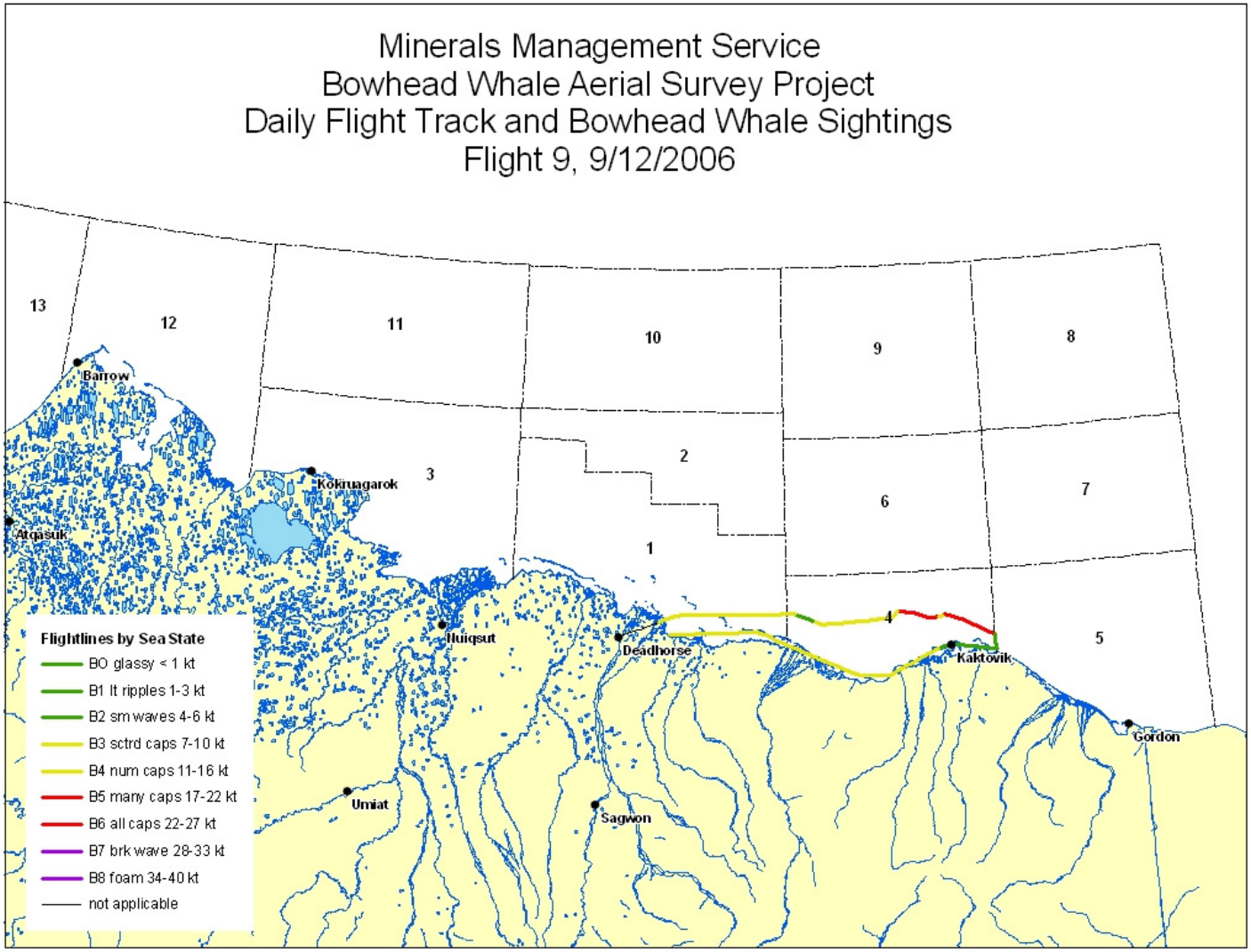

Figure C-9 – Aerial survey flight track, 12 September 2006.

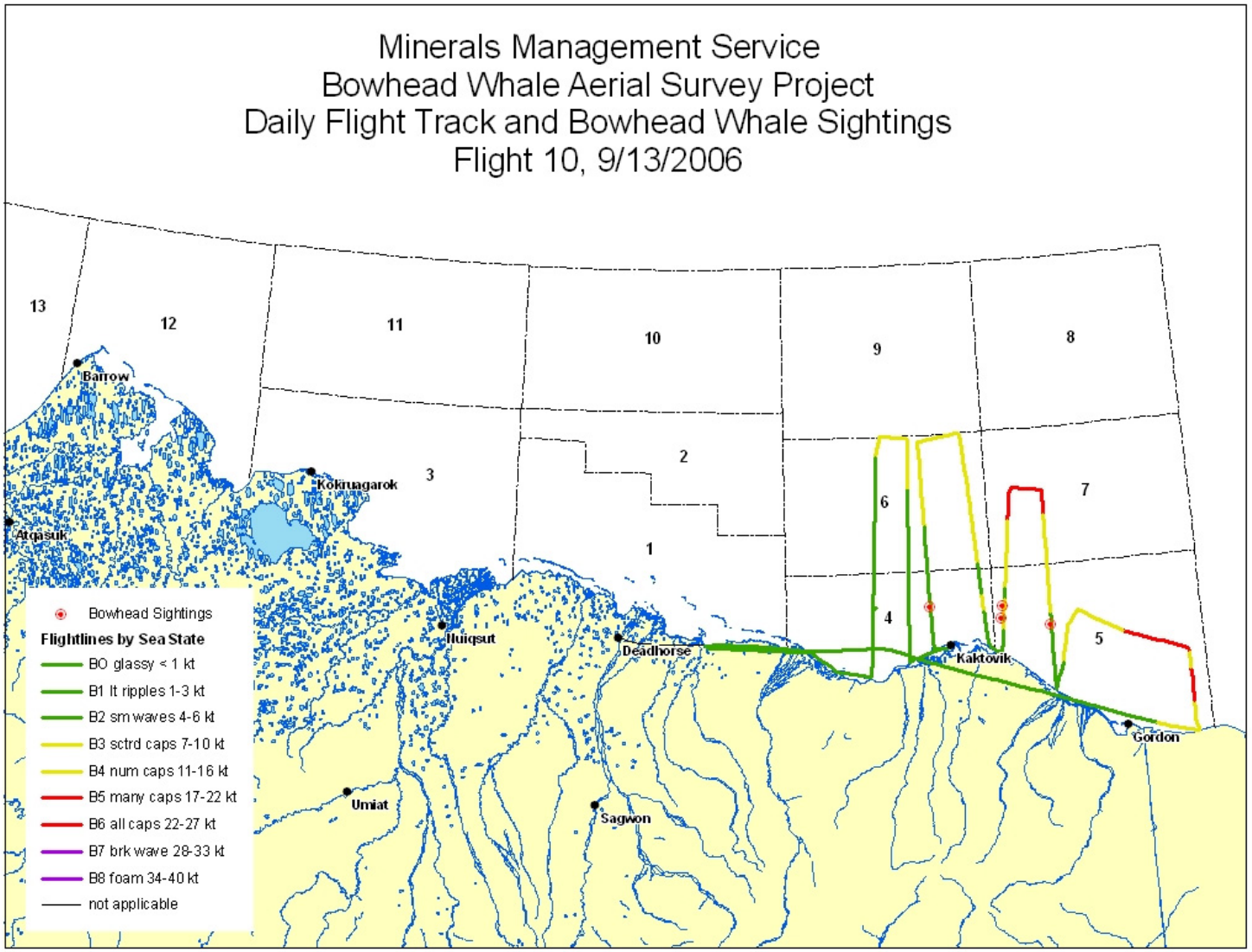

Figure C-10 – Aerial survey flight track, 13 September 2006.

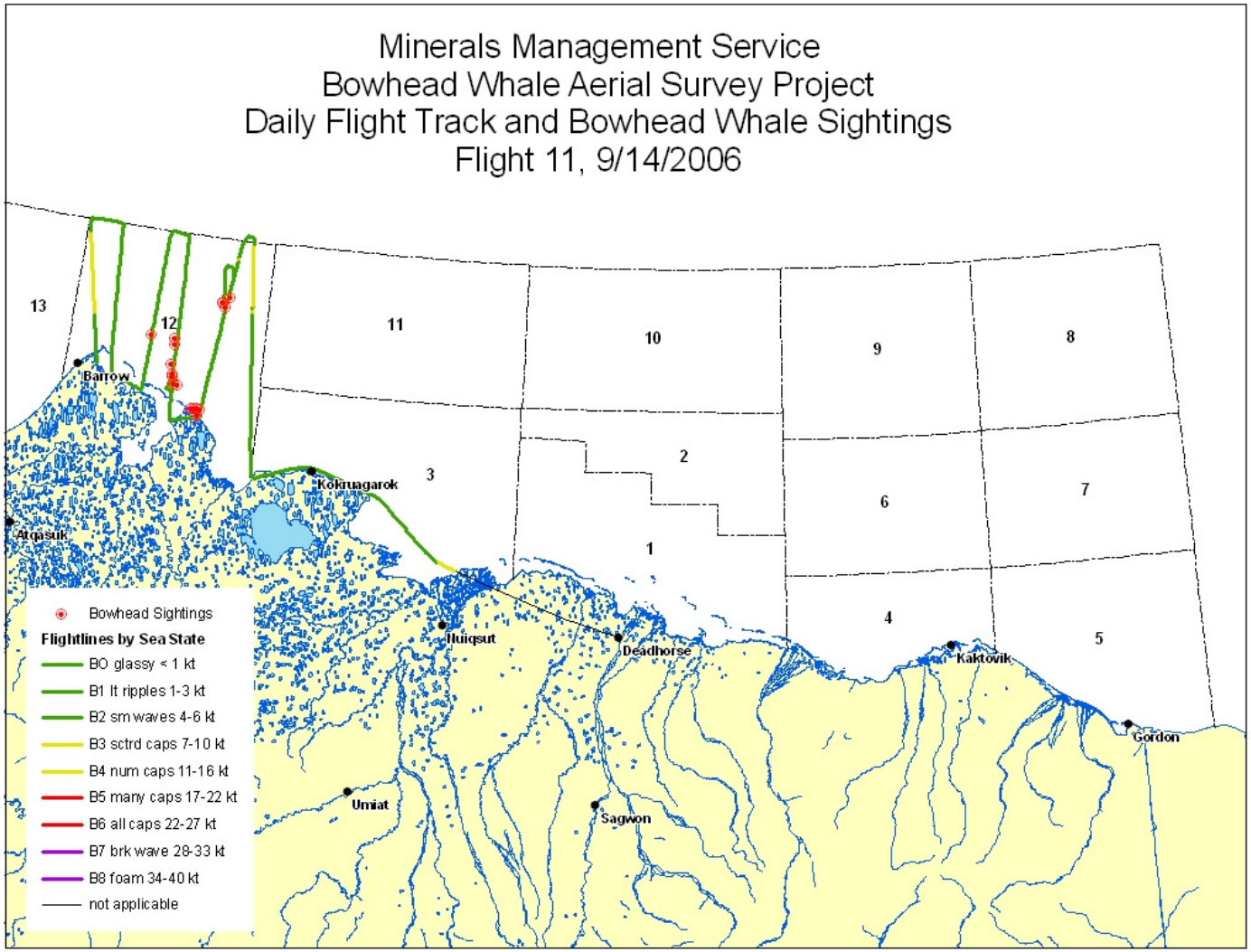

Figure C-11 – Aerial survey flight track, 14 September 2006.

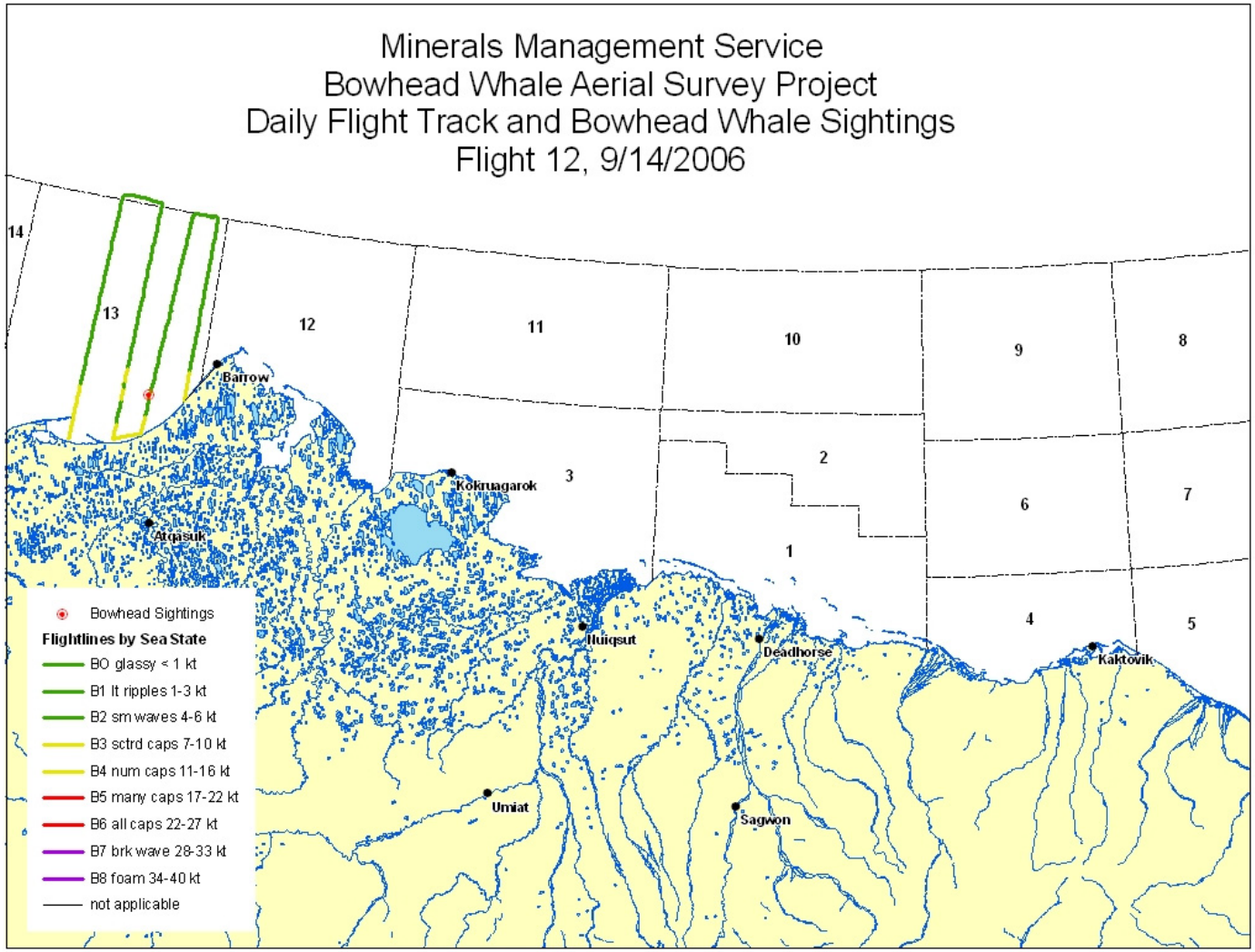

Figure C-12 – Aerial survey flight track, 14 September 2006.

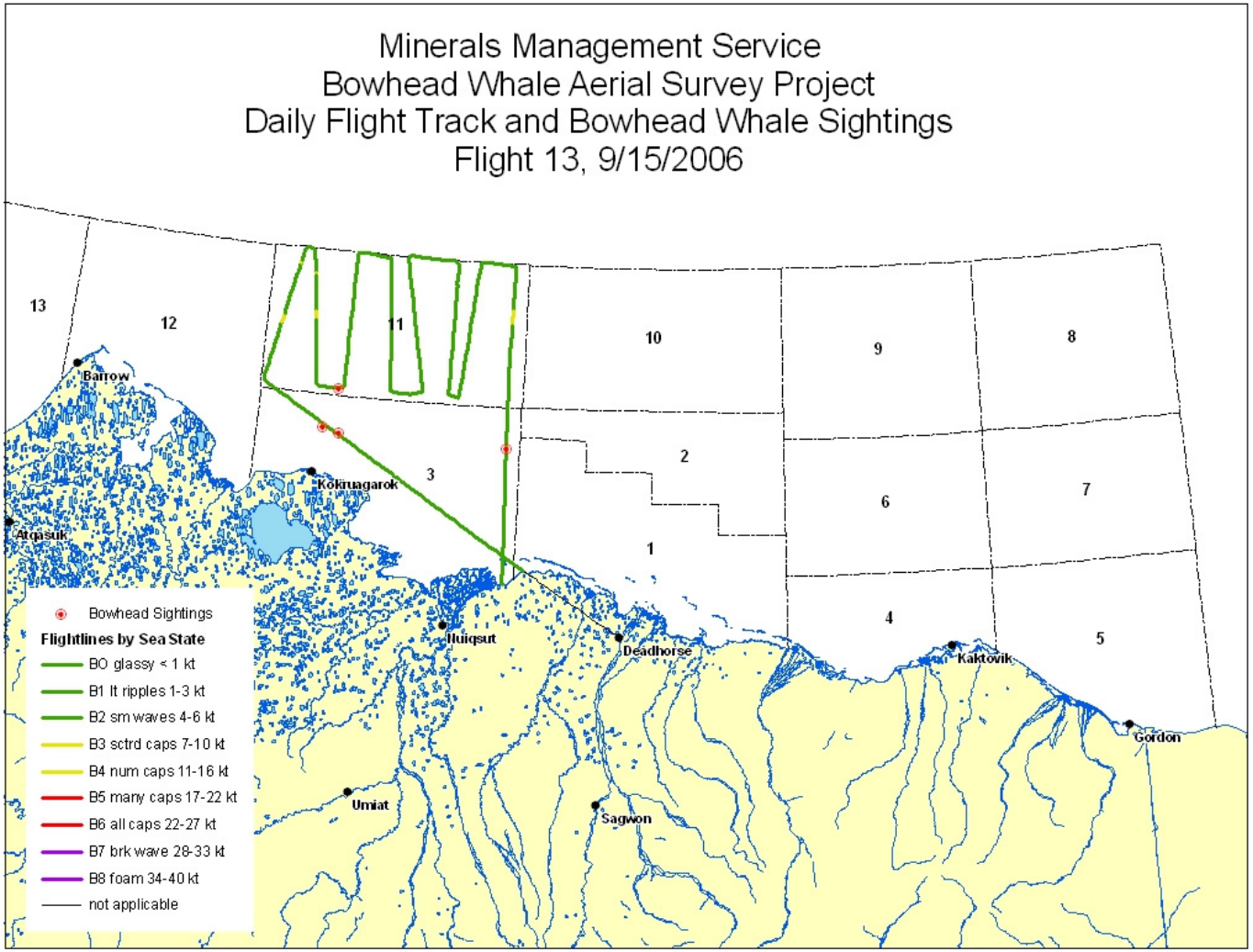

Figure C-13 – Aerial survey flight track, 15 September 2006.

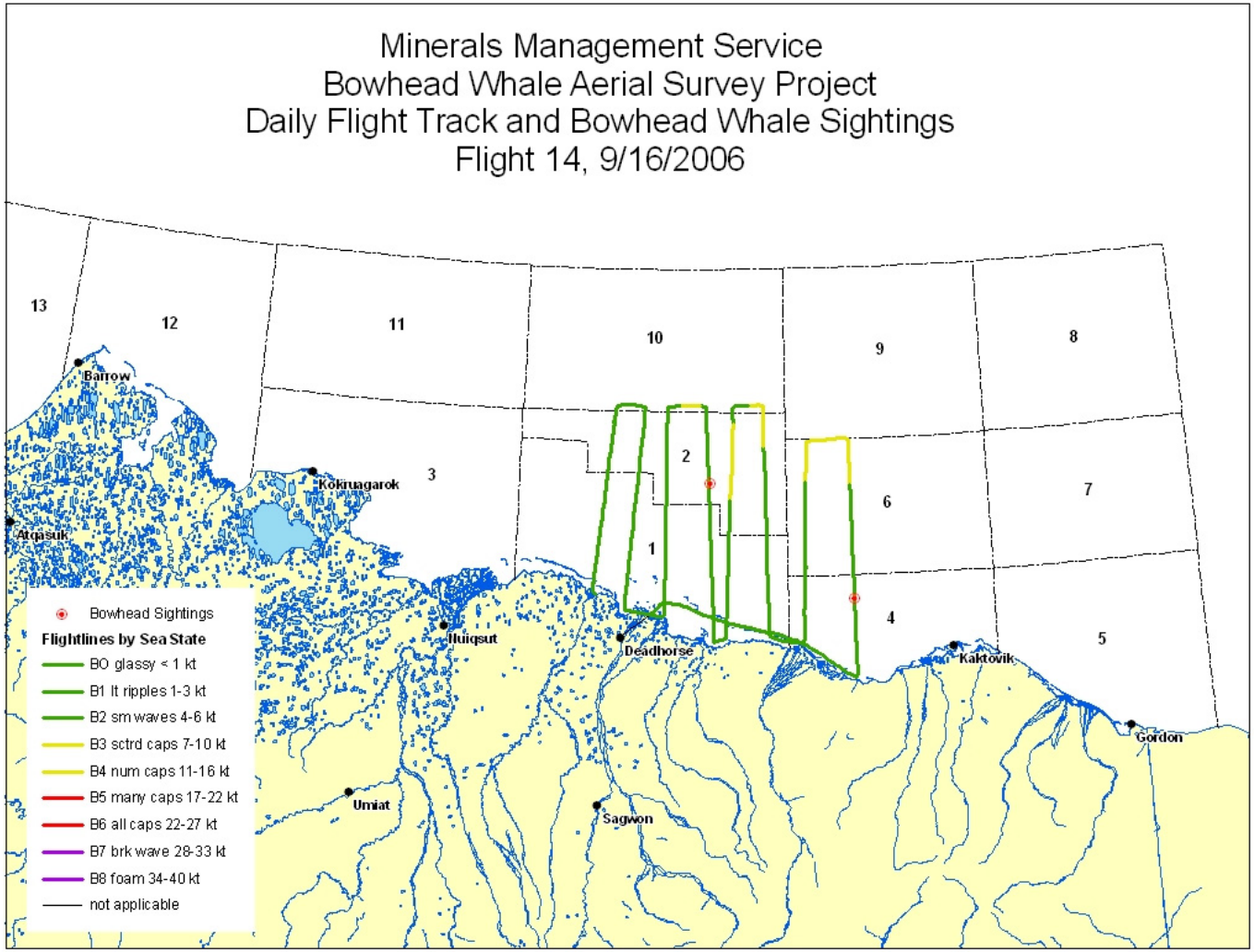

Figure C-14 – Aerial survey flight track, 16 September 2006.

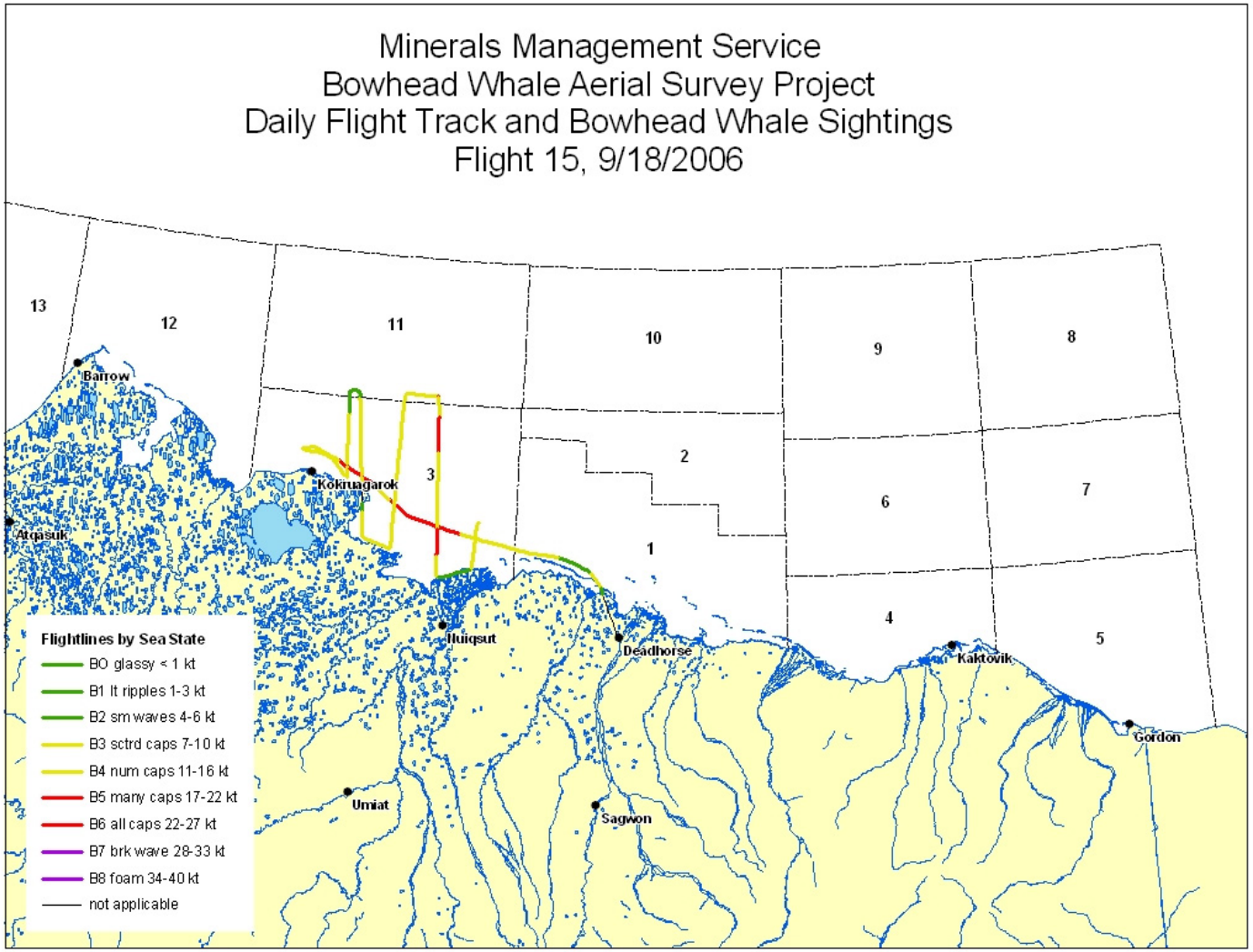

Figure C-15 – Aerial survey flight track, 18 September 2006.

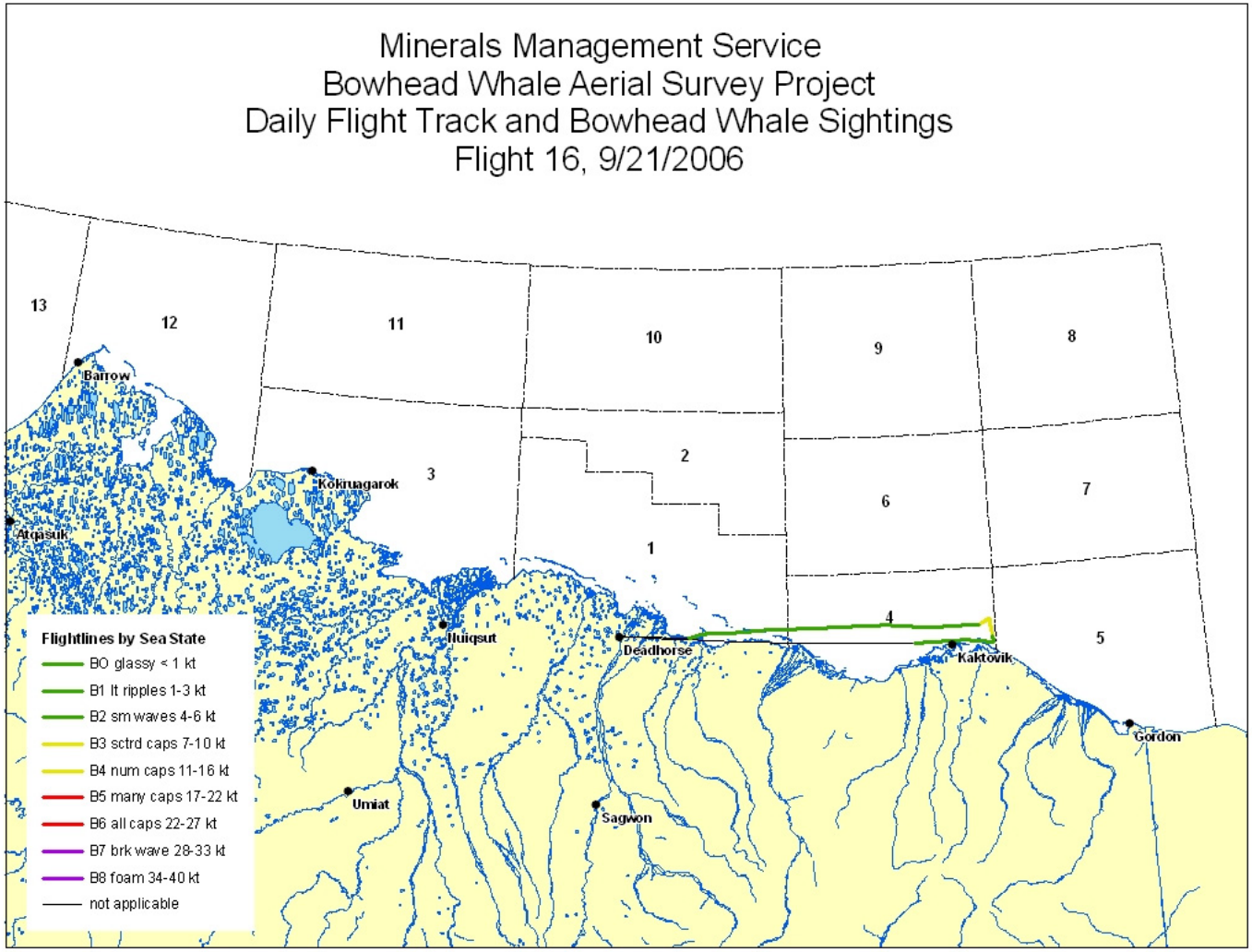

Figure C-16 – Aerial survey flight track, 21 September 2006.

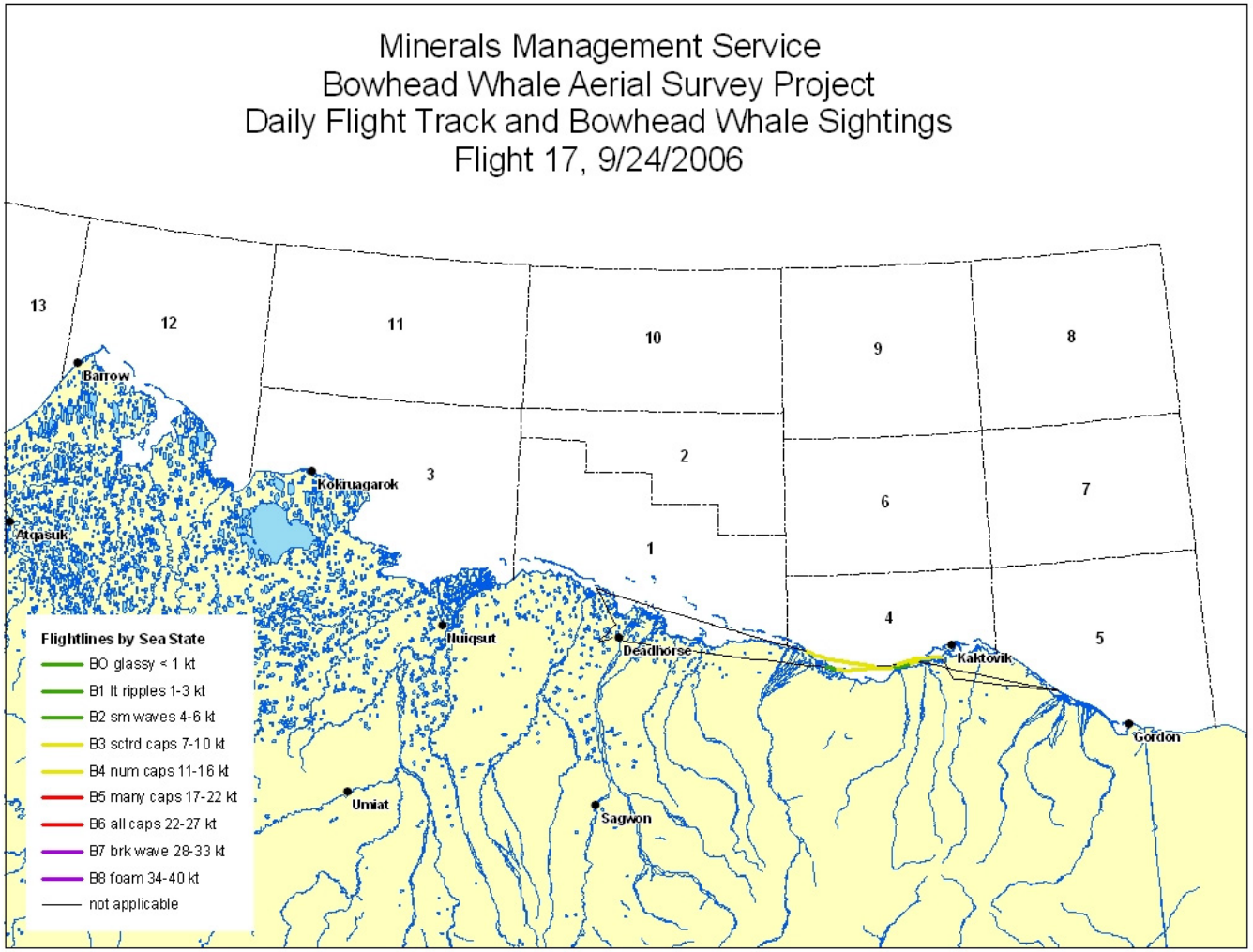

Figure C-17 – Aerial survey flight track, 24 September 2006.

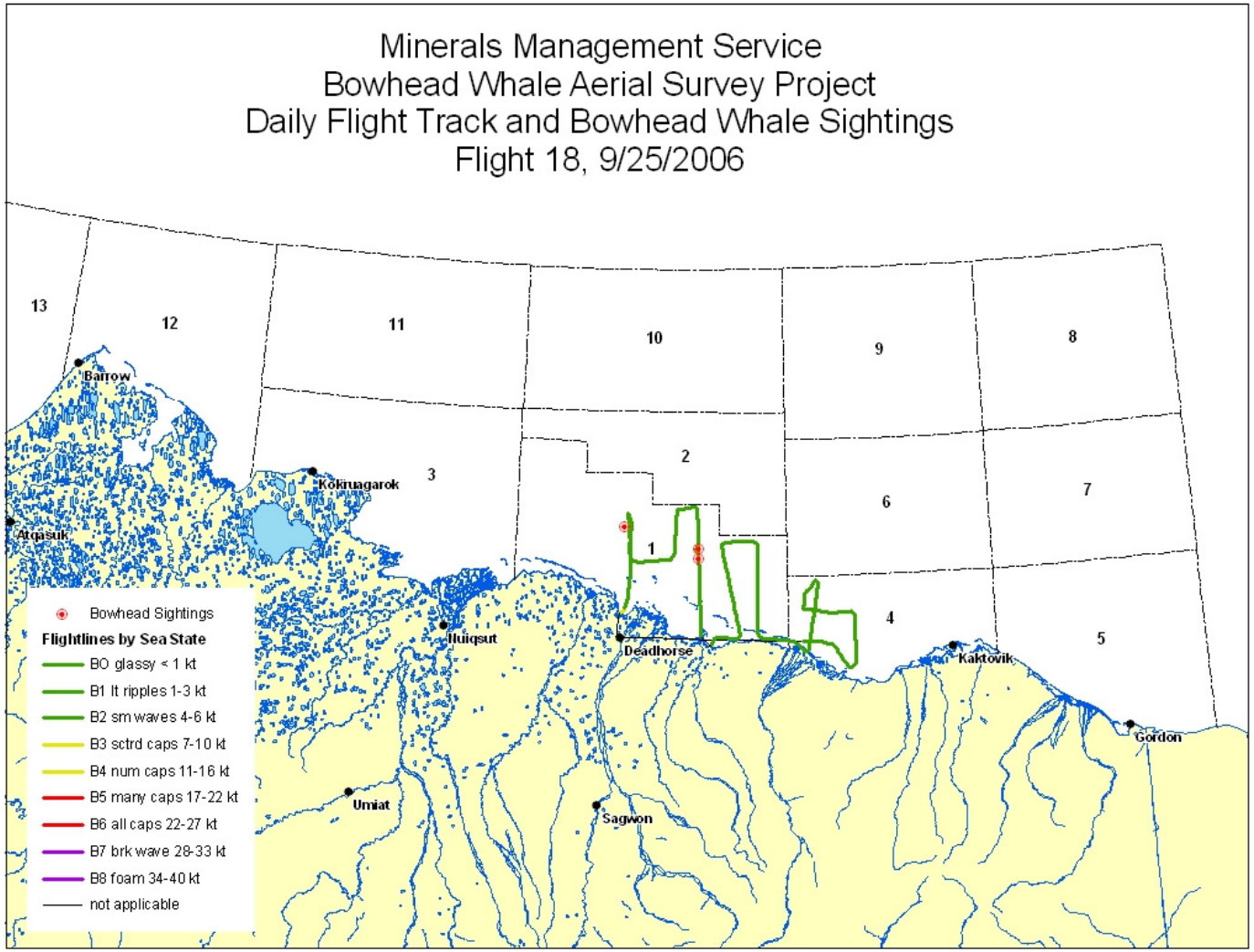

Figure C-18 – Aerial survey flight track, 25 September 2006.

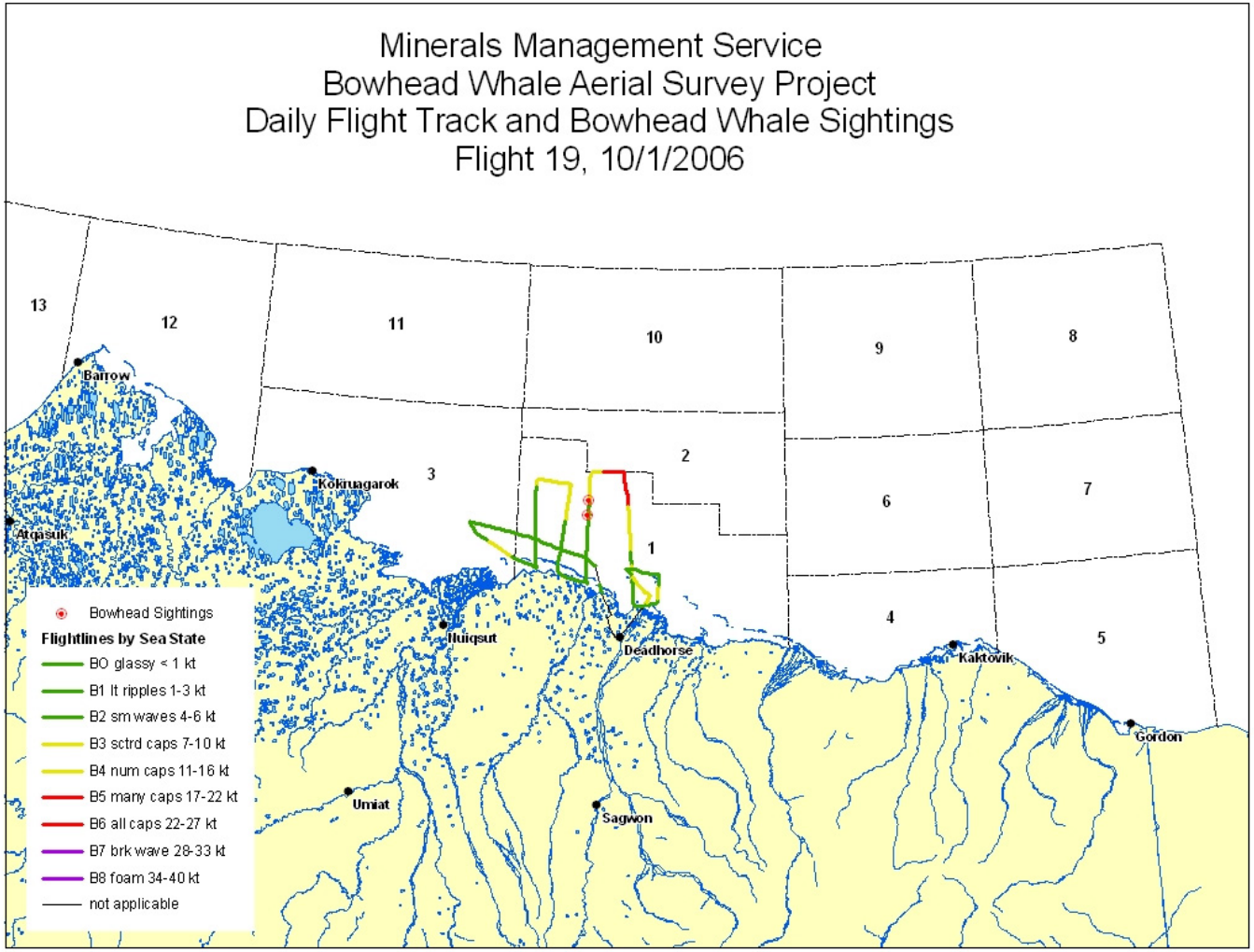

Figure C-19 – Aerial survey flight track, 1 October 2006.

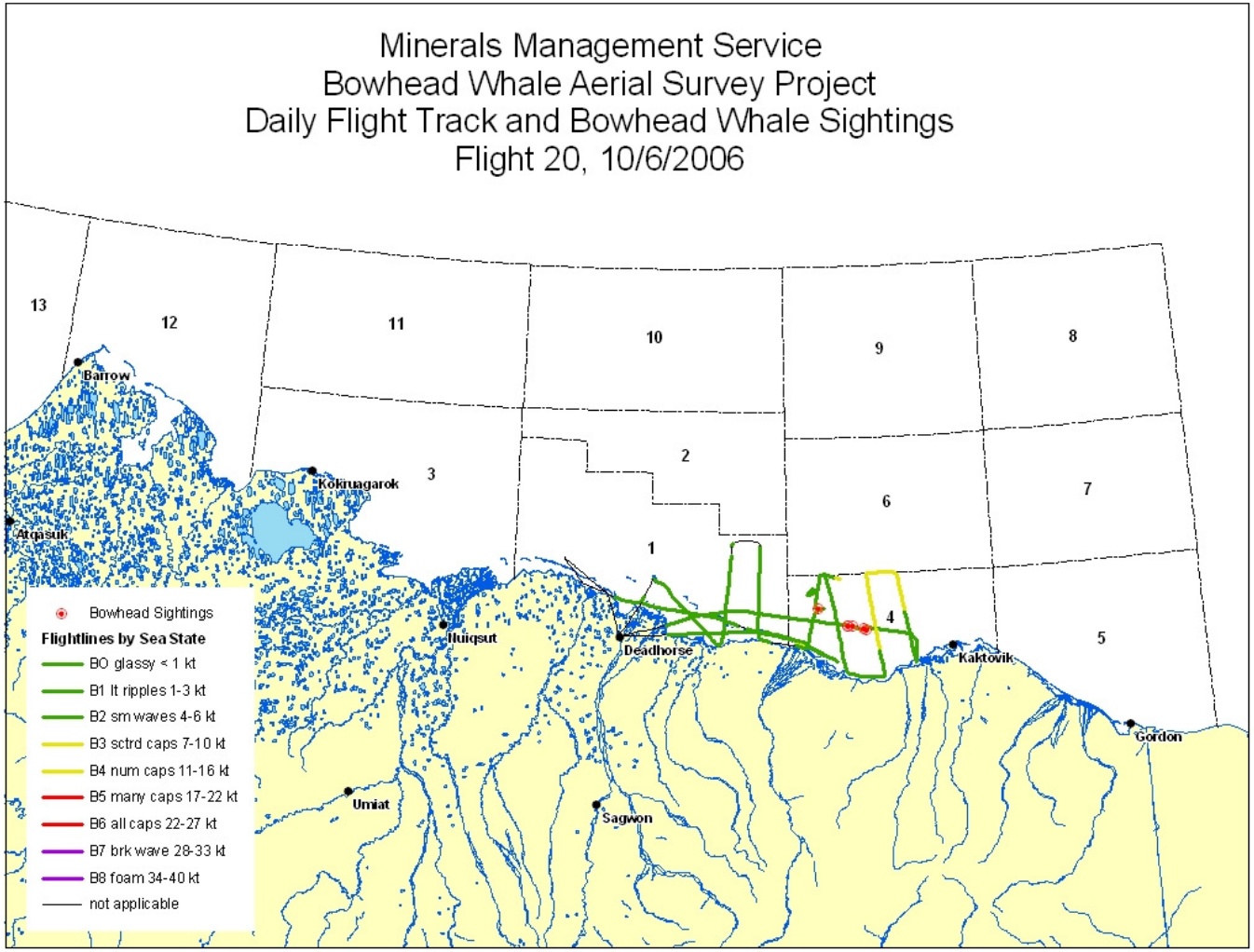

Figure C-20 – Aerial survey flight track, 6 October 2006.

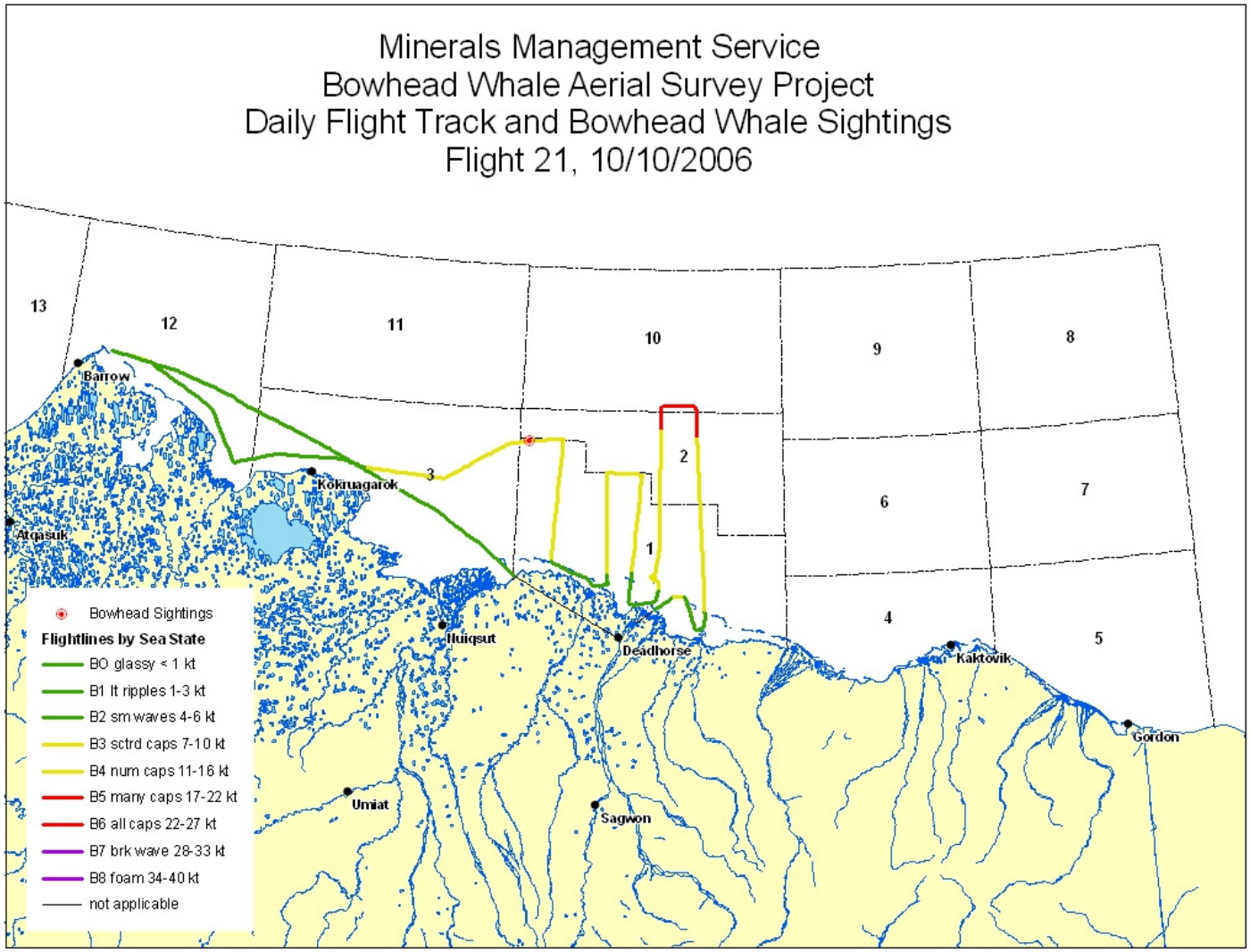

Figure C-21 – Aerial survey flight track, 10 October 2006.

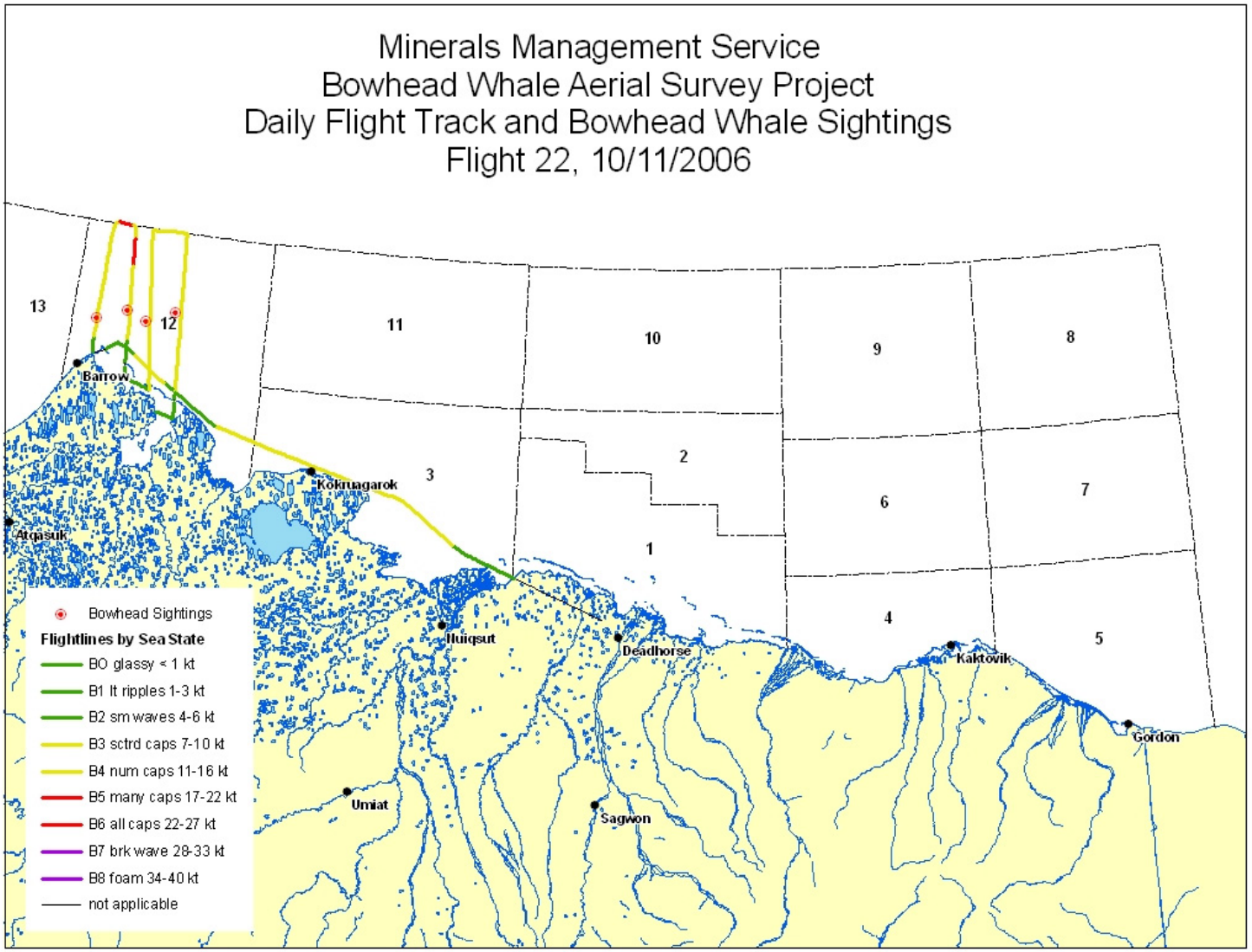

Figure C-22 – Aerial survey flight track, 11 October 2006.

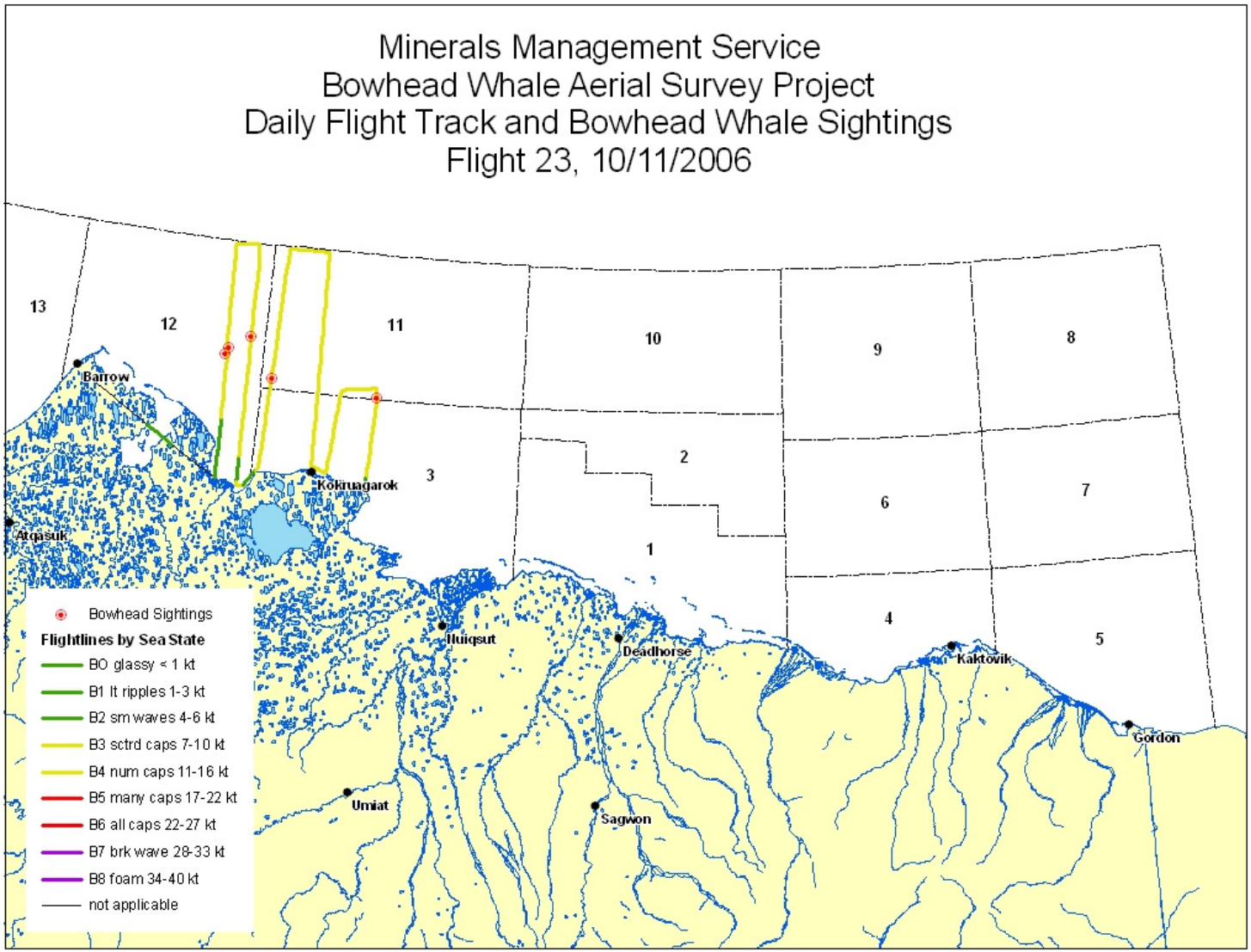

Figure C-23 – Aerial survey flight track, 11 October 2006.

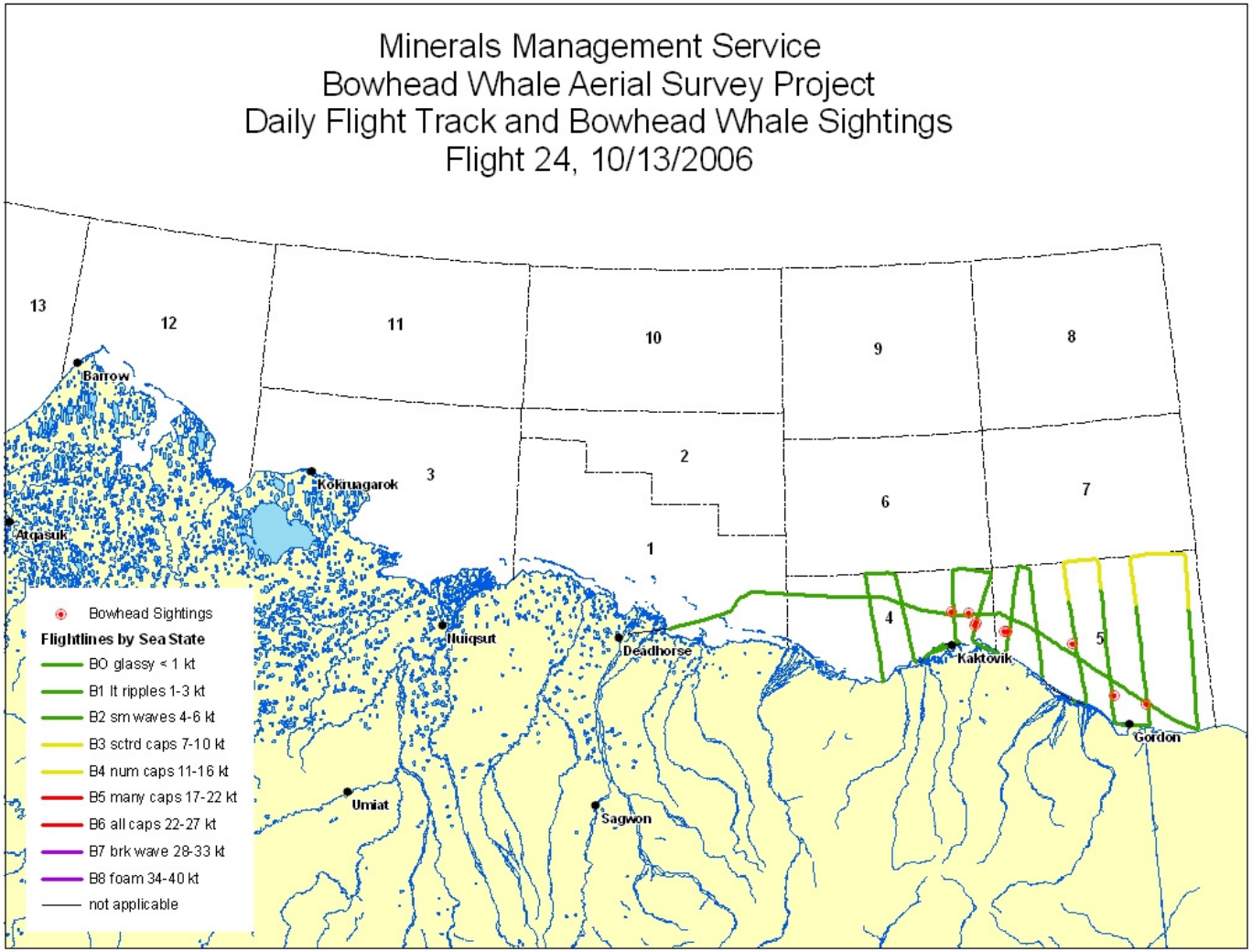

Figure C-24 – Aerial survey flight track, 13 October 2006.

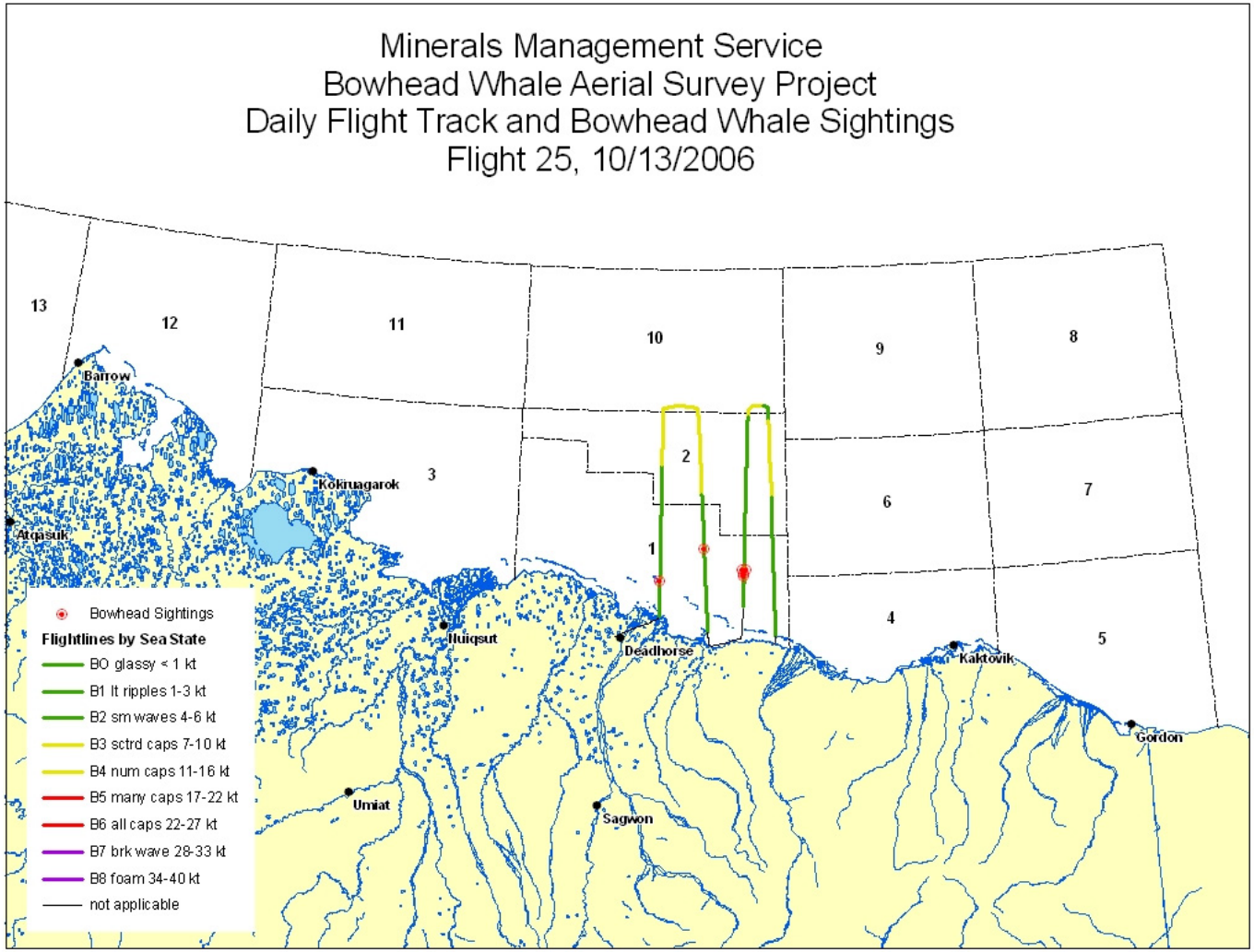

Figure C-25 – Aerial survey flight track, 13 October 2006.

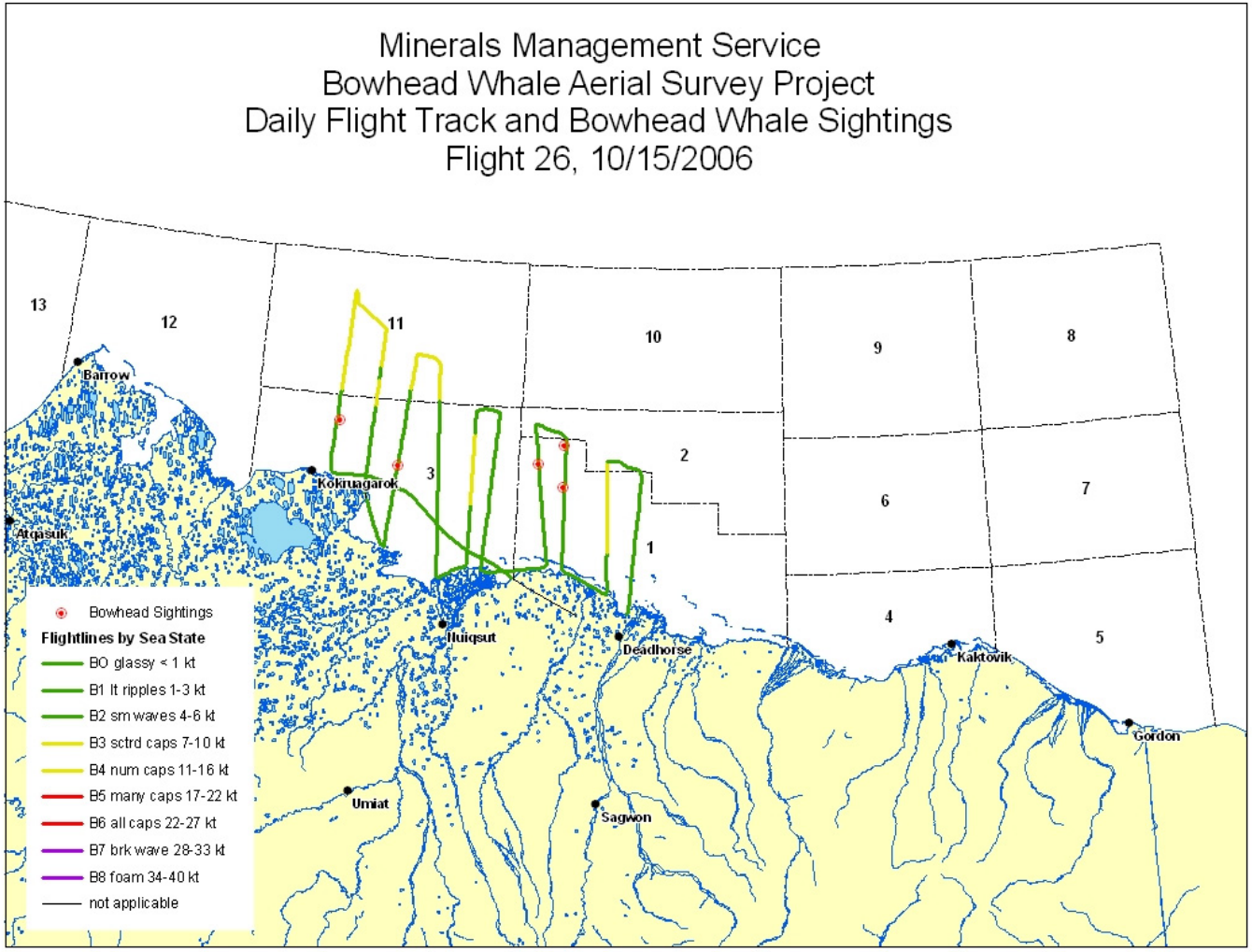

Figure C-26 – Aerial survey flight track, 15 October 2006.

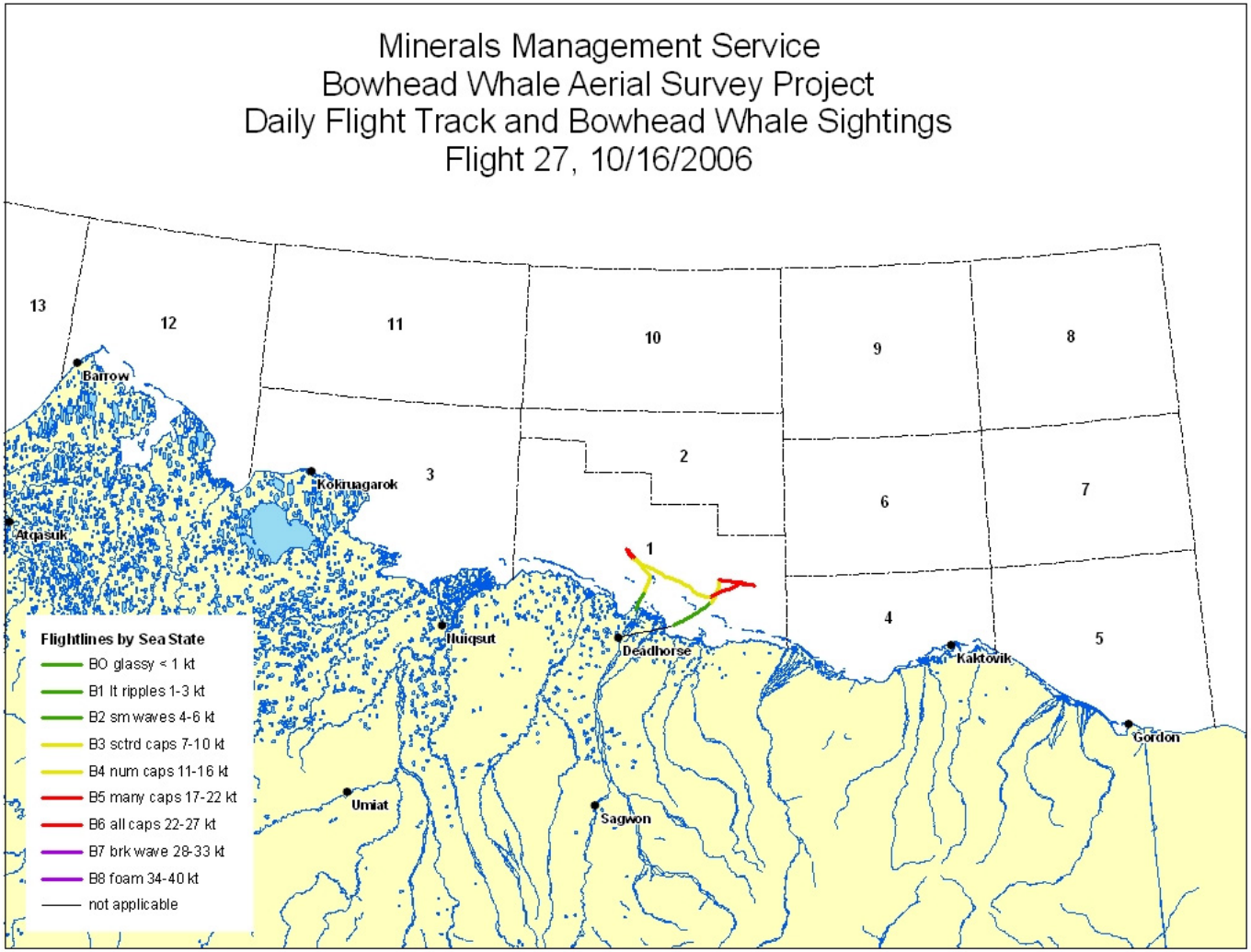

Figure C-27 – Aerial survey flight track, 16 October 2006.

APPENDIX D: FALL 2007 ICE CONCENTRATION MAPS – ALASKAN BEAUFORT SEA

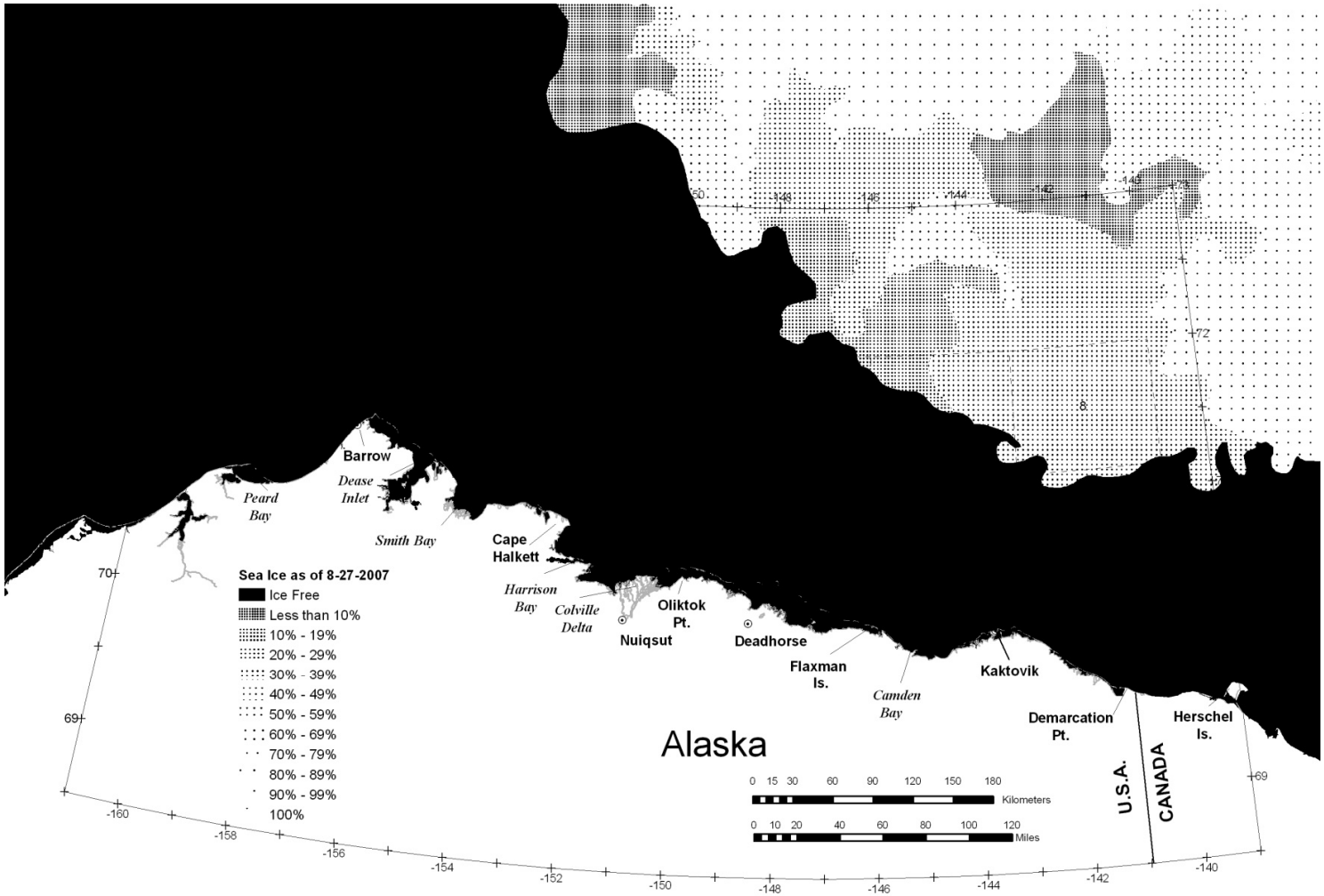

Figure D-1 – Ice concentrations in the Alaskan Beaufort Sea, 27 August 2007.

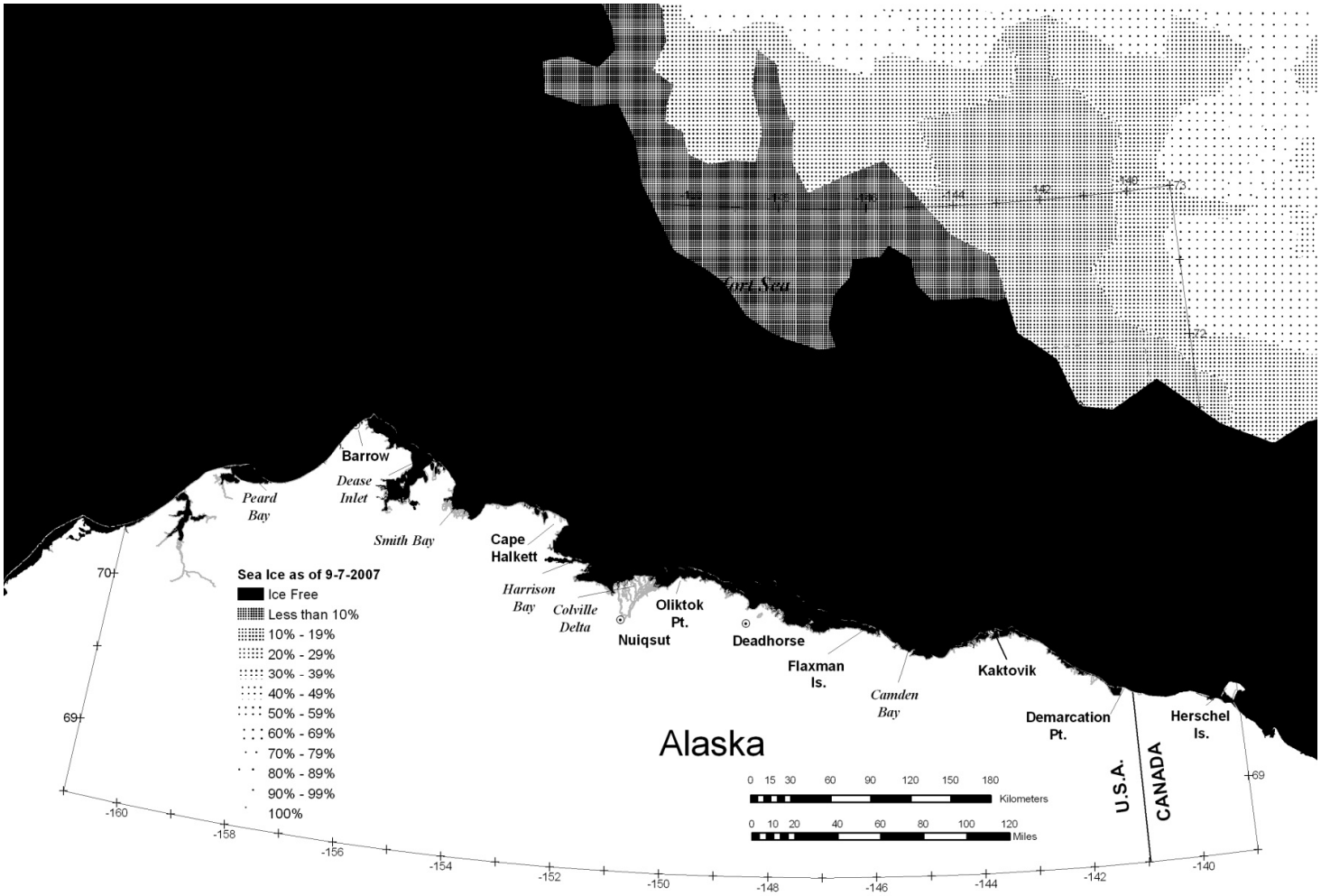

Figure D-2 – Ice concentrations in the Alaskan Beaufort Sea, 7 September 2007.

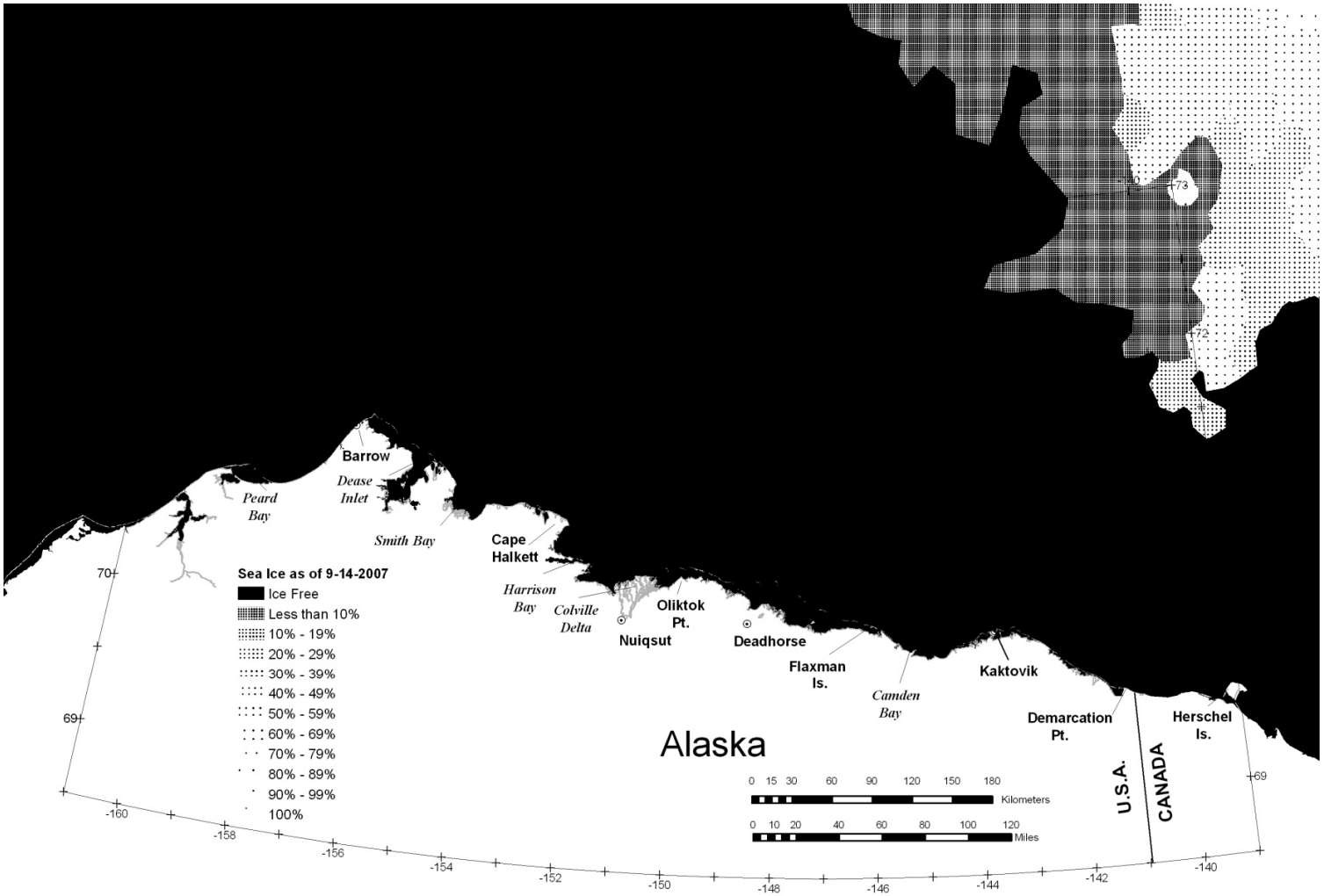

Figure D-3 – Ice concentrations in the Alaskan Beaufort Sea, 14 September 2007.

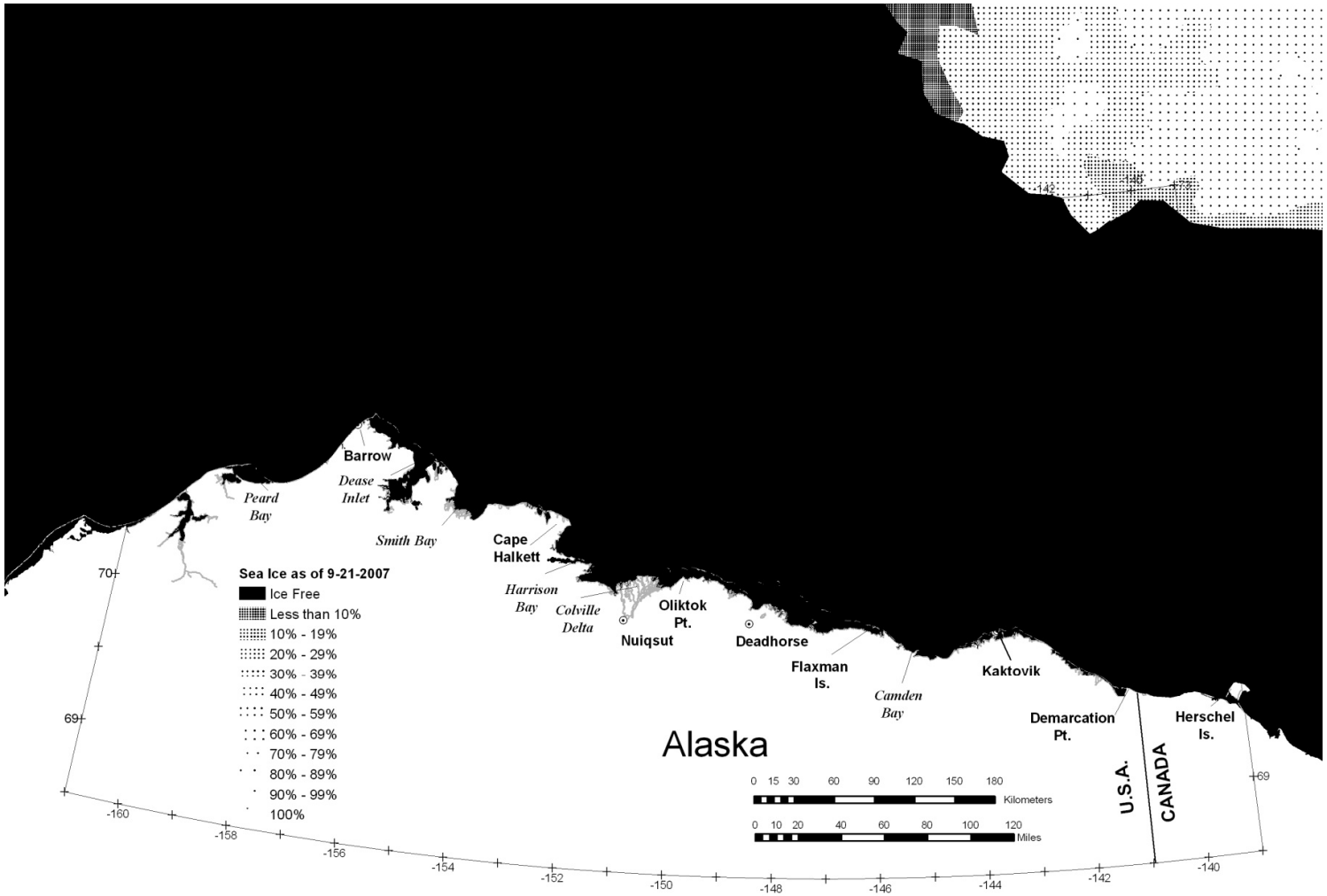

Figure D-4 – Ice concentrations in the Alaskan Beaufort Sea, 21 September 2007.

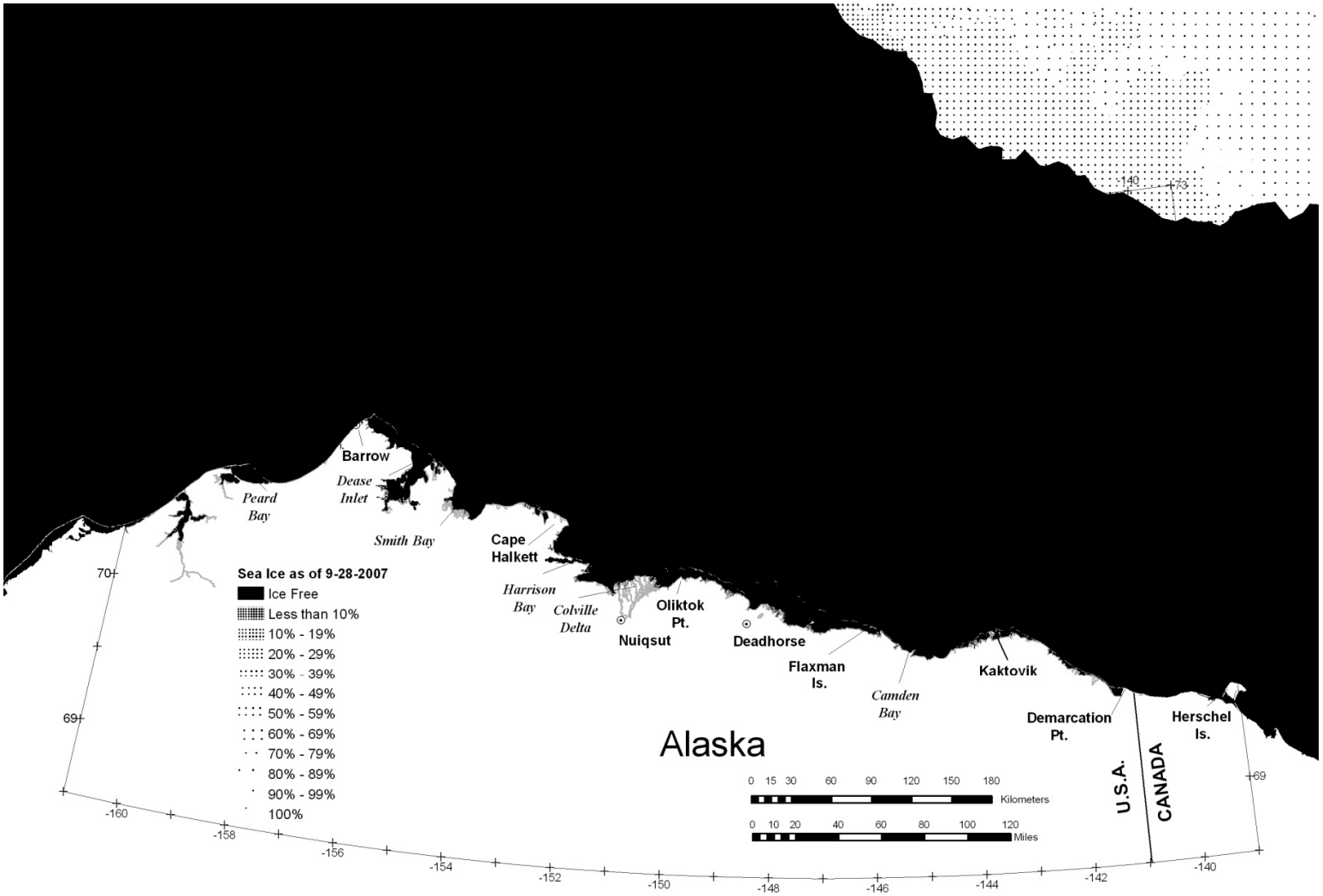

Figure D-5 – Ice concentrations in the Alaskan Beaufort Sea, 28 September 2007.

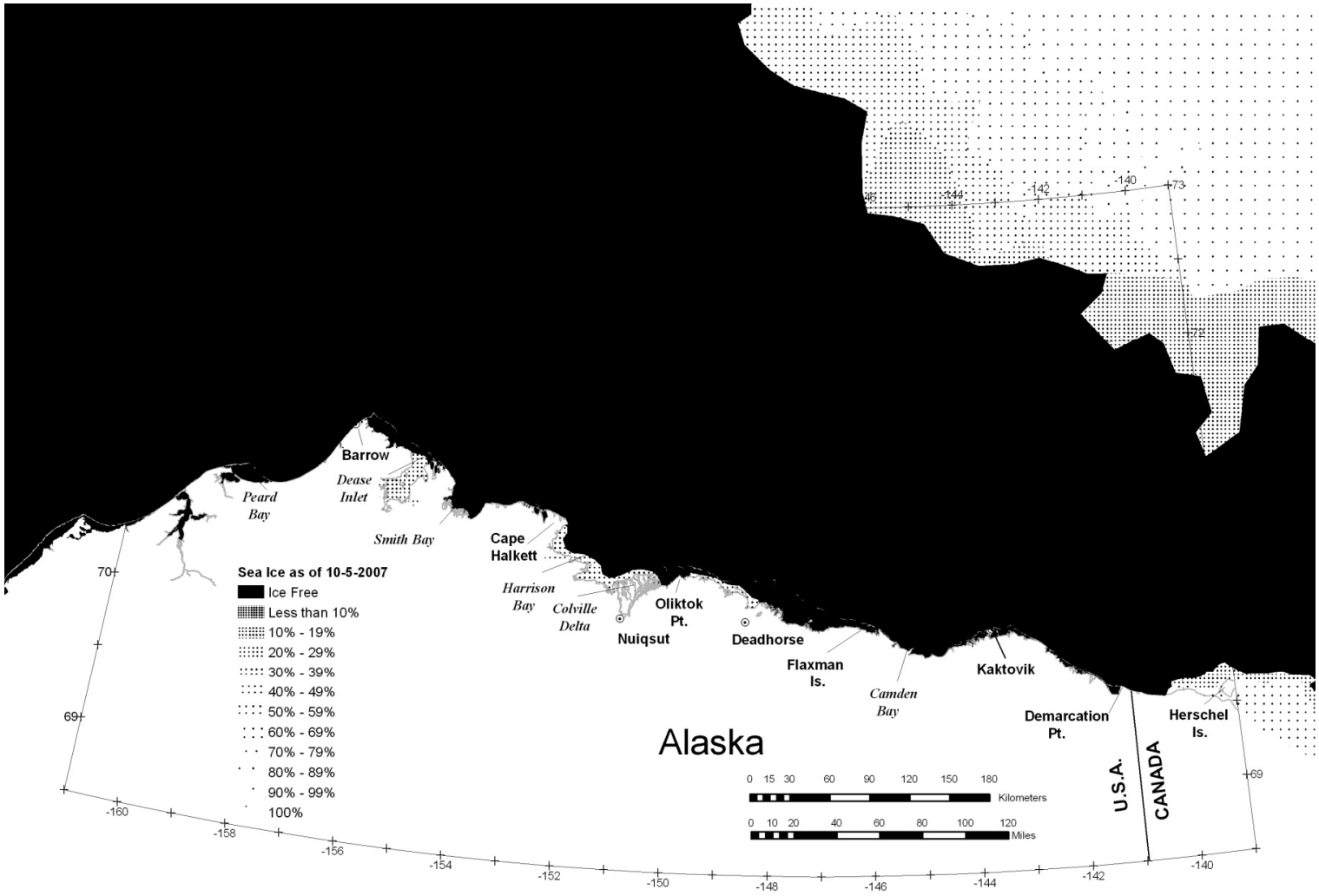

Figure D-6 – Ice concentrations in the Alaskan Beaufort Sea, 5 October 2007.

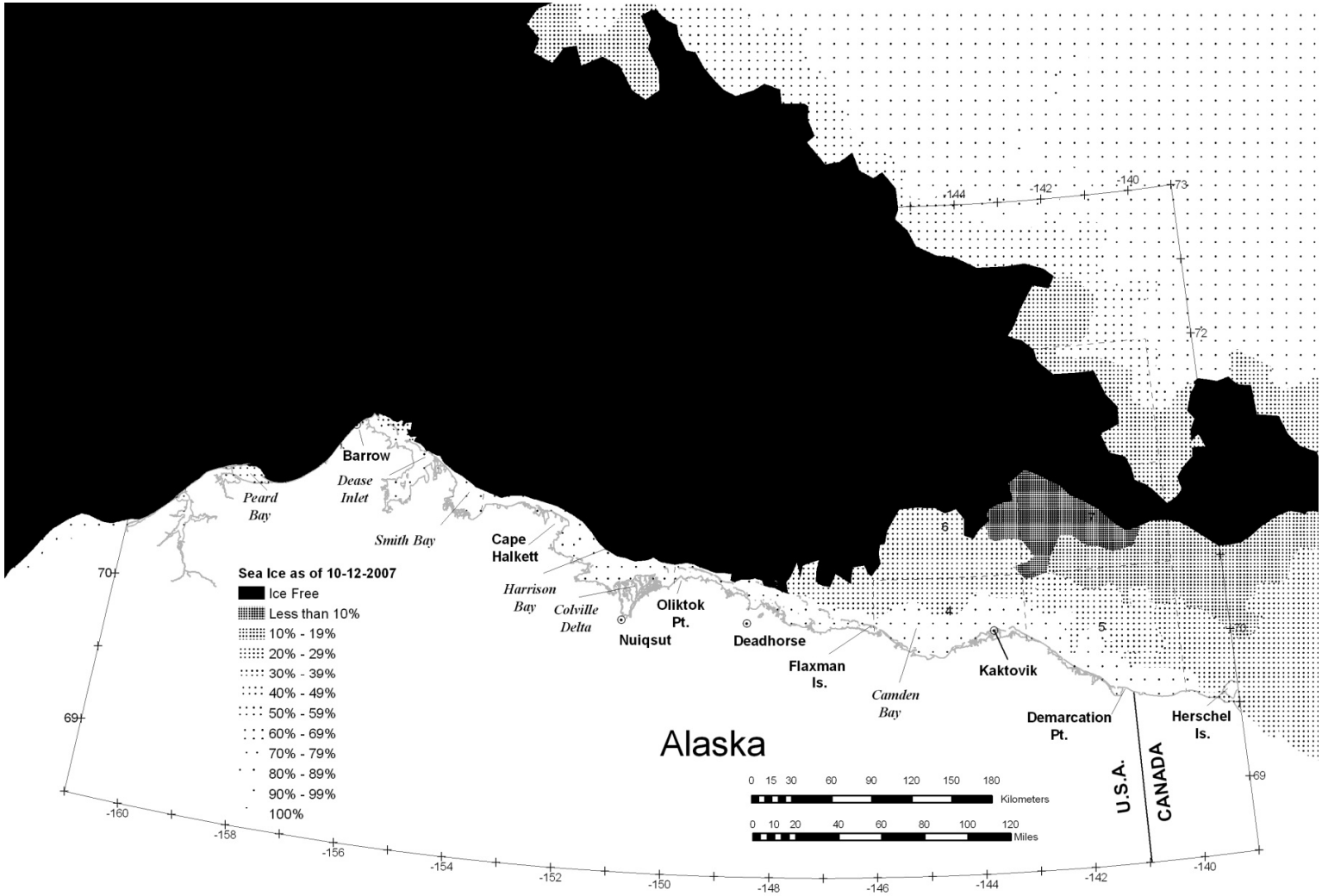

Figure D-7 – Ice concentrations in the Alaskan Beaufort Sea, 12 October 2007.

APPENDIX E: FALL 2007 BOWHEAD WHALE SIGHTING DATA

Table E-1
Selected data for bowhead whale sightings, fall 2007
([1]not recorded)

Flight No	Day	Total Whales	No of Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Wind Force
1	3 Sep	1	0	70º10.5'	145º32.0'	swim	160º	0	3
1	3 Sep	1	0	70º09.2'	144º44.5'	swim	94º	0	2
1	3 Sep	1	0	70º09.0'	144º15.4'	swim	180º	0	2
1	3 Sep	1	0	70º08.2'	142º35.5'	swim	229º	0	4
1	3 Sep	1	0	70º03.9'	142º18.2'	swim	242º	0	3
1	3 Sep	2	0	70º03.0'	142º14.2'	swim	312º	0	3
1	3 Sep	28	0	69º48.2'	141º16.6'	mill	[1]	0	3
1	3 Sep	1	0	69º47.3'	141º35.3'	swim	[1]	0	2
1	3 Sep	2	0	69º47.7'	141º37.2'	swim	121º	0	2
1	3 Sep	1	0	69º48.0'	141º39.1'	swim	243º	0	2
1	3 Sep	8	0	69º49.2'	141º44.1'	mill	[1]	0	2
1	3 Sep	3	0	69º50.5'	141º50.4'	swim	[1]	0	2
1	3 Sep	4	0	69º51.6'	141º56.6'	swim	[1]	0	2
1	3 Sep	1	0	69º52.6'	142º01.9'	swim	87º	0	2
1	3 Sep	1	0	69º57.8'	142º22.7'	swim	127º	0	3
1	3 Sep	2	0	69º58.4'	142º25.1'	swim	247º	0	3
1	3 Sep	3	0	69º59.0'	142º27.3'	swim	312º	0	3
1	3 Sep	3	0	69º59.6'	142º28.9'	swim	349º	0	3
1	3 Sep	2	0	70º02.9'	142º38.6'	mill	[1]	0	3
1	3 Sep	3	0	70º03.7'	142º41.7'	swim	127º	0	3
1	3 Sep	1	0	70º04.7'	142º45.6'	swim	[1]	0	3
1	3 Sep	5	0	70º07.1'	144º46.4'	mill	[1]	0	2
1	3 Sep	1	0	70º07.1'	144º48.7'	swim	239º	0	2
1	3 Sep	1	0	70º16.6'	145º14.8'	swim	270º	0	3
1	3 Sep	4	0	70º16.6'	145º14.8'	mill	[1]	0	3
2	4 Sep	1	0	70º00.2'	142º06.7'	swim	52º	0	3
3	7 Sep	1	0	70º18.6'	144º20.0'	swim	248º	0	2
3	7 Sep	1	0	70º18.4'	145º14.4'	swim	120º	0	2
3	7 Sep	1	0	70º19.3'	146º23.6'	swim	250º	0	2
3	7 Sep	10	0	70º19.2'	146º33.0'	mill	[1]	0	2
3	7 Sep	3	0	70º22.4'	146º34.2'	swim	[1]	0	2
4	10 Sep	1	0	70º06.4'	142º40.0'	swim	90º	0	3
4	10 Sep	1	0	69º52.2'	141º56.3'	dive	135º	0	2
4	10 Sep	5	0	69º55.1'	141º56.0'	mill	[1]	0	2
4	10 Sep	1	0	69º55.6'	141º55.9'	mill	180º	0	2
4	10 Sep	1	0	69º56.2'	141º55.8'	mill	185º	0	2

Flight No	Day	Total Whales	No of Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Wind Force
4	10 Sep	1	0	69º56.6'	141º55.8'	mill	272º	0	2
4	10 Sep	1	0	70º01.1'	141º02.6'	rest	59º	0	3
4	10 Sep	17	0	69º52.3'	141º40.3'	dive	[1]	0	2
4	10 Sep	1	0	69º52.3'	141º40.3'	swim	129º	0	2
4	10 Sep	8	0	69º52.3'	141º40.3'	mill	309º	0	2
4	10 Sep	3	0	69º52.3'	141º40.3'	dive	[1]	0	2
4	10 Sep	1	0	69º52.3'	141º40.3'	mill	9º	0	2
4	10 Sep	1	0	69º57.2'	141º52.6'	mill	[1]	0	2
4	10 Sep	2	0	69º57.8'	141º47.7'	mill	[1]	0	2
4	10 Sep	1	0	69º54.6'	142º05.3'	swim	163º	0	2
4	10 Sep	2	0	69º54.6'	142º05.3'	swim	163º	0	2
4	10 Sep	1	0	69º58.0'	142º14.4'	swim	296º	0	2
4	10 Sep	1	0	70º01.6'	142º22.8'	swim	327º	0	2
4	10 Sep	1	0	70º02.8'	142º29.8'	dive	114º	0	2
4	10 Sep	4	0	70º02.8'	142º29.8'	mill	[1]	0	2
4	10 Sep	5	0	70º05.2'	142º38.8'	mill	357º	0	2
4	10 Sep	2	1	70º05.5'	142º38.7'	swim	105º	0	2
4	10 Sep	2	0	70º08.2'	142º52.5'	swim	350º	0	2
4	10 Sep	1	0	70º08.6'	142º55.9'	swim	202º	0	2
4	10 Sep	3	0	70º10.7'	143º09.3'	feed	245º	0	2
4	10 Sep	3	0	70º10.7'	143º09.3'	tail slap	245º	0	2
4	10 Sep	6	0	70º11.5'	143º24.2'	feed	319º	0	2
4	10 Sep	1	0	70º11.7'	143º24.9'	feed	317º	0	2
4	10 Sep	4	0	70º12.8'	143º32.3'	swim	269º	0	2
6	11 Sep	1	0	70º09.5'	144º56.5'	feed	[1]	0	2
6	11 Sep	1	0	70º09.4'	144º50.3'	swim	332º	0	2
6	11 Sep	2	1	70º09.4'	144º49.4'	mill	93º	0	2
6	11 Sep	2	0	70º15.3'	143º29.8'	swim	216º	0	3
6	11 Sep	1	0	70º14.2'	143º28.6'	swim	180º	0	3
6	11 Sep	5	2	70º25.7'	143º42.4'	mill	[1]	0	2
6	11 Sep	8	0	70º17.3'	146º24.4'	mill	[1]	0	1
8	17 Sep	1	0	70º39.9'	151º03.7'	dive	328º	0	2
8	17 Sep	19	0	70º31.3'	147º34.8'	mill	[1]	0	2
8	17 Sep	1	0	70º43.9'	147º35.3'	swim	58º	0	2
8	17 Sep	1	0	70º31.0'	147º13.5'	swim	358º	0	2
9	18 Sep	1	0	70º08.3'	144º40.1'	swim	272º	0	2
9	18 Sep	2	0	70º08.7'	144º37.1'	swim	42º	0	2
9	18 Sep	1	0	70º09.0'	144º33.6'	swim	21º	0	2
9	18 Sep	4	0	70º18.4'	143º15.8'	feed	[1]	0	2

Flight No	Day	Total Whales	No of Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Wind Force
9	18 Sep	1	0	70º17.3'	143º15.7'	swim	[1]	0	2
9	18 Sep	1	0	70º18.8'	144º12.2'	rest	[1]	0	2
9	18 Sep	6	0	70º44.0'	144º11.5'	[1]	[1]	0	2
9	18 Sep	1	0	70º18.0'	144º51.2'	dive	89º	0	2
9	18 Sep	1	0	70º12.3'	145º12.0'	swim	87º	0	2
9	18 Sep	1	0	70º13.8'	145º12.0'	swim	90º	0	2
9	18 Sep	1	0	70º21.9'	145º11.9'	swim	180º	0	2
9	18 Sep	2	1	70º28.4'	145º11.8'	swim	149º	0	2
9	18 Sep	1	0	70º22.8'	145º53.7'	swim	31º	2	2
9	18 Sep	1	1	70º21.3'	146º23.3'	rest	231º	0	4
9	18 Sep	1	0	70º22.4'	146º22.8'	rest	335º	0	3
9	18 Sep	2	0	70º23.7'	146º22.5'	rest	189º	0	3
9	18 Sep	3	0	70º27.2'	146º21.3'	swim	216º	0	3
9	18 Sep	1	0	70º38.6'	146º40.9'	swim	80º	0	2
9	18 Sep	7	1	70º32.3'	146º38.3'	swim	[1]	0	3
9	18 Sep	1	0	70º31.2'	146º38.1'	swim	54º	0	3
9	18 Sep	1	0	70º26.1'	146º35.9'	swim	112º	0	3
9	18 Sep	13	0	70º25.4'	146º35.6'	swim	[1]	0	3
10	20 Sep	1	0	70º15.2'	143º06.8'	swim	89º	0	5
10	20 Sep	8	0	70º14.4'	143º06.8'	swim	90º	0	5
10	20 Sep	4	1	70º15.0'	143º05.4'	swim	[1]	0	5
10	20 Sep	3	1	70º13.6'	143º03.1'	swim	[1]	0	5
10	20 Sep	1	0	70º11.7'	143º30.1'	dive	173º	0	5
10	20 Sep	1	0	70º14.7'	143º30.4'	swim	87º	0	5
10	20 Sep	2	1	70º17.6'	143º41.1'	swim	140º	0	5
10	20 Sep	1	0	70º15.0'	144º10.6'	swim	273º	0	5
10	20 Sep	2	1	70º15.2'	144º19.6'	swim	7º	0	5
10	20 Sep	1	0	70º15.8'	144º20.5'	swim	37º	0	5
10	20 Sep	2	0	70º15.2'	144º26.0'	swim	218º	0	5
10	20 Sep	1	0	70º15.7'	144º25.9'	swim	[1]	0	5
11	21 Sep	1	0	70º25.5'	144º56.4'	swim	160º	0	5
11	21 Sep	2	0	70º11.1'	143º52.1'	mill	[1]	0	3
11	21 Sep	1	0	69º55.0'	142º04.1'	swim	242º	0	2
11	21 Sep	1	0	70º04.9'	142º04.4'	swim	298º	0	3
11	21 Sep	2	0	70º05.0'	142º08.5'	swim	[1]	0	3
11	21 Sep	1	0	70º04.3'	142º05.4'	swim	[1]	0	3
11	21 Sep	22	2	70º06.9'	142º04.4'	mill	[1]	0	3
11	21 Sep	1	0	70º00.1'	142º06.9'	swim	261º	0	3
11	21 Sep	1	0	70º12.2'	142º55.2'	feed	[1]	0	3

Flight No	Day	Total Whales	No of Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Wind Force
11	21 Sep	1	0	70º10.5'	143º19.0'	swim	332º	0	2
11	21 Sep	1	0	70º30.1'	146º50.3'	rest	253º	0	3
11	21 Sep	27	0	70º33.0'	147º20.1'	mill	56º	0	3
11	21 Sep	2	0	70º36.3'	147º20.4'	swim	60º	0	3
11	21 Sep	1	0	70º32.3'	147º40.2'	swim	240º	0	4
13	30 Sep	1	0	70º25.3'	146º22.0'	swim	290º	0	5
13	30 Sep	3	0	70º26.7'	146º27.8'	swim	96º	0	5
14	2 Oct	1	0	70º16.3'	146º20.5'	swim	258º	0	6
14	2 Oct	1	0	70º12.8'	143º38.8'	swim	247º	0	6
14	2 Oct	1	0	70º13.5'	145º09.9'	swim	256º	0	7
15	3 Oct	1	0	70º50.0'	151º46.0'	rest	[1]	0	3
15	3 Oct	3	0	71º25.8'	156º25.1'	feed	[1]	0	3
16	3 Oct	1	0	71º27.1'	154º40.0'	dead	[1]	0	5
16	3 Oct	9	0	71º17.6'	154º41.8'	mill	[1]	0	3
16	3 Oct	2	0	71º05.8'	154º10.5'	swim	269º	0	3
16	3 Oct	5	1	71º13.7'	154º12.0'	swim	87º	0	5
16	3 Oct	1	0	71º17.6'	154º11.5'	swim	232º	0	5
17	4 Oct	1	0	69º59.9'	142º26.7'	breach	108º	0	8
18	7 Oct	1	0	70º16.2'	146º11.7'	swim	337º	90	1
18	7 Oct	1	0	70º42.0'	148º01.2'	swim	307º	0	5
19	8 Oct	1	0	70º56.7'	149º34.9'	rest	316º	0	4
19	8 Oct	1	0	70º57.0'	149º39.6'	rest	320º	0	4
19	8 Oct	1	0	70º56.8'	150º23.7'	dive	[1]	0	5
20	9 Oct	1	0	70º23.3'	144º40.8'	breach	277º	0	3
20	9 Oct	1	0	70º19.2'	142º47.7'	swim	285º	0	3
20	9 Oct	1	0	70º20.9'	142º49.0'	swim	285º	0	3
20	9 Oct	1	0	70º16.6'	141º09.3'	swim	272º	0	4
20	9 Oct	1	0	70º13.4'	141º08.8'	swim	267º	0	4
21	10 Oct	3	0	70º35.3'	146º52.8'	swim	285º	1	3
21	10 Oct	1	0	70º37.0'	147º10.5'	swim	296º	10	3
21	10 Oct	1	0	70º46.8'	148º13.3'	swim	266º	0	3

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APPENDIX F: FALL 2007 DAILY FLIGHT SUMMARIES

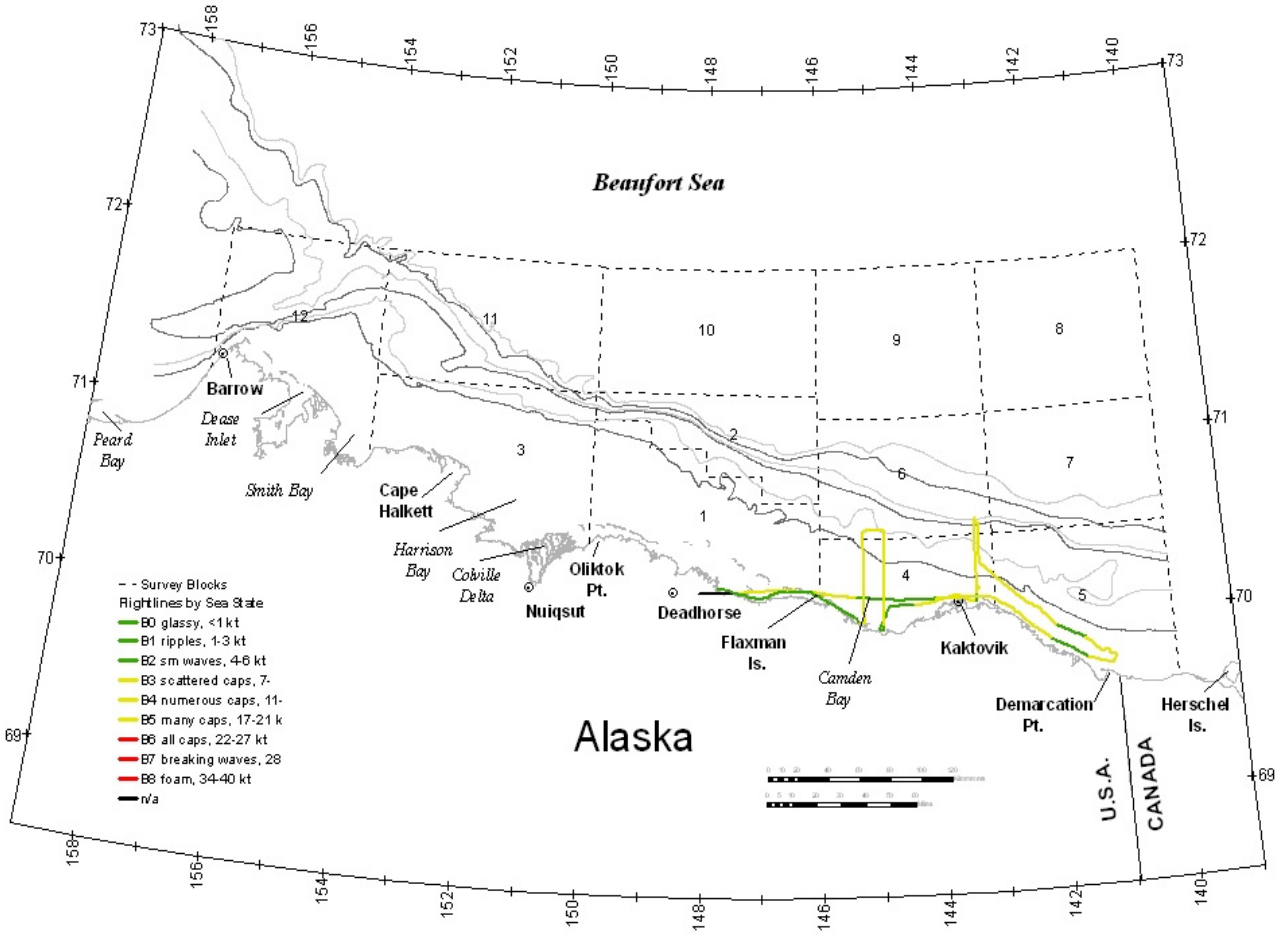

Figure F-1 - Aerial survey flight track, 3 September 2007.

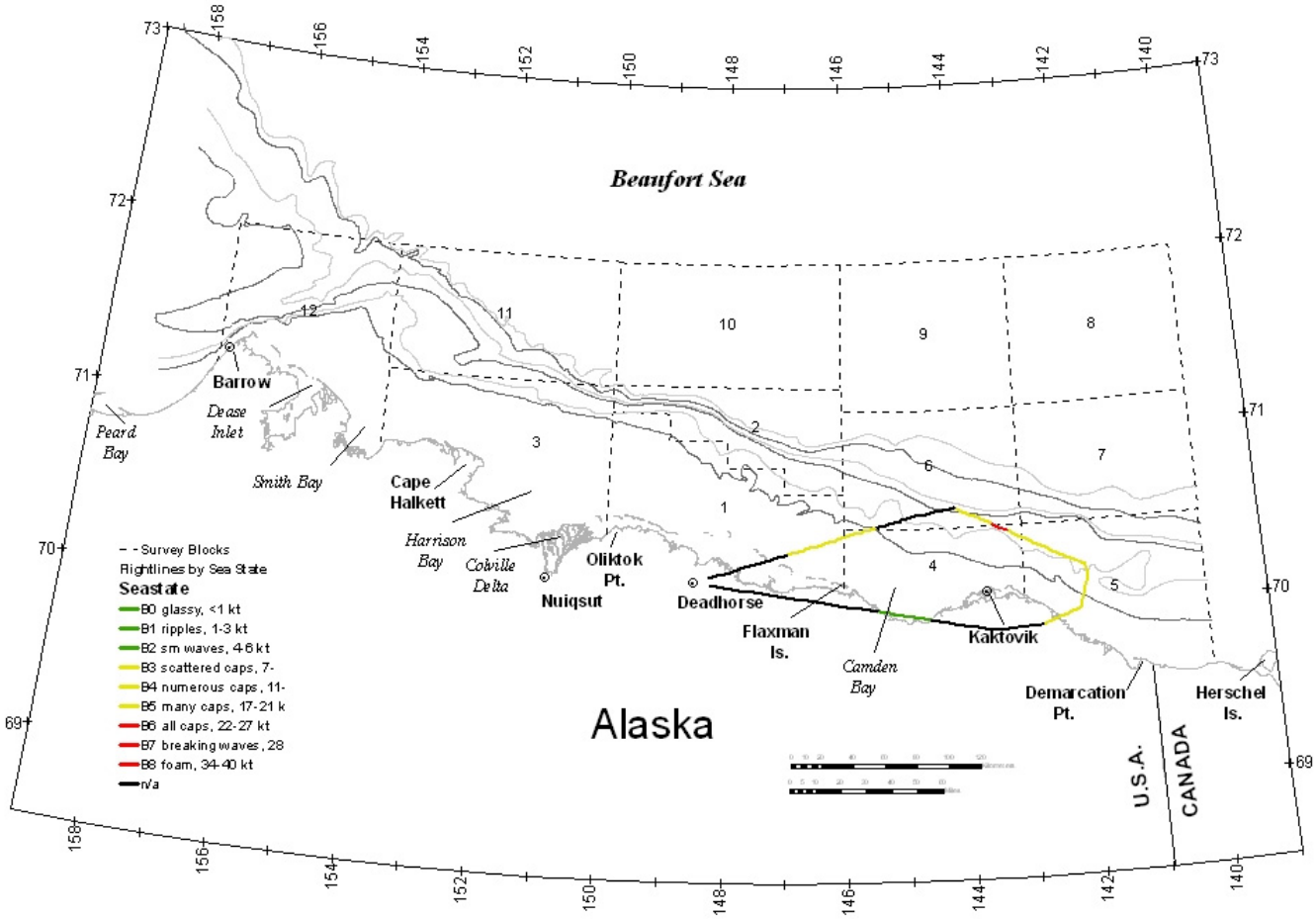

Figure F-2 - Aerial survey flight track, 4 September 2007.

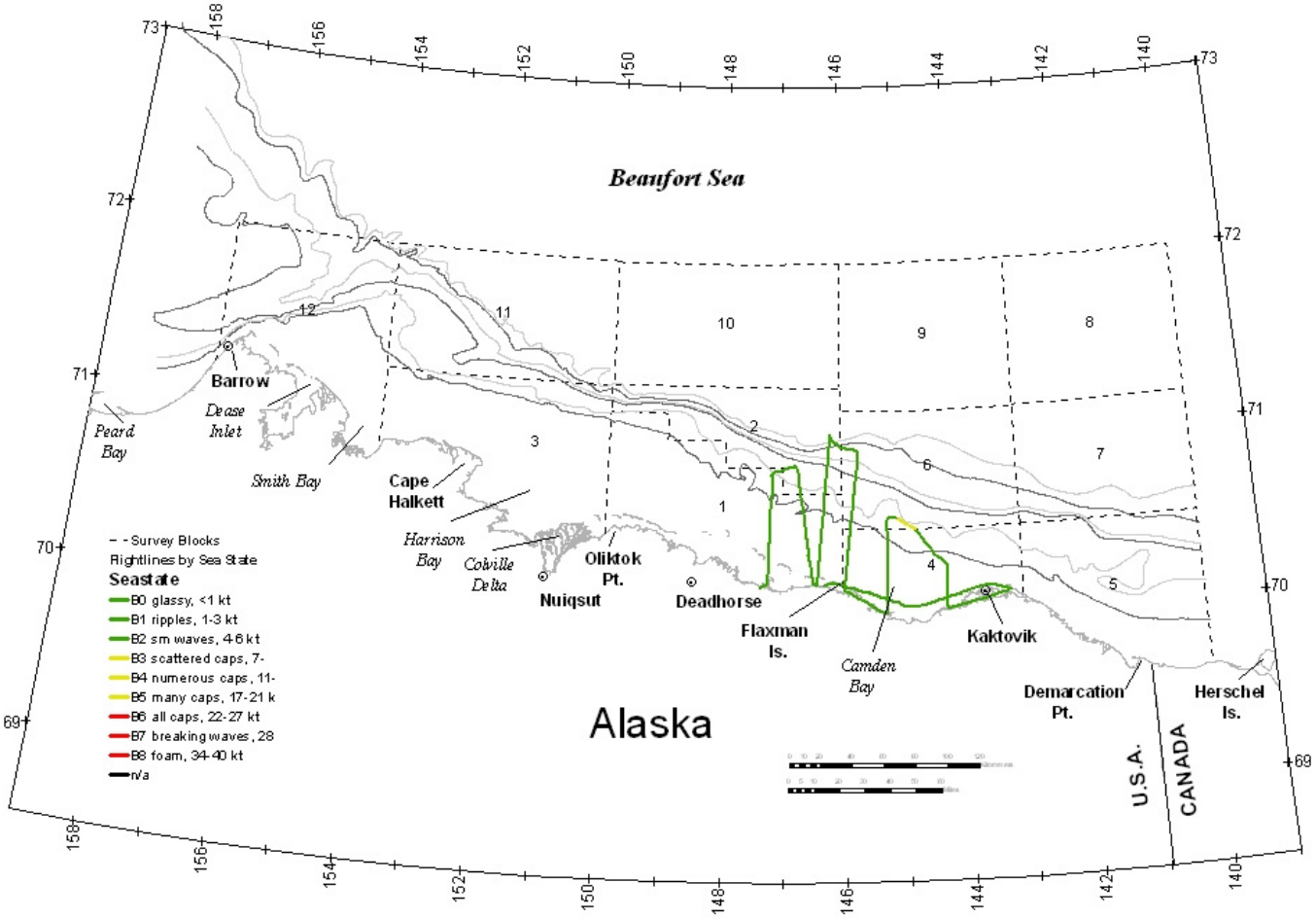

Figure F-3 - Aerial survey flight track, 7 September 2007.

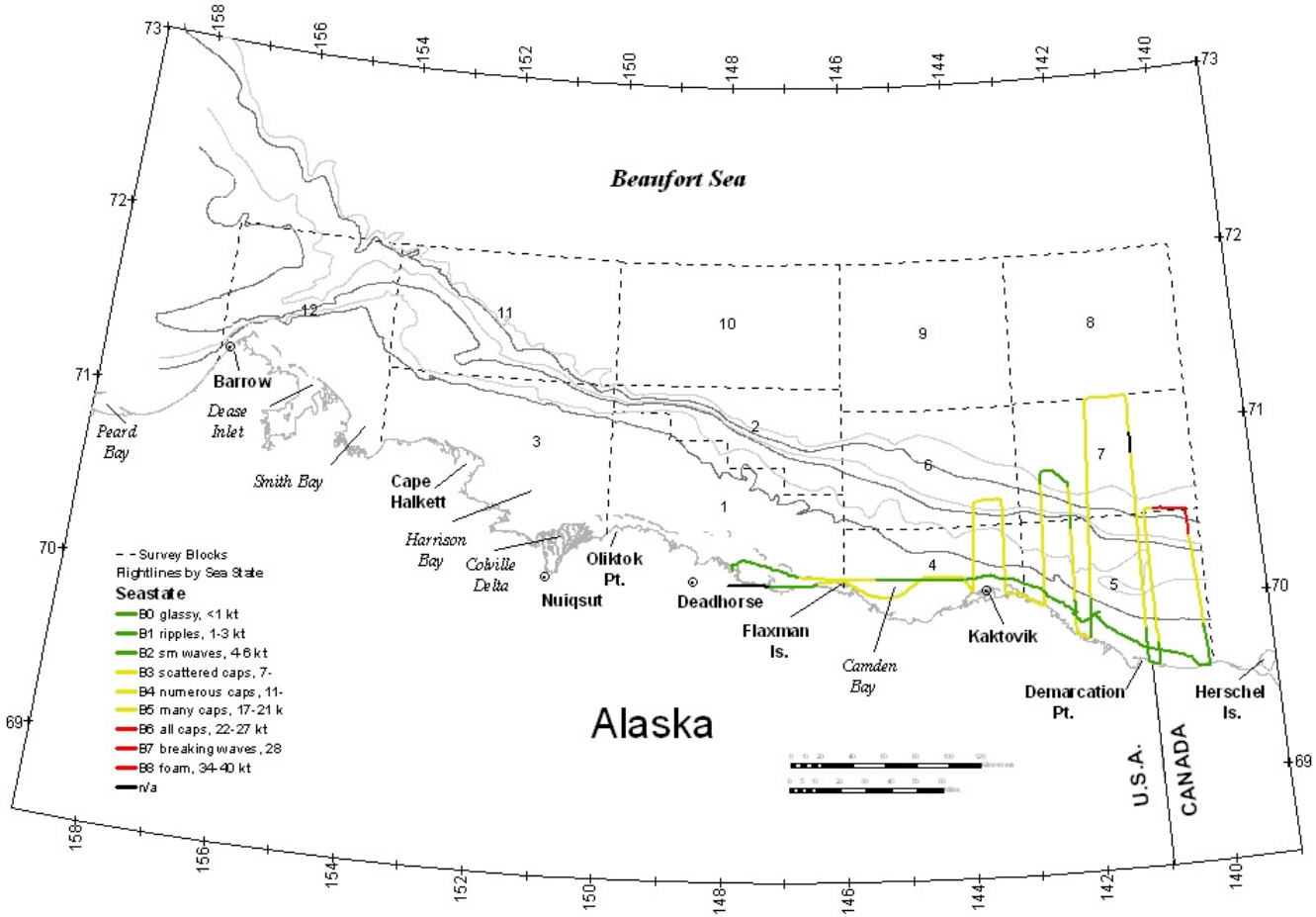

Figure F-4 - Aerial survey flight track, 10 September 2007.

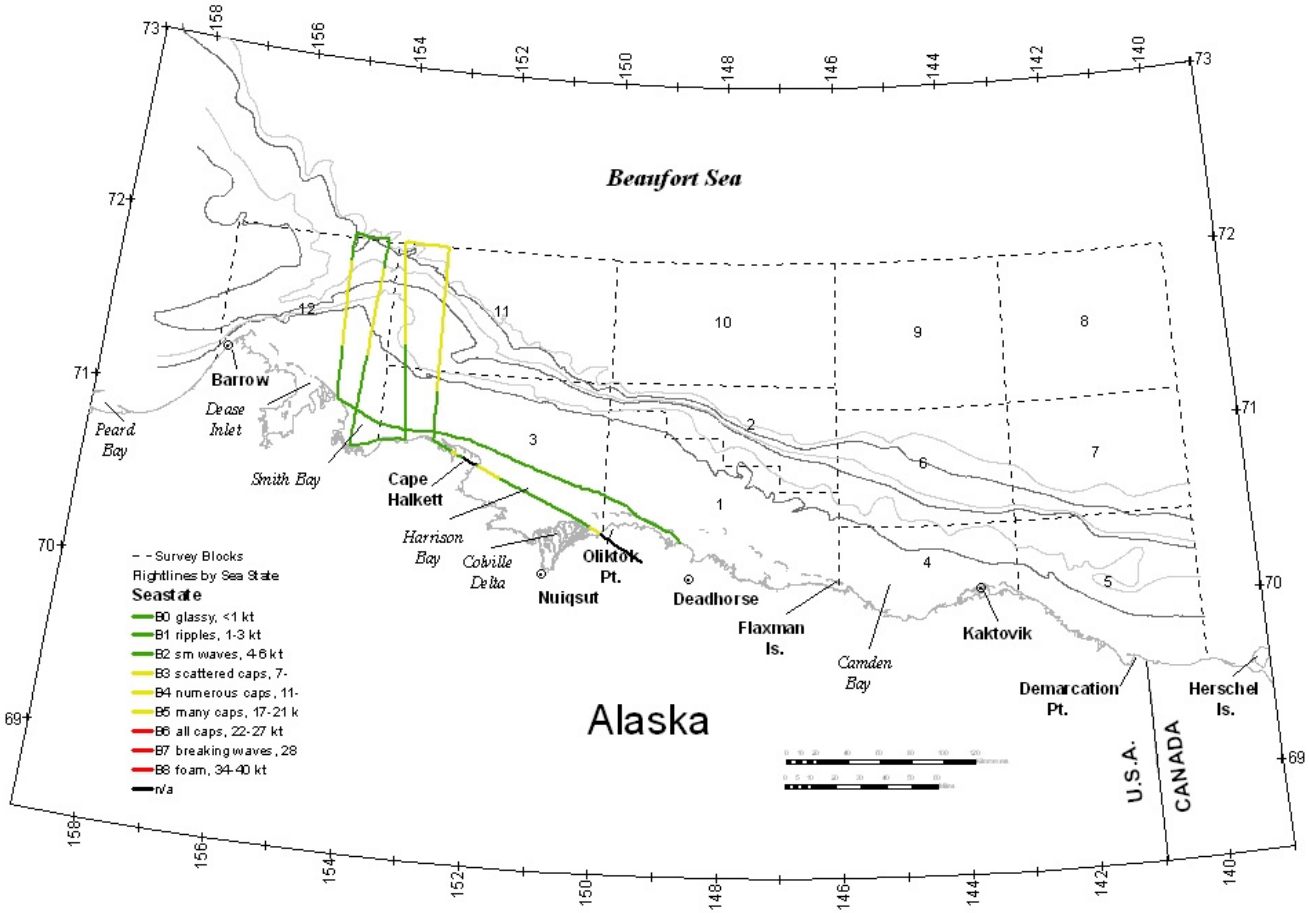

Figure F-5 - Aerial survey flight track, 11 September 2007.

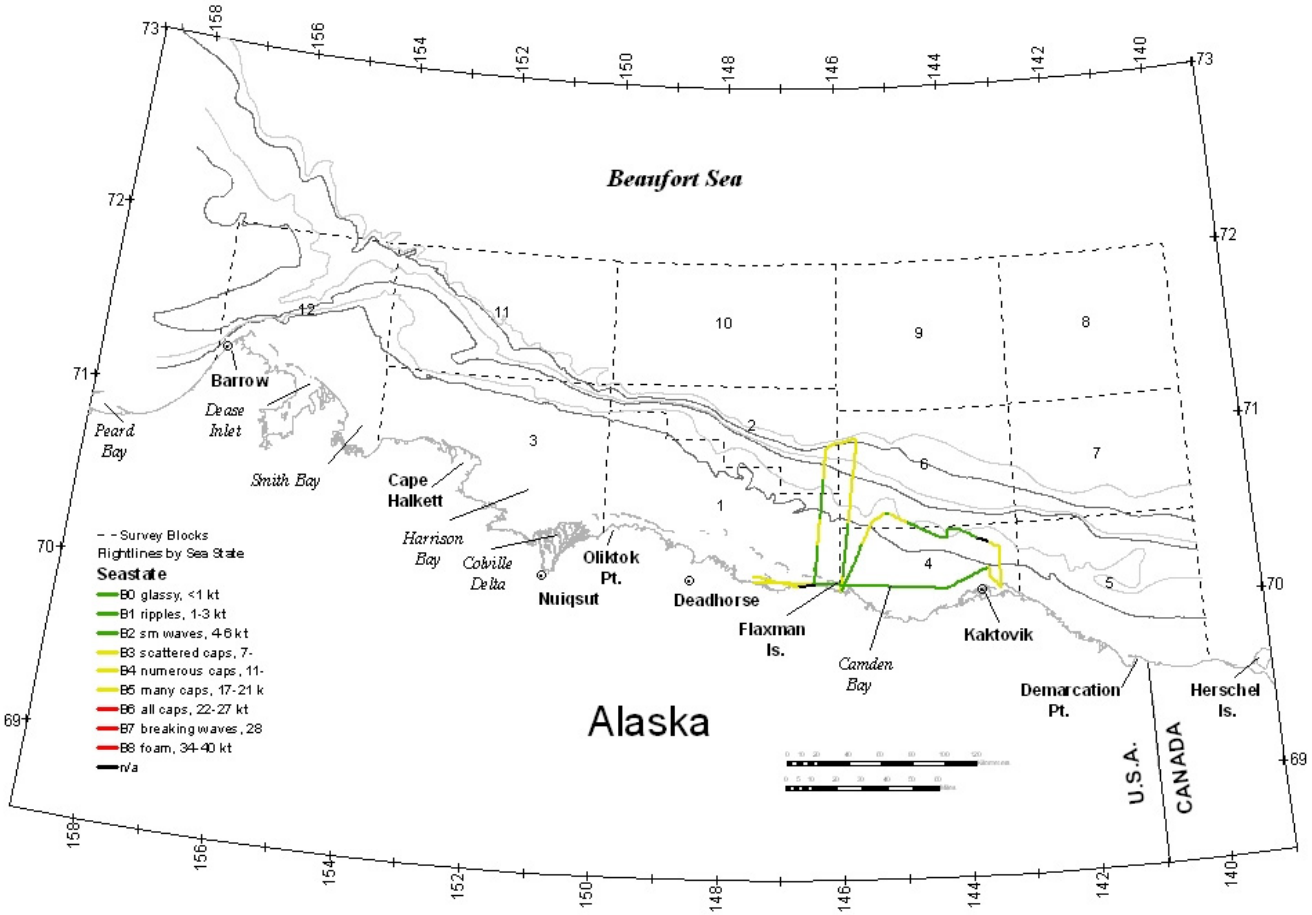

Figure F-6 - Aerial survey flight track, 11 September 2007.

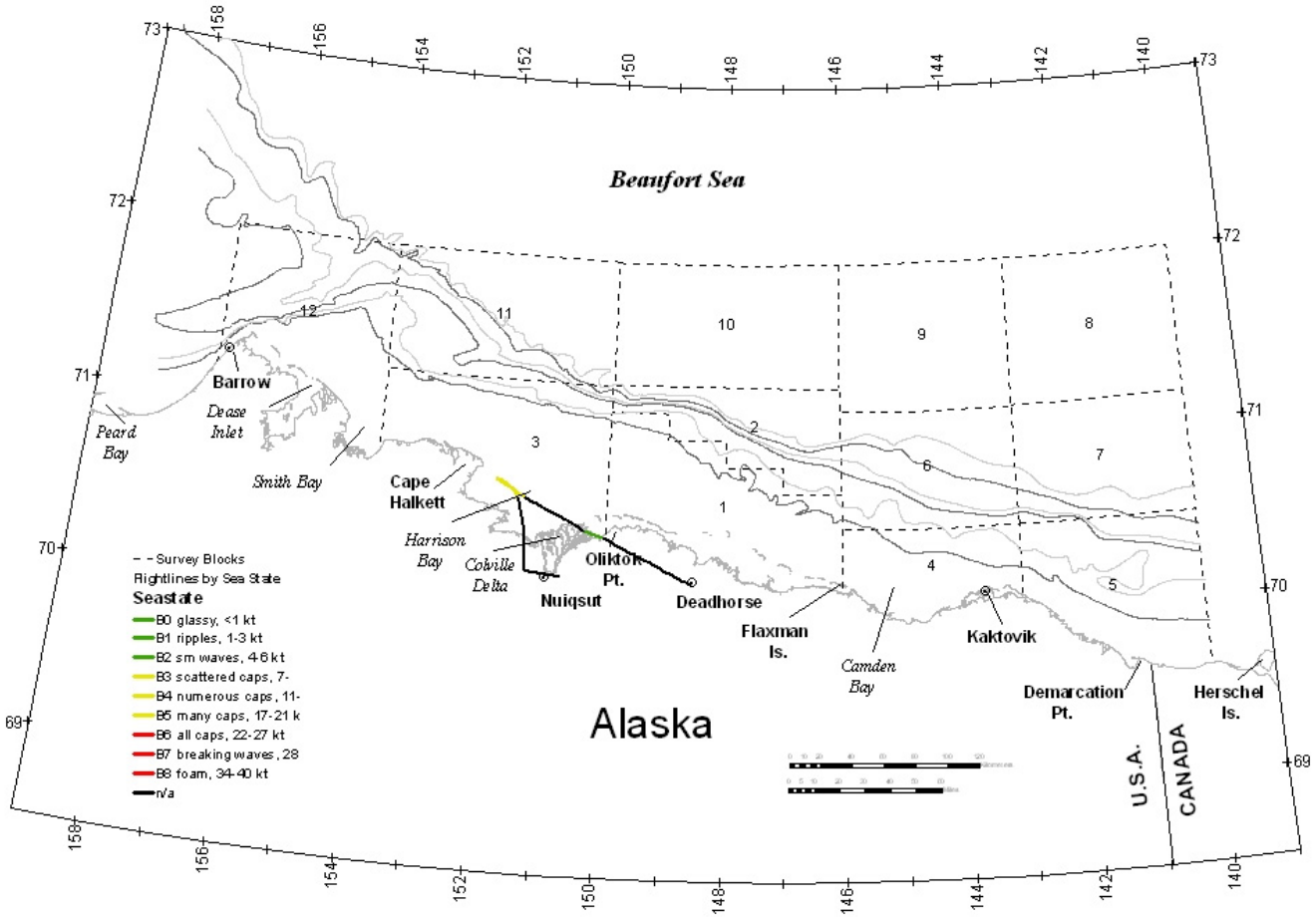

Figure F-7 - Aerial survey flight track, 14 September 2007.

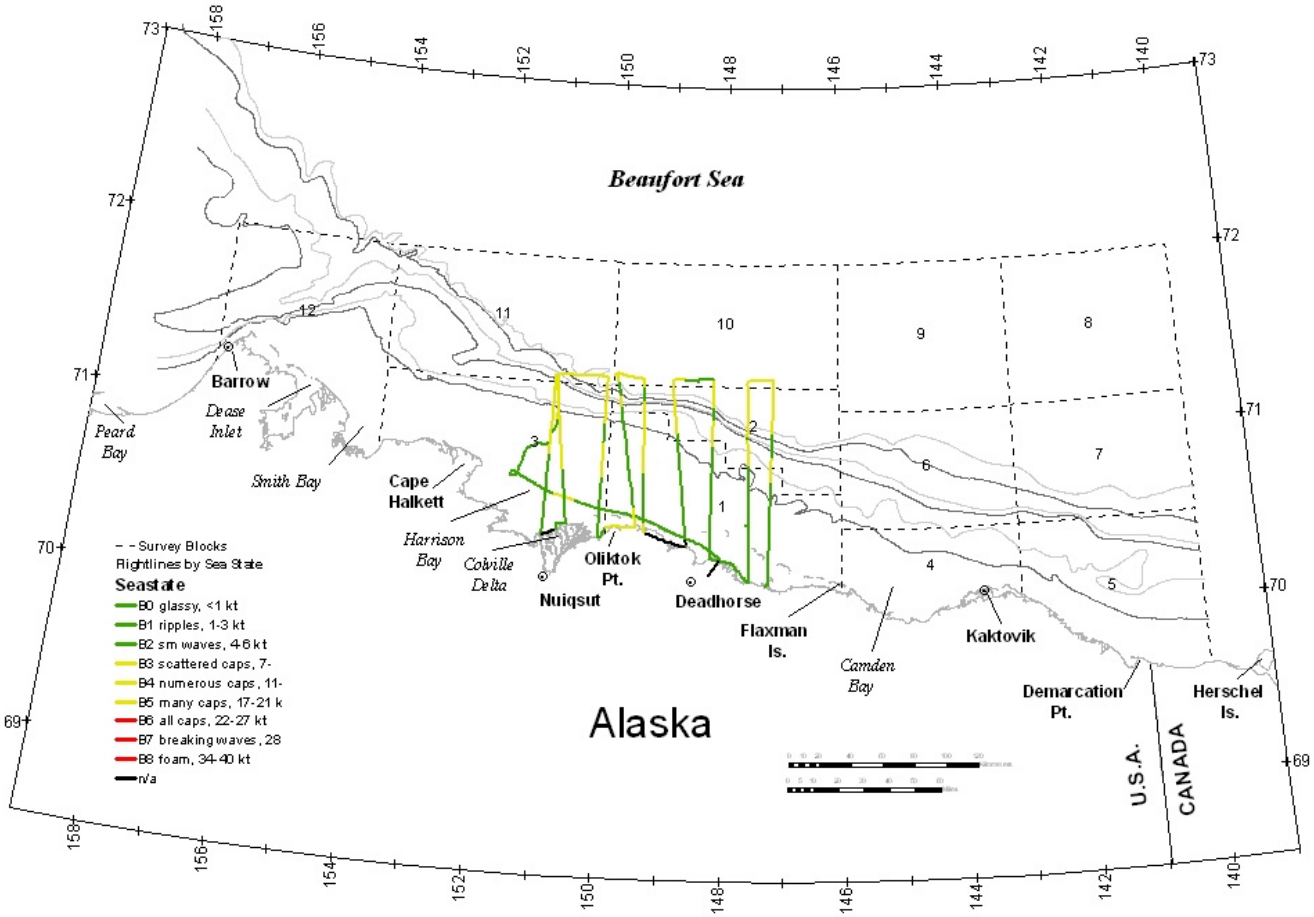

Figure F-8 - Aerial survey flight track, 17 September 2007.

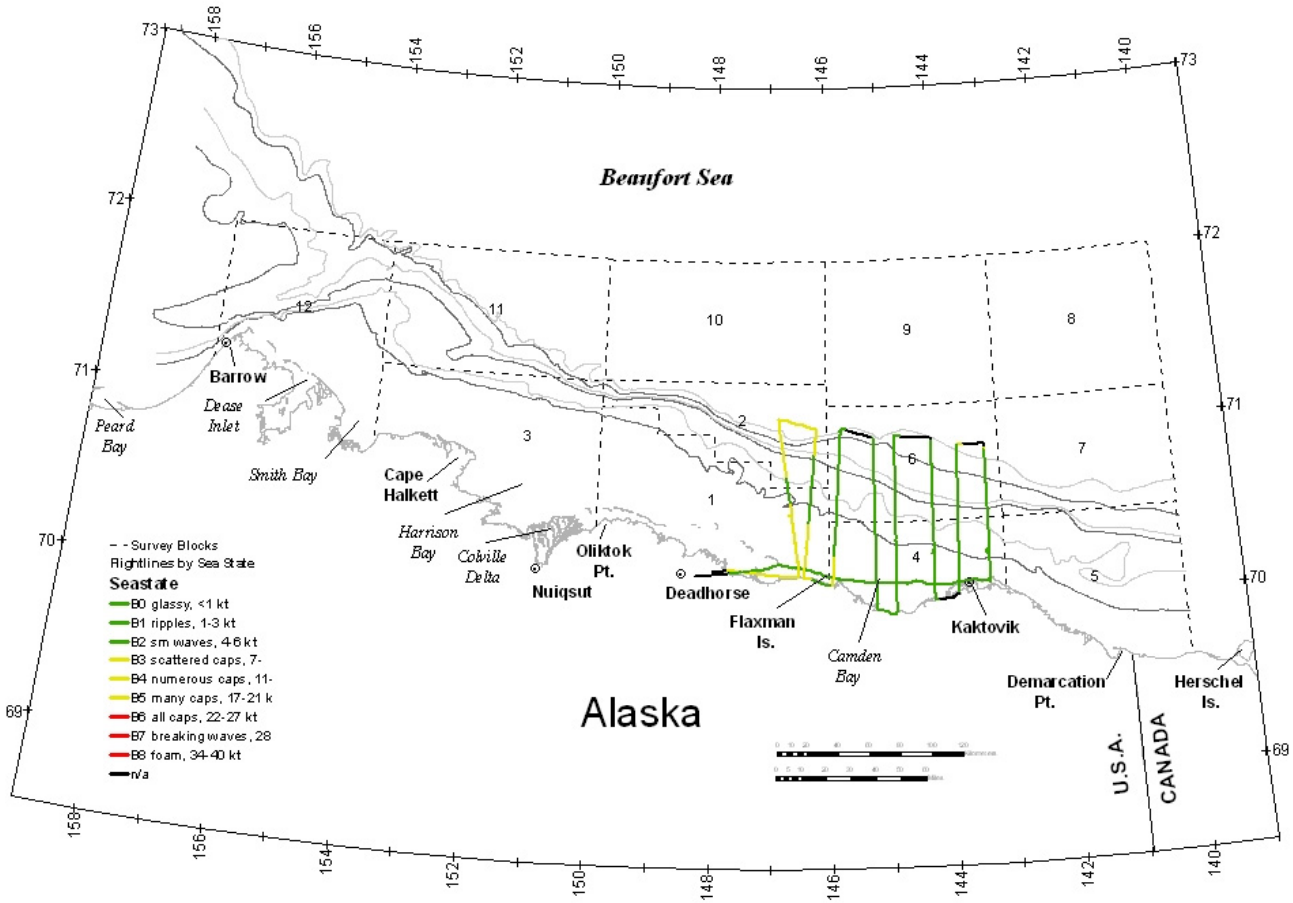

Figure F-9 - Aerial survey flight track, 18 September 2007.

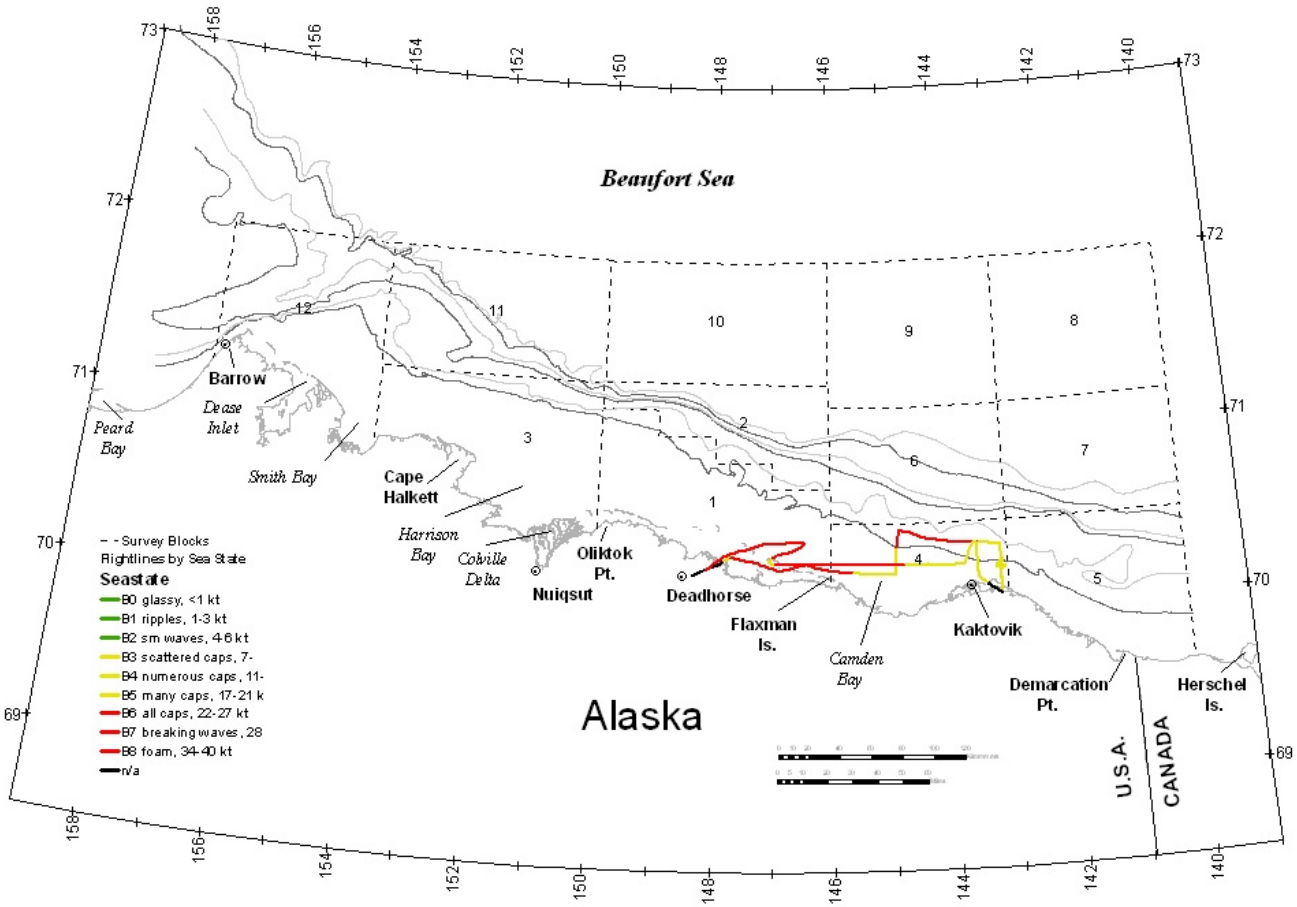

Figure F-10 - Aerial survey flight track, 20 September 2007.

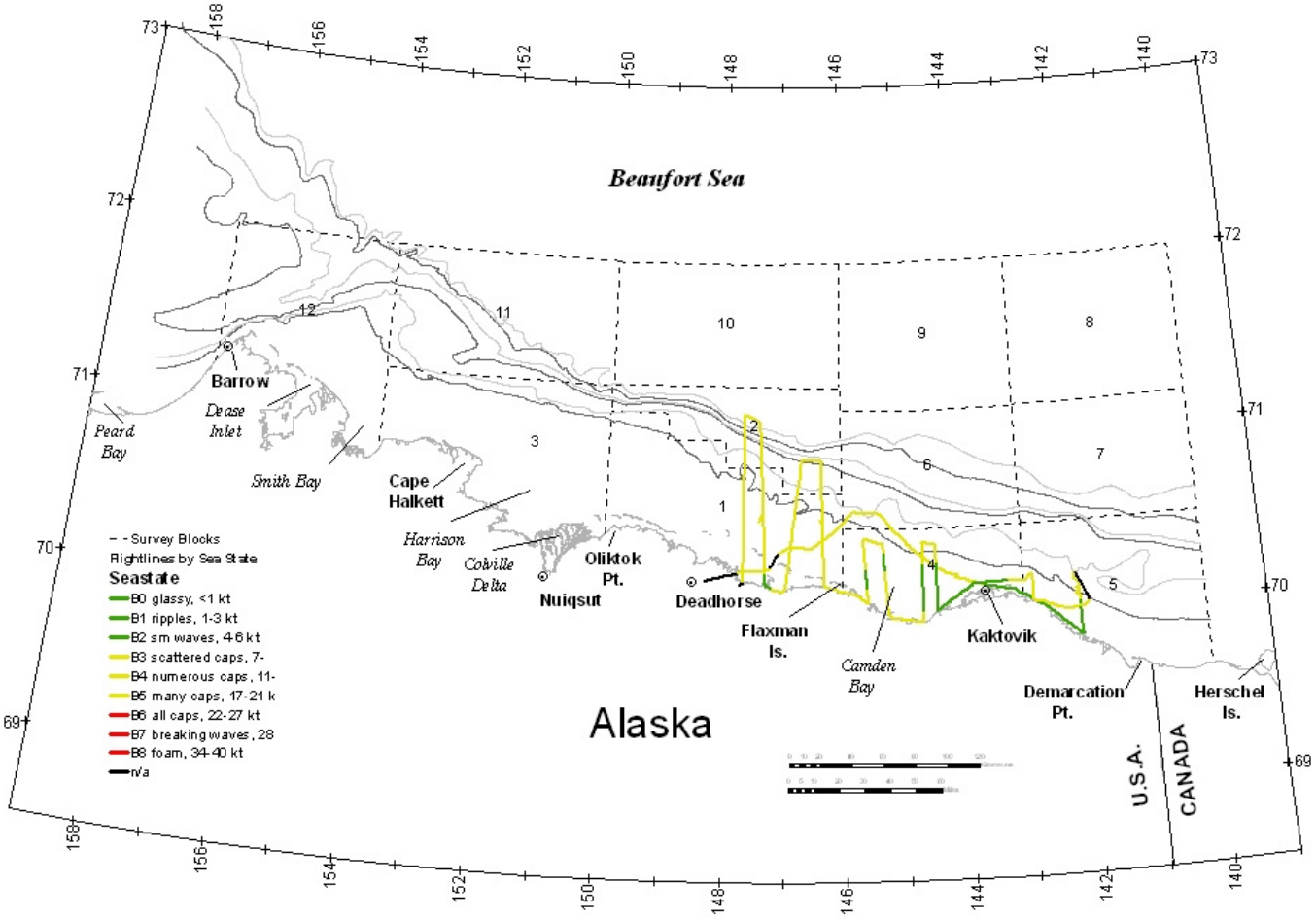

Figure F-11 - Aerial survey flight track, 21 September 2007.

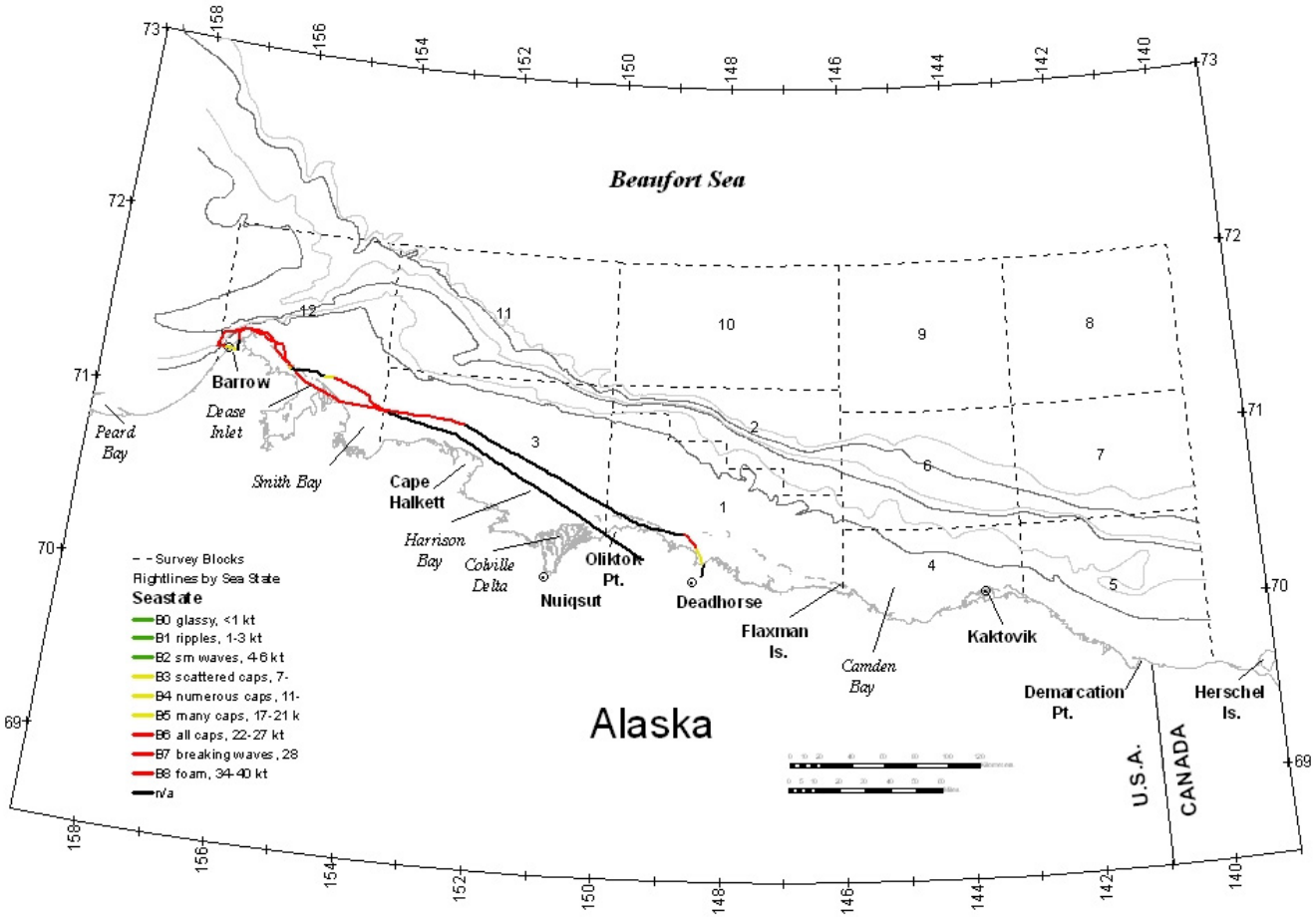

Figure F-12 - Aerial survey flight track, 26 September 2007.

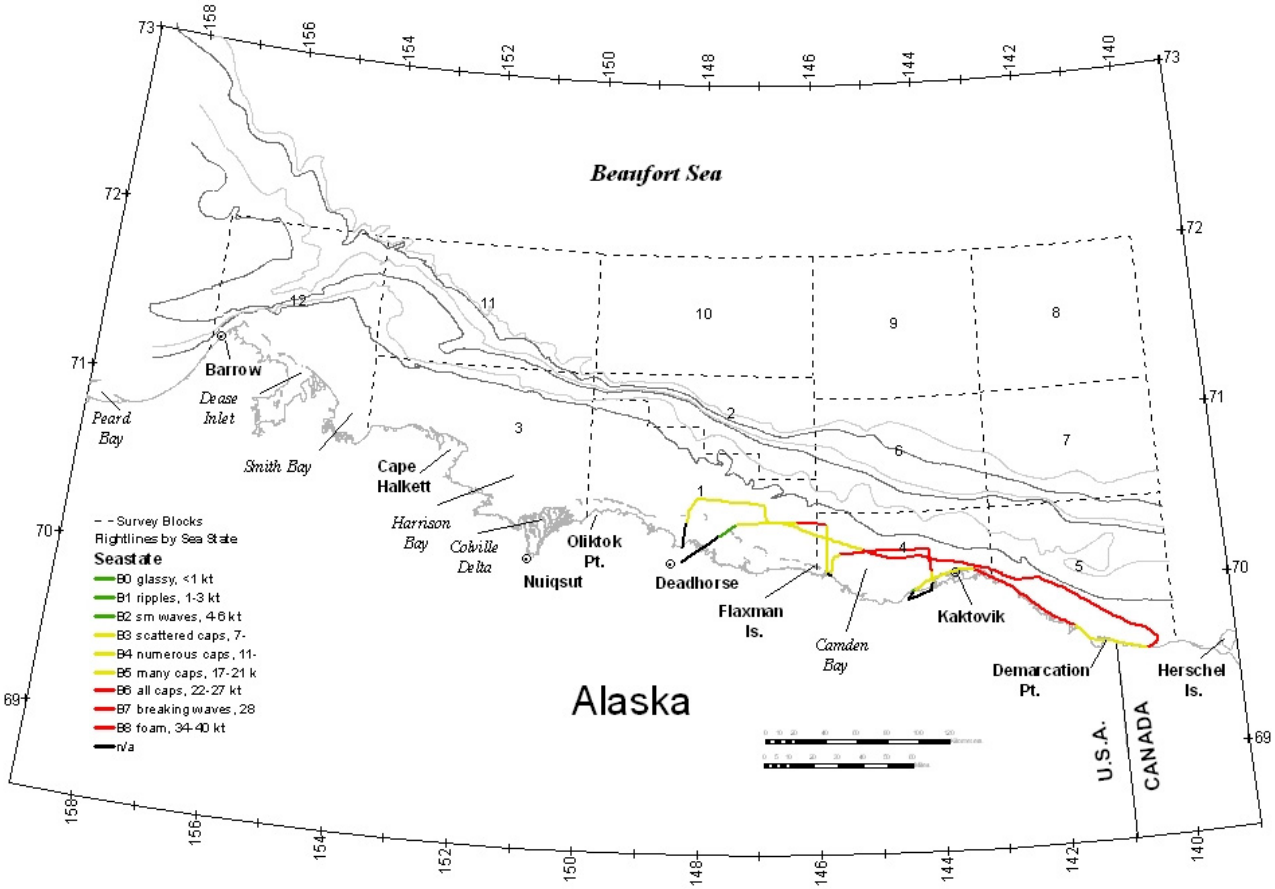

Figure F-13 - Aerial survey flight track, 30 September 2007.

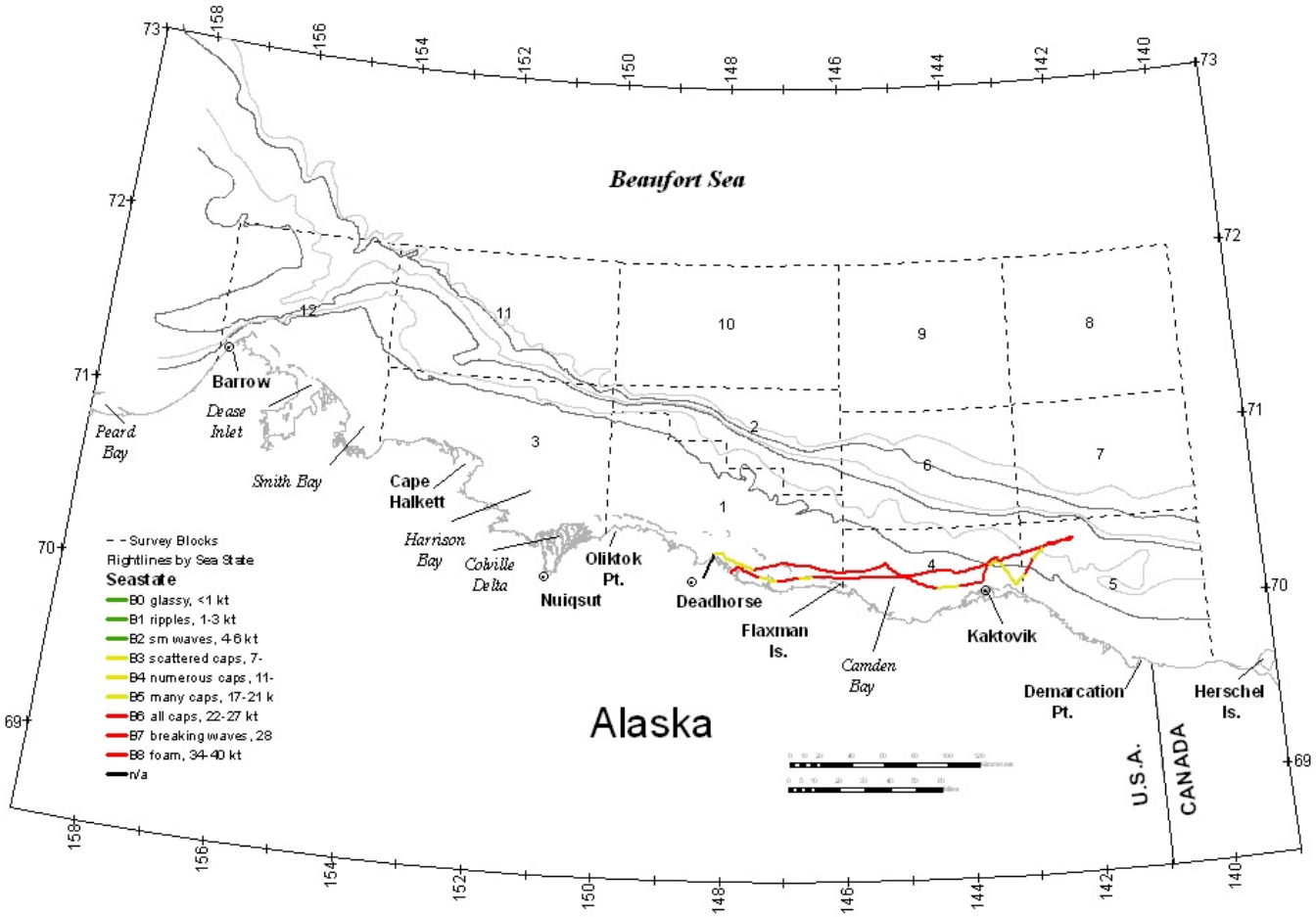

Figure F-14 - Aerial survey flight track, 2 October 2007.

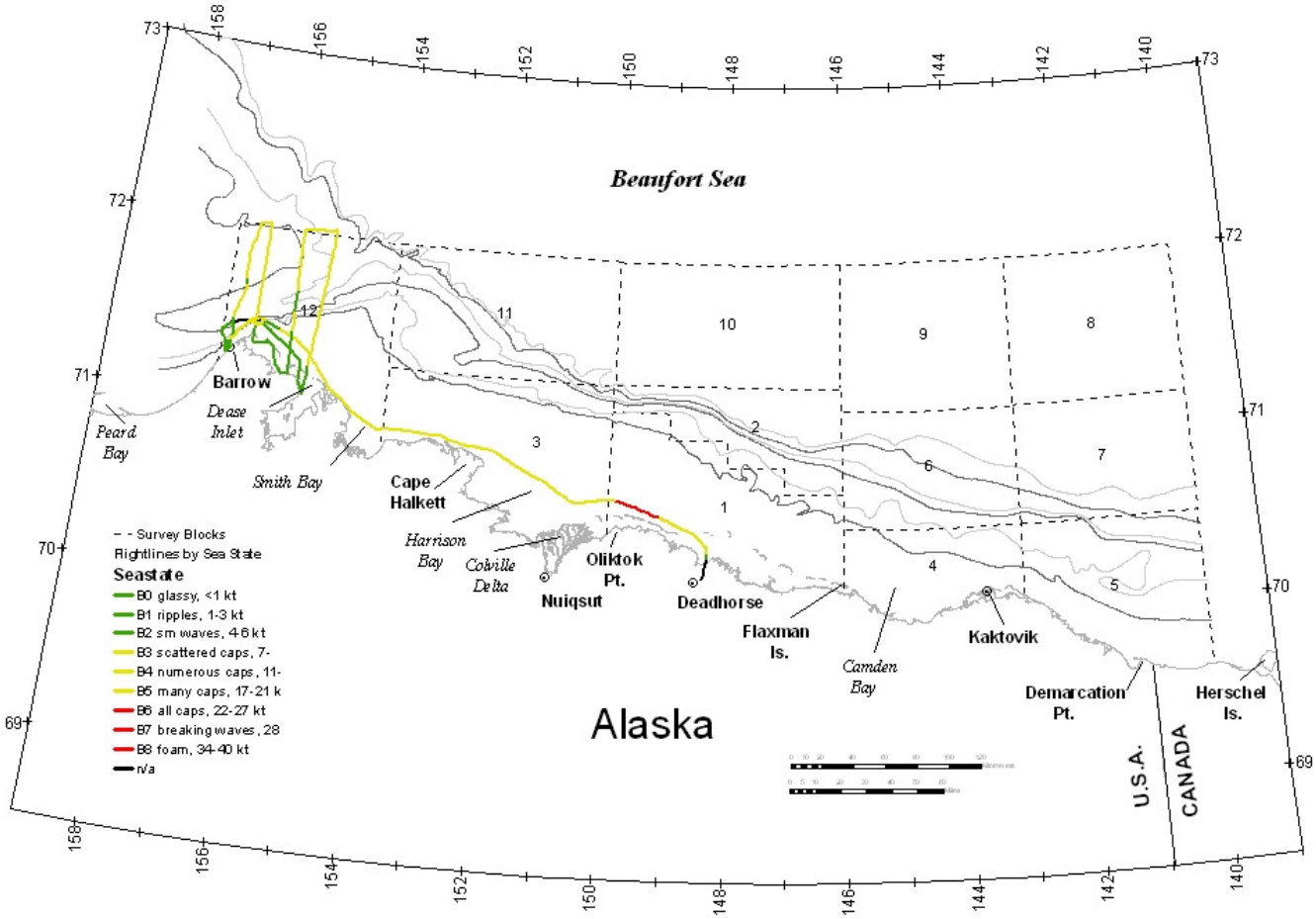

Figure F-15 - Aerial survey flight track, 3 October 2007.

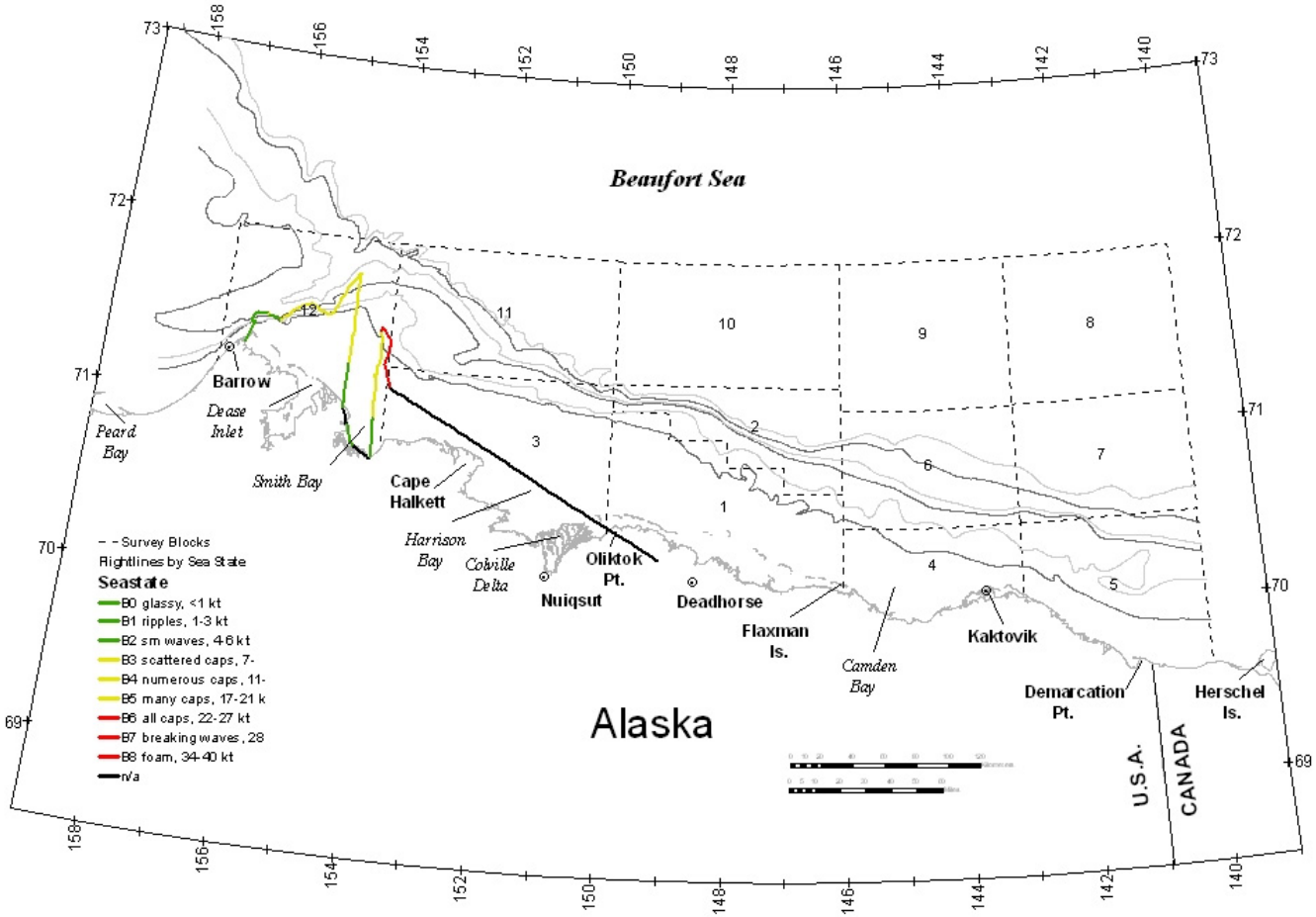

Figure F-16 - Aerial survey flight track, 3 October 2007.

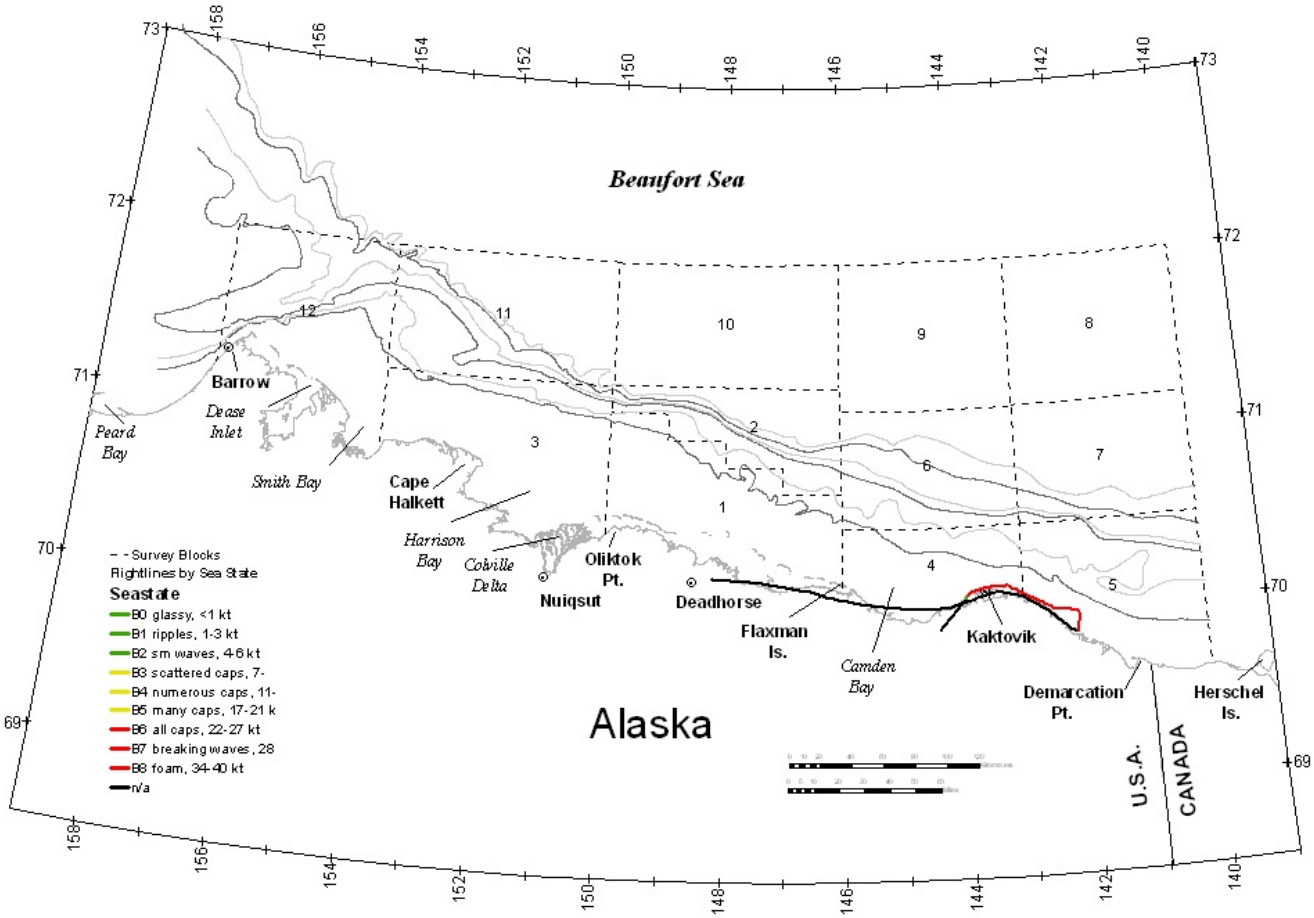

Figure F-17 - Aerial survey flight track, 4 October 2007.

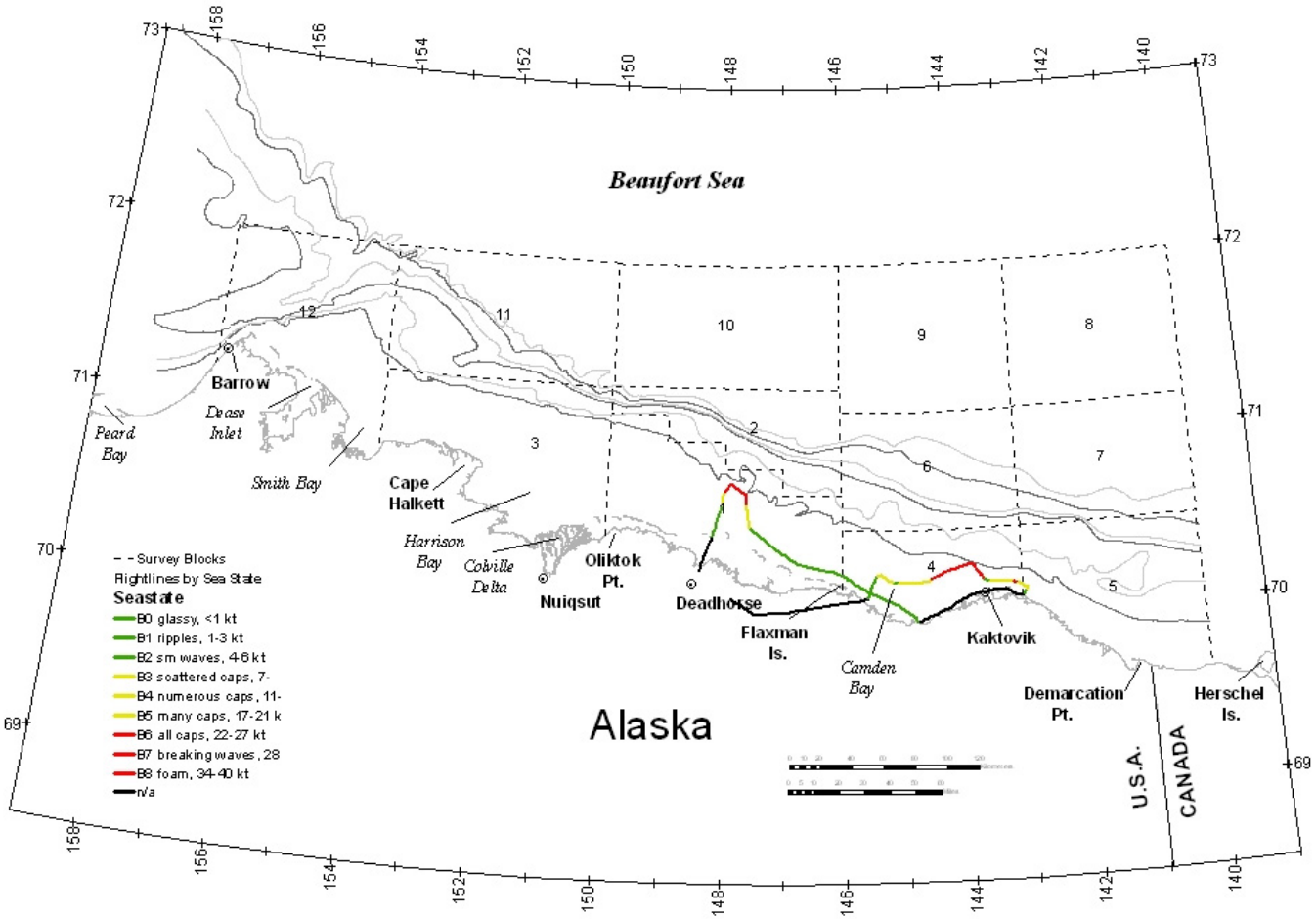

Figure F-18 - Aerial survey flight track, 7 October 2007.

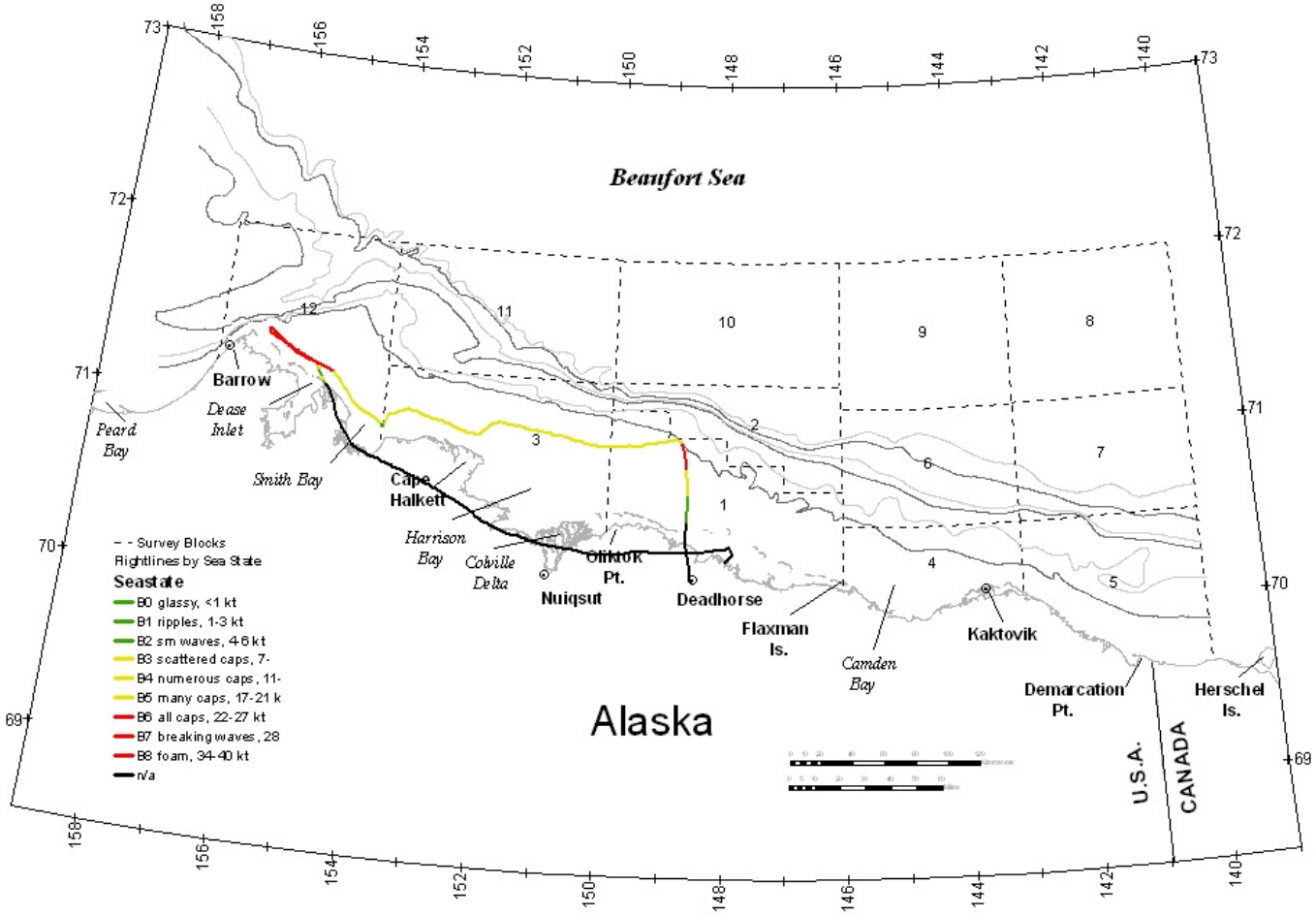

Figure F-19 - Aerial survey flight track, 8 October 2007.

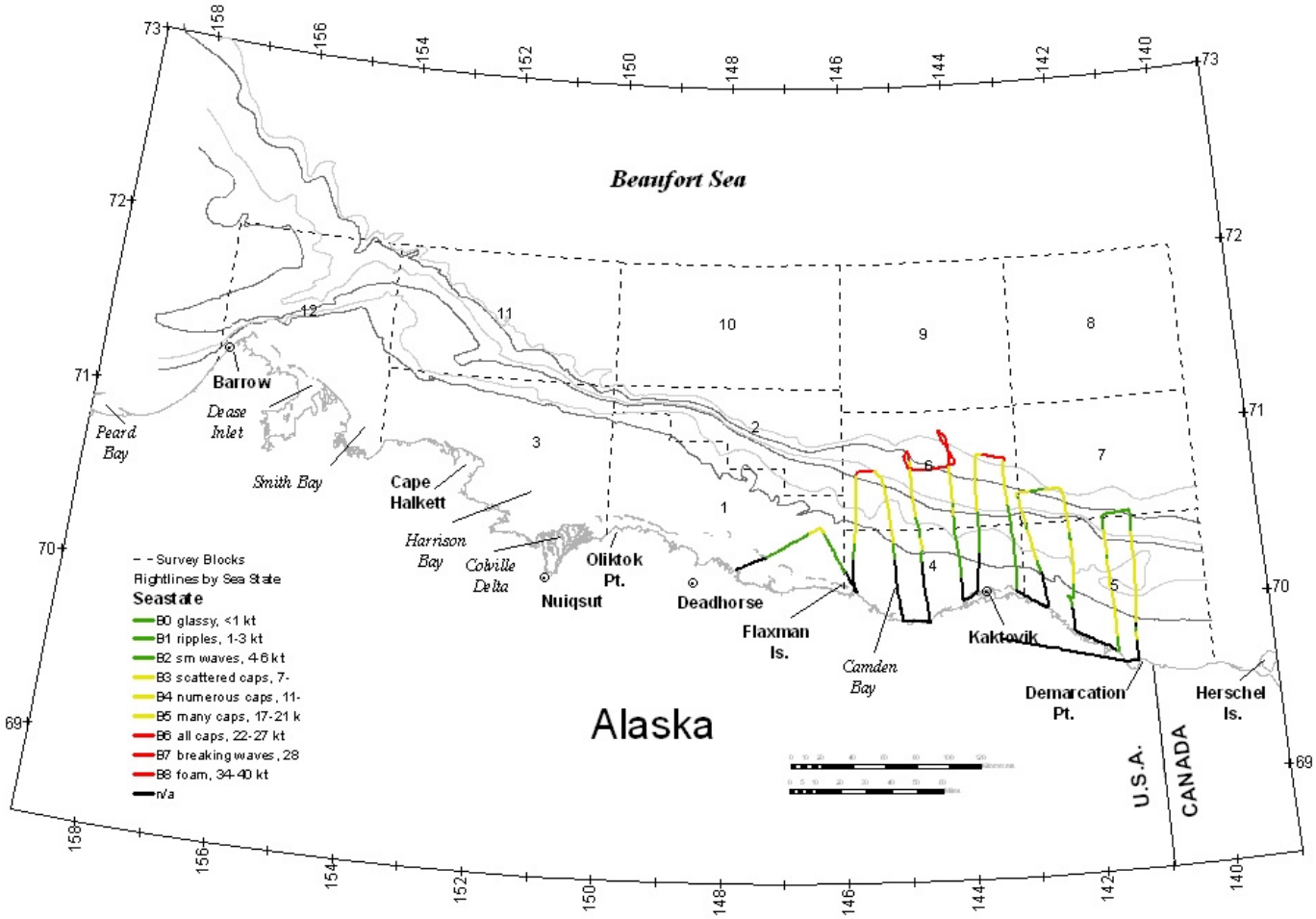

Figure F-20 - Aerial survey flight track, 9 October 2007.

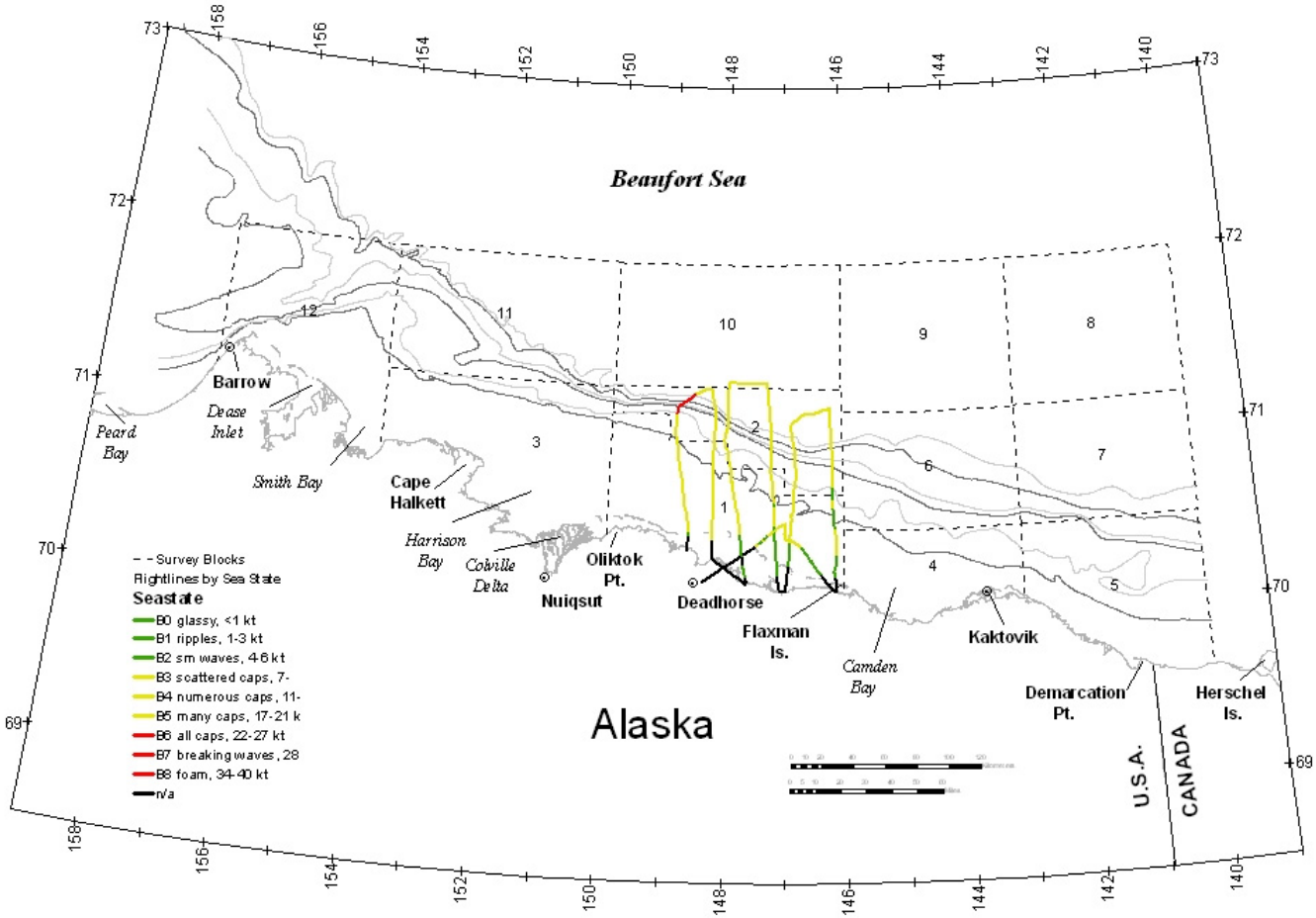

Figure F-21 - Aerial survey flight track, 10 October 2007.

APPENDIX G: FALL 2008 ICE CONCENTRATION MAPS – ALASKAN BEAUFORT SEA

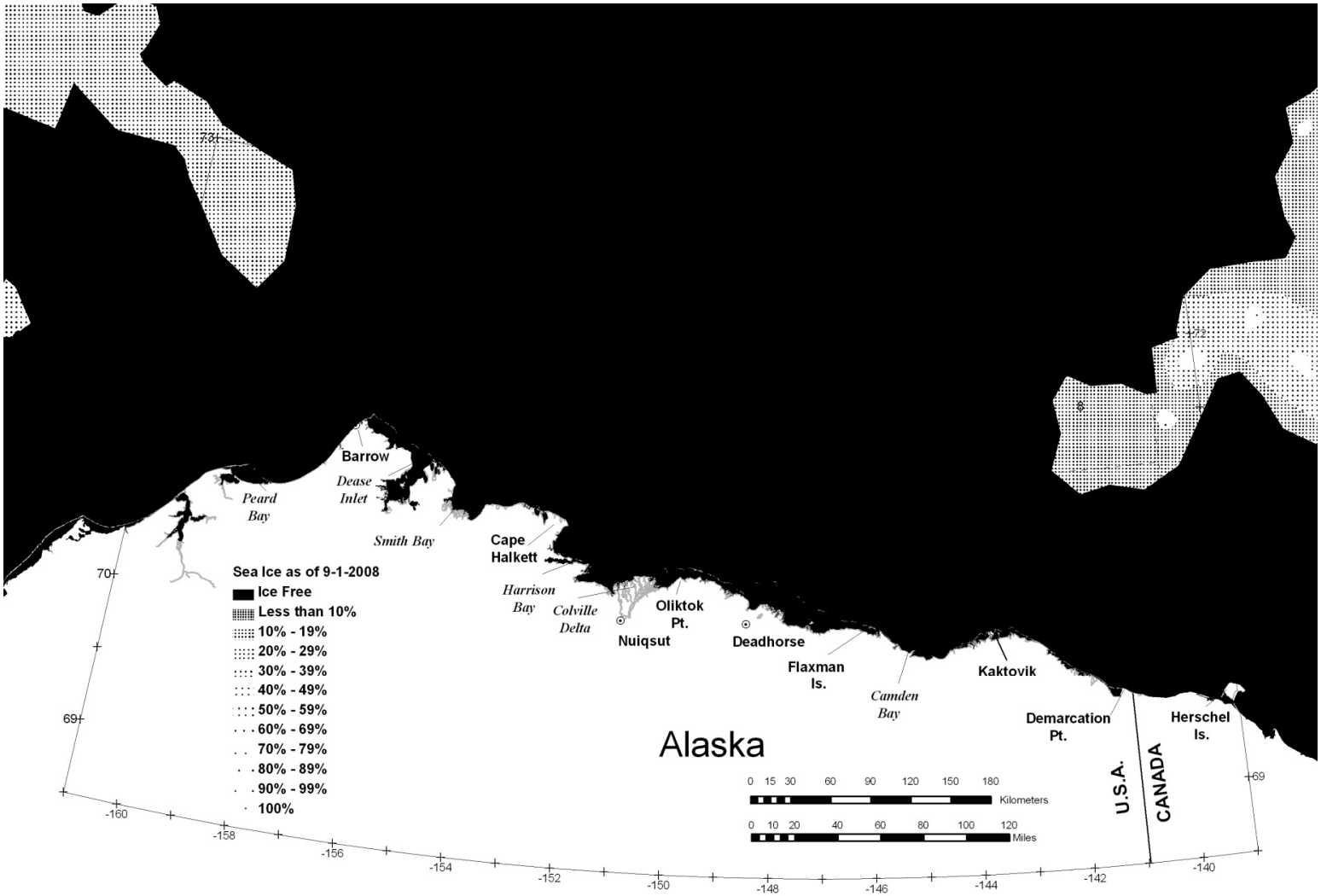

Figure G-1 – Ice concentrations in the Alaskan Beaufort Sea, 1 September 2008.

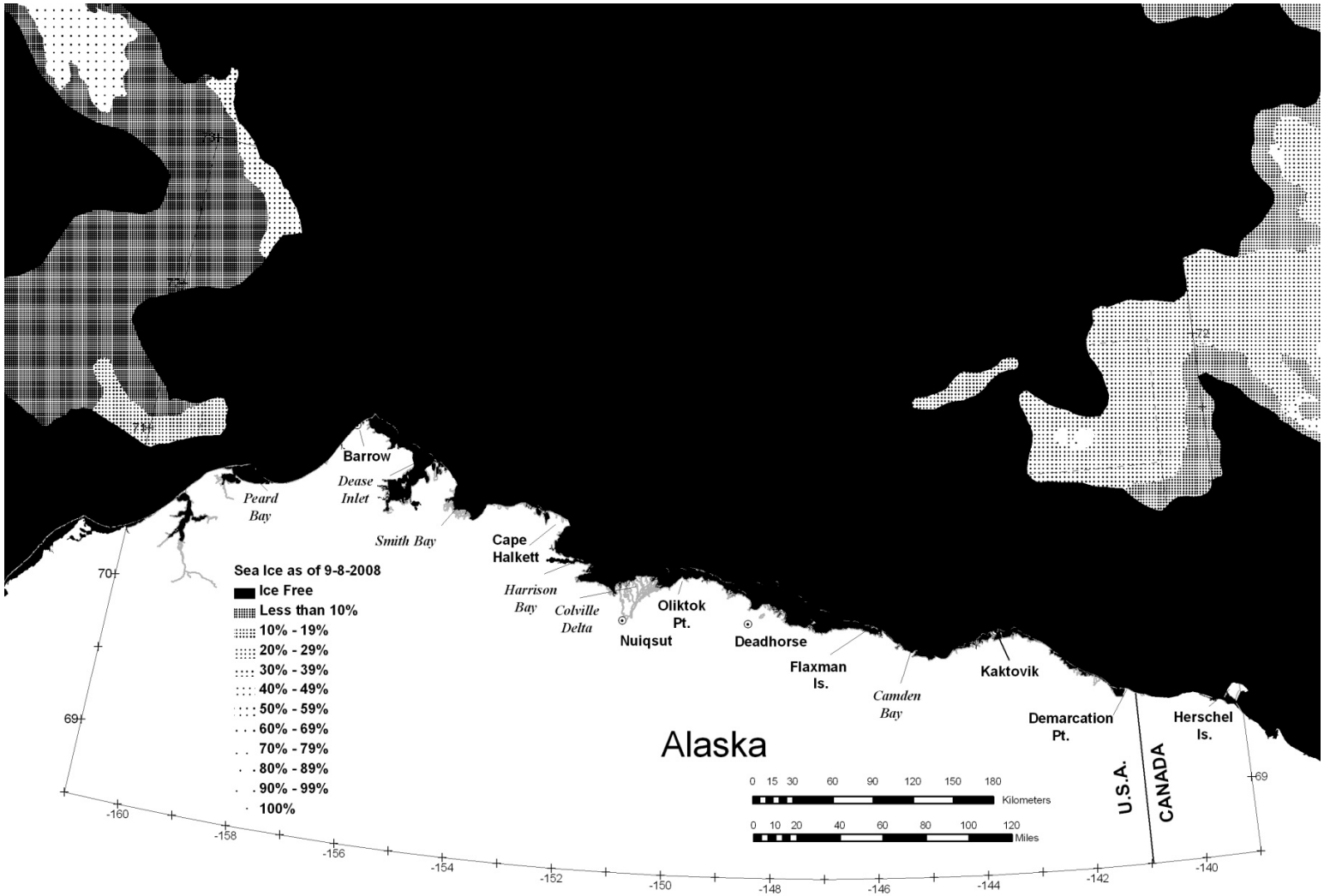

Figure G-2 – Ice concentrations in the Alaskan Beaufort Sea, 8 September 2008.

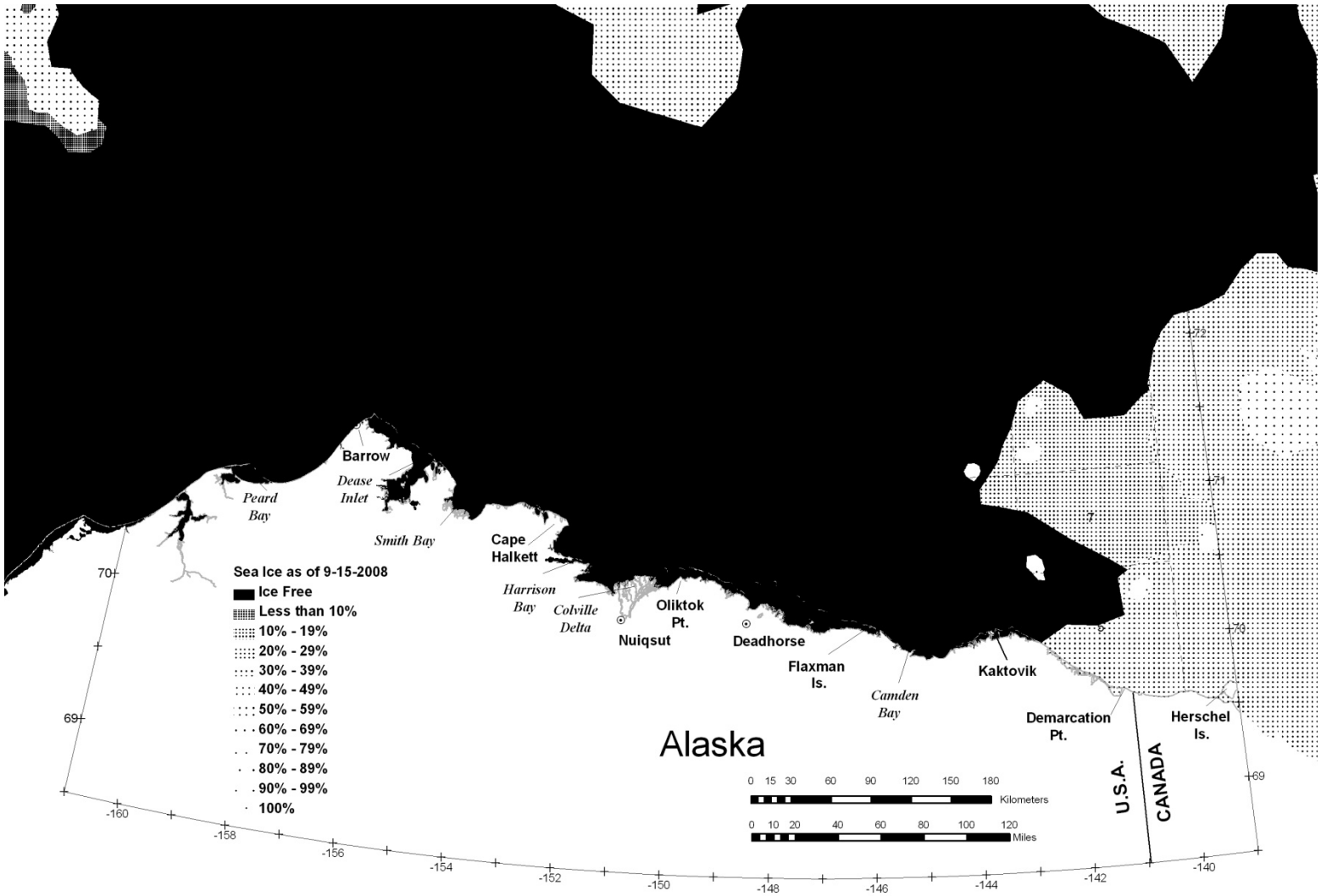

Figure G-3 – Ice concentrations in the Alaskan Beaufort Sea, 15 September 2008.

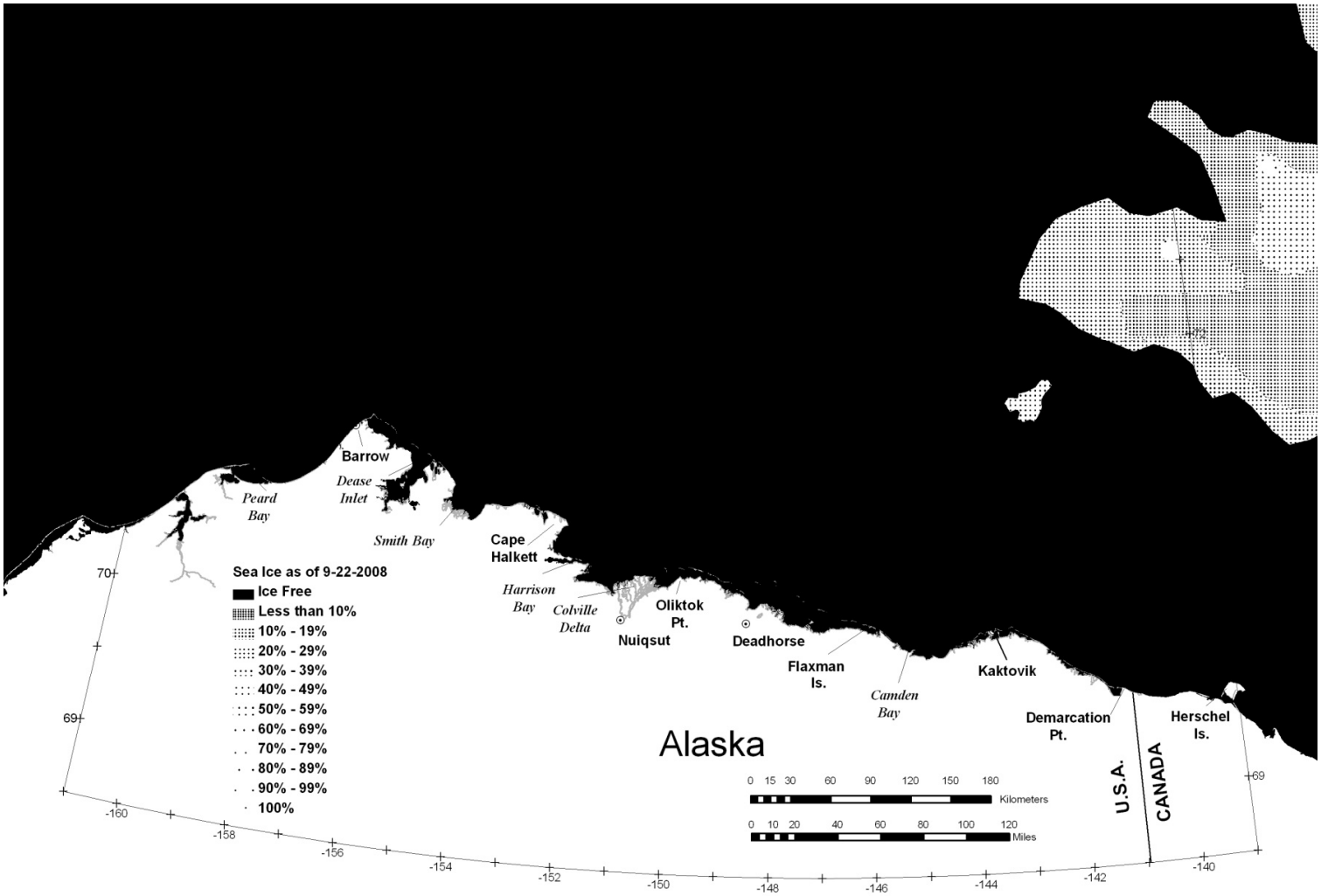

Figure G-4 – Ice concentrations in the Alaskan Beaufort Sea, 22 September 2008.

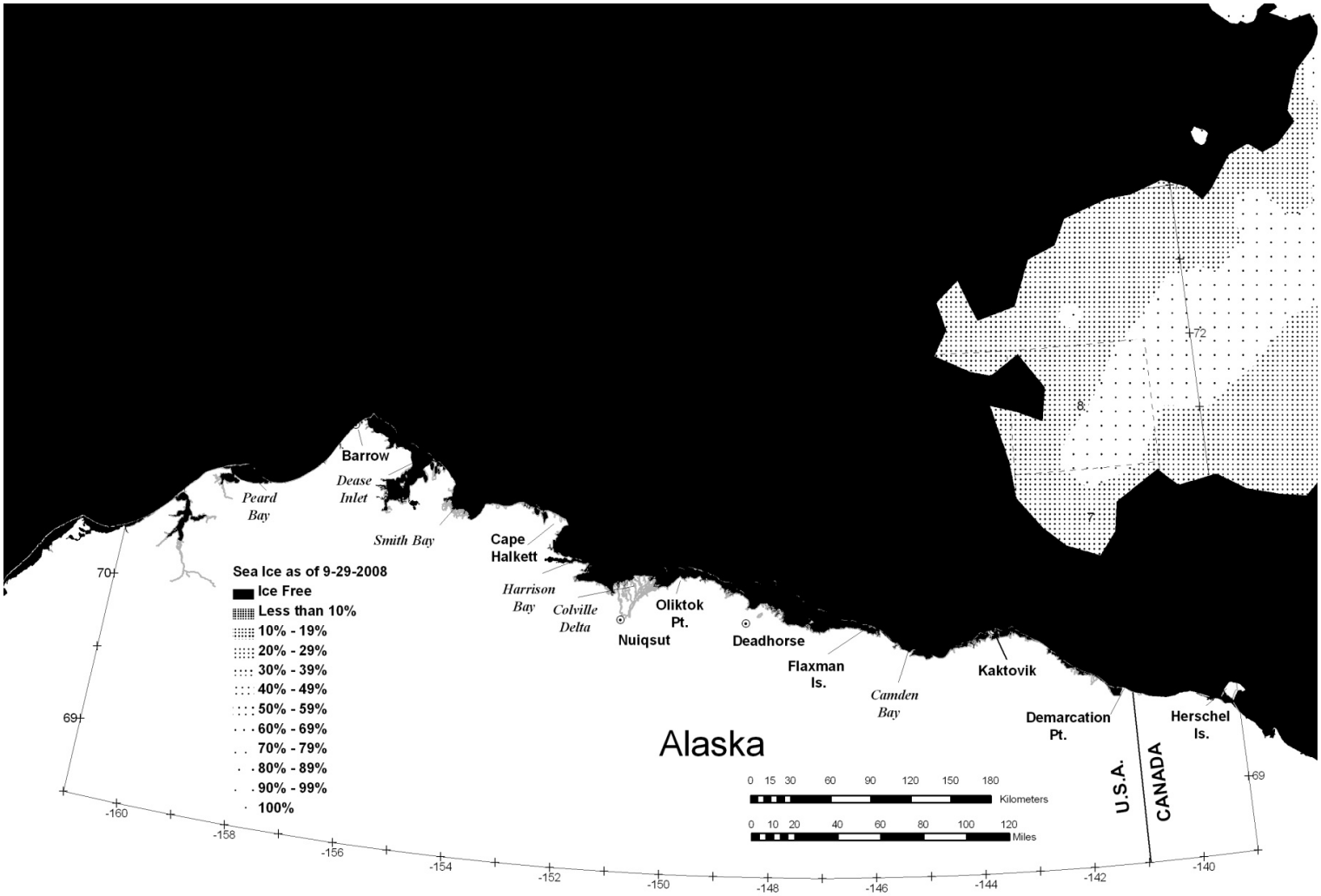

Figure G-5 – Ice concentrations in the Alaskan Beaufort Sea, 29 September 2008.

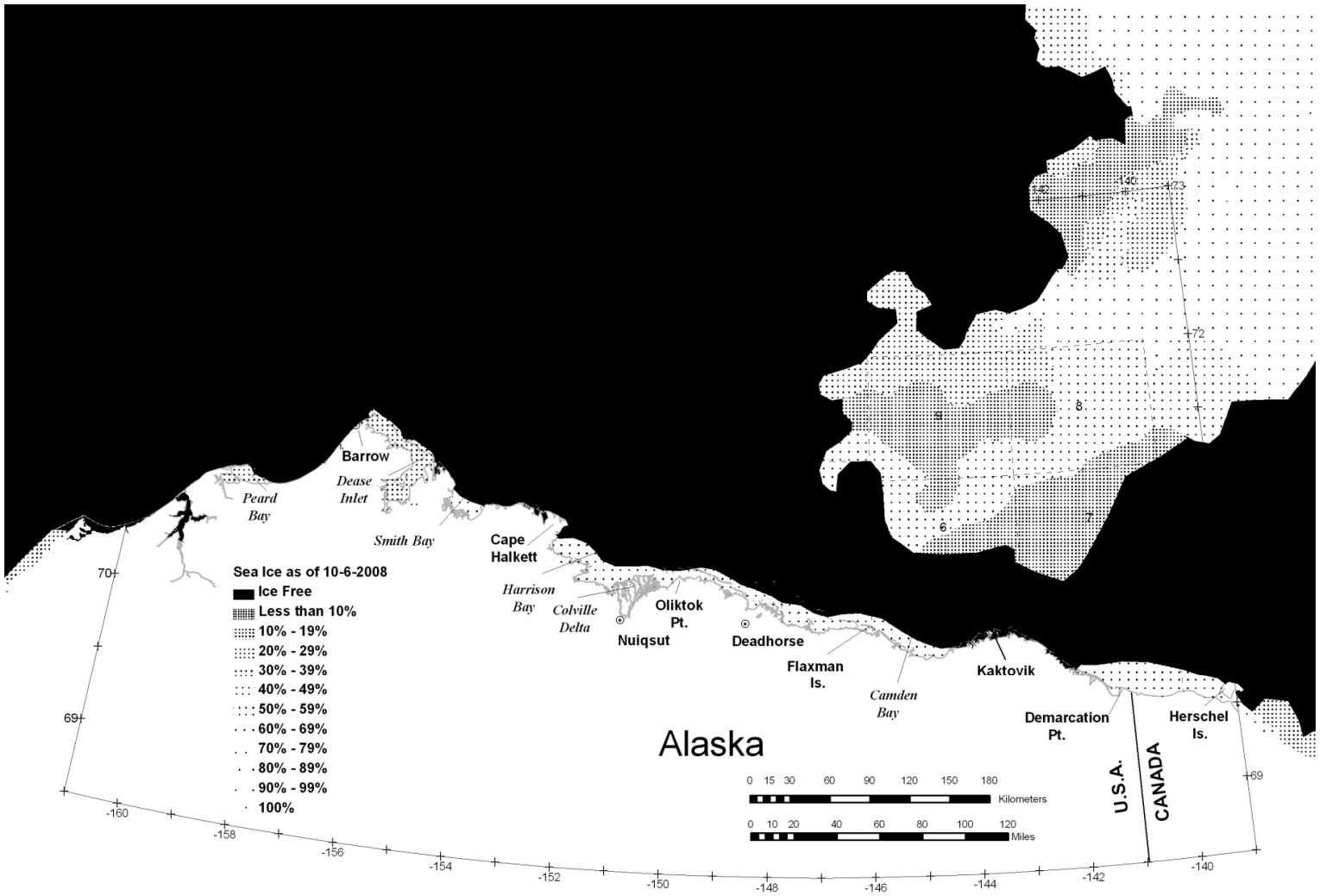

Figure G-6 – Ice concentrations in the Alaskan Beaufort Sea, 6 October 2008.

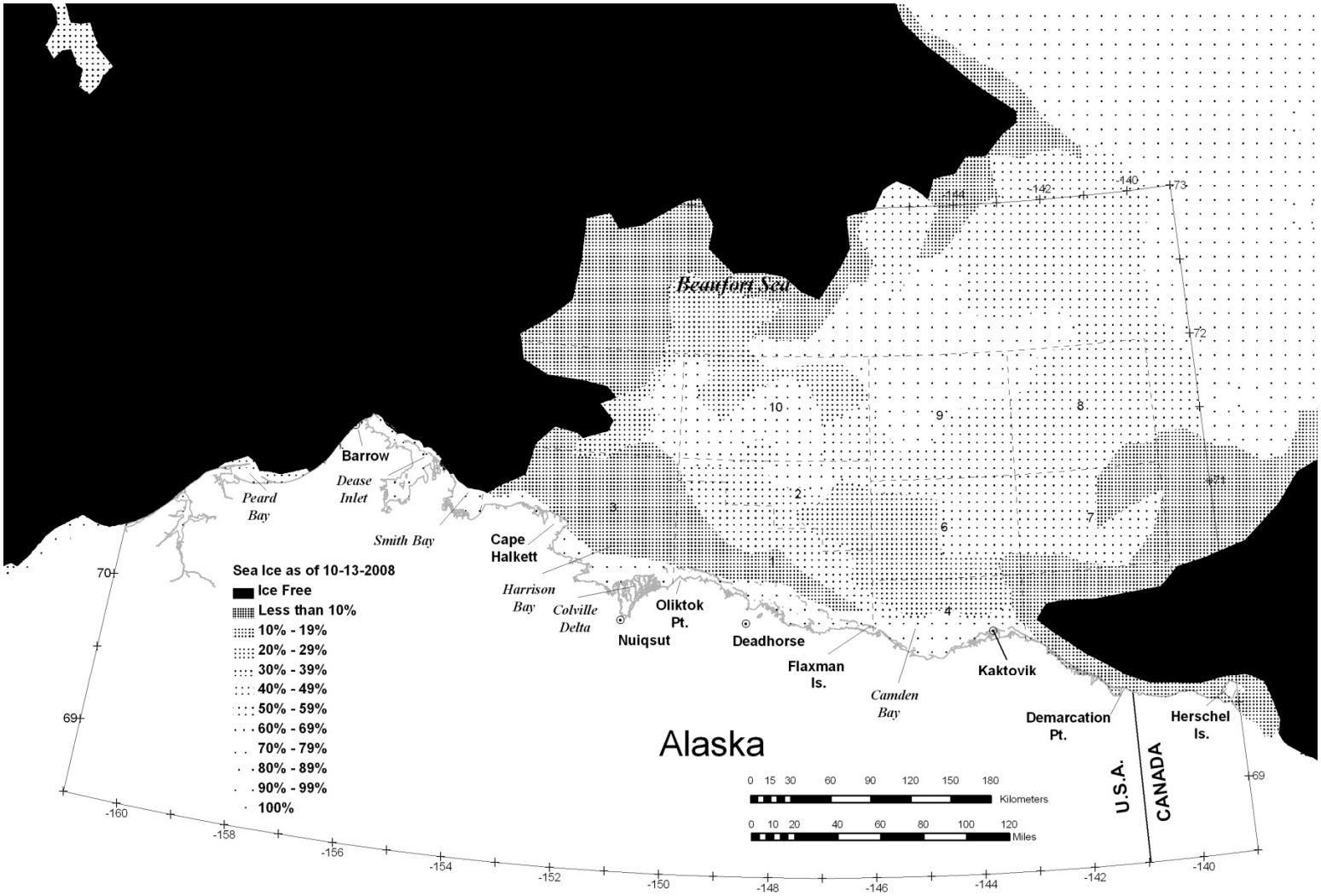

Figure G-7 – Ice concentrations in the Alaskan Beaufort Sea, 13 October 2008.

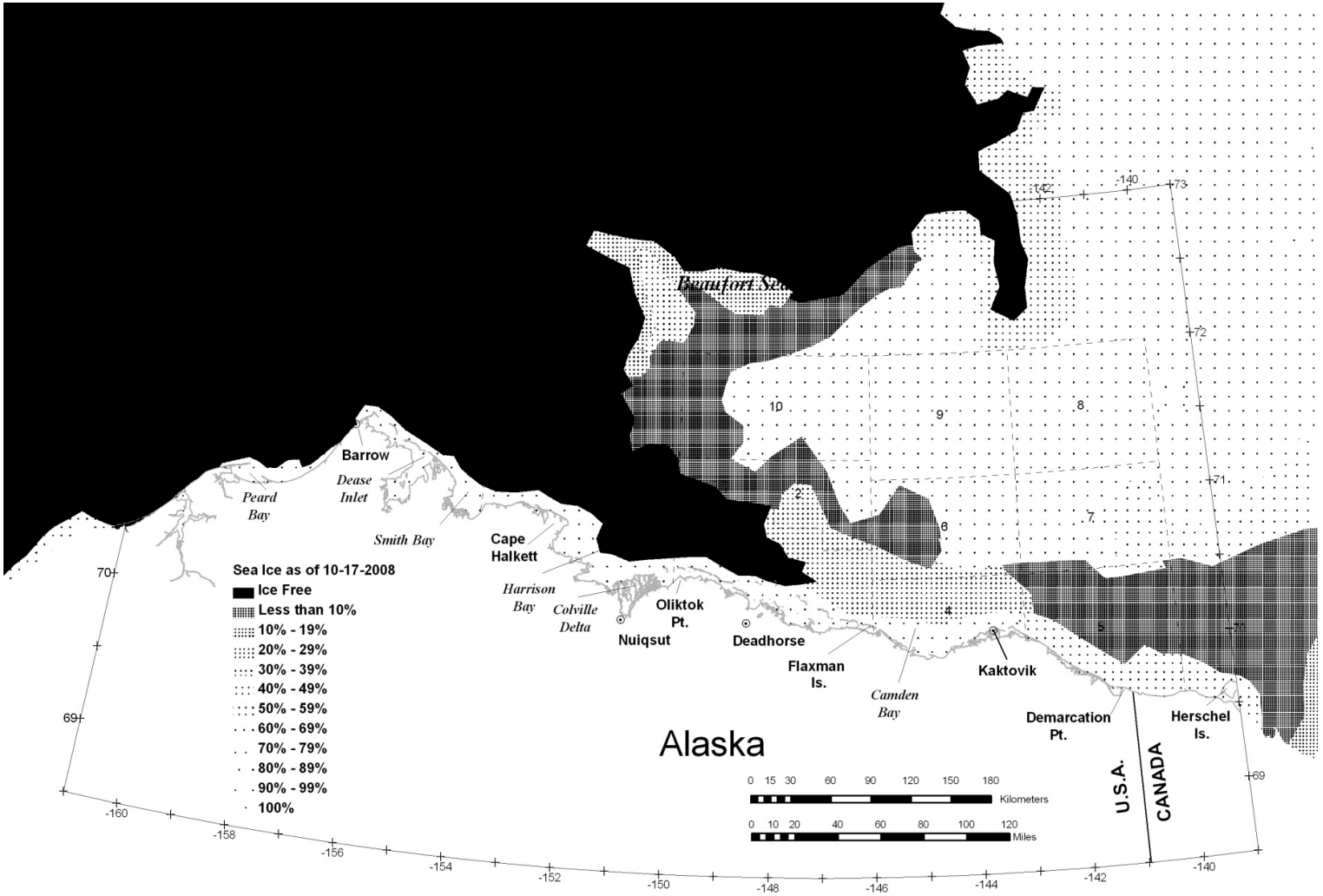

Figure G-8 – Ice concentrations in the Alaskan Beaufort Sea, 17 October 2008.

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APPENDIX H: FALL 2008 BOWHEAD WHALE SIGHTING DATA

Table H-1
Selected data for bowhead whale sightings, fall 2008
([1]not recorded)

Flight No	Day	Total Whales	No of Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Wind Force
20	5 Sep	2	0	70º17.9'	146º15.0'	swim	340º	0	3
20	5 Sep	3	0	70º45.5'	149º14.9'	swim	331º	0	2
20	5 Sep	1	0	70º50.2'	149º43.2'	swim	293º	0	2
20	5 Sep	1	0	70º53.4'	150º02.2'	swim	299º	0	3
20	5 Sep	1	0	70º58.1'	150º18.4'	swim	274º	0	4
21	7 Sep	1	0	70º07.9'	143º44.0'	swim	105º	0	4
21	7 Sep	1	0	70º09.3'	142º59.7'	swim	[1]	0	2
21	7 Sep	2	0	70º05.8'	142º12.7'	rest	[1]	0	1
21	7 Sep	1	0	70º05.8'	142º15.3'	dive	52º	0	1
22	10 Sep	1	0	70º21.4'	145º36.4'	swim	59º	0	3
22	10 Sep	4	0	70º25.3'	145º18.5'	swim	275º	0	4
22	10 Sep	1	0	70º23.1'	145º19.0'	swim	305º	0	4
22	10 Sep	1	0	70º22.0'	145º19.6'	swim	12º	0	3
22	10 Sep	1	0	70º13.3'	144º57.4'	swim	[1]	0	4
22	10 Sep	1	0	70º14.0'	144º49.2'	swim	[1]	0	4
22	10 Sep	1	0	70º13.9'	144º57.4'	swim	[1]	0	4
22	10 Sep	1	0	70º14.8'	144º58.7'	swim	[1]	0	4
22	10 Sep	1	0	70º16.3'	144º57.3'	swim	272º	0	4
22	10 Sep	1	0	70º26.5'	144º54.3'	swim	[1]	0	4
22	10 Sep	1	0	70º26.8'	144º50.4'	swim	[1]	0	4
22	10 Sep	4	2	70º27.0'	146º03.6'	cow with calf	[1]	0	3
22	10 Sep	1	0	70º27.8'	146º03.6'	swim	[1]	0	3
23	12 Sep	1	0	70º28.0'	146º20.2'	swim	5º	0	3
23	12 Sep	1	0	70º33.0'	146º20.9'	swim	299º	0	3
23	12 Sep	2	0	70º42.1'	147º14.8'	swim	111º	0	3
23	12 Sep	1	0	70º43.0'	147º09.7'	swim	[1]	0	3
23	12 Sep	1	0	70º43.0'	147º15.0'	swim	90º	0	3
23	12 Sep	1	0	70º56.3'	149º10.7'	swim	272º	0	2
23	12 Sep	1	0	70º58.5'	149º39.1'	swim	334º	0	2
23	12 Sep	1	0	70º58.7'	149º41.0'	swim	[1]	0	2
23	12 Sep	1	0	71º01.4'	150º10.8'	swim	268º	0	2
23	12 Sep	3	0	71º01.9'	150º06.8'	swim	[1]	0	2
23	12 Sep	1	0	71º00.6'	150º06.6'	swim	[1]	0	2
25	18 Sep	1	0	70º46.2'	148º45.4'	swim	293º	0	3

Flight No	Day	Total Whales	No of Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Wind Force
25	18 Sep	3	0	70º48.3'	148º46.3'	swim	3º	0	3
25	18 Sep	1	0	70º49.6'	148º47.5'	swim	160º	0	3
25	18 Sep	1	0	70º48.8'	148º48.1'	swim	[1]	0	3
25	18 Sep	1	0	70º25.3'	147º04.4'	swim	329º	0	2
25	18 Sep	1	0	70º24.9'	147º04.3'	swim	298º	0	2
25	18 Sep	1	0	70º26.2'	147º05.0'	swim	289º	0	2
25	18 Sep	1	0	70º22.4'	146º38.9'	swim	98º	0	2
25	18 Sep	1	0	70º22.6'	146º38.8'	swim	278º	0	2
25	18 Sep	4	2	70º26.5'	146º22.4'	swim	[1]	0	3
25	18 Sep	1	0	70º26.5'	146º22.4'	swim	[1]	0	3
25	18 Sep	2	0	70º24.5'	146º22.8'	[1]	[1]	0	3
25	18 Sep	6	3	70º24.1'	146º24.5'	cow with calf	[1]	0	3
25	18 Sep	3	1	70º23.5'	146º25.1'	cow with calf	[1]	0	3
25	18 Sep	2	0	70º22.7'	146º22.6'	swim	[1]	0	3
25	18 Sep	10	0	70º23.9'	146º24.0'	swim	[1]	0	3
25	18 Sep	4	2	70º23.2'	146º19.5'	swim	[1]	0	3
25	18 Sep	1	0	70º20.7'	146º22.7'	swim	[1]	0	3
25	18 Sep	1	0	70º20.6'	146º22.7'	swim	332º	0	3
26	19 Sep	1	0	70º11.1'	145º48.9'	swim	210º	0	2
26	19 Sep	1	0	70º09.8'	145º40.4'	swim	30º	0	2
26	19 Sep	1	0	70º08.5'	145º39.2'	swim	209º	0	2
26	19 Sep	2	1	70º14.9'	143º16.6'	swim	259º	0	2
26	19 Sep	1	0	69º51.0'	141º24.7'	swim	88º	0	2
26	19 Sep	1	0	69º48.9'	140º18.9'	swim	181º	0	3
27	23 Sep	1	0	71º01.7'	154º08.1'	swim	14º	0	2
27	23 Sep	1	0	71º01.9'	154º10.9'	swim	284º	0	2
27	23 Sep	6	0	71º02.5'	154º33.2'	swim	264º	0	3
27	23 Sep	1	0	71º06.8'	154º37.2'	swim	[1]	0	3
27	23 Sep	3	0	71º17.4'	155º33.7'	breach	[1]	0	3
27	23 Sep	4	0	71º17.6'	155º33.7'	[1]	[1]	0	3
27	23 Sep	2	0	71º18.3'	155º34.1'	swim	[1]	0	3
27	23 Sep	1	0	71º18.0'	155º38.9'	swim	[1]	0	3
27	23 Sep	3	0	71º19.8'	155º34.1'	[1]	[1]	0	3
27	23 Sep	3	0	71º17.8'	155º38.9'	swim	[1]	0	3
27	23 Sep	2	0	71º20.6'	155º33.6'	breach	[1]	0	3
27	23 Sep	2	0	71º21.2'	155º33.8'	mill	[1]	0	3
27	23 Sep	1	0	71º22.0'	155º33.9'	[1]	267º	0	3

Flight No	Day	Total Whales	No of Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Wind Force
27	23 Sep	2	0	71º22.3'	155º33.9'	dive	[1]	0	3
27	23 Sep	4	0	71º28.5'	155º34.0'	feed	[1]	0	3
27	23 Sep	4	0	71º28.5'	155º37.1'	mate	[1]	0	3
27	23 Sep	1	0	71º27.3'	155º38.8'	swim	[1]	0	3
27	23 Sep	1	0	71º30.0'	155º33.8'	swim	172º	0	3
27	23 Sep	2	0	71º12.7'	155º02.8'	swim	206º	0	4
28	24 Sep	1	0	71º03.2'	154º33.9'	swim	268º	0	2
28	24 Sep	2	1	71º09.3'	154º33.9'	cow with calf	60º	0	2
28	24 Sep	2	0	71º09.5'	154º33.8'	swim	[1]	0	2
28	24 Sep	12	2	71º09.9'	154º33.8'	cow with calf	[1]	0	2
28	24 Sep	2	1	71º11.1'	154º33.1'	cow with calf	[1]	0	2
28	24 Sep	1	0	71º13.9'	154º33.7'	swim	270º	0	2
28	24 Sep	2	0	71º07.5'	154º08.6'	swim	[1]	0	2
28	24 Sep	1	0	71º06.4'	154º11.0'	swim	272º	0	2
28	24 Sep	3	0	71º06.0'	154º08.4'	mill	[1]	0	2
28	24 Sep	6	0	71º05.5'	154º07.9'	swim	[1]	0	2
28	24 Sep	4	0	71º05.7'	154º06.7'	mill	[1]	0	2
28	24 Sep	1	0	71º04.8'	154º08.2'	swim	116º	0	2
28	24 Sep	1	0	71º02.8'	153º43.5'	rest	[1]	0	2
28	24 Sep	1	0	71º08.1'	153º43.1'	swim	271º	0	2
28	24 Sep	2	0	71º05.1'	152º37.4'	mill	[1]	0	2
28	24 Sep	1	0	71º05.6'	152º39.4'	swim	[1]	0	2
28	24 Sep	1	0	71º04.8'	152º35.9'	swim	[1]	0	2
28	24 Sep	1	0	71º06.7'	152º37.8'	swim	267º	0	2
28	24 Sep	2	1	71º07.3'	152º37.9'	cow with calf	268º	0	2
29	25 Sep	1	0	71º00.8'	150º44.8'	swim	267º	0	1
29	25 Sep	1	0	70º51.7'	149º55.3'	swim	273º	0	2
30	26 Sep	2	0	70º35.7'	148º53.8'	mill	[1]	0	3
30	26 Sep	4	0	70º36.7'	148º54.4'	feed	[1]	0	3
30	26 Sep	1	0	70º36.4'	148º57.0'	swim	[1]	0	3
30	26 Sep	1	0	70º34.3'	147º39.7'	swim	300º	0	3
30	26 Sep	2	0	70º19.4'	146º38.4'	swim	270º	0	2
30	26 Sep	1	0	70º21.1'	146º38.2'	swim	358º	0	2
32	28 Sep	1	0	70º34.7'	148º33.3'	swim	355º	0	2
32	28 Sep	2	0	71º04.4'	151º45.3'	swim	248º	0	2
32	28 Sep	2	0	71º05.6'	151º49.8'	mill	[1]	0	2

Flight No	Day	Total Whales	No of Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Wind Force
32	28 Sep	1	0	71º05.7'	151º50.2'	dive	308º	0	2
34	8 Oct	1	0	71º11.5'	154º37.5'	swim	280º	0	4
34	8 Oct	1	0	71º16.6'	154º54.8'	swim	26º	0	4
34	8 Oct	1	0	71º16.9'	154º56.5'	swim	[1]	0	4
34	8 Oct	5	0	71º17.4'	154º60.0'	[1]	25º	0	4
34	8 Oct	2	0	71º17.7'	155º01.9'	mill	[1]	0	4
34	8 Oct	1	0	71º18.2'	155º04.7'	[1]	[1]	0	4
34	8 Oct	1	0	71º18.6'	155º07.3'	[1]	[1]	0	4
34	8 Oct	21	0	71º18.9'	155º09.6'	feed	[1]	0	4
34	8 Oct	7	0	71º19.0'	155º10.1'	swim	207º	0	4
34	8 Oct	2	0	71º24.1'	156º41.0'	swim	57º	0	3
34	8 Oct	3	0	71º24.2'	156º41.0'	swim	267º	0	3
34	8 Oct	1	0	71º22.3'	156º04.5'	rest	[1]	0	4
34	8 Oct	2	0	71º21.0'	155º57.8'	[1]	[1]	0	3
34	8 Oct	1	0	71º21.4'	155º58.3'	[1]	[1]	0	3
34	8 Oct	5	0	71º19.2'	155º15.3'	swim	[1]	0	4
34	8 Oct	12	0	71º18.8'	155º12.8'	[1]	268º	0	4
35	9 Oct	1	0	69º41.8'	140º49.4'	swim	61º	20	3
37	13 Oct	1	0	70º40.8'	151º06.9'	swim	299º	50	2
37	13 Oct	1	0	70º53.3'	150º16.4'	feed	[1]	5	1

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APPENDIX I: FALL 2008 DAILY FLIGHT SUMMARIES

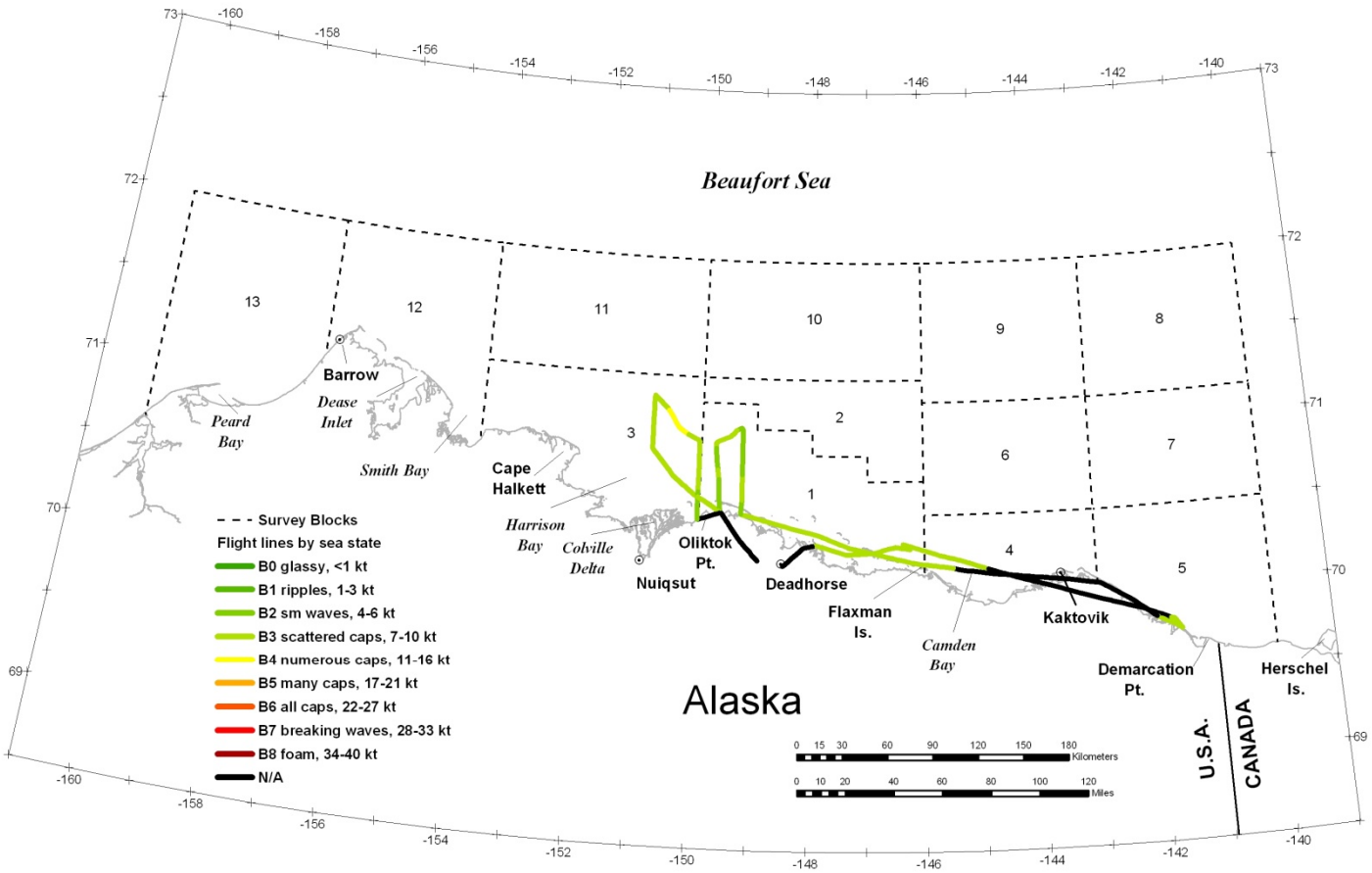

Figure I-1 - Aerial survey flight track, 5 September 2008.

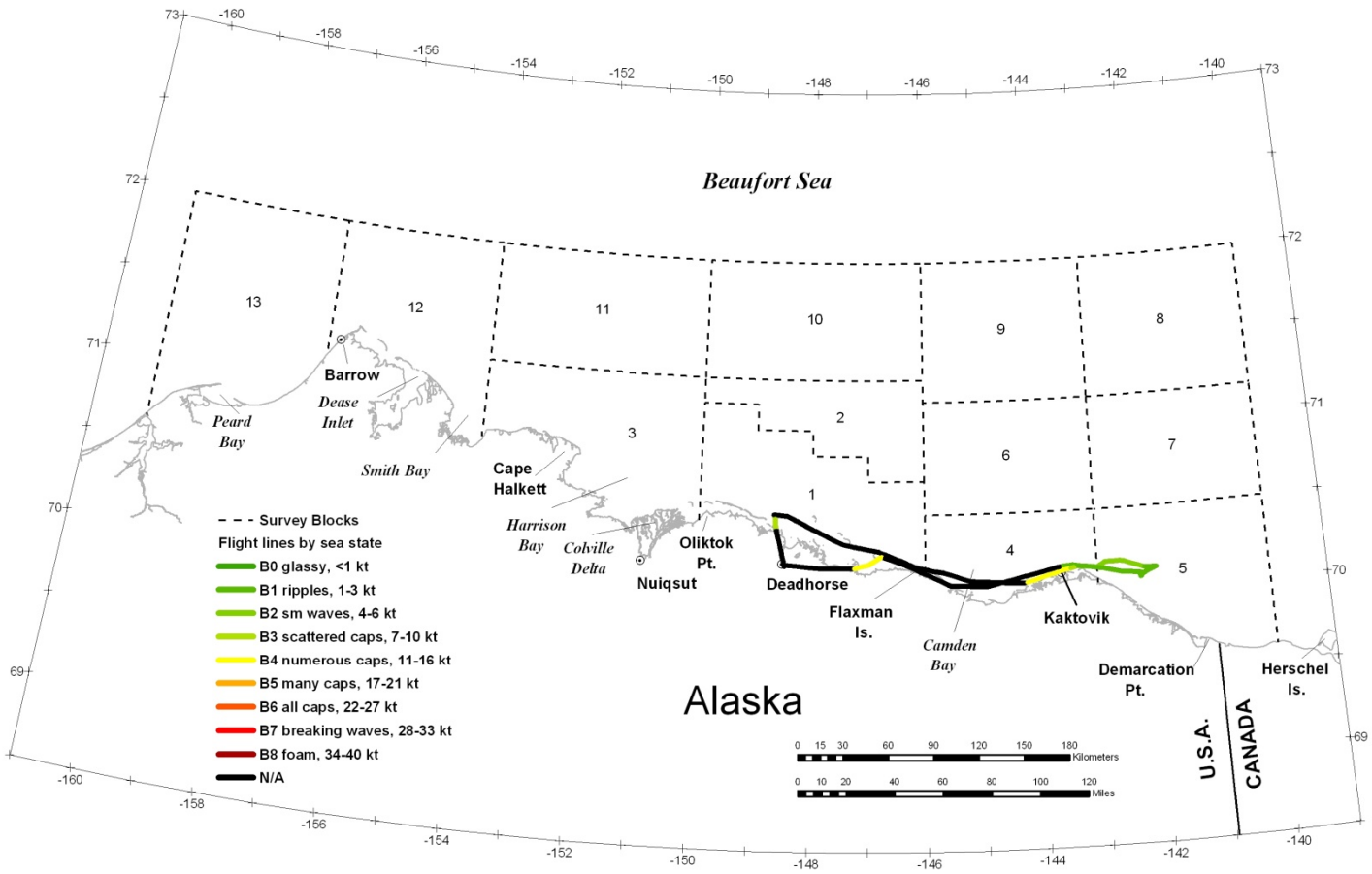

Figure I-2 - Aerial survey flight track, 7 September 2008.

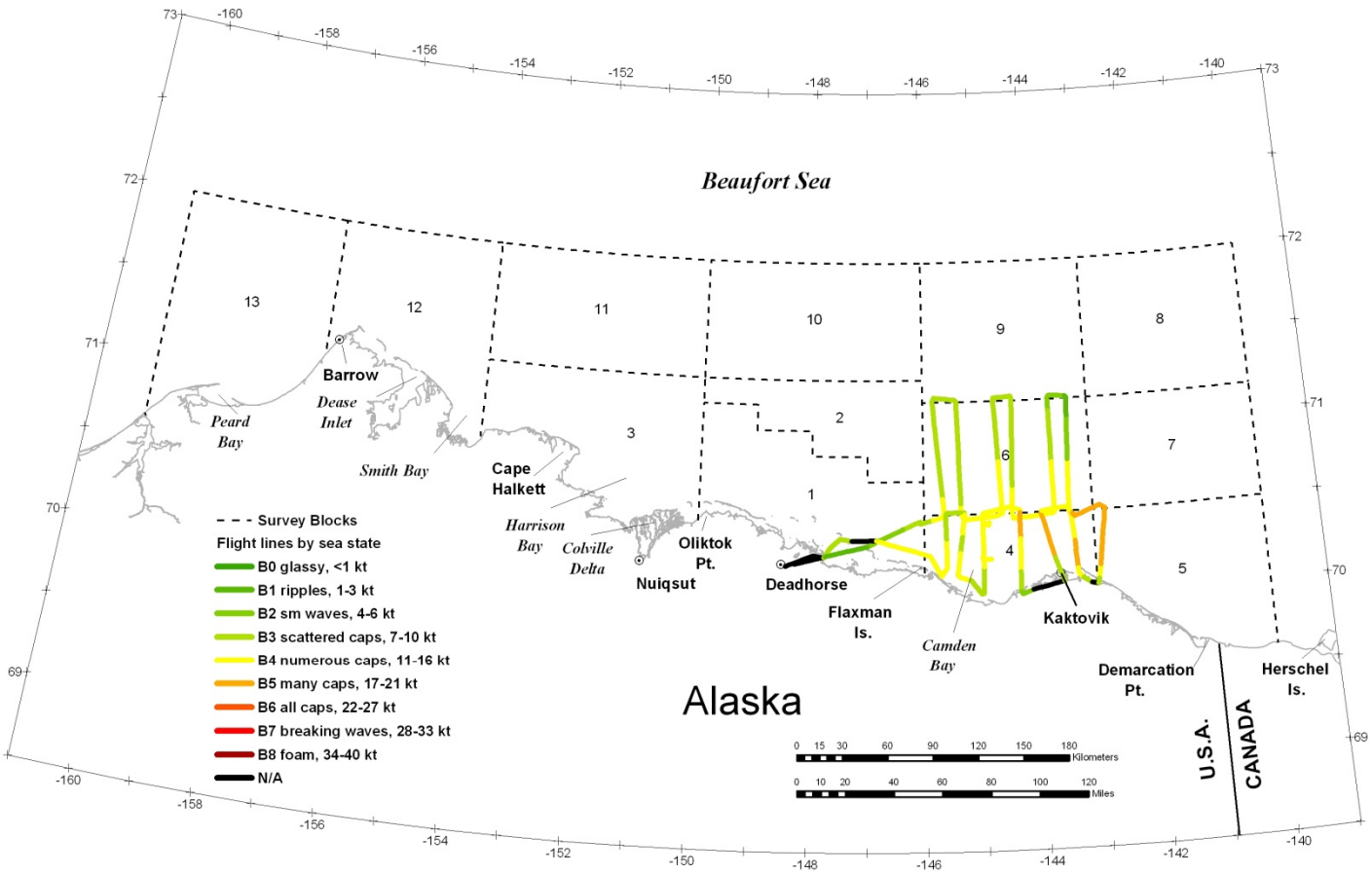

Figure I-3 - Aerial survey flight track, 10 September 2008.

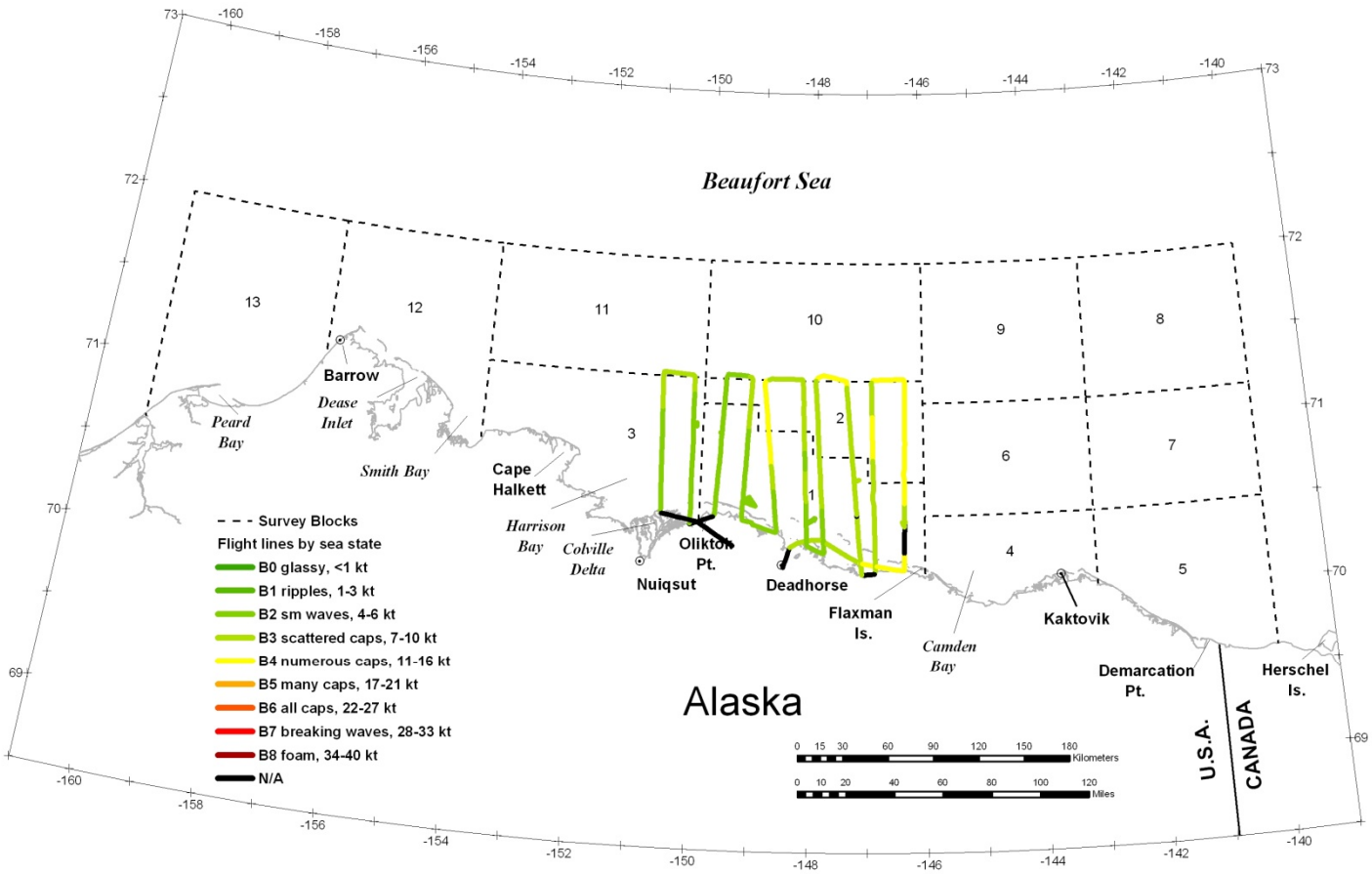

Figure I-4 - Aerial survey flight track, 12 September 2008.

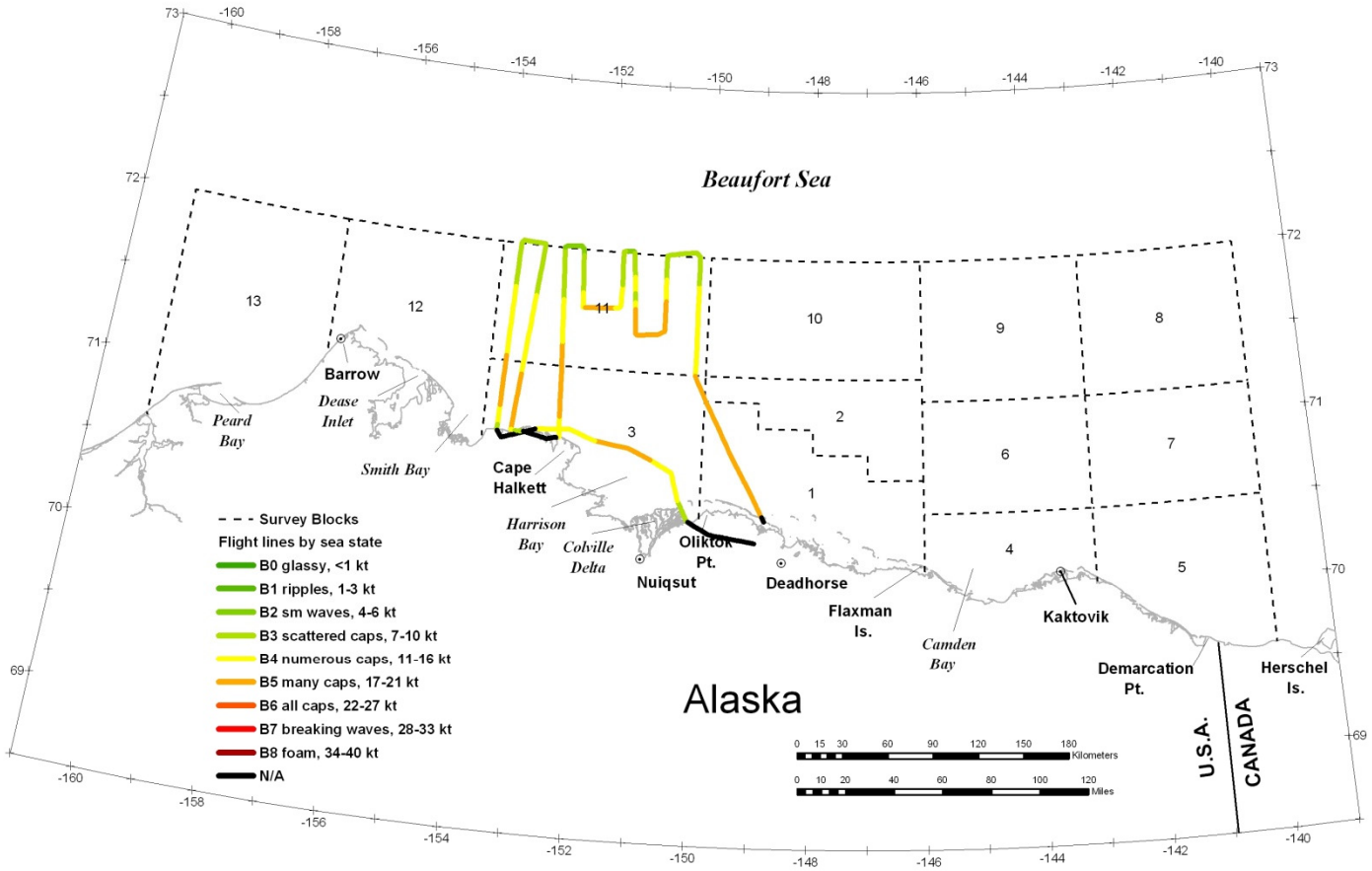

Figure I-5 - Aerial survey flight track, 14 September 2008.

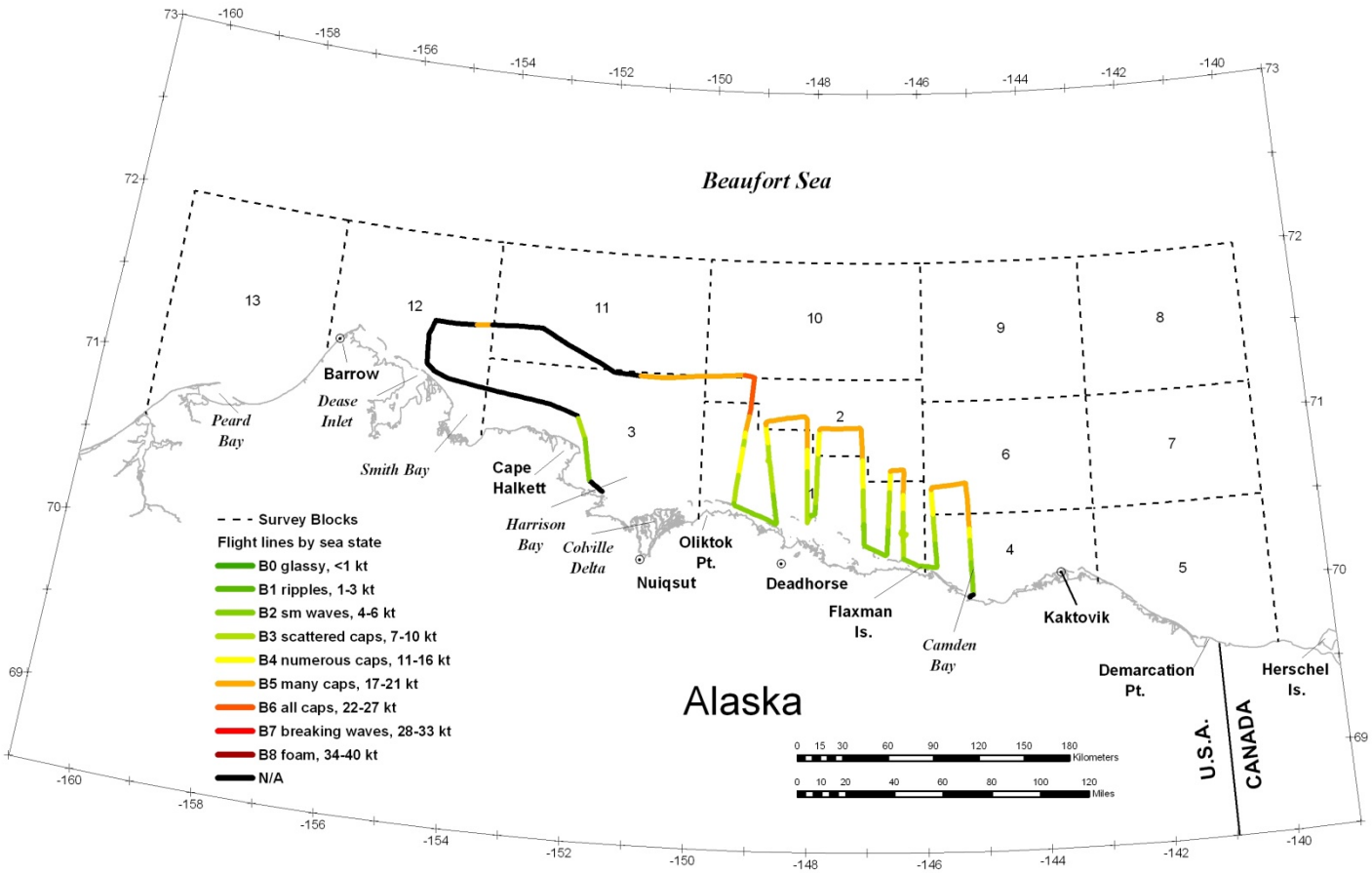

Figure I-6 - Aerial survey flight track, 18 September 2008.

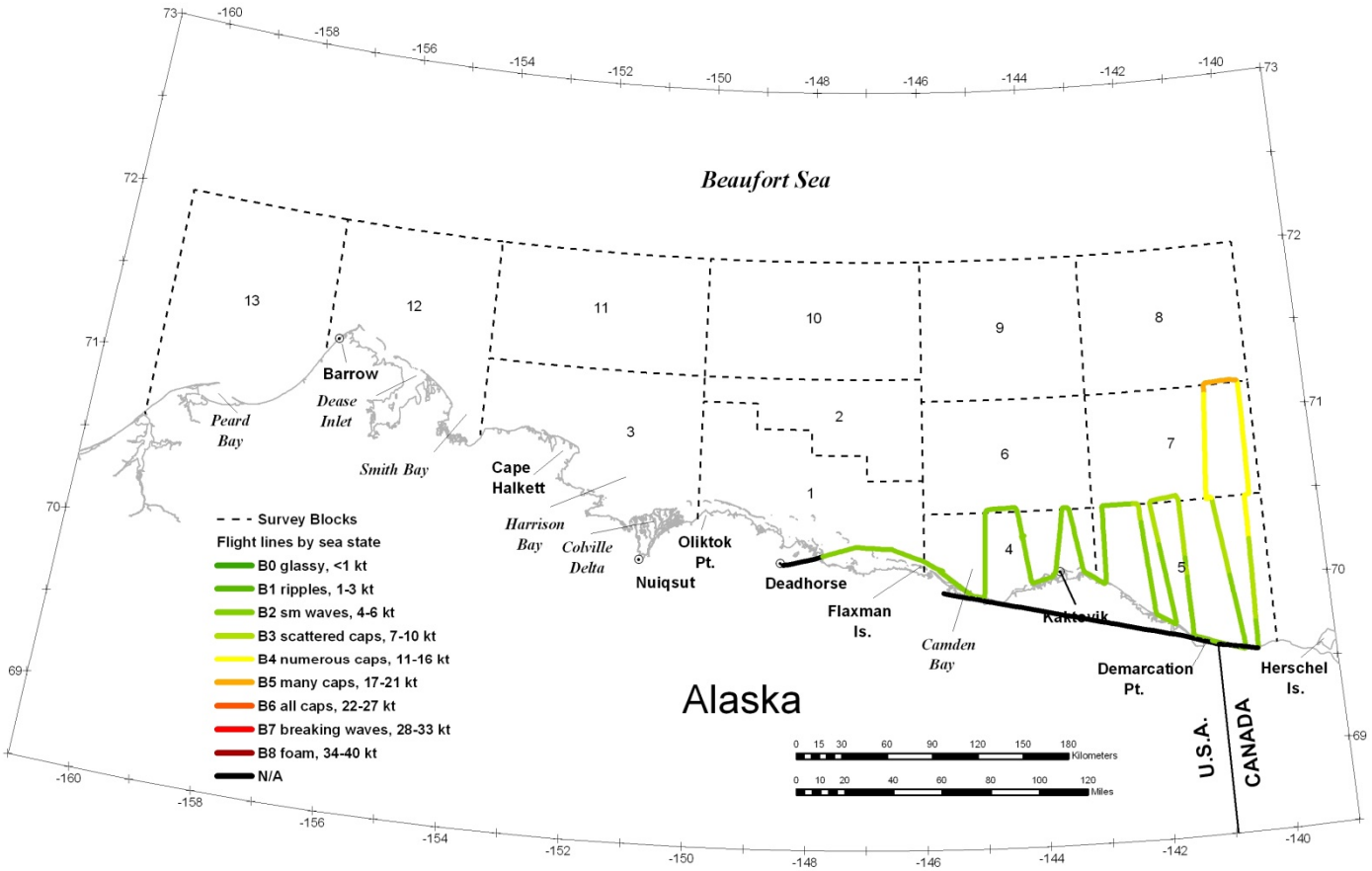

Figure I-7 - Aerial survey flight track, 19 September 2008.

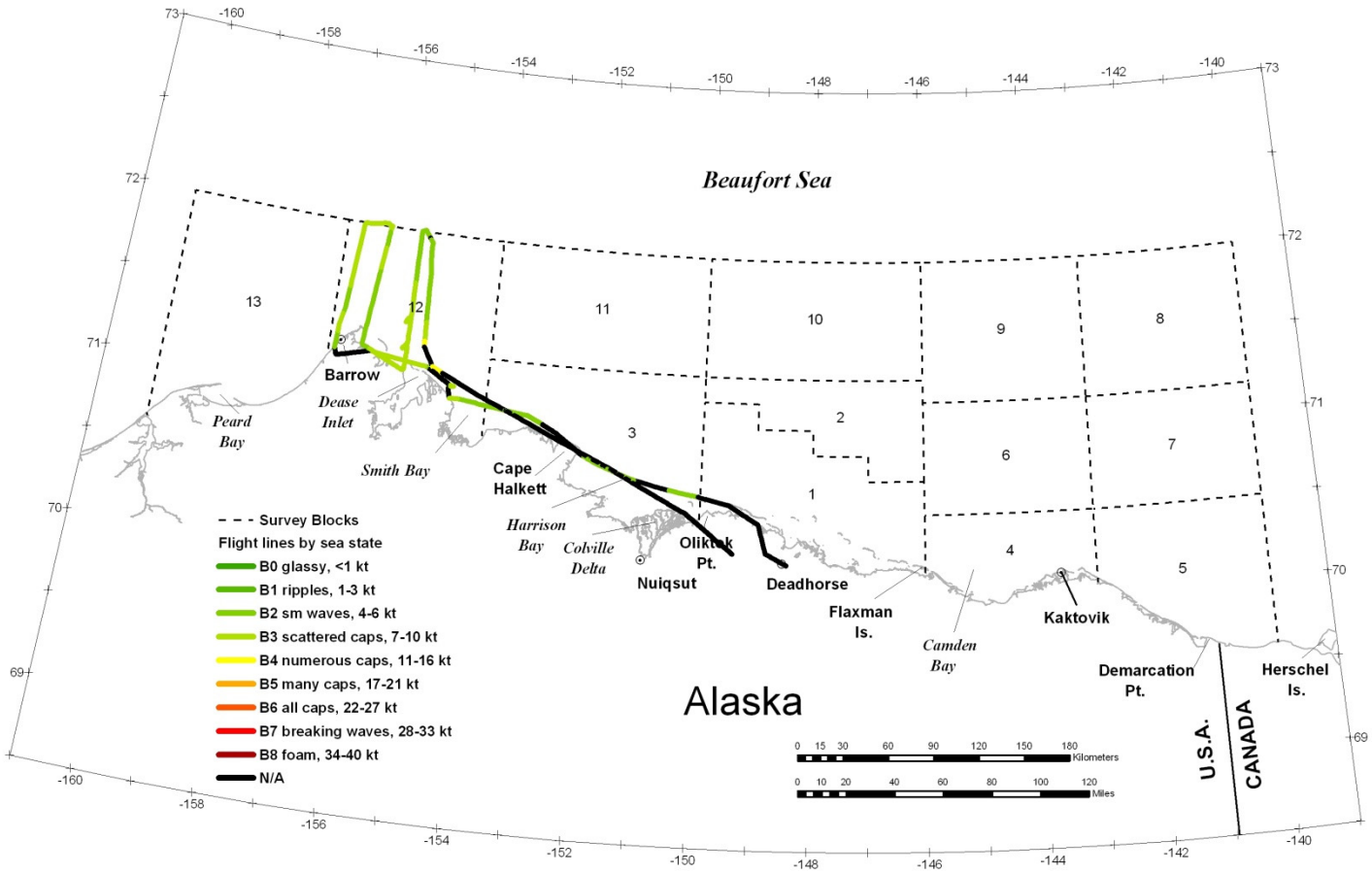

Figure I-8 - Aerial survey flight track, 23 September 2008.

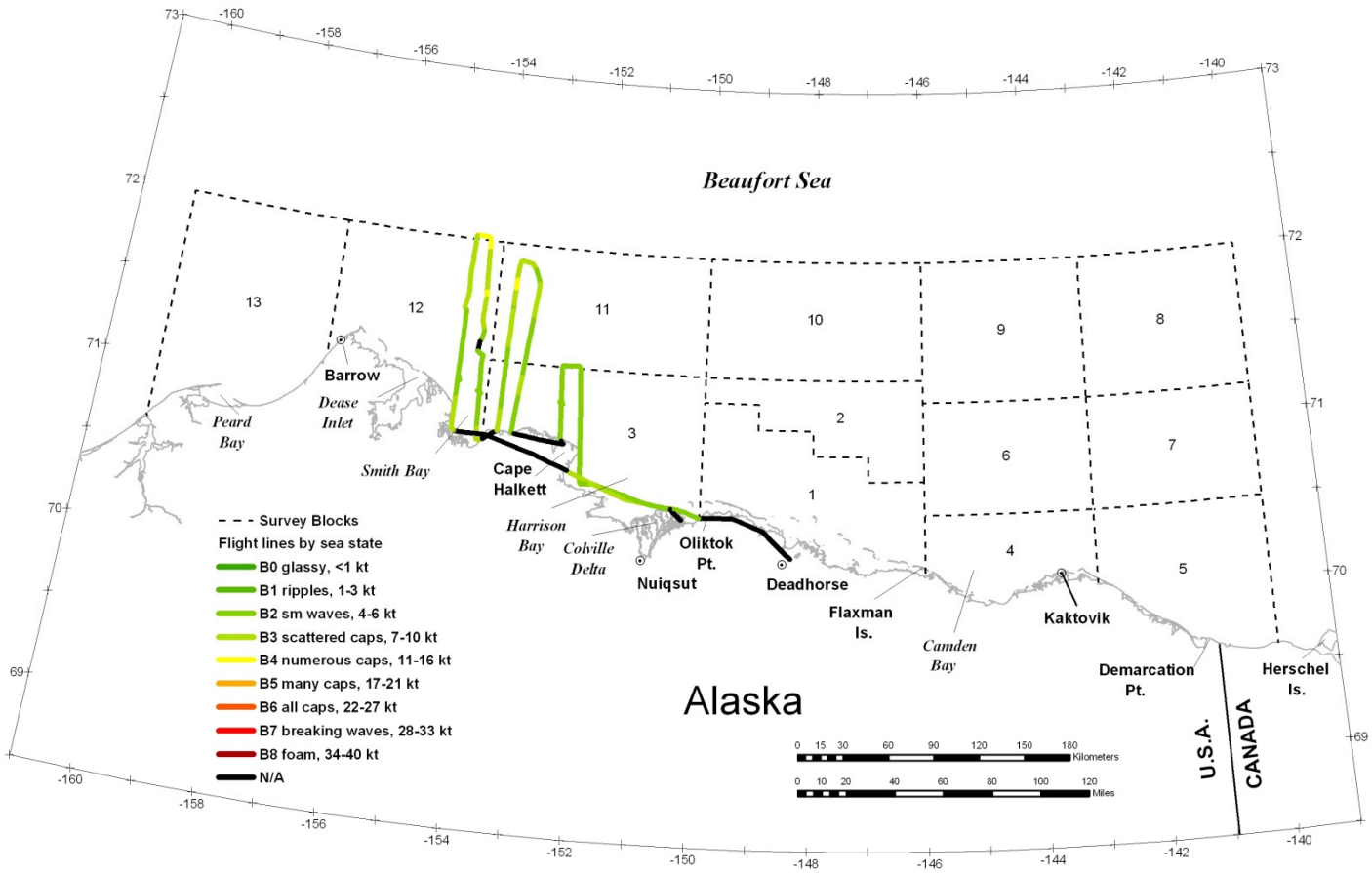

Figure I-9 - Aerial survey flight track, 24 September 2008.

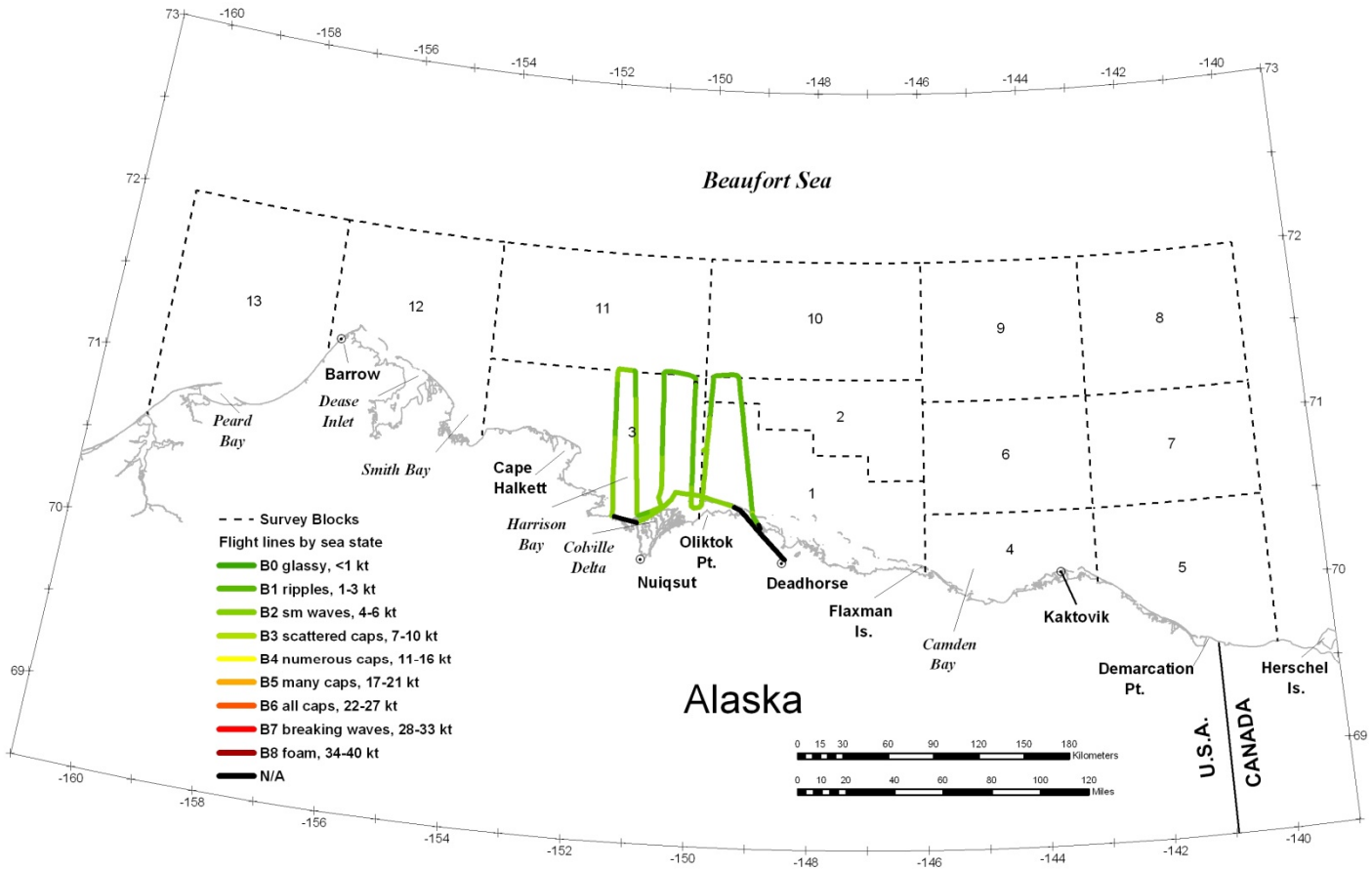

Figure I-10 - Aerial survey flight track, 25 September 2008.

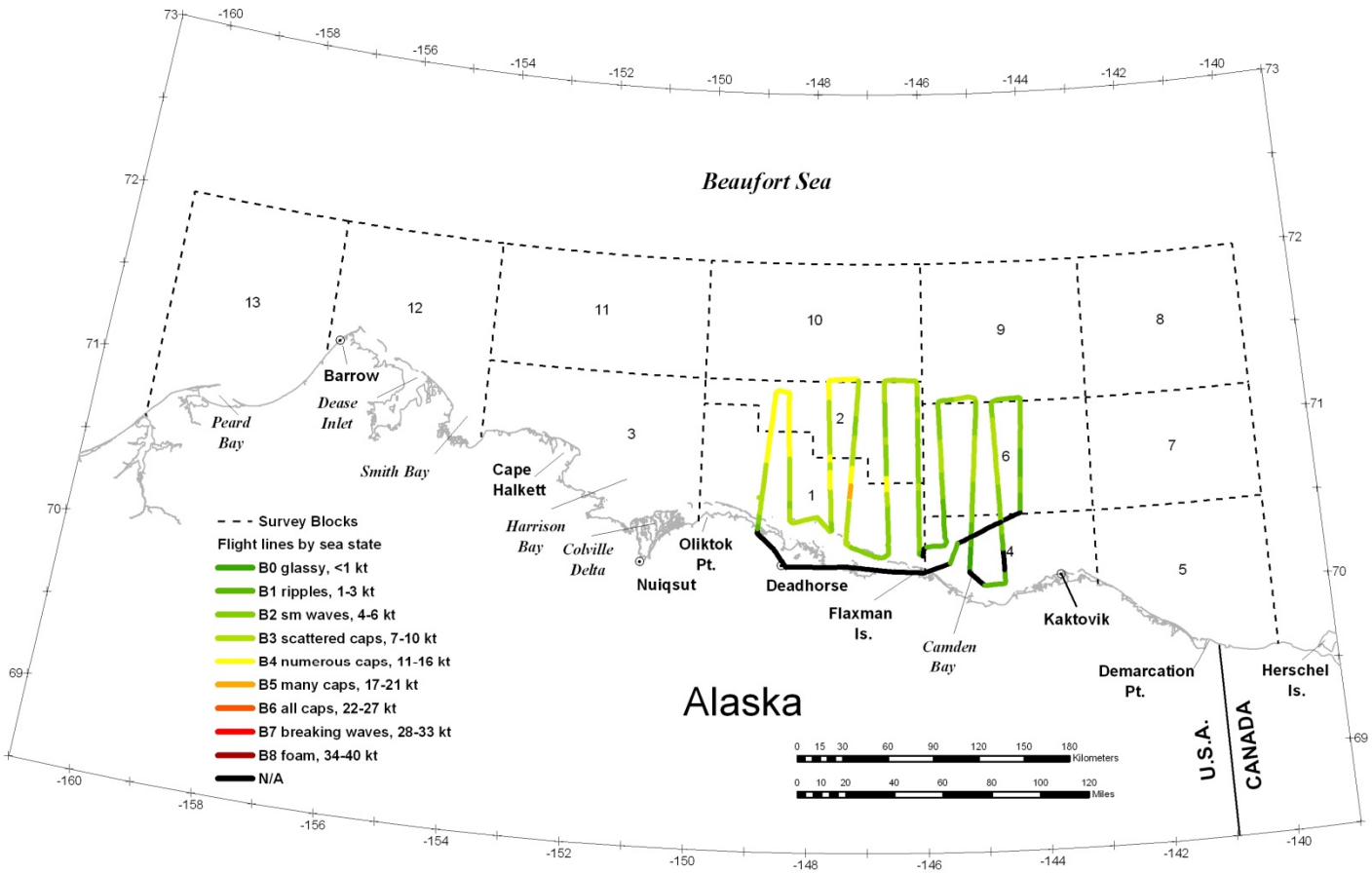

Figure I-11 - Aerial survey flight track, 26 September 2008.

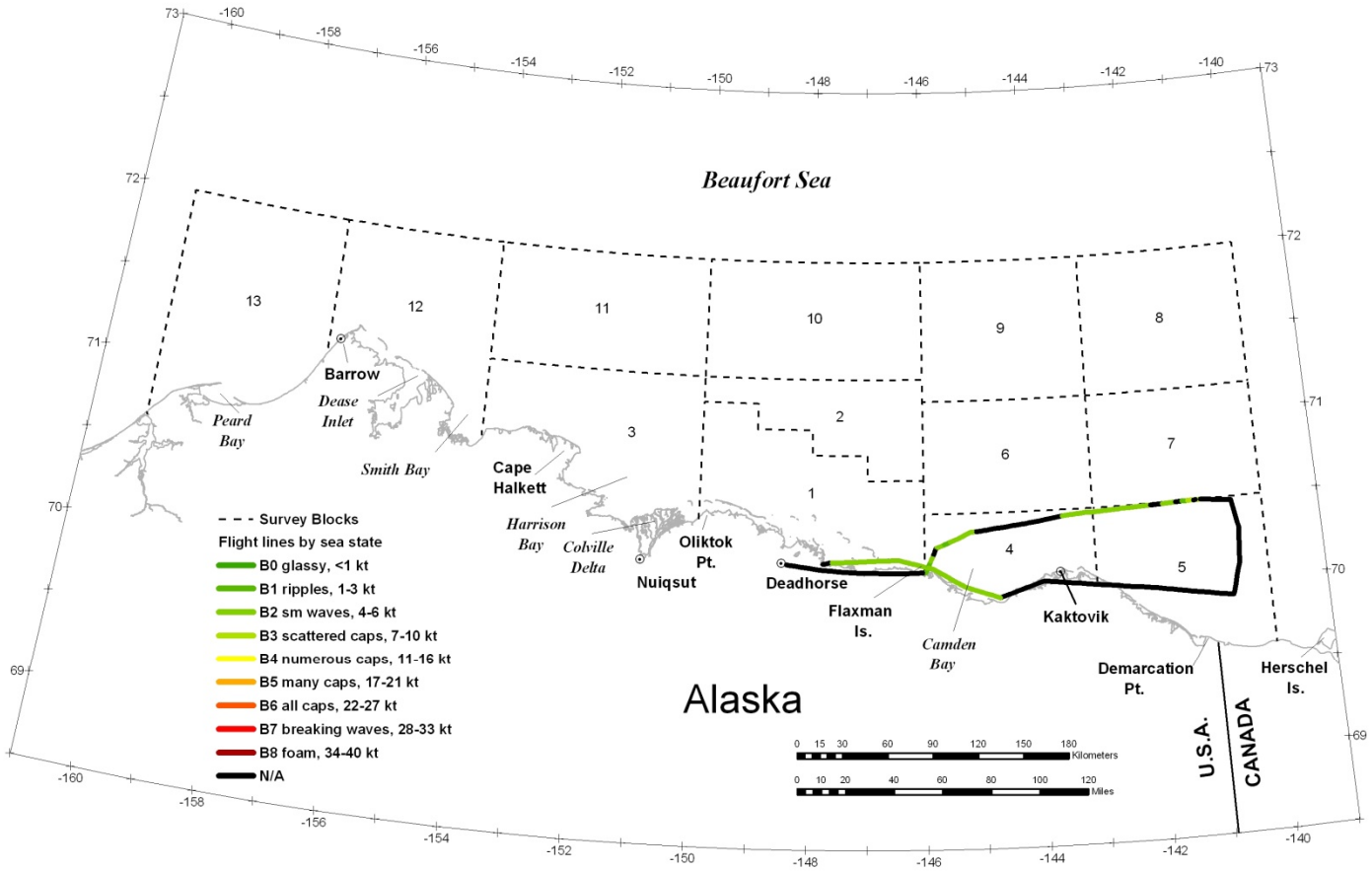

Figure I-12 - Aerial survey flight track, 27 September 2008.

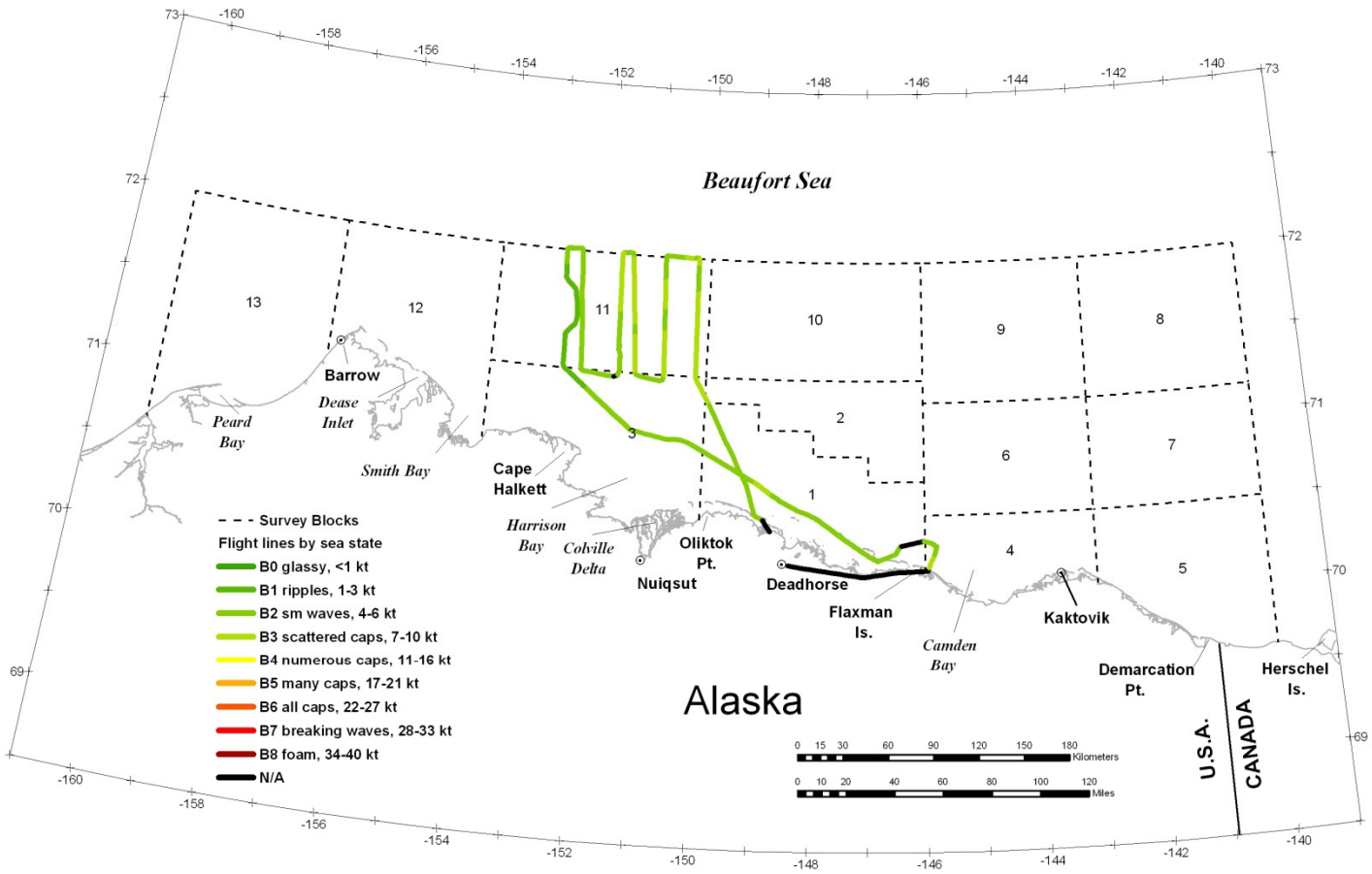

Figure I-13 - Aerial survey flight track, 28 September 2008.

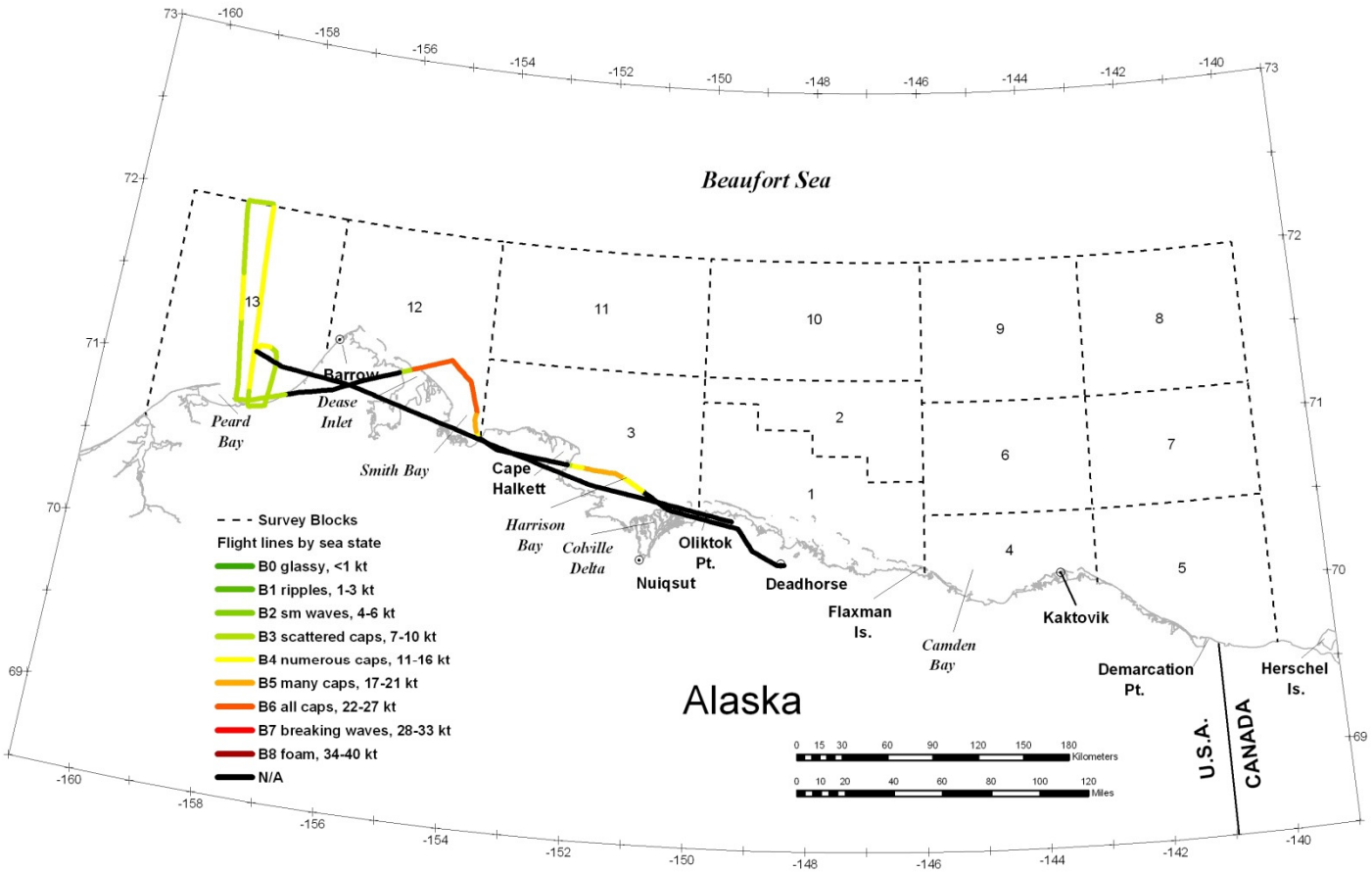

Figure I-14 - Aerial survey flight track, 1 October 2008.

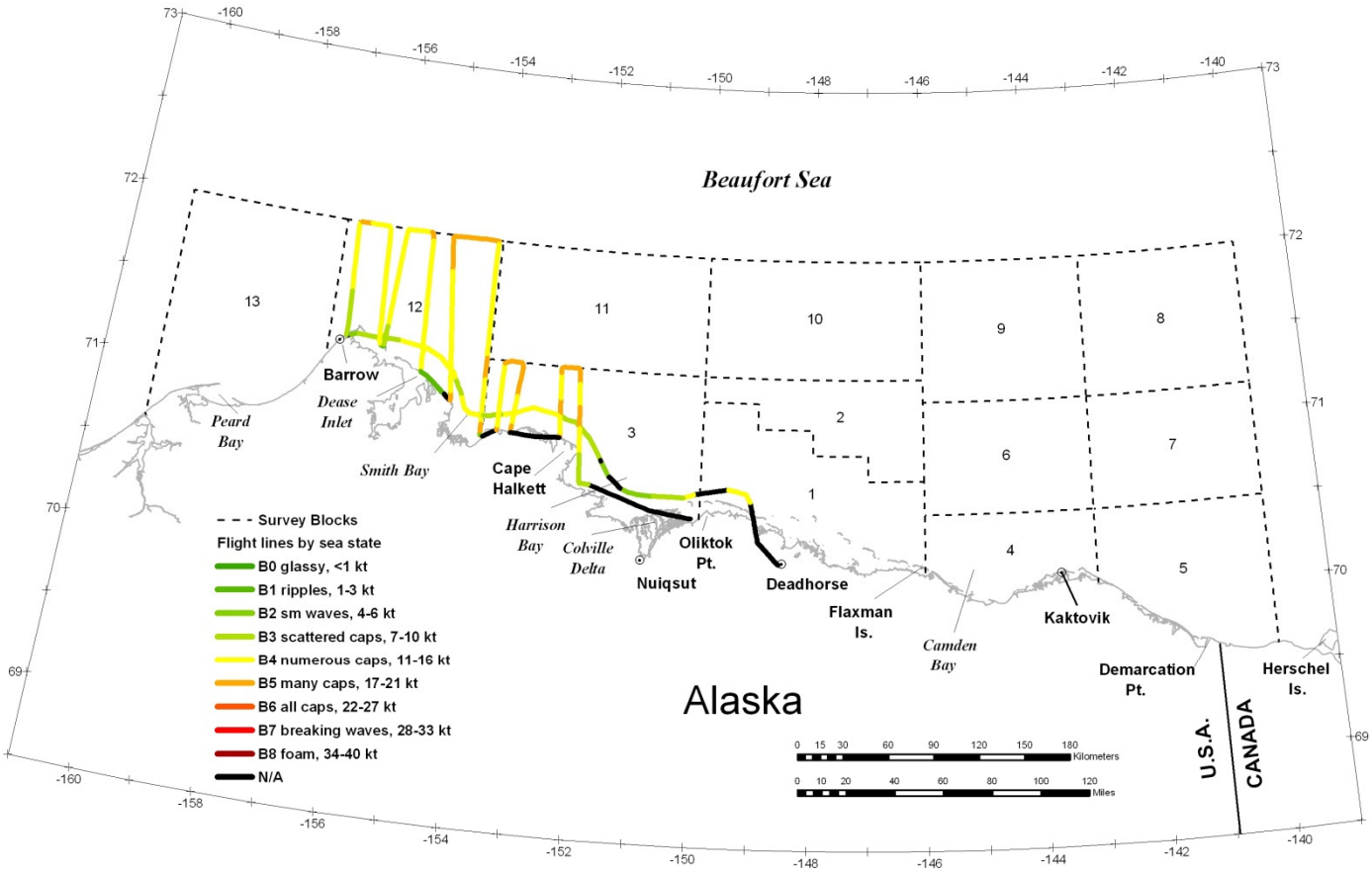

Figure I-15 - Aerial survey flight track, 8 October 2008.

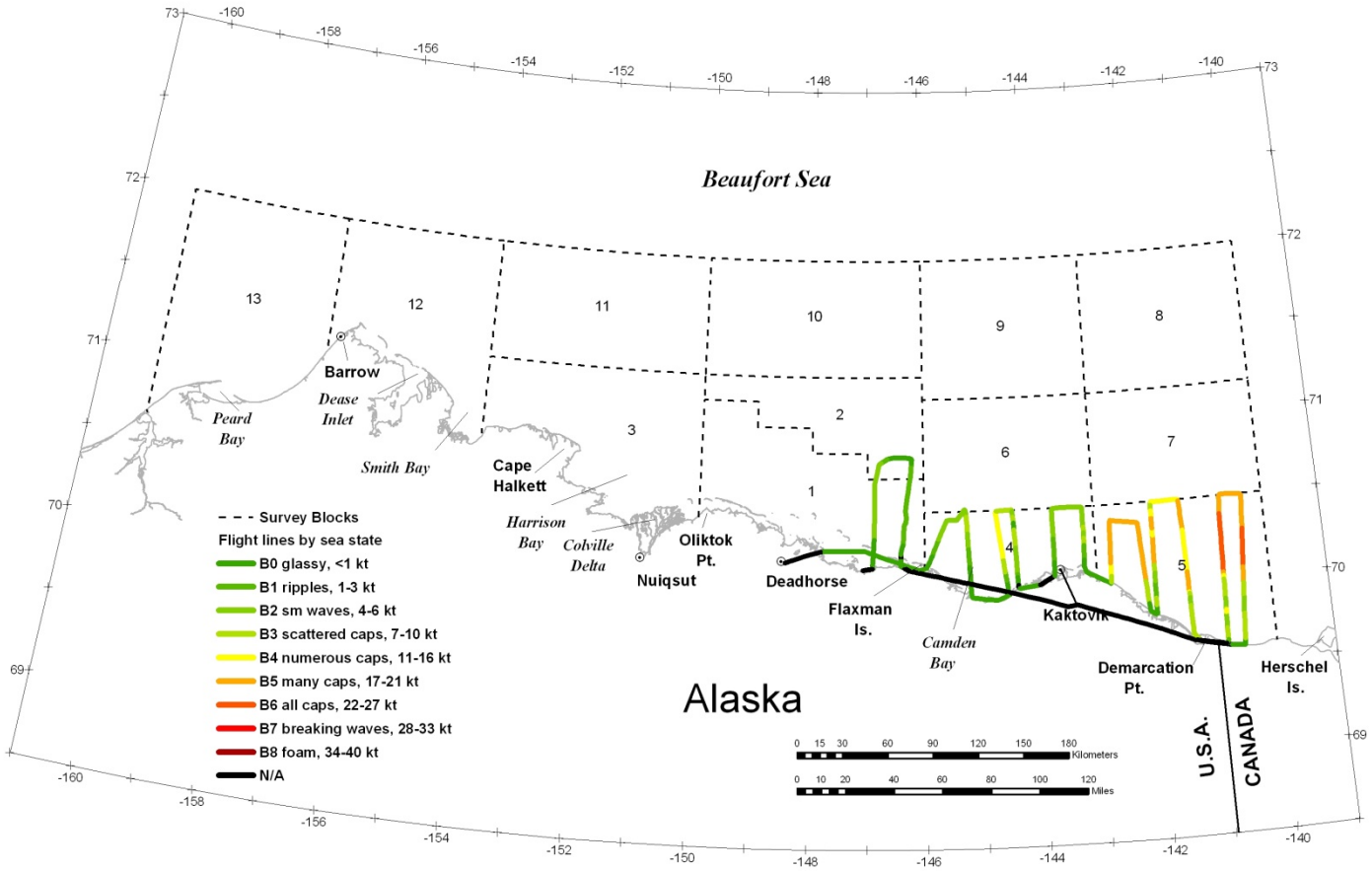

Figure I-16 - Aerial survey flight track, 9 October 2008.

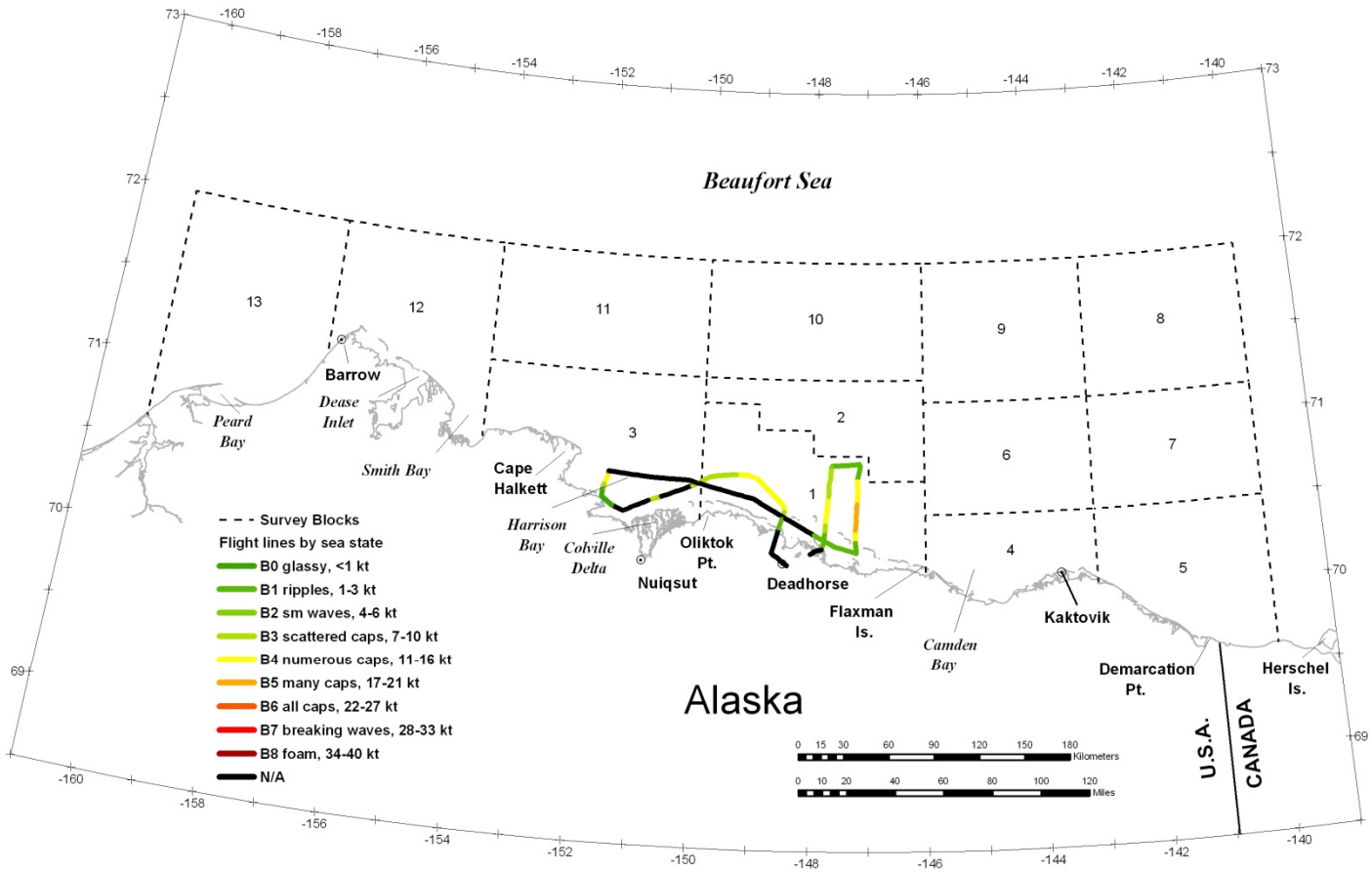

Figure I-17 - Aerial survey flight track, 11 October 2008.

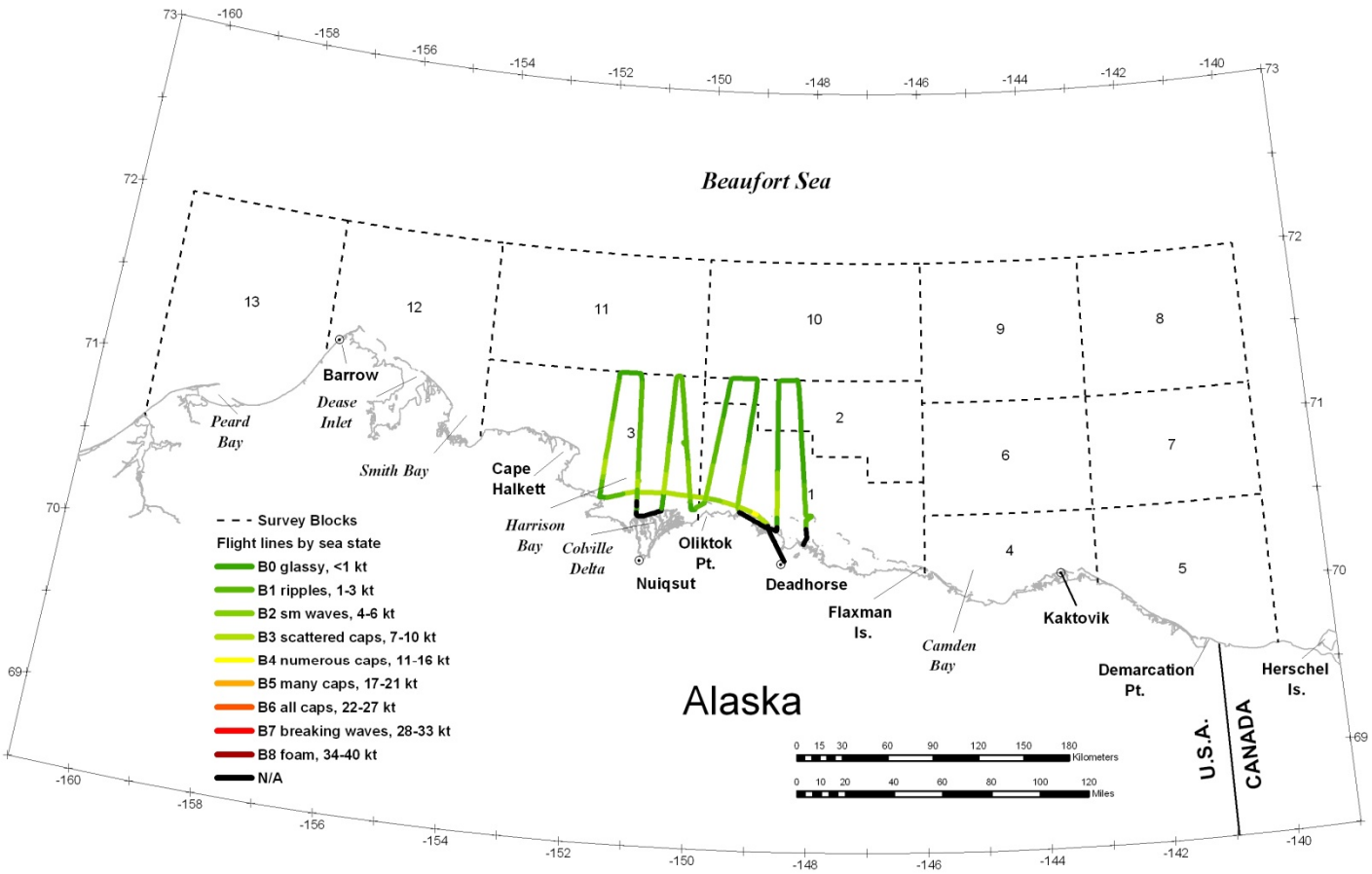

Figure I-18 - Aerial survey flight track, 13 October 2008.

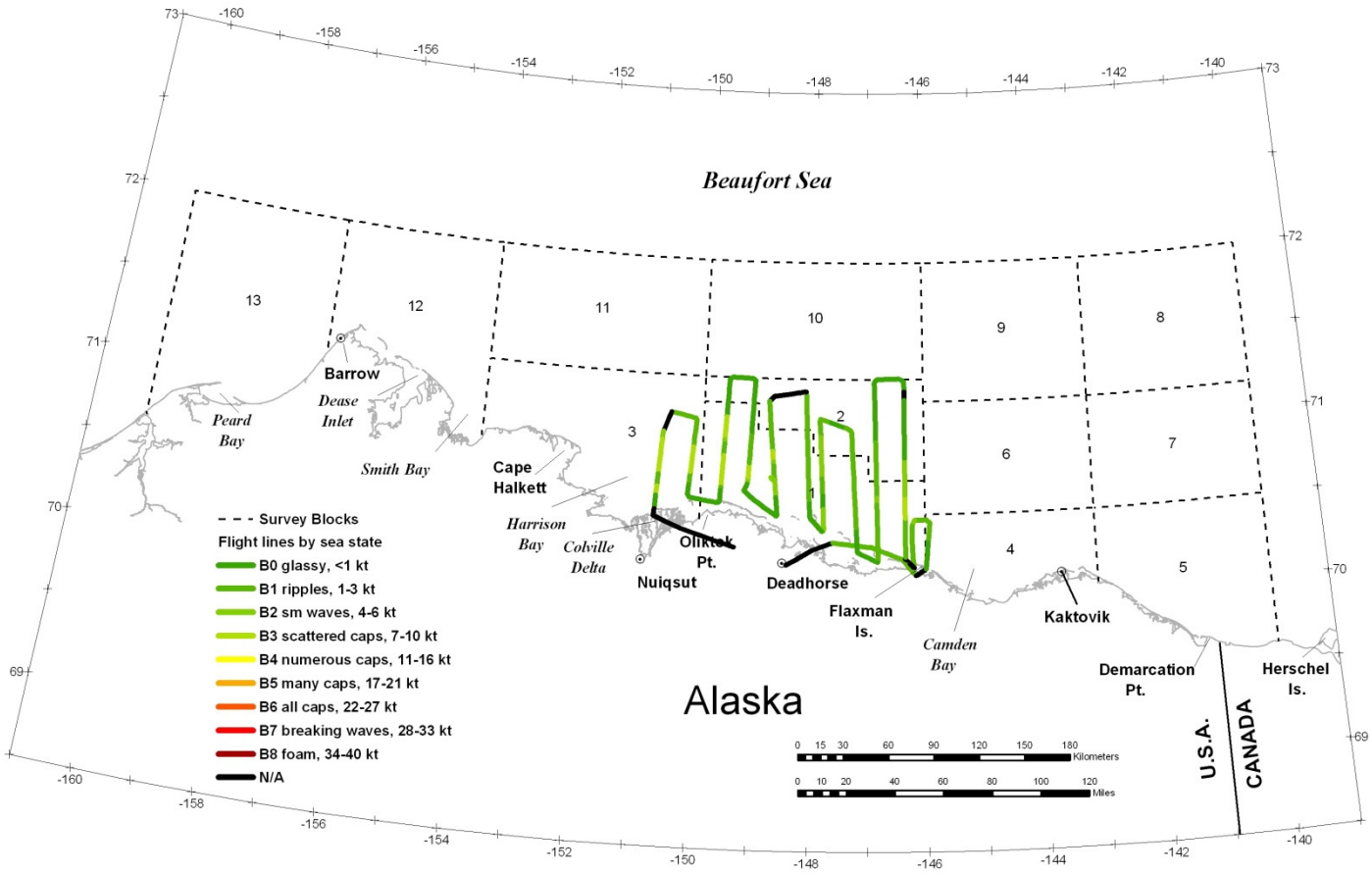

Figure I-19 - Aerial survey flight track, 17 October 2008.

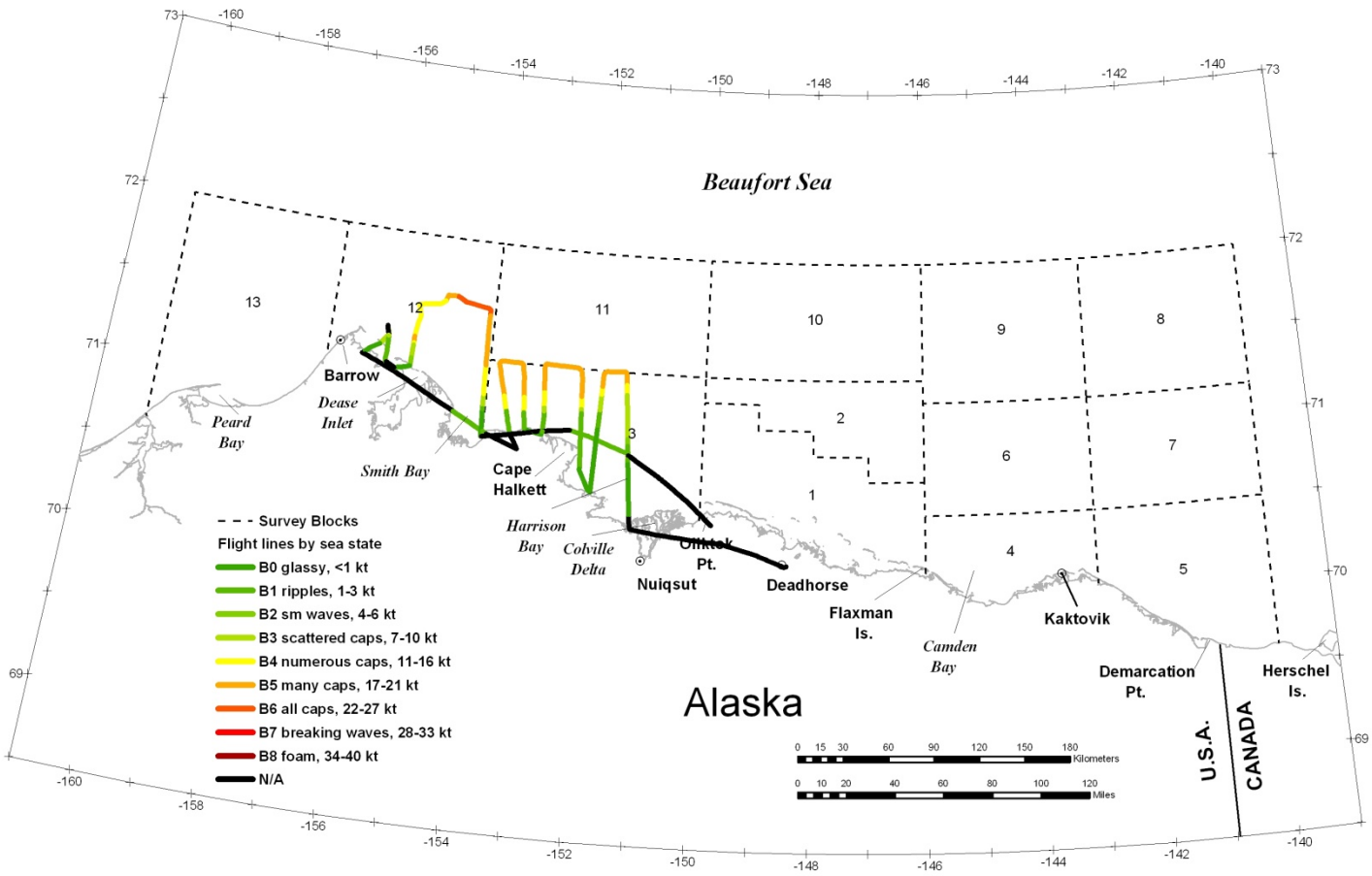

Figure I-20 - Aerial survey flight track, 18 October 2008.

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APPENDIX J: GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND INITIALISMS

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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.