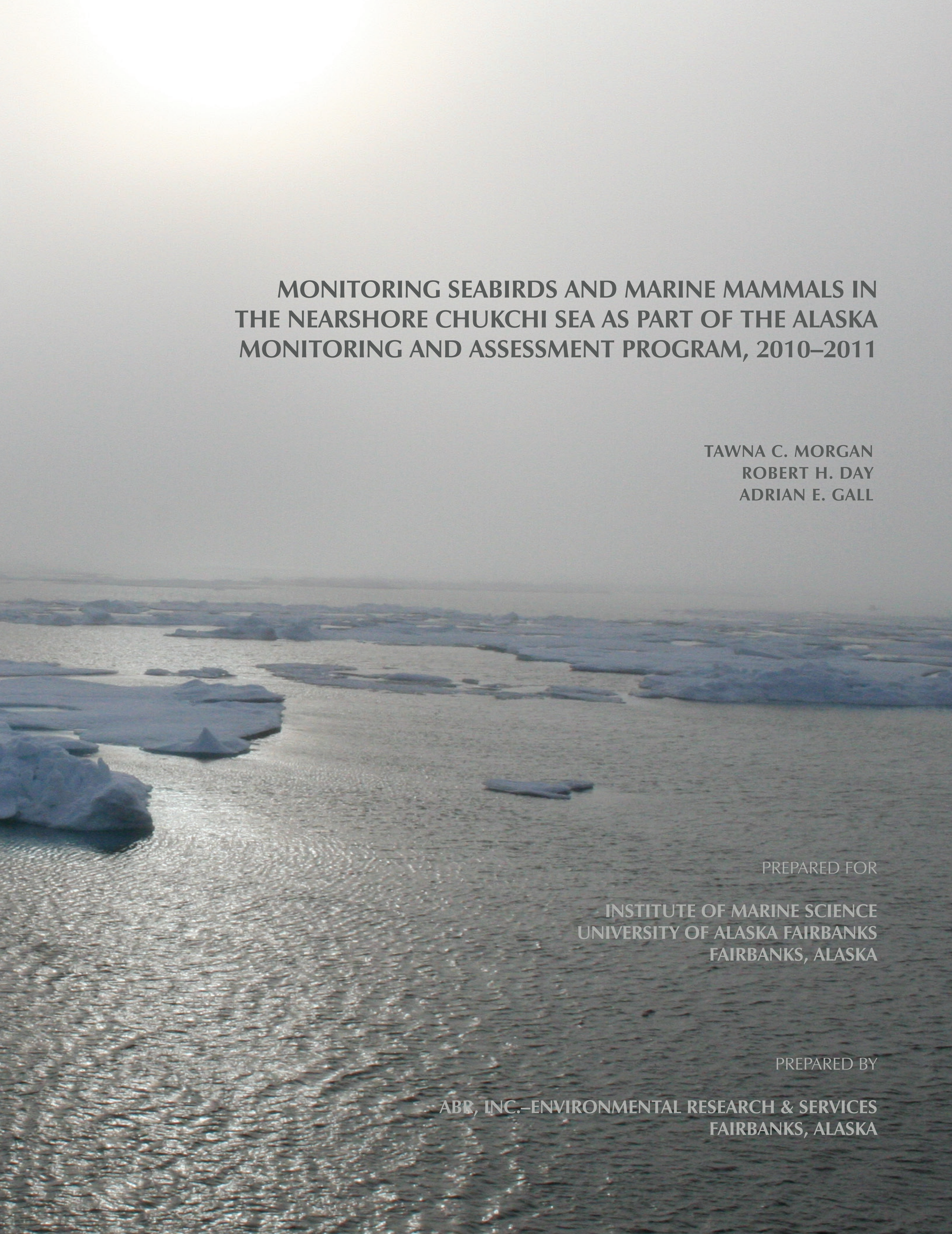

MONITORING SEABIRDS AND MARINE MAMMALS IN THE NEARSHORE CHUKCHI SEA AS PART OF THE ALASKA MONITORING AND ASSESSMENT PROGRAM, 2010–2011

TAWNA C. MORGAN
ROBERT H. DAY
ADRIAN E. GALL

PREPARED FOR

INSTITUTE OF MARINE SCIENCE
UNIVERSITY OF ALASKA FAIRBANKS
FAIRBANKS, ALASKA

PREPARED BY

ABR, INC.–ENVIRONMENTAL RESEARCH & SERVICES
FAIRBANKS, ALASKA

MONITORING SEABIRDS AND MARINE MAMMALS IN THE NEARSHORE CHUKCHI SEA AS PART OF THE ALASKA MONITORING AND ASSESSMENT PROGRAM, 2010–2011

Final Report

Prepared for

Institute of Marine Science
University of Alaska Fairbanks
P.O. Box 757220
Fairbanks, AK 99775–7220

Prepared by

Tawna C. Morgan
Robert H. Day
Adrian E. Gall

ABR, Inc.—Environmental Research & Services
P.O. Box 80410
Fairbanks, AK 99708–0410

July 2012

This report is funded (in part) with qualified outer continental shelf oil and gas revenues by the Coastal Impact Assistance Program, Fish and Wildlife Service, U.S. Department of the Interior.

EXECUTIVE SUMMARY

In 2010 and 2011, we sampled the nearshore marine waters of northwestern Alaska between Point Hope and Point Barrow as part of the Alaska Monitoring and Assessment Program (AKMAP). AKMAP previously has monitored water chemistry, sedimentology, contaminants, and benthic, epifaunal, and fish communities in south-central and southeastern Alaska and the Aleutian Islands. The current sampling effort was the first AKMAP project to include surveys of seabirds and mammals in conjunction with oceanographic sampling. We conducted surveys for seabirds and mammals in the nearshore waters of the Chukchi Sea from Point Hope to Point Lay between 23 August and 3 September 2010 and from Point Lay to Barrow between 5 September and 16 September 2011.

- We recorded 26 species of seabirds and 8 species of marine mammals within the AKMAP study area. Short-tailed Shearwaters were the most abundant seabird, followed by murres. Walruses were the most abundant marine mammal.
- We recorded 3 seabird species and 2 marine mammal species of concern within the AKMAP study area. These observations included 10 Spectacled Eiders (threatened), 36 Kittlitz's Murrelets (candidate), and 3 Yellow-billed Loons (candidate), plus bowheads (threatened) near Barrow Canyon and walruses (candidate) near Cape Lisburne.
- We used zero-inflated negative binomial (ZINB) models to address relationships between oceanographic variables and the distribution of 5 common bird species, 2 taxonomic groups, and 2 foraging guilds. Either sea-surface temperature (SST), horizontal thermal gradients in SST or both environmental characteristics were important environmental characteristics for influencing abundance of both taxonomic groups, both foraging guilds and 4 out of 5 common seabird species (Glaucous Gull, Short-tailed Shearwater, Common and Thick-billed murres). Either depth of the upper mixed layer (UML), strength of the pycnocline or both UML and strength of the pycnocline were important in influencing abundance of both surface/near-surface feeder and diving feeder foraging guilds, as well as many of the individual species that made up these guilds.
- We used data from the North Pacific Pelagic Seabird Database (NPPSD) to examine changes in bird species-richness, species-composition, and at-sea distribution over a 35-year period. Species-composition shifted from a waterfowl-dominated system during 1975–1981 to a shearwater-dominated system with few seaducks in 2007–2010. This shift in species-composition parallels an increase in planktivorous seabirds observed in the Chukchi Sea offshore area.

The addition of seabird and marine mammal monitoring to the AKMAP studies in 2010 and 2011 provided a means to assess shifts in the communities of apex predators in Alaska coastal waters. Gradual shifts in predator communities may reflect changes in benthic and epifaunal fish and plankton communities over time. During the present surveys, we identified a change in seabird species-composition in the nearshore waters of the Chukchi Sea that parallels shifts in community composition observed elsewhere in the Chukchi Sea and that presumably reflects large-scale regional changes to the ecosystem. We also identified several relationships between seabirds and oceanographic characteristics that will be valuable in predicting seabird community-composition in relation to gradual and catastrophic oceanographic changes.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGMENTS

This study was supported through funding provided by Shell Exploration and Production Company, Anchorage, AK, and the Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE; http://www.boemre.gov) to Alaska Department of Natural Resources Coastal Impact Assistance Program at the University of Alaska, Institute of Marine Sciences, as part of the Alaska Monitoring and Assessment Program. We thank Douglas Dasher of the Alaska Department of Environmental Conservation (DEC) and Stephen Jewett of the Institute of Marine Science for logistical and scientific coordination and thank the Principal Investigators and scientific crews aboard the R/V *Norseman II*. We also thank the researchers who contributed data to the NPPSD, the scientists at USGS and the USFWS who diligently maintain this valuable database, and Olgoonik Fairweather LLC for permitting temporary use of data collected during separate research cruises for calculating accurate detection functions. At ABR, Tim Obritschkewitsch (seabirds) and Amber Stephens (marine mammals) conducted the surveys with much-appreciated assistance from the Captain and crew; Allison Zusi-Cobb provided artistic genius and GIS assistance; Pam Odom assisted with travel and report preparation; and Tom DeLong and Davya Flaharty provided project support. This report has benefited from the reviews of Douglas Dasher of DEC and Stephen Jewett of the University of Alaska, Fairbanks.

INTRODUCTION

During the mid-1990s, the Environmental Protection Agency (EPA) developed the Environmental Monitoring and Assessment Program (EMAP), which was designed to provide information on current and changing "ecological health." The Alaska Department of Environmental Conservation subsequently established the Alaska Monitoring and Assessment Program (AKMAP) as part of a monitoring effort focused on freshwater and coastal regions within the state of Alaska. The goal of the AKMAP program is to use applied research to provide estimates of ecosystem health, as characterized by the spatial extent of chemical contaminants, water-quality parameters, physical changes, and biological indicators. From 2002 through 2009, the AKMAP program focused on coastal sampling efforts in south-central and southeastern Alaska and the Aleutian Islands by monitoring water chemistry, sediments, contaminants, and benthic, epifaunal, and fish communities in these areas. In 2010, the AKMAP program sampled the nearshore marine waters of northwestern Alaska between Point Hope and Point Lay as part of a two-stage process to produce a baseline of environmental information for nearshore waters in the Chukchi Sea between Point Hope and Barrow (Figure 1). In 2011, the AKMAP program completed sampling of the nearshore waters of the Chukchi Sea by sampling between Point Lay and Barrow. This report presents the results of seabird and marine mammal surveys conducted during both 2010 and 2011 and provides an overall assessment of these communities in the nearshore waters of the Chukchi Sea.

The Chukchi Sea has one of the highest rates of primary productivity in the world ocean (Grebmeier et al. 2006). This extraordinary productivity supports rich benthic and planktonic communities that, in turn, support large communities of apex predators such as seabirds, pinnipeds, and whales. Although the region is ice-covered for much of the year, the ice-free waters and the ice edges become important habitat for breeding, staging, and migrating seabirds and marine mammals from mid-July to mid-October (Swartz 1966, 1967; Johnson et al. 1967; Divoky 1987). In the winter, polynyas and leads in the ice provide foraging opportunities for marine mammals and birds taking advantage of upwelling and productivity along ice edges. Several species of seabirds and marine mammals, such as Ivory Gulls and ribbon seals (scientific names of birds and marine mammals recorded in this study are listed in Appendix A), are tightly coupled with the development and movement of ice in this region and depend on annual ice formation for foraging, pupping, and protection from predators.

Although the nearshore area between Point Hope and Barrow is characterized by generally northward-flowing Alaska Coastal Water (ACW), changes in water density, temperature, velocity, and current direction within this area can create micro- to mesoscale features that concentrate prey resources for both seabirds and marine mammals. ACW typically is warmer (>1.5 °C) and less saline (<31.5) than the adjacent Bering Sea Water (BSW; Coachman et al. 1975; Ladd and Overland 2009). The difference in temperature and salinity between the two water-masses creates a dynamic oceanographic front along the boundary where they meet, upwelling plankton and increasing foraging opportunities for surface-feeding and near-surface-feeding seabirds. In this region, several species of planktivorous seabirds, such as Short-tailed Shearwaters, Least Auklets, phalaropes, and Ancient Murrelets frequently concentrate at fronts (Day 1992; Elphick and Hunt 1993). Northeast of Cape Lisburne, a periodic anticyclonic gyre mixes northward-flowing ACW with slower-moving ACW close to shore (Coachman et al. 1975). Small fishes such as arctic cod (*Boreogadus saida*) and Pacific sand lance (*Ammodytes hexapterus*) concentrate here, providing foraging opportunities for piscivorous seabirds (Fadely et al. 1989) and marine mammals.

Large colonies of Common Murres, Thick-billed Murres, and Black-legged Kittiwakes nest along the cliffs between Cape Thompson and Cape Lisburne and are common offshore during late summer and early fall (Divoky 1987; Divoky and Springer 1988; Hatch et al. 2000). Parakeet Auklets and Tufted and Horned puffins also nest on these cliffs, although in low numbers. Glaucous Gulls breed along cliff-side colonies and intersperse with Arctic Terns on sandy coastal islands and the mainland farther north all the way to Barrow. Species that nest on the nearby tundra, such as phalaropes and jaegers, move out to sea in

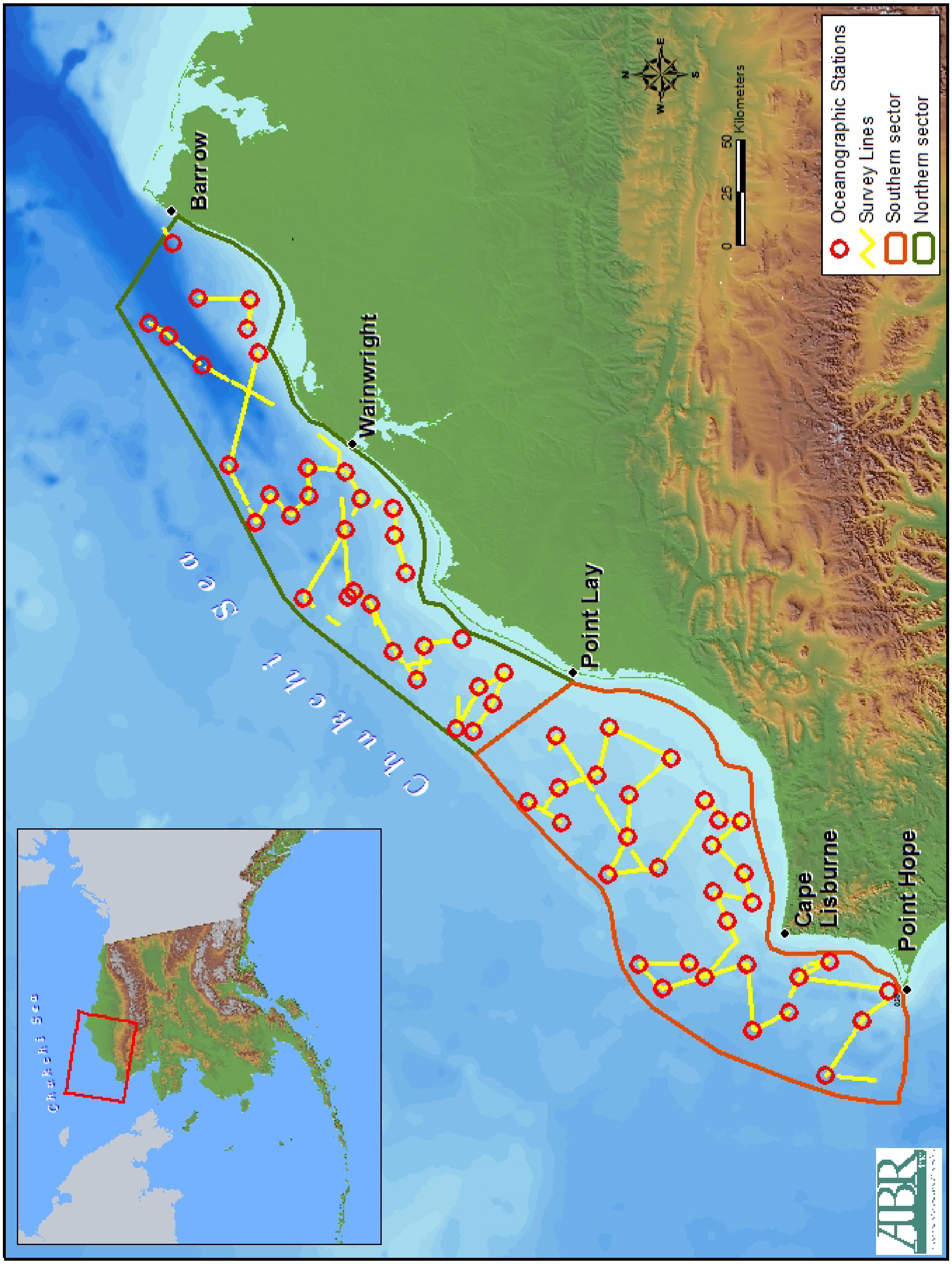

Figure 1. Seabird and mammal survey lines and oceanographic stations in the AKMAP study area, 2010–2011.

early fall and join millions of migratory Short-tailed Shearwaters from the Southern Hemisphere that are foraging in the area (Divoky 1987; Divoky and Springer 1988). As ice forms in the late fall, Ross's and Ivory gulls move into the area, making use of leads in the ice for foraging (Divoky 1981; Divoky et al. 1988).

When the ice begins to melt in the spring, belugas and bowheads push through the ice-leads on their northward migration. The Chukchi Polynya and nearshore open-water leads provide highly used migration pathways for birds and mammals headed for a summer in the Beaufort Sea and nearby tundra (Johnson et al. 1967; Moore and Reeves 1993; Petersen 2009). Belugas and bowheads are closely followed by gray, minke, and killer whales, all of which spend their summers in the Chukchi Sea, foraging in the habitat northeast of Cape Lisburne. These whales move south in the winter and are replaced by ice-adapted species such as ringed seals and polar bears that move in to exploit prey resources under the ice.

For most of the year, the ocean's surface in the Chukchi Sea nearshore zone is frozen and laced with a shifting network of open-water leads. The Chukchi Polynya persists over much of the winter and can extend from Cape Lisburne to Point Barrow during some winters (Stringer 1981; Stringer and Groves 1991). This large area of open water provides foraging habitat for wintering marine mammals and birds and supports high rates of primary productivity leading to benthic "hotspots" (Grebmeier and Cooper 1995). Phytoplankton produced during spring and summer settle on the ocean floor, promoting rich benthic communities (Grebmeier et al. 2006) and supporting apex predators such as seabirds and marine mammals. Just north of Icy Cape, the benthic community has some of the highest biomass found in the Chukchi Sea (Feder et al. 1994; Dunton et al. 2005). This area also supports a large number of migrating, staging, and molting seaducks (Johnson et al. 1993; Dau and Bollinger 2009) and is used by belugas and bowheads, walruses, and bearded seals (Christman et al. 2010; 2011; Clarke et al. 2010). As a whole, the Chukchi Sea nearshore zone is characterized by a seasonally shifting suite of birds and marine mammals.

PREVIOUS RESEARCH

SEABIRDS

Bird records are found in the notes of early explorers and whaling vessels venturing into the Chukchi Sea, starting with notes collected in 1825 on the H.M.S. *Blossom*. Bailey (1948) summarized both early naturalists' notes and specimen collections and his own detailed records for the Chukchi Sea coastline in his book *Birds of Arctic Alaska*. The first systematic effort to study the distribution and abundance of seabirds in the eastern Chukchi Sea was funded by the Atomic Energy Commission (AEC) in an effort to collect baseline biological information on seabird distribution and abundance between Cape Lisburne and Cape Thompson (Swartz 1966, 1967). Ship-based surveys by Watson and Divoky (1970) followed the work by Swartz and further documented the spatial distribution of seabirds between Point Hope and Icy Cape in the late summer and fall.

As the prospect of oil and gas development in the Chukchi Sea increased, further studies were initiated in this area. Seabird colonies at Cape Lisburne were first monitored in 1976 as part of the National Oceanic and Atmospheric Administration/Bureau of Land Management's Outer Continental Shelf Environmental Assessment Program (OCSEAP). This program included the monitoring of colonies at Cape Thompson and Cape Lisburne and birds in coastal waters between Cape Thompson and Barrow (Divoky et al. 1980; Roseneau et al. 1982; Springer et al. 1984, 1985; Divoky and Springer 1988). Additional studies were undertaken to identify the importance of the littoral zone along the Chukchi and Arctic coastlines to migrating shorebirds (Connors et al. 1978); both Kasegaluk Lagoon and Peard Bay were identified as important stop-over areas for shorebirds during fall migration. Between 1984 and 1993, the Alaska Marine National Wildlife Refuge (AMNWR) and Minerals Management Service (MMS) periodically supported monitoring and research at Cape Lisburne, Cape Thompson, and nearby waters. In addition, shipboard surveys covering offshore areas between Cape Thompson and Cape Lisburne were conducted in conjunction with productivity monitoring at Cape Thompson in 1988 (Fadely et al. 1989). These ship-based seabird surveys were combined with data on sea-surface temperature and salinity and data from acoustic fish surveys.

The Alaska Maritime National Wildlife Refuge (AMNWR) was established in 1980 and began a systematic program of monitoring Alaska's seabird colonies, including those at Cape Lisburne, starting in 1995. The species chosen for monitoring (Common and Thick-billed murres and Black-legged Kittiwakes) are thought to be good indicators of ecosystem health and permit comparisons of productivity and population size across years. Roseneau et al. (2000) monitored colonies at Cape Lisburne and Cape Thompson during 1995–1997, and this monitoring is continued today (Dragoo et al. 2011).

North of the cliffs of Cape Lisburne, tussocks and tundra of the Arctic Coastal Plain roll down to the shore, meeting a network of lagoons and beaches. Research and monitoring in this region have focused on lagoons where terrestrial and marine ecosystems meet. Bailey (1948) studied migrating and breeding waterbirds and reported high numbers of Yellow-billed Loons and King Eiders migrating along the coast at Wainwright. Watson and Divoky (1970) also reported a diversity of tundra breeders and migrants using nearshore waters between Wainwright and Cape Thompson.

Johnson et al. (1993) conducted aerial surveys in Kasegaluk Lagoon, which lies in the northern sector of the AKMAP Chukchi Sea nearshore study area, during 1989–1991. Their work focused on the distribution and abundance of seabirds that were using the lagoon systems in this area. Importantly, they recorded large numbers of Brant and high interannual variability in species composition. Starting in 1999, the USFWS annually has conducted aerial surveys along nearshore waters for Common Eiders and waterbirds along the Arctic Coastal Plain during July (e.g., Dau and Bollinger 2009). These surveys are designed to monitor the Common Eider population along the Arctic Coastal Plain, but they also record other waterbirds observed in the nearshore Chukchi Sea.

Species-specific studies have focused on the eastern Chukchi Sea as a migration pathway and staging area for birds breeding on the North Slope. Birds migrating west in the fall tend to constrict into a narrow zone as they pass Point Barrow, making it an ideal location to assess migration; this location is especially good for monitoring populations of migrating eiders (Thompson and Person 1963, Woodby and Divoky 1982; Suydam et al. 1997, 2000a, 2000b; Day et al. 2004). Large numbers of Long-tailed Ducks, eiders, and loons have been recorded migrating past Point Barrow between August and October (Thompson and Person 1963, Suydam et al. 1997, Day et al. 2004). Aerial surveys for and satellite telemetry of migrating and staging King, Spectacled, and Steller's eiders in the Chukchi Sea have indicated that shallow nearshore waters of Ledyard Bay form important stopover areas for migrating eiders in both the summer and fall (Larned and Balogh 1997; Oppel et al. 2009). Both Spectacled and Steller's eiders are protected under the Endangered Species Act (ESA) of 1973, as amended (PL 93–205; 16 USC §1531). In August and September, most of the North Slope population of breeding female Spectacled Eiders and some male Spectacled Eiders from both North Slope and Yukon–Kuskokwim Delta breeding populations use this area for molting. The recognized importance of this area to Spectacled Eiders has led to the designation of ~14,000 km^2 of Ledyard Bay as Critical Habitat (USFWS 2001; 50 CFR Part 17, RIN 1018-AF92) for the species. Several areas also have been identified as high-use shorebird stopover habitat (Powell et al. 2010; Taylor et al. 2010).

Currently, the Chukchi Offshore Monitoring in the Drilling Area (COMIDA) program also collects data on seabird distribution and abundance in the Chukchi Sea (Prentki 2009). The COMIDA program largely focuses on the offshore area west of the AKMAP study area; however, some of their surveys overlap or border the AKMAP study area. In addition, the Chukchi Sea Environmental Studies Program (CSESP) conducts systematic seabird surveys in the offshore Chukchi Sea as well as opportunistic surveys during transits to Wainwright and neighboring areas (Gall et al. 2011).

MARINE MAMMALS

Marine mammals in the Chukchi Sea have a complicated history of population fluctuations linked to commercial harvest (Lentfer 1988). Management programs are plagued with imprecise estimates of population size for most species, limited assessment of harvest rates, and variable effects of a rapidly changing environment. Initial descriptions of species distributions came from notes collected on ships venturing into the Chukchi Sea for whaling and exploration activities and from Native communities (Bockstoce et al. 2005). Early commercial whaling and hunting activities led to the first documented declines in walrus, bowhead whale, and ribbon seal populations (Bockstoce and Burns 1993; Bockstoce et al. 2005) and the eventual development of management plans for marine mammals in the Chukchi Sea. Today, knowledge of distribution, abundance, and habitat requirements for marine mammals in this region is much better, but managers still are faced with the difficulties of managing many ice-dependent species in a region with rapidly decreasing ice and a limited ability to conduct population-estimation surveys.

At least twelve species of marine mammals occur in the nearshore zone of the northeastern Chukchi Sea. For the Native communities along the Chukchi Sea coastline, several species have played a key role in their culture and persistence. Ringed seals and polar bears depend on annual ice formation and traditionally have been hunted by coastal communities during the winter months (McLaren 1958; Johnson 1966; Lentfer 1988). Walruses, bearded seals, and ribbon seals all are associated with the ice edge and migrate with the shifting ice in the spring and fall (Johnson et al. 1966; Burns 1970, 1981; Braham et al. 1984a). These ice-edge-associated species are followed by early-spring migrants preparing to summer in the northeastern Chukchi and Beaufort seas. Belugas and bowhead whales migrate in shallow nearshore waters in late spring and fall (Braham et al. 1980), whereas gray, killer, minke, and humpback whales and harbor porpoises arrive only after the ice melts. Three species—polar bear (USFWS 2010) and bowhead and humpback whales (NMFS 2010)—currently have federal protection because of concerns about their populations, and a fourth (the walrus) is under review for listing under the ESA. Records of subsistence harvest play an important role in deciphering annual migration routes and timing of seasonal distributions (Huntington et al. 1999), and current management programs use this information in assessing population trends and making management decisions (Allen and Angliss 2010).

Commercial and subsistence harvest activity provides some of the earliest information about marine-mammal populations in the Chukchi Sea. Bockstoce et al. (1982, 1983, 2005) used whaleship records to estimate historical bowhead whale populations and distributions between 1849 and 1914. The highest number of bowhead whales captured in the nearshore Chukchi Sea occurred in August and September, coinciding with their southerly migration ahead of the pack-ice. After depletion of the bowhead whale population, commercial efforts switched to harvesting walruses. Bockstoce and Botkin (1982) estimated that 200,000 walruses were harvested in the brief window between 1869 and 1880. Fay (1982) also discussed commercial and subsistence harvests of walruses during the Nineteenth Century and provided evidence of a drastic decline in numbers during the latter part of that century. A second decline caused by overharvesting occurred in the late 1950s (Fay 1982).

In 1959, the AEC funded the first systematic assessment of the distribution and abundance of marine mammals in the Chukchi Sea nearshore zone. Scientists studied marine-mammal distribution in the vicinity of Cape Thompson from 1960 to 1963, with aerial surveys flown between Cape Thompson and Point Lay, specimen collections, and communication with Native hunters. During this period, they recorded high numbers of ringed seals near Point Thompson during the winter and spring. Bearded seals also were present in the winter, but peak numbers were recorded in late spring (Johnson et al. 1966). Johnson and others also reported on the general biology of both ringed and bearded seals and documented the importance of arctic cod in the diets of both species. Although rare in the Chukchi Sea, two northern fur seal specimens were collected from Point Hope in 1960.

Coincident with these in-depth studies of marine mammals of the Cape Thompson area and with Alaska statehood (1959), the Alaska Department of Fish and Game (ADFG) assumed management of the harvest of walruses and whales, both of which had undergone significant population declines from commercial hunting activities. Harvest was restricted, and populations recovered between 1960 and 1980.

With the establishment of the Marine Mammal Protection Act (MMPA) in 1972, management authority for marine mammals in the Chukchi Sea passed into the hands of the federal government. In recognition that marine mammals using Alaska waters are part of a larger population influenced by activities in both U.S. and Russian waters, the Agreement on Cooperation in the Field of Environmental Protection (ACFEP) also was established in 1972. This agreement provided the framework for cooperation between the U.S. and U.S.S.R on the research and management of environmental resources in the Bering and Chukchi seas. Under the auspices of the ACFEP–Marine Mammal Program, several international survey efforts were undertaken in the Bering and Chukchi seas between 1972 and 1975 (Fay and Fedoseev 1984). These surveys focused on large portions of both seas and were designed to understand large-scale population distributions, breeding phenology, and morphology of several marine mammal species.

During this same period, the push to develop offshore drilling for oil spawned the OSCEAP program. Similar to the role that OCSEAP had in providing baseline information on seabird distributions, surveys and intensive studies were conducted in the Chukchi Sea nearshore zone to describe the seasonal distribution and abundance of marine mammals and to assess potential environmental impacts of increased human activity in the area. Between 1975 and 1979, belugas and bowheads were counted from both the air and land during the spring and fall (Braham et al. 1984b; Seaman et al. 1985), and extensive work was done to understand their biology in the nearshore area of the Chukchi Sea (Burns and Seaman 1985). Lowry et al. (1983) characterized the seasonal distribution of marine mammals in the Chukchi Sea nearshore zone and documented the importance of several food items. Arctic cod, an ice-associated fish, was an important food resource for several marine-mammal species such as ringed seals and belugas, especially in the fall, which is when large schools of these fishes move into the warm, low-salinity nearshore zone (Johnson et al. 1966; Lowry et al. 1981). In contrast, crabs, clams, and shrimp were important to benthic-feeding bearded seals and walruses (Lowry et al. 1981).

The National Marine Fisheries Service (NMFS) has produced stock assessments of marine mammals annually since 1995 (e.g., Bengston et al. 2005). Stock assessments provide valuable information on harvest, distribution, and the stock structure of marine mammals; however, they are limited by imprecise population estimates. Aerial surveys typically are used, but counts from aerial surveys are limited to animals swimming at the surface or hauled out on shore or ice. Without knowing the proportion of the population that is submerged at any given time, it is impossible to produce an accurate estimate of abundance. Recently, technological advances such as satellite tracking and thermal imaging to detect underwater animals (Suydam et al. 2005, Burn et al. 2009), have permitted the development of correction factors to produce estimates of abundance more accurate than those from visual counts alone.

Research during the last two decades has focused largely on refining estimates of seasonal movements, migration pathways, and methods for correcting population estimates. This information has become of critical importance as the duration and extent of sea-ice in this region declines (Gradinger 2008). For endangered bowheads, both traditional knowledge (Huntington et al. 1999; Huntington and Quakenbush 2009) and advanced research techniques such as acoustic moorings (Moore et al. 2006) and satellite transmitters (Suydam et al. 2005) have contributed significantly to our understanding of their distribution and movements in the Chukchi Sea. In the spring, bowhead whales migrate northward along the coastline by using leads in the ice and polynyas (Braham et al. 1984b; Huntington and Quakenbush 2009). Cape Lisburne is a prominent point along their migration, and both pair-bonding behaviors and copulation have been observed there (Rugh and Cubbage 1980). The use of acoustic moorings has shown that some bowheads overwinter in the Chukchi Sea; however, most migrate into the Bering Sea (Moore et al. 2006, 2010).

Impacts of reduced sea ice and changes in oceanography in the nearshore Chukchi Sea are the focus of active research on marine mammals in this area (Hopcroft et al. 2008). Currently, several monitoring programs are being undertaken in the

Chukchi Sea. The COMIDA program supports ship- and aircraft-based surveys for marine mammals in the Chukchi Sea nearshore zone and surrounding waters during the open-water season. The NMFS Cetacean Assessment and Ecology Program supports acoustic research to monitor whale movements in the Chukchi Sea throughout the year. Finally, the CSESP program focuses on waters farther offshore, using systematic ship-based marine-mammal surveys and hydroacoustic mooring arrays to monitor spatial and temporal habitat use by marine mammals (Aerts et al. 2010, 2011; Delarue et al. 2010).

In addition to the AKMAP program, these studies provide information that may be used to assess population health in response to changing oceanographic conditions. Although the loss of sea ice may not negatively affect some species (e.g., humpback whales), populations of many of the ice-dependent seals, walruses, and polar bears probably will decline. In addition, some species such as bowheads show sensitivity to increased human activity (Schick and Urban 2000), so the combined effects of changing ice conditions and industrial development are being monitored to manage these populations effectively. In 2010, several areas along the Chukchi Sea shoreline were designated as critical habitat for polar bears, which are listed as threatened under the ESA (USFWS 2010). This designation stems from continuing work on polar bear–ice habitat associations and includes Kasegaluk Lagoon, a biologically diverse area important to seabirds (Johnson et al. 1993), belugas, and spotted seals (Frost et al. 1993).

STUDY OBJECTIVES

We studied the distribution and abundance of seabirds and marine mammals in the Chukchi Sea nearshore zone between Point Hope and Barrow. The objectives of this study were to: (1) describe species richness and species composition; (2) describe spatial variation in the distribution and abundance of seabirds and marine mammals, including location and abundance information for species of concern; and (3) compare our results with historical data available for this part of the northeastern Chukchi Sea nearshore zone.

STUDY AREA

Our study area was the nearshore zone of the northeastern Chukchi Sea between Point Hope and Barrow (Figure 1). The study area was divided into two sectors that were sampled in consecutive years. The bathymetry in this area is generally shallow, ranging from 5 m to 50 m in depth, depending on the distance from shore. The area is ice-covered during much of the year and is available for ship-based sampling only during the summer–fall period. This nearshore water, which is known as Alaskan Coastal Water (ACW), is characterized by a general northward flow and is warm (>1.5 °C) and hyposaline (<31.5; Coachman et al. 1975; Ladd and Overland 2009).

The study area consisted of 64 randomly selected oceanographic stations and seabird and marine-mammal survey lines that were sampled during transit between the stations (Figure 1). In both 2010 and 2011, surveys began at the northern end of the sample areas and generally advanced southward as the cruise progressed; however, the 2 final stations in 2011 were the farthest north, along the edge of Barrow Canyon. Transects and stations were located 10–95 km from shore.

METHODS

DATA COLLECTION

We conducted seabird and marine-mammal surveys from the bridge of a 35-m research vessel, the R/V *Norseman II*, during 23 August–3 September 2010 and 5–16 September 2011. We collected seabird and marine-mammal data during daylight hours whenever the vessel was in transit between oceanographic stations and traveling at a velocity of ≥9.2 km/h (≥5 kt), following recommendations of Tasker et al. (1984) and Gould and Forsell (1989). We conducted surveys as consecutive 10-min counts (hereafter, transects) for seabirds and 30-min transects for marine mammals 9–12 h/day, weather and ice conditions permitting. We generally stopped surveys when sea height was Beaufort 6 (seas ~2–3 m [~6–10 ft]) or greater, although we occasionally continued to sample if observation conditions were still acceptable (e.g., if seas were at the lower end of Beaufort 6 and we were traveling with the wind).

We used DLog software (R. G. Ford Consulting, Portland, OR) to enter observations of all birds and mammals directly into computers that were connected to a global-positioning system (GPS). This program time-stamped and geo-referenced every observation as it was entered. We used separate GPS units and computers for each discipline to provide a double backup of GPS tracklines, which were downloaded after every survey. On 6 occasions, 1 of the GPS units lost communication with the computer for up to 2.5 min, resulting in a loss of location information for observations and transect endpoints. We used the saved GPS tracklines to identify these missing locations.

We collected samples of physical oceanography, contaminants, sedimentology, and benthic, epifaunal, zooplankton, and fish communities while the vessel was stationary at fixed oceanographic stations. We used a Conductivity–Temperature–Depth recorder (CTD) to sample the water-column at each station and used a set of vertical profiles of temperature and salinity from 47 stations for analysis with the seabird and marine-mammal data.

SEABIRD SURVEYS

One observer stationed on the bridge of the vessel recorded all birds seen within a radius of 300 m in a 90° arc from the bow to the beam on the port side of the ship. We used Leupold 10×50 binoculars with optical reticles to locate and identify seabirds. For each bird or group of birds, we recorded:

- species (to lowest possible taxon);
- total number of individuals observed;
- perpendicular distance of individuals or groups from the ship when sighted (in categories; 0–50 m [0–164 ft], 51–100 m [165–328 ft], 101–150 m [329–492 ft], 151–200 m [493–656 ft], 201–300 m [657–984 ft]);
- radial angle of the observation from the ship's centerline (to the nearest 1°);
- number of birds in each age-class (juvenile, subadult, adult, unknown age);
- habitat (air, water, flotsam/jetsam, ice); and
- behavior (flying, sitting, feeding, comfort behavior, courtship behavior, other).

For birds on the water, we counted all birds seen within the count zone. For flying birds, however, we conducted scans approximately every 1.5–2 min (exact frequency varied with ship's speed) and recorded an instantaneous ("snapshot") count of all birds flying within the count zone. This "snapshot" method reduces the bias of overestimating the density of flying birds (Tasker et al. 1984; Gould and Forsell 1989). We counted flying birds that entered the count zone only from the sides or front and not from behind the ship (i.e., an area that already had been surveyed), to avoid the possibility of counting birds following the research vessel.

MARINE-MAMMAL SURVEYS

One observer stationed on the bridge of the vessel recorded all marine mammals seen within a 180° arc from the port beam of the vessel to the starboard beam of the vessel. We used Fujinon 7×50 binoculars with optical reticles to locate and identify marine mammals. For each marine mammal observation, we recorded:

- species (to lowest possible taxon);
- total number of individuals in the observation;
- perpendicular distance from the ship when sighted (in meters);
- number of reticles below the horizon;
- direction in which the animal was moving relative to the vessel;
- number of mammals in age-class (juvenile, subadult, adult, unknown age);
- radial angle of the observation from the ship's centerline (to the nearest 1°);
- behavior (sitting, swimming, feeding, comfort behavior, courtship behavior, interacting with marine mammals, other);
- cue for the observation (e.g., splash, head, blow) used to identify the sighting;
- any reaction to the vessel; and
- reliability of the identification (i.e., how positive the observer was of the identification to species).

DATA ANALYSIS

The data analysis consisted of three components. First, we analyzed species richness, species composition, and abundance of seabirds and marine mammals for each sector. Second, we analyzed species-specific spatial distributions in relation to environmental characteristics; because we recorded so few marine mammals during these surveys, we lacked the sample size to analyze those data in relation to environmental gradients and instead concentrated on seabirds. Third, we compared species composition, densities, and distribution of seabirds and marine mammals in the AKMAP study area during the last 35 years, grouped into 4 periods for which data were available (1975–1976, 1980–1981, 2007–2009, and the present study). We conducted all statistical analyses in program R (R Development Core Team 2010).

COMMUNITY COMPOSITION

We summarized species richness and species composition of all seabirds and marine mammals for both AKMAP study sectors. We calculated species richness as the total number (on and off transect) of seabird or marine mammal species observed within the study area (Magurran and McGill 2011). Species composition is presented as the percentage of the total community that each group composed. For ease of summarizing the species composition of seabirds, we aggregated seabird species into 6 taxonomic species-groups. These 6 groups included waterfowl (eiders and Long-tailed Ducks), loons, tubenoses (fulmars and shearwaters), phalaropes (small shorebirds that winter at sea), larids (gulls/terns, and jaegers), and alcids (murres, murrelets, auklets, and puffins). Because we saw so few marine mammals, we present species composition for marine mammals by individual species.

DENSITY CALCULATIONS AND ANALYSES

Knowing how well animals are detected during surveys is critical for producing accurate estimates of density and abundance (Buckland et al. 2001, 2004). For line-transect surveys, detectability will vary with both the perpendicular distance of a target organism from the ship's centerline and environmental and observation conditions (e.g., weather, survey platform, observer). We estimated detection-corrected densities (hereafter, corrected densities) of birds for both study sectors by using line-transect sampling analyses available in the program DISTANCE 6.0, Release 2 (Thomas et al. 2010a, 2010b) and by following analytical methods described by Buckland et al. (2001, 2004). This approach accounts for the decrease in probability of detecting a bird with increased distance from the survey's centerline. A minimum of ~60 observations for each species/species-group was necessary to fit detection functions accurately. To meet this minimal criterion and estimate species-specific detection functions, we combined seabird observations collected during this cruise with observations collected using the same methodology and research vessel during separate research cruises in the Chukchi Sea in 2010 (e.g., Gall and Day 2010). We assigned each species to one of 7 detection-groups: ducks, loons, tubenoses, larids, phalaropes, murres, and all alcids other than murres. Marine mammals typically are seen in low frequencies, so a large study area or a study of long duration is needed to collect adequate sample sizes for analysis of spatial distributions. We lacked adequate sample sizes of observations to calculate a detection function for any species of marine mammals, so we present only the raw counts.

We estimated seabird densities in three steps. First, we fitted a detection function for each detection-group to estimate its probability of detection, based on the perpendicular distance of the observation from the survey line (i.e., the ship's centerline). Next, we used the observed group sizes to estimate the mean flock size for each taxon. Finally, we estimated the corrected density of each taxon for the entire study area and individual transects by incorporating the probability of detection, the area surveyed, and the mean group size.

For each taxon, we fitted two models that used one of two possible key detection functions (half-normal or hazard-rate) to the distribution of observation distances to find the model that best estimated the probability of detection. We selected the model with the lowest Akaike Information Criterion (AIC) to be the one that best fit the data. The fit of each model was assessed with diagnostic plots and a Kolmogorov–Smirnov goodness-of-fit test (following Buckland et al. 2004). Once we had selected a detection model for a taxonomic group, we used a filter to apply the fitted detection function to each species within that taxonomic group and calculated species-specific densities for each study sector as well as the entire AKMAP study area. We calculated these corrected density estimates with the formula:

$$\hat{D} = \frac{n \cdot \hat{E}(s)}{L \cdot \hat{P}_a}$$

where $\hat{D}$ is the corrected density estimate, n is the total number of observations seen on transects, $\hat{E}(s)$ is the mean flock size, L is the total length of transects sampled, and $\hat{P}_a$ is the probability of detection estimated by the model (Buckland et al. 2001). We then produced confidence intervals with bootstrap procedures (Buckland et al. 2001).

ANALYSIS OF SPATIAL DISTRIBUTIONS

We used several environmental variables to analyze habitat relationships for the at-sea distribution and abundance of 5 common species, 2 taxonomic groups, and 2 foraging guilds of seabirds. We focused our analysis on 5 common species for which we had at least 60 observations. This list included Black-legged Kittiwake, Glaucous Gull, Short-tailed Shearwater and Common, Murre, Thick-billed Murre. Taxonomic groups included loons (Pacific, Red-throated, and Yellow-billed loons) and ducks (King, Common, and Spectacled eiders and Long-tailed Duck). We also analyzed relationships between environmental gradients and 2 foraging guilds: surface-/near-surface-feeders and diving-feeders. All gulls, terns, jaegers, Northern Fulmars, and Short-tailed Shearwaters were included in the surface-/near-surface feeding guild. All loons, murres, murrelets, auklets, and puffins were included in the diving guild.

We used the CTD vertical profiles (Figure 2) from 47 stations (measured in 0.5–1-m increments) to extract several oceanographic variables pertinent to seabird distribution. Pycnoclines, or gradients in water density, may concentrate prey resources for seabirds at their boundaries (e.g., Harrison et al. 1990). We used the statistical package oce in R (R. Development Team 2011, v 0.8-8) to calculate water density at each oceanographic station based on salinity and temperature. We then determined the depth of the upper mixed layer (UML; i.e., the depth to the upper edge of the pycnocline) and the strength of the pycnocline (maximal rate of vertical change in density; in 1-m increments). In addition, we used measures of sea-surface temperature (SST) to detect strong horizontal gradients in SST that indicate thermal fronts or boundaries between water-masses.

We fit spherical variograms to the empirical data for UML, pycnocline strength and SST. We used fitted variograms with ordinary kriging to produce kriged surface maps of UML depth, pycnocline strength, and SST over the entire study area (Figure 3). Grid cells for surface maps were 5 km on a side. We used the program GRASS (Open Source Geospatial Foundation) to calculate the maximal difference in SSTs between adjacent cells and produce a surface map of horizontal thermal gradients (Figure 4).

We overlaid the 450 seabird transect midpoints on each of the 4 surface grids to extract the value of each environmental variable for each transect by using the spatial-analysis package rgdal in R (R. Development Team, 2012, v 0.7-8). We then used the environmental variables for each transect to analyze relationships between environmental gradients and seabird abundance.

For all species and species-groups, a large number of transects contained no birds, resulting in a zero-inflated statistical distribution. Zero-inflated negative-binomial (ZINB) analysis uses a mixed-model approach, permitting the analysis of datasets with a high proportion of zeroes (Zuur et al. 2009). ZINB models produce coefficients for the portion of zeros that represent areas where the habitat is suitable but birds were not seen ("false zeros") and coefficients for a distribution that includes a portion of the zero-count transects as well as positive-count information. Coefficients for this count portion of the model describe differences in abundance between suitable and unsuitable habitat. We used ZINB models to analyze environmental (habitat) relationships of each species and species-group. Species that did not contain enough observations (n < 30) for ZINB analysis were pooled with other species to form our 2 taxonomic groups and 2 foraging guilds.

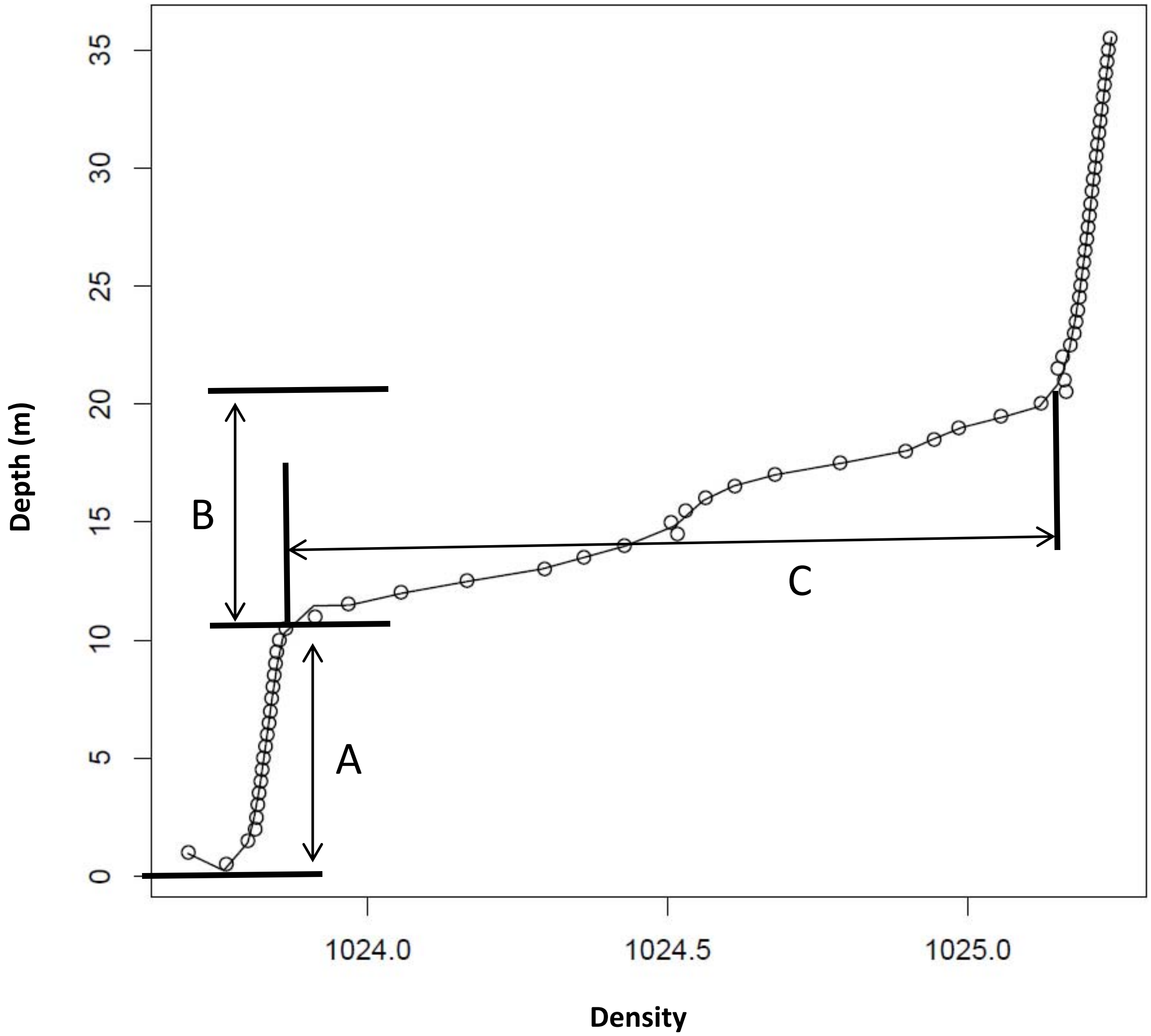

Figure 2. Example of a vertical CTD density profile. (A) is the depth of the upper mixed layer (UML),(B) is the pycnocline thickness, and (C) is the change in density. We calculated pycnocline strength by dividing the change in density by pycnocline thickness.

Environmental variables used in these analyses included UML, pycnocline strength, SST, thermal change, study sector, and distance from shore. We evaluated the full model, which consisted of all environmental variables and an interaction term for pycnocline strength and UML for each species/species-group. Models were evaluated with Akaike Information Criteria (AIC). We evaluated terms in the count and zero portions of the model separately and removed non-significant terms from each portion of the model until we identified that model with the lowest AIC value (Zuur et al. 2009).

COMPARISON WITH HISTORICAL DATA

We compared our data from 2010 and 2011 with historical data from the USFWS North Pacific Pelagic Seabird Database (NPPSD). We used a GIS (Arcview 10.0; ESRI, Redlands, CA) to identify all historical transects that fell within the AKMAP study area (Figure 5). We first excluded those transects for which data were collected from

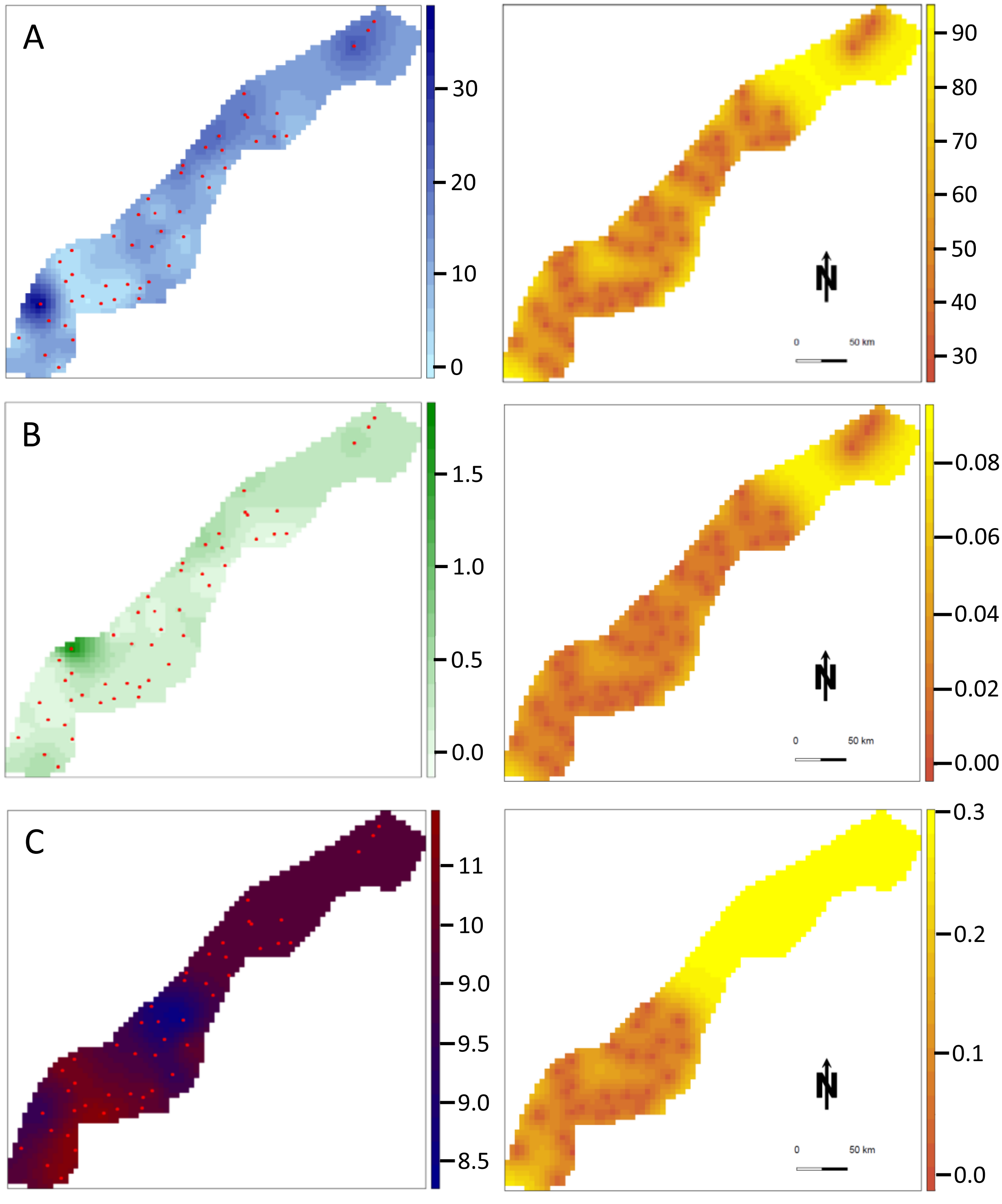

Figure 3. Pycnocline depth (A), pycnocline strength (B), and SST (C) estimates and variance for the AKMAP study area produced from ordinary kriging, based on salinity, temperature, and depth measurements at 47 CTD stations. Variance maps for each kriged surface are shown in the right column.

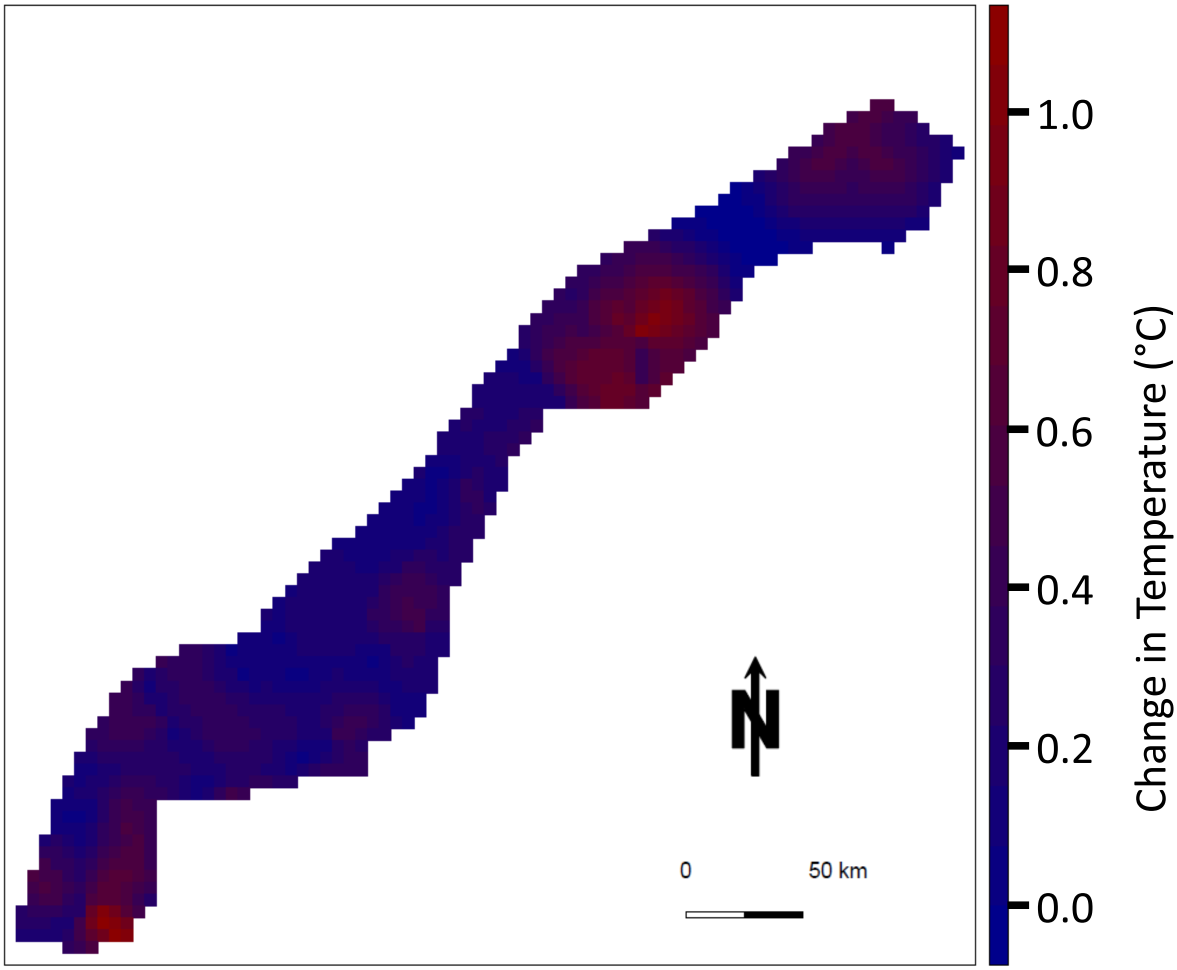

Figure 4. Horizontal thermal gradient in SST between adjacent 5-km-grid cells. Change in temperature was calculated as the maximal change in SST between adjacent cells, based on kriged SSTs that were produced from measurements at 47 CTD stations.

land-based or aerial surveys and those transects that fell outside of the general summer/fall survey season of 1 August–15 October (Figure 6). We then plotted NPPSD transects based on either their centroid latitude and longitude or their starting-point latitude and longitude, depending on which coordinates were provided in the NPPSD. In addition, we excluded from our density calculations all off-transect observations. Because historical data were collected as strip-transects and not line-transects, only uncorrected densities were available for comparison through time. To facilitate comparisons between current and historical data, we calculated uncorrected transect densities (i.e., those without corrections for detectability) from the current study.

We used species richness and composition to evaluate changes in the seabird community over time. We summarized the total number of species observed and percent species composition in each study sector during each study period: 1975–1976, 1980–1981, 2007–2009, and 2010–2011.

RESULTS

We surveyed the distribution and abundance of seabirds over 687 km of survey trackline in 2010 and over 656 km of survey trackline in 2011. We

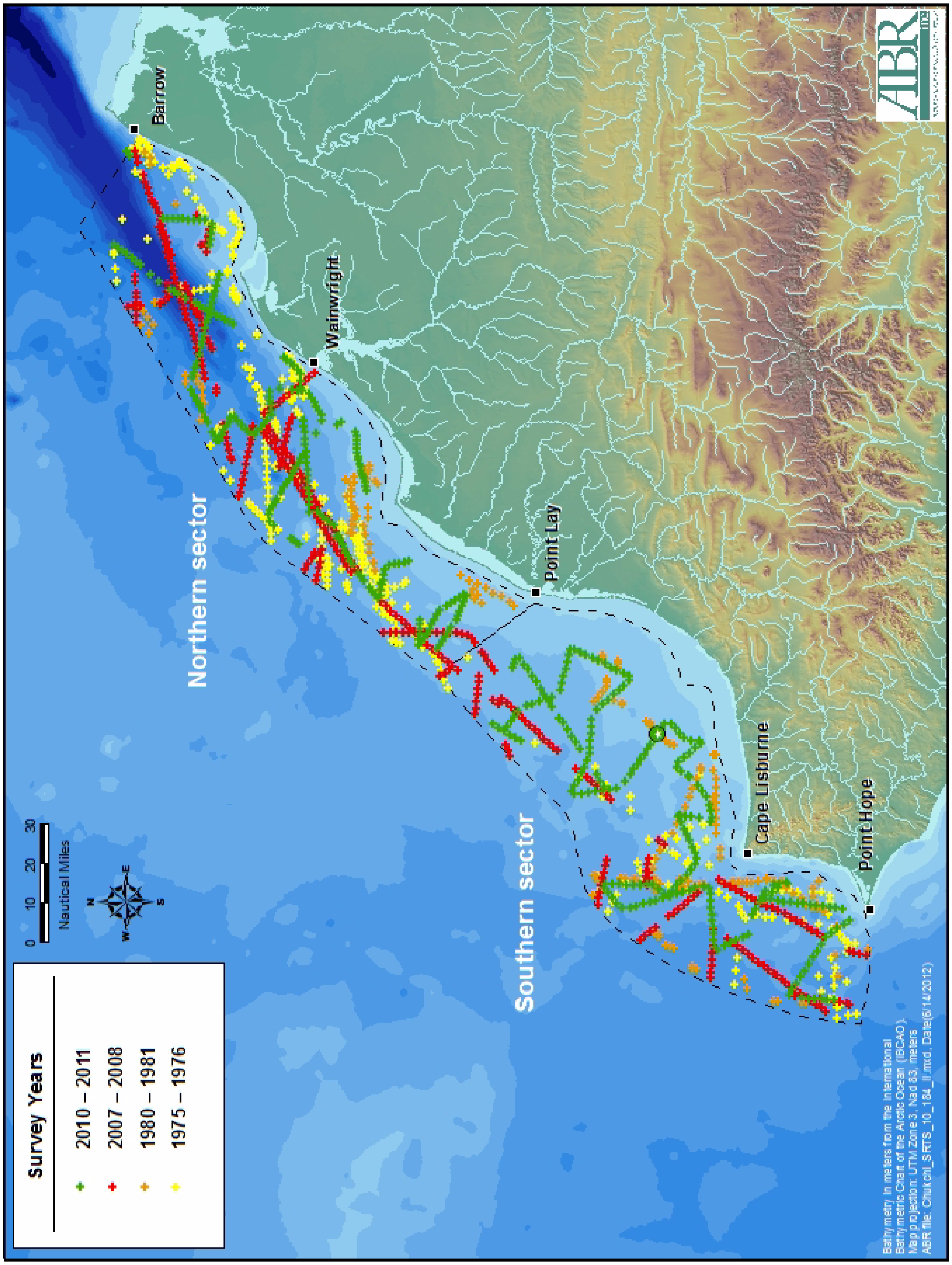

Figure 5. Spatial overlap of historical transects (NPPSD) with survey lines during the AKMAP study, 2010–2011. Mapped locations are the centroid of each transect.

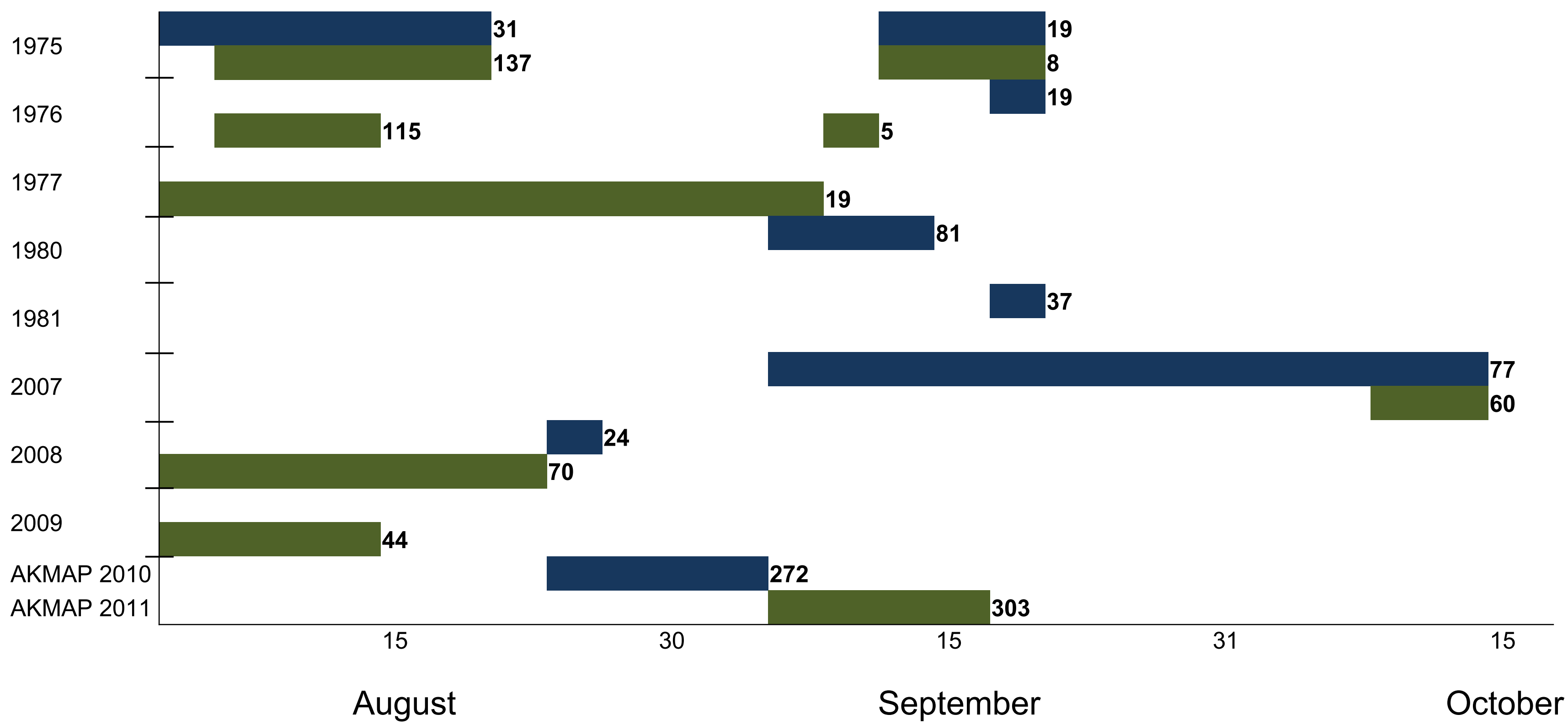

Figure 6. Temporal overlap of historical studies in the AKMAP study area. Blue bars indicate transects surveyed within the southern sector; green bars indicate transects surveyed within then northern sector. The number of transects falling within each sector are shown next to color bars.

had 1,088 observations (records) of seabirds in 2010 and 633 observations of seabirds in 2011.

Marine-mammal survey lines and effort differed slightly from seabird survey lines due to the difference in transect duration. We surveyed the distribution and abundance of marine mammals over 599 km of survey trackline in 2010 and 624 km of survey trackline in 2011. We had 17 observations (records) of marine mammals in 2010 and 61 observations of marine mammals in 2011.

We observed seabirds both on the water and in flight. Alcids (murres, auklets, Horned Puffins) occurred most frequently on the water, whereas larids (gulls, terns, and jaegers) occurred most frequently in flight; Short-tailed Shearwaters occurred equally both in flight and on the water (Table 1). We recorded only 1 foraging flock, a mixed-species flock of 10 Glaucous Gulls and 50 Black-legged Kittiwakes ~25 km offshore from Cape Lisburne on 1 September 2010.

We detected marine mammals through various cues. Whales were detected most frequently by observing blow spouts. In contrast, seals were detected most frequently when they poked their heads out of the water (Table 2).

ENVIRONMENTAL CHARACTERISTICS

Oceanographic characteristics differed between study sectors. The AKMAP northern sector had colder SSTs (t = –24.69, df = 448, P < 0.001) and pycnoclines that were deeper (t = 12.34, df = 448, P < 0.001) and stronger (t = 2.44, df = 448, P = 0.015) than the AKMAP southern sector (Figure 7).

COMMUNITY COMPOSITION

SEABIRDS

We recorded 26 species of seabirds in the AKMAP study area across both years combined (Table 3). In addition to the list of species recorded on-transect, we recorded one Surf Scoter on the water outside of our survey zone (i.e., off transect) on 7 September 2011. The community-composition of the AKMAP study area was numerically dominated by tubenoses and alcids (Figure 8).The species encountered most frequently in both study sectors was Short-tailed Shearwater, followed by murres. Short-tailed Shearwaters and murres composed 74.6% and 9.5% of the avian community, respectively, for both study sectors combined. Other common species included Black-legged Kittiwakes (3.5% of the avian community), Horned Puffins (1.1%), and Glaucous Gulls (1.1%); collectively, these 5 species composed 89.5% of the avian community during both years combined. Species richness was highest in the vicinity of Cape Lisburne and nearby breeding colonies.

We recorded three bird species of concern (USFWS 2010) during the surveys. The three species include Spectacled Eiders (2 in 2010, 8 in 2011), which are currently listed as threatened; Yellow-billed Loons (1 in 2010, 2 in 2011); and Kittlitz's Murrelets (5 in 2010, 31 in 2011). Both Kittlitz's Murrelets and Yellow-billed Loons are Candidate Species for listing under the U.S. Endangered Species Act (USFWS 2010).

MARINE MAMMALS

We recorded 8 species of marine mammals, including 3 species of pinnipeds and 5 species of cetaceans (Table 4). Walruses were the most abundant marine mammals, composing 40.6% of all individuals observed (Figure 9), followed by bearded seals. The southern sector was dominated numerically by walruses, whereas the northern sector was dominated numerically by seals, with bearded seal being the most frequently detected species (Figure 9, Table 4).

We recorded 2 marine mammal species of conservation concern. Walruses, which are a Candidate Species for listing under the U.S. Endangered Species Act (USFWS 2010), were observed in both study sectors, with the highest densities occurring near Cape Lisburne in 2010. Bowhead whales, which currently are listed as threatened (USFWS 2010), were recorded in the northern sector near Barrow Canyon, where they are known to feed during the fall (Moore et al. 2010).

DISTRIBUTION AND ABUNDANCE

Ducks

Eider density was highest in the southern sector that included surveys of the Ledyard Bay Critical Eider Habitat Unit (Figure 10); however Long-tailed Duck density was highest in the northern sector (Figure 11, Table 3). The abundance model for ducks (including eiders and

Table 1. Behavioral information for seabird observations recorded on-transect during the AKMAP study, 2010–2011.

Species-group/common name	Number of observations	Percent		
		Flying	Sitting on water	Feeding
WATERFOWL				
Spectacled Eider	3	0	100	0
King Eider	6	67	33	0
Common Eider	9	44	56	0
Unidentified eider	8	88	13	0
Long-tailed Duck	6	50	50	0
LOONS/GREBES				
Red-throated Loon	2	0	100	0
Pacific Loon	44	73	27	0
Yellow-billed Loon	2	50	50	0
Unidentified loon	2	50	50	0
TUBENOSES				
Northern Fulmar	31	90	10	0
Short-tailed Shearwater	927	58	42	0
SHOREBIRDS				
Unidentified phalarope	21	62	38	0
Unidentified shorebird	1	100	0	0
GULLS/TERNS/JAEGERS				
Black-legged Kittiwake	160	88	10	2
Sabine's Gull	2	50	50	0
Herring Gull	3	100	0	0
Glaucous Gull	60	70	28	2
Arctic Tern	4	100	0	0
Pomarine Jaeger	18	72	28	0
Parasitic Jaeger	9	89	11	0
Long-tailed Jaeger	2	100	0	0
Unidentified jaeger	1	100	0	0
ALCIDS				
Common Murre	52	4	96	0
Thick-billed Murre	71	3	96	1
Unidentified murre	313	40	60	0
Kittlitz's Murrelet	16	0	100	0
Ancient Murrelet	1	0	100	0
Parakeet Auklet	9	0	100	0
Least Auklet	1	0	100	0
Crested Auklet	18	0	100	0
Horned Puffin	36	39	61	0
Tufted Puffin	2	100	0	0
Unidentified alcid	21	38	62	0

Table 2. Behavioral cues used for detection of marine mammals recorded on-transect during the AKMAP study, 2010–2011.

Species-group/ common name	Number of observations	Percent detected by behavior cue			
		Blow	Dorsal fin	Head	Splash
PINNIPEDS					
Walrus	10	0	0	100	0
Bearded Seal	13	0	0	100	0
Spotted Seal	4	0	0	100	0
Unidentified seal	15	0	0	93	7
Unidentified pinniped	1	0	0	100	0
CETACEANS					
Bowhead Whale	1	100	0	0	0
Minke Whale	3	67	33	0	0
Gray Whale	6	100	0	0	0
Beluga	1	0	0	100	0
Harbor Porpoise	1	0	0	0	100
Unidentified whale	5	80	20	0	0

Long-tailed Ducks) indicated positive relationships with pycnocline strength and distance from shore and negative relationships with UML, SST, horizontal thermal gradient, and the interaction between UML and pycnocline strength (Table 5).

Loons

Loon density was higher in the northern sector than the southern sector (Figure 12, Table 3). Pacific Loons were the most abundant species, whereas both Red-throated Loons and Yellow-billed Loons were rare (Table 3). We pooled all loon species for analysis with environmental variables. As a group, loon abundance was positively associated with the interaction between UML and pycnocline strength and negatively associated with pycnocline strength, SST, horizontal thermal gradients and distance from shore (Table 5).

Tubenoses

Short-tailed Shearwaters were widely distributed throughout the entire AKMAP study area (Figure 13) and occurred in the highest density (Table 3). Short-tailed Shearwater abundance was positively associated with pycnocline strength but negatively associated with SST, horizontal thermal gradients and the interaction between UML and pycnocline strength (Table 5). Shearwaters were most abundant when the pycnocline strength was <0.50 σ_t/m, the UML was 5–15 m deep, and SST was low. In contrast, abundance was low when the UML was <5 m and pycnocline strength was >0.50 σ_t/m, such as was seen near Cape Lisburne (Figure 3).

Northern Fulmars were recorded infrequently in both study sectors (Figure 14). We lacked the sample size to analyze the relationship between Northern Fulmar abundance and environmental gradients; however, they were pooled with other surface-/near-surface-feeding species for analysis (see below).

Phalaropes

Phalaropes were recorded in small groups throughout the study area; however, phalarope density was higher in the northern sector than in the southern sector (Figure 15, Table 3). We did not have enough observations to analyze the relationship between phalarope abundance and environmental gradients; however, they were pooled with other surface-/near-surface-feeding species for analysis (see below).

Gulls/terns and jaegers

Black-legged Kittiwake density was higher in the northern sector than in the southern sector (Figure 16, Table 3). Black-legged Kittiwake

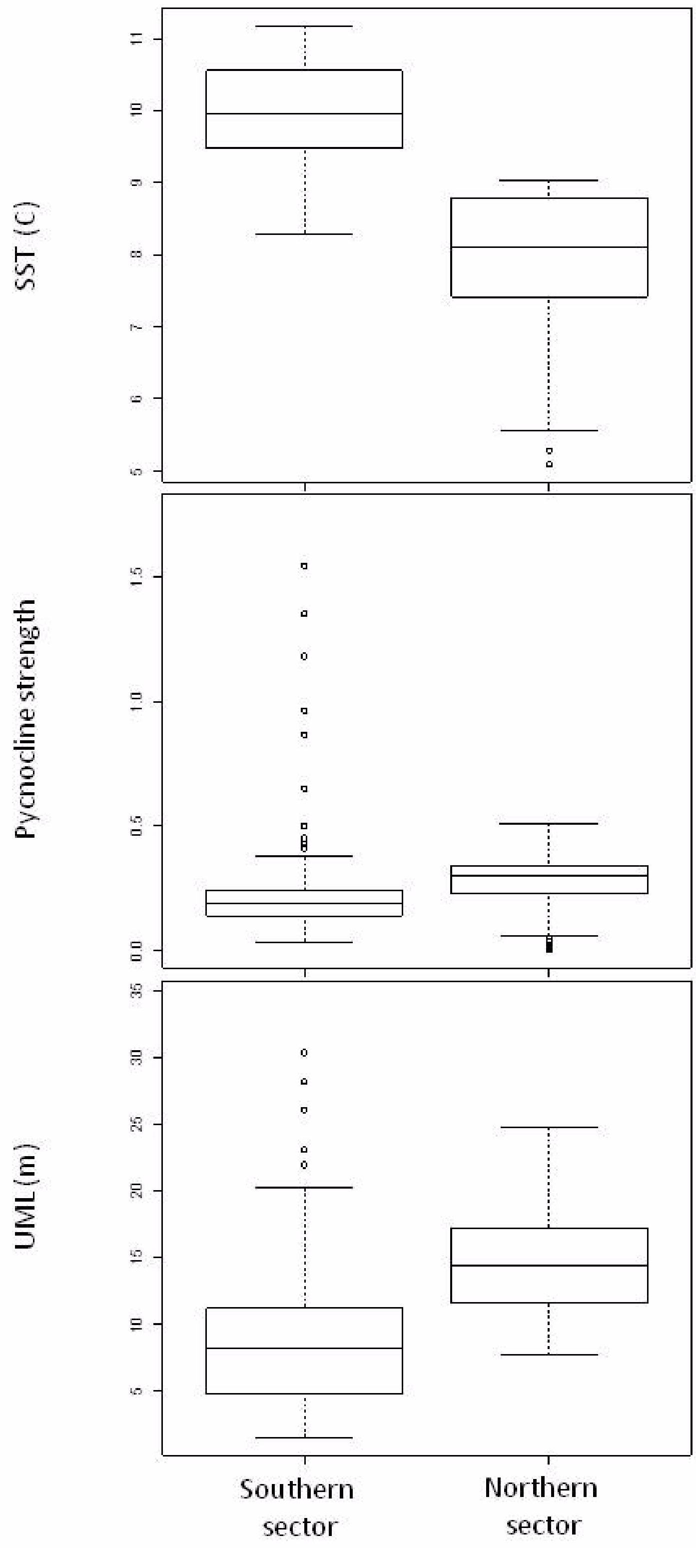

Figure 7 Median SST, pycnocline strength, and UML for CTD stations in the southern and northern sectors. Boxes indicate 25% and 75% quartile ranges. Whiskers show 1.5 interquartile ranges. Potential outliers are shown with bubbles.

Table 3. Estimated abundance and density of seabirds in the AKMAP study area, 2010–2011. Density estimates are corrected for detectability and include birds seen only on-transect. Values in parentheses are 95% confidence intervals.

Common name	Abundance southern sector	Abundance northern sector	Density birds/km^2 southern sector	Density birds/km^2 northern sector
WATERFOWL				
Spectacled Eider	0	456 (126–1,646)	0	0.03 0.01–0.10)
King Eider	0	3,189 (1,287–7,899)	0	0.20 (0.08–0.48)
Common Eider	0	10,136 (2,957–3,4743)	0	0.62 (0.18–2.13)
Unidentified eider	30,572 (7,375–126,723)	911 (207–4,003)	1.71 (0.41–7.08)	0.06 (0.01–0.25)
Long-tailed Duck	0	27,676 (7,706–99,395)	0	1.69 (0.47–6.09)
LOONS/GEBES				
Red-throated Loon	0	341(97–1205)	0	0.02 (0.01–0.07)
Pacific Loon	961 (384–2,402)	13,138 (7375–2,3402)	0.05 (0.02–0.13)	0.81 (0.45–1.43)
Yellow-billed Loon	0	341(96–1,218)	0	0.02 (0.01–0.07)
Unidentified loon	160 (31–835)	171 (33–891)	0.01 (<0.01–0.05)	0.01 (<0.01–0.05)
TUEBENOSES				
Northern Fulmar	3,105 (1,722–5,598)	1,965 (1,067–3,623)	0.17 (0.10–0.31)	0.12(0.7–0.22)
Short-tailed Shearwater	372,246 (236,155586,765)	331,736 (188,478583,881)	20.78 (13.19–32.76)	20.34 (11.56–35.80)
SHOREBIRDS				
Unidentified phalarope	9,798 (4,323–22,202)	5,317 (9–2,996,470)	0.55 (0.24–1.24)	0.32 (<0.01–183.74)
GULLS/TERNS/JAEGERS				
Black-legged Kittiwake	29,921 (16,252–55,084)	17,059 (8,089–35,934)	1.67 (0.91–3.08)	1.04 (0.50–2.20)
Sabine's Gull		0	0.01 (<0.01–0.03)	0
Herring Gull	779 (249–2,438)	0	0.04 (0.01–0.14)	0
Glaucous Gull	11,941(4,872–29,270)	2,017 (1,045–3,892)	0.67 (0.27–1.63)	0.12 (0.06–0.24)
Arctic Tern	1473 (285–7619)	1,565 (341–7,196)	0.08 (0.02–0.43)	0.10 (0.02–0.44)
Pomarine Jaeger	2,458 (1,148–4,172)	0	0.13 (0.08–0.23)	0
Parasitic Jaeger	517 (204–1,309)	327 (93–1,155)	0.03 (0.01–0.07)	0.02 (0.01–0.07)
Long-tailed Jaeger	0	164 (32–847)	0	0.01 (<0.01–0.05)
ALCIDS				
Common Murre	3,361 (1,785–6,328)	7,739 (4,715–12,702)	0.19 (0.10–0.35)	0.47 (0.29–0.78)
Thick-billed Murre	10,069 (6,964–14,557)	3,582 (1,365–9,395)	0.56 (0.39–0.81)	0.22 (0.08–0.58)

Table 3. Continued.

Common name	Abundance southern sector	Abundance northern sector	Density birds/km^2 southern sector	Density birds/km^2 northern sector
Unidentified murre	73,172 (57,231–93,552)	3,750 (1,910–7,361)	4.09 (3.19–5.22)	0.23 (0.12–0.45)
Ancient Murrelet	0	152 (29–786)	0	0.01 (<0.01–0.05)
Kittlitz's Murrelet	408 (104–1,594)	2,492 (1,160–5,354)	0.02 (0.01–0.09)	0.15 (0.07–0.33)
Parakeet Auklet	1,355 (558–3,288)	0	0.08 (0.03–0.18)	0
Least Auklet	0	152 (29–786)	0	0.01 (<0.01–0.05)
Crested Auklet	286 (82–1,001)	2,640 (1,511–4,614)	0.02 (<0.01–0.06)	0.16 (0.09–0.28)
Horned Puffin	1,660 (844–3,265)	0	0.09 (0.05–0.18)	0
Tufted Puffin	285 (1–928,457)	0	0.02 (<0.01–51.84)	
Unidentified alcid	758 (200–2,880)	152 (29–786)	0.04 (0.01–0.16)	0.01(<0.01–0.05)

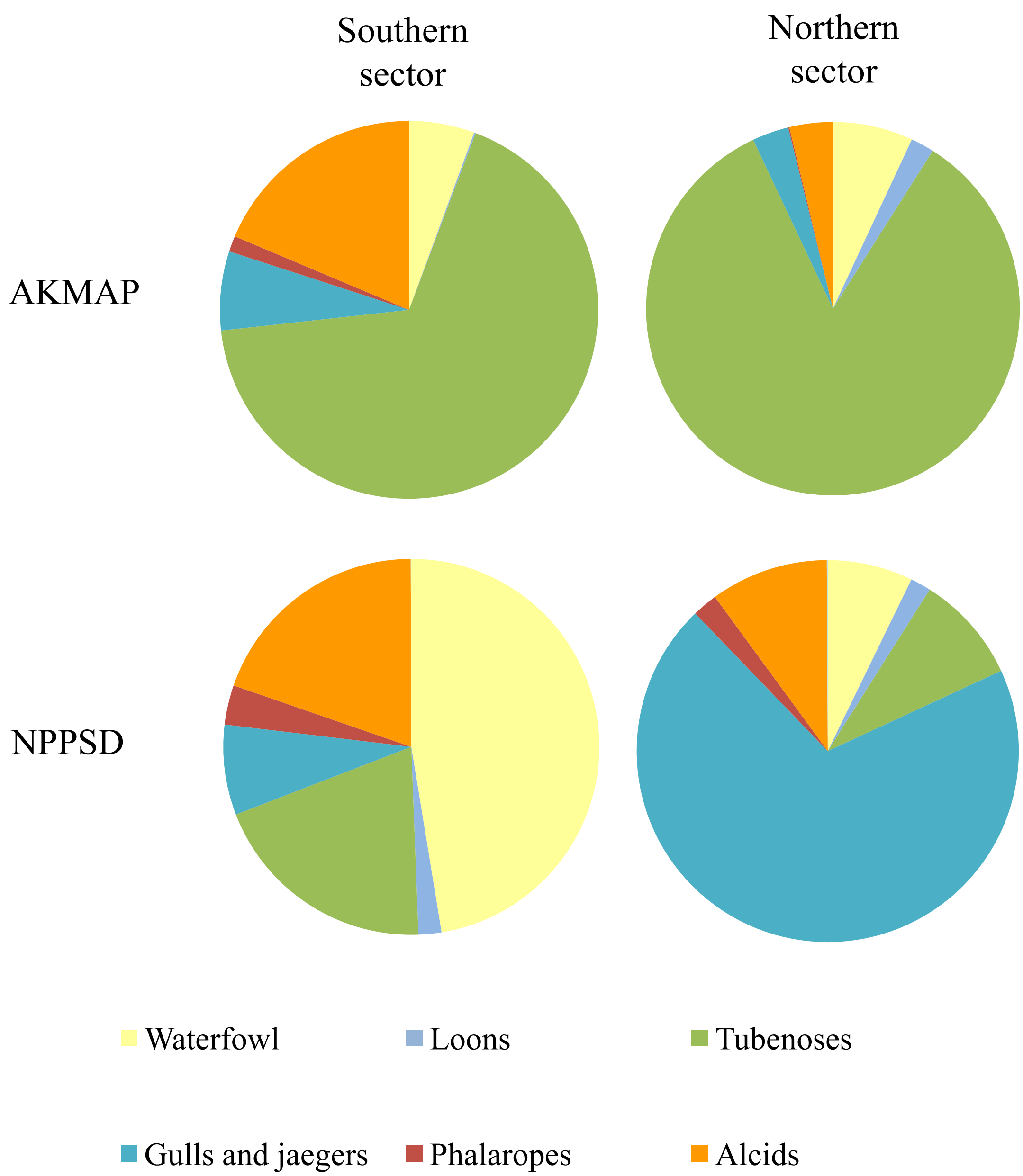

Figure 8. Marine bird species-composition within the AKMAP study area, 1975–2009 (NPPSD) and 2010–2011 (AKMAP).

Table 4. Conservation status, typical seasons present, and number of marine mammals found in the AKMAP study area, 2010–2011.

	Seasonal presence				Number observed		
Species-group/common name	Winter	Spring	Summer	Fall	2010	2011	Conservation status
Walrus		X	X	X	54	4	candidate[a]
Northern fur seal			X		0	0	none
Bearded seal	X	X		X	0	14	none
Ribbon seal	X	X		x	0	0	none
Ringed seal	X	X	X	X	0	0	none
Spotted seal		X	X	X	4	0	none
Ringed or spotted seal		X	X	X	0	21	
Unidentified seal	X	X	X	X	0	16	
Polar bear	X	X		X	0	0	threatened[a]
Bowhead whale		X	X	X	0	2	special concern[b,c]
Minke whale			X		1	2	none
Fin whale			X		0	0	none
Humpback whale			X		0	0	none
Gray whale			X		0	10	none
Killer whale			X		0	0	none
Beluga			X		15	0	none[b]
Harbor porpoise			X		2	0	strategic stock[b]
Unidentified whale		X	X	X	0	8	

[a] USFWS (2010).
[b] NOAA (2010).
[c] ADFG (2010).

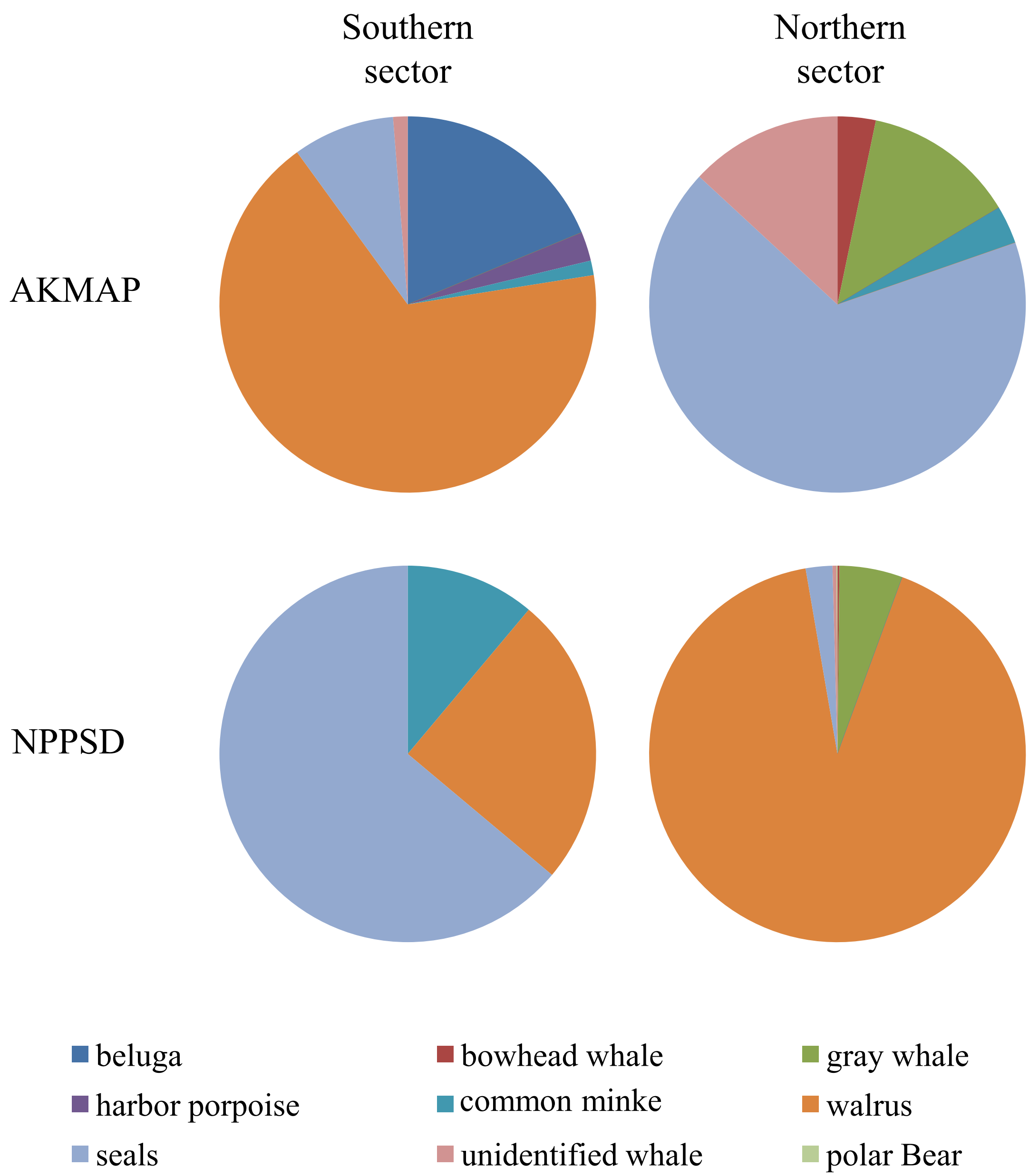

Figure 9. Marine mammal species composition within the AKMAP study area, 1975–2009 (NPPSD) and 2010–2011 (AKMAP).

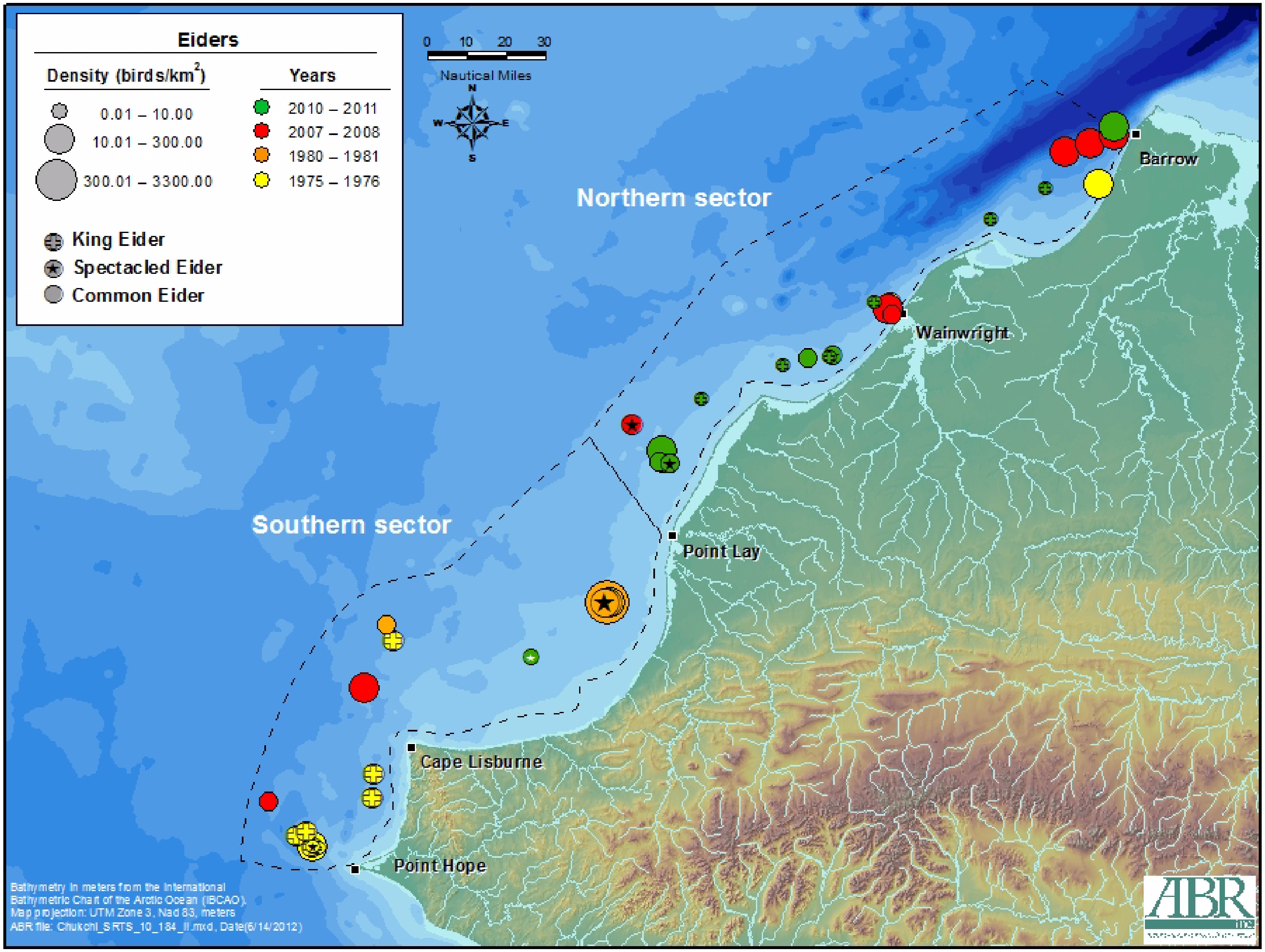

Figure 10. Distribution of eiders in the AKMAP study area, 1975–2011. This figure also includes locations of Spectacled Eiders seen off-transect.

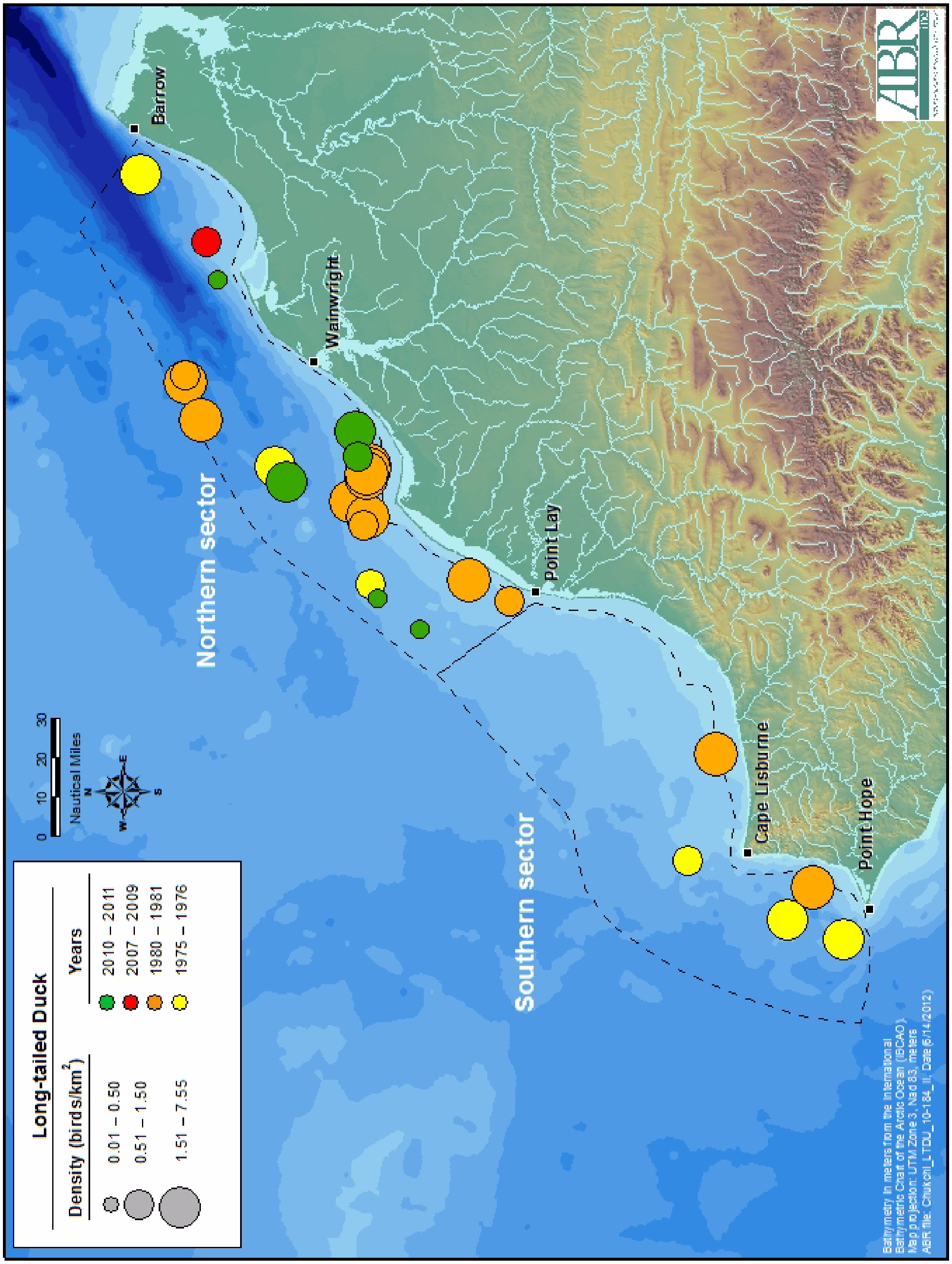

Figure 11. Distribution of Long-tailed Ducks in the AKMAP study area, 1975–2011.

Table 5. Environmental gradient model coefficients and AIC weights for ZINB mixture models. AIC scores and weights are for the complete model. Coefficients are for the count portion of ZINB mixture models.

			Count coefficient							
Species/species-group/feeding guild	AIC	Model AIC Weight	Intercept	Study sector	UML	Pycnocline strength	SST	Thermal gradient	Distance from shore	UML* strength
SPECIES/SPECIES-GROUP										
Ducks	323.58	0.48	12.97	NA	–0.30	26.53	–1.39	–3.51	0.15	–1.68
Loons	419.48	0.48	11.44	NA	–0.05	–1.73	–0.73	–7.56	–0.11	0.75
Black-legged Kittiwake	759.85	0.44	1.22	NA	–0.02	–2.16	NA	NA	NA	0.25
Glaucous Gull	364.19	0.51	0.13	–0.89	NA	NA	NA	–0.11	NA	NA
Short-tailed Shearwater	2421.21	1.00	8.211	–0.18	0.01	1.91	–0.54	–0.13	NA	–0.28
Common Murre	390.89	0.76	–1.36	0.51	NA	NA	0.24	NA	NA	NA
Thick-billed Murre	439.21	0.39	–0.07	NA	NA	NA	NA	2.36	0.01	NA
FEEDING GUILD										
Diving-feeders	1799.40	0.53	–0.23	NA	NA	–0.89	0.20	NA	0.01	NA
Surface-/near surface-feeders	969.41	0.53	–0.17	NA	0.01	–2.43	0.14	NA	NA	0.20

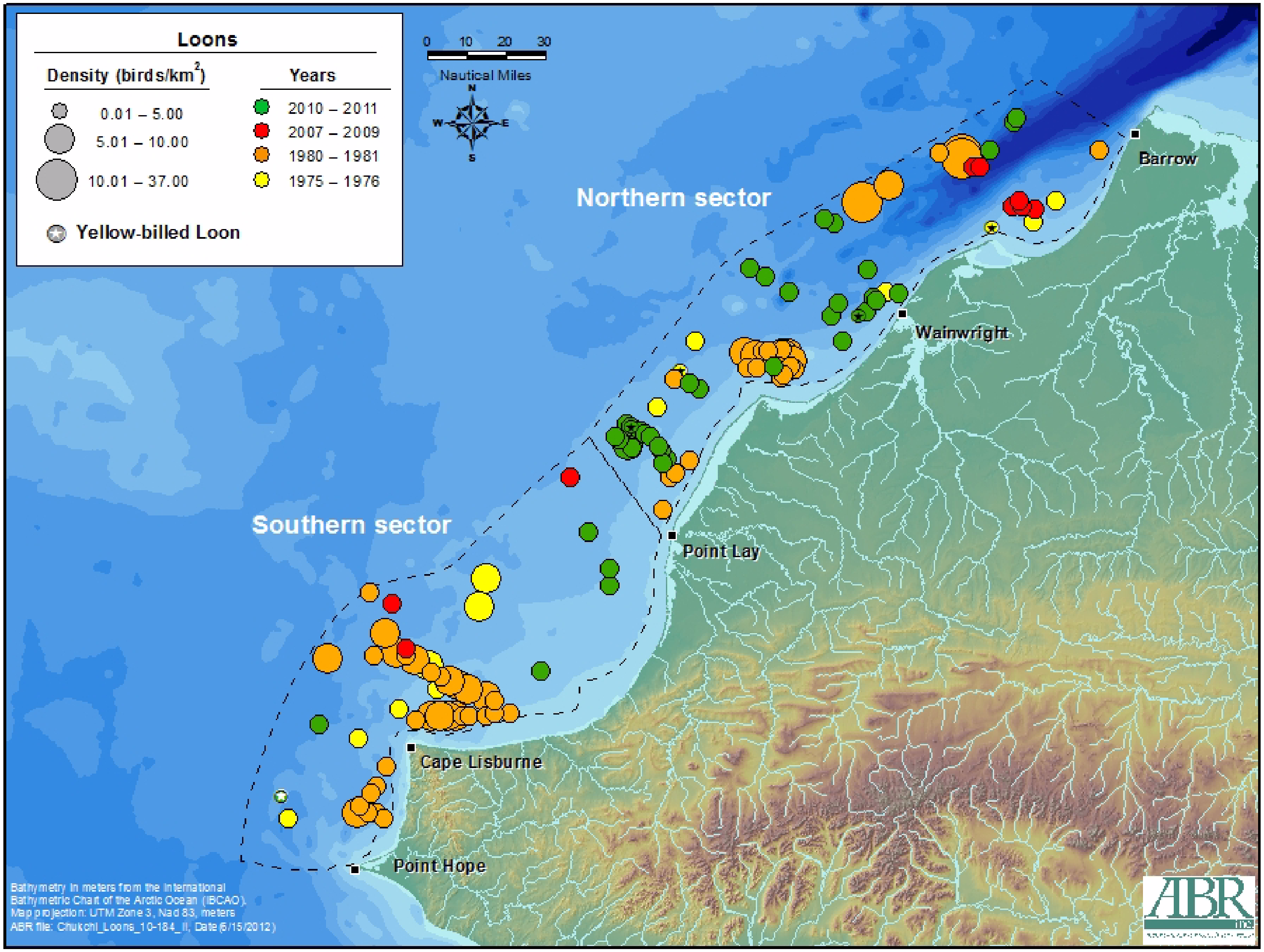

Figure 12. Distribution of loons in the AKMAP study area, 1975–2011. This figure also includes locations of Yellow-billed Loons seen off-transect.

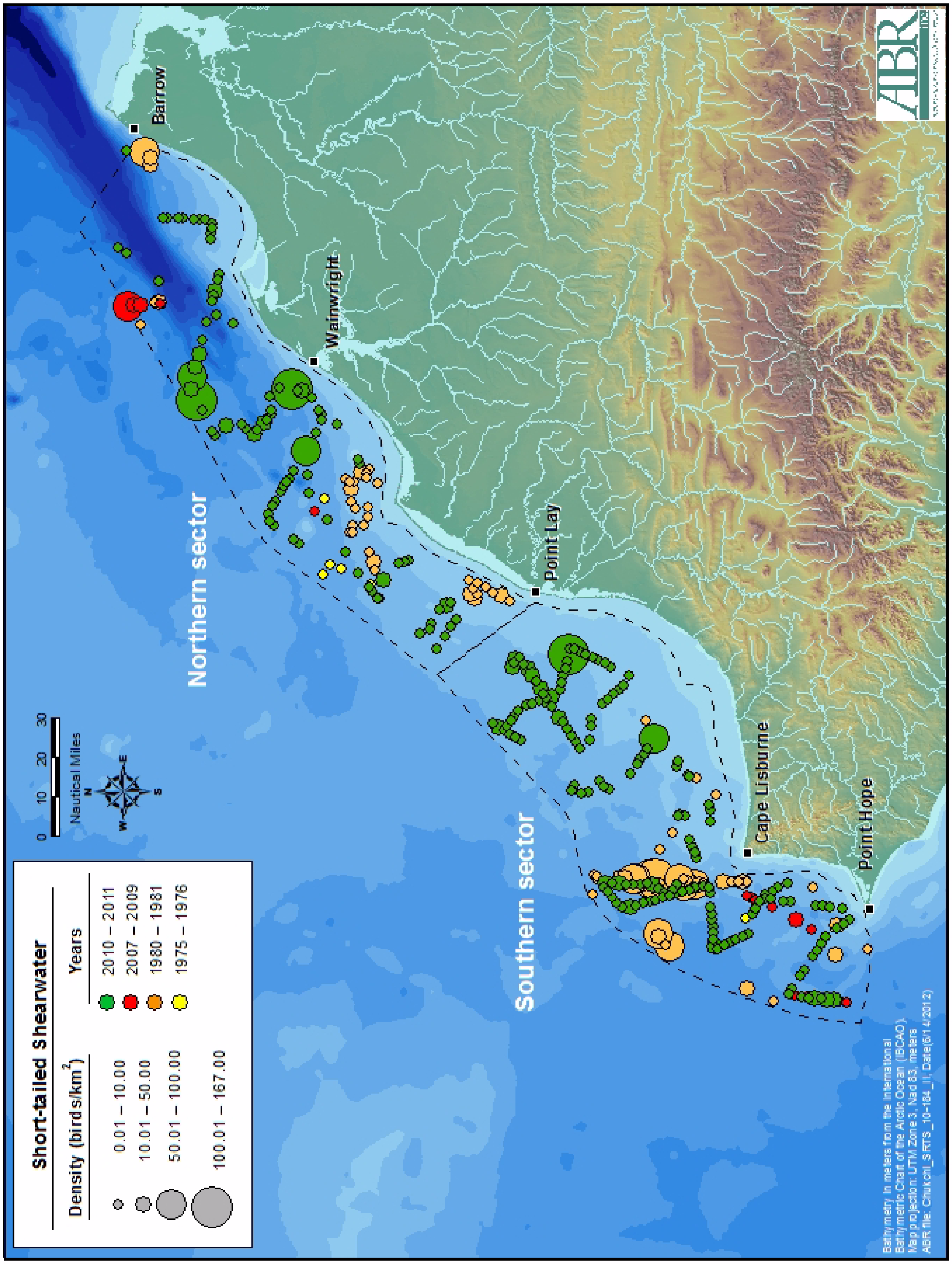

Figure 13. Distribution of Short-tailed Shearwaters in the AKMAP study area, 1975–2011.

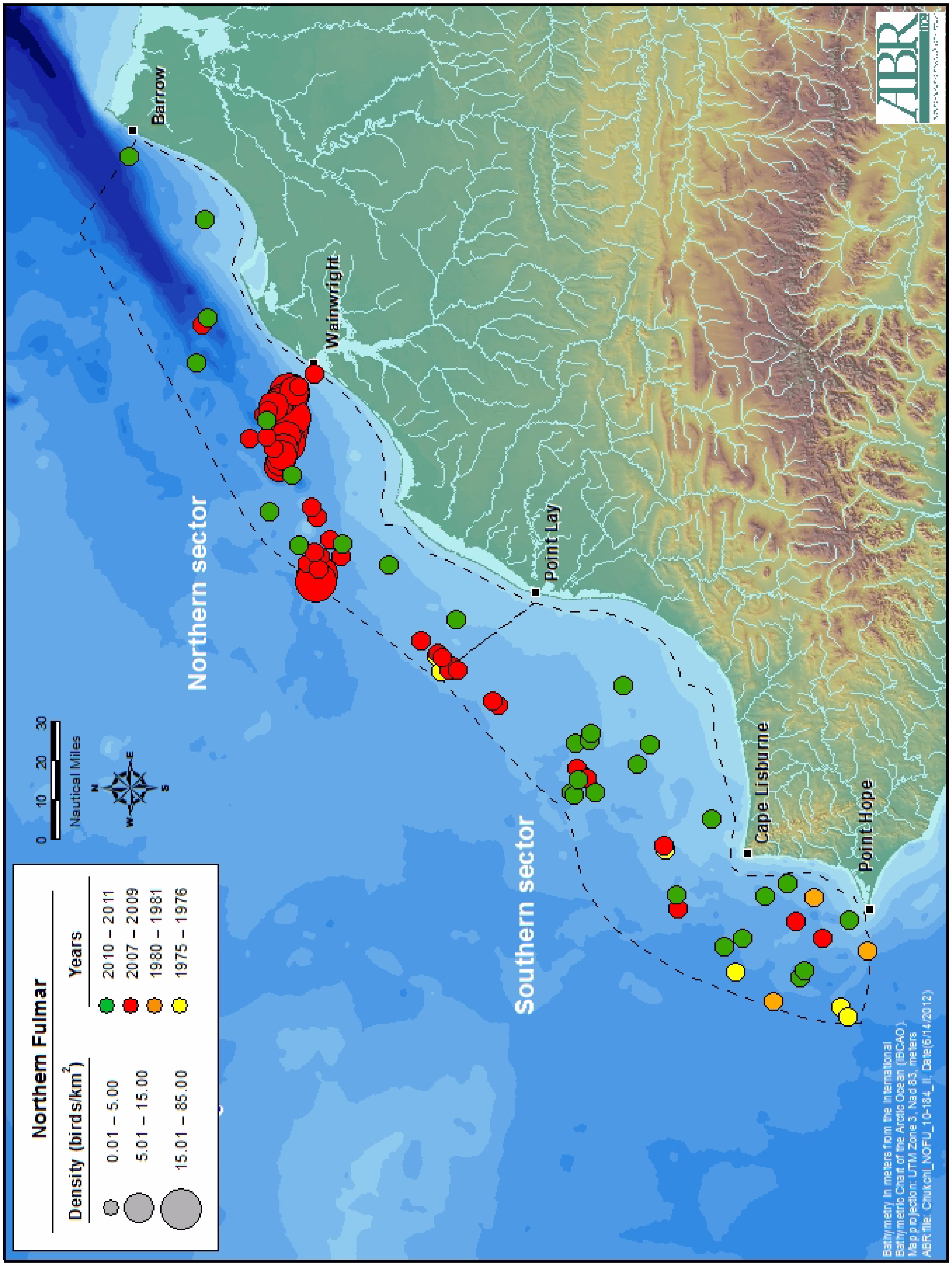

Figure 14. Distribution of Northern Fulmars in the AKMAP study area, 1975–2011.

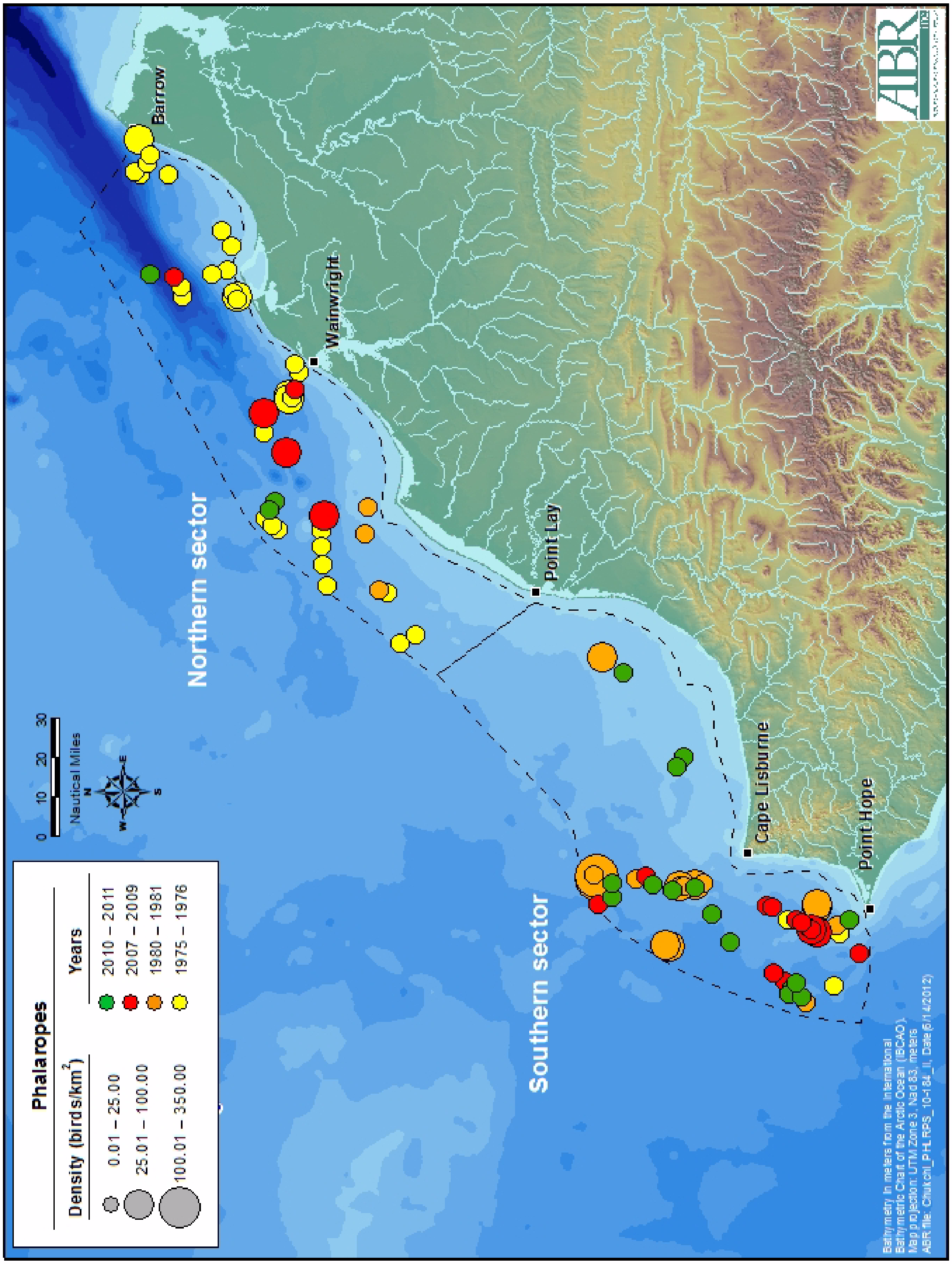

Figure 15. Distribution of phalaropes in the AKMAP study area, 1975–2011.

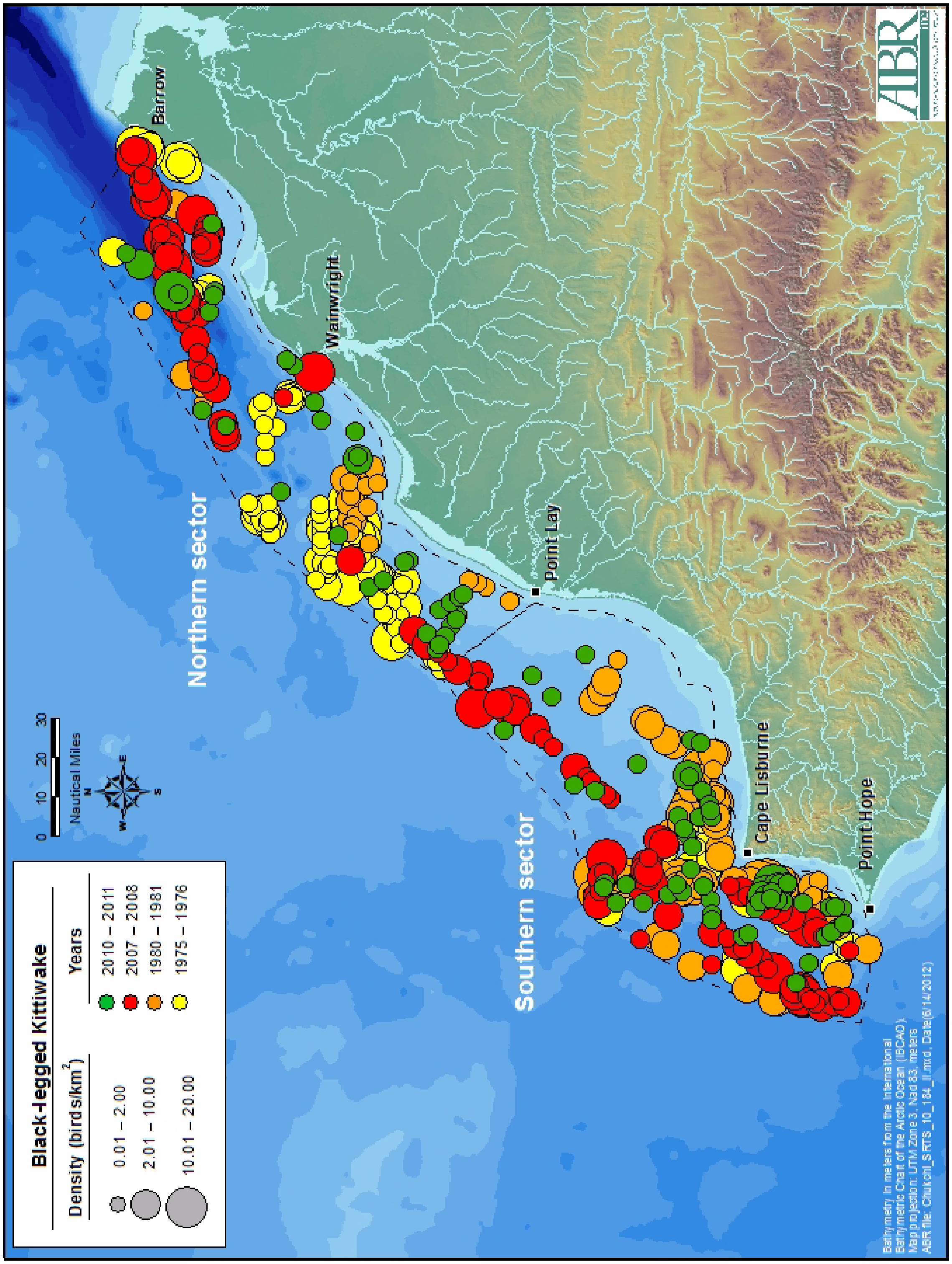

Figure 16. Distribution of Black-legged Kittiwakes in the AKMAP study area, 1975–2011.

abundance was negatively associated with UML and pycnocline strength but positively associated with the interaction between UML and pycnocline strength.

Glaucous Gull density also was higher in the southern sector than in the northern one (Figure 17, Table 3), presumably reflecting the proximity of the southern sector to the large breeding colonies at Cape Lisburne and Cape Thompson. Glaucous Gull abundance was also negatively associated with horizontal thermal gradient (Table 5).

Both terns and jaegers were uncommon in the AKMAP study area (Figures 18 and 19, respectively). Arctic Tern was the only tern species we encountered, whereas we recorded all three species of jaegers. These species were pooled with other surface-/near-surface-feeders for analysis (see below).

Alcids

Murres were widely distributed throughout the entire AKMAP study area (Figure 20). Common Murre abundance was positively associated with the northern sector and SST. Thick-billed Murre abundance was positively associated with distance from the shoreline and strong horizontal thermal gradients, such as those found around Cape Lisburne.

In contrast to murres, auklets were observed infrequently throughout the AKMAP study area, with the highest densities of Crested Auklet recorded in the northern sector (Figure 21, Table 3). Puffins were observed only in the southern sector, with the highest densities being recorded near the breeding colonies at Cape Lisburne (Figure 22). Kittlitz's Murrelets also were observed infrequently in both AKMAP sectors, with the highest density occurring in the northern sector (Figure 23, Table 3).

Diving-feeders

This group consisted primarily of murres and loons, all of which are large bodied piscivores. The abundance of diving species was positively associated with distance from the shoreline and SST and negatively associated with pycnocline strength (Table 5).

Surface-/near-surface-feeders

Surface-/near-surface-feeders included gulls, terns, jaegers, phalaropes, fulmars, and shearwaters. The abundance of surface-/near-surface-feeders was positively associated with UML, SST, and the interaction between UML and pycnocline strength; they also had a strong negative association with pycnocline strength (Table 5).

MARINE MAMMALS

We lacked the sample size to calculate marine mammal densities (Table 6) or to conduct any rigorous statistical tests of spatial distribution. Thus, our presentation of data on the distribution and abundance of marine mammals is limited to overall counts and general locations of observations.

Whales

We recorded three species of pelagic-feeding whales in the AKMAP study area (Figure 24). We recorded a single pod of 15 belugas along the western edge of the southern AKMAP sector, harbor porpoises in waters >30 m deep, and common minke whales in both shallow and deep water. Benthic feeding gray whales were recorded only in the northern AKMAP sector (Figure 25), and both bowhead and gray whale were recorded near the entrance to Barrow Canyon in water >30 m deep.

Walrus

We recorded walruses in both AKMAP sectors. Group sizes of walruses ranged from 1 to 23 individuals, with the largest numbers recorded just north of Cape Lisburne (Figure 26). Nearly all walrus sightings occurred in water <30 m deep and close to shore.

Seals

We observed seals in both AKMAP sectors. Spotted and ringed seals were recorded more frequently in the southern sector, generally in deep water (Figure 27), whereas bearded seals were recorded only in and were widely distributed in the northern sector (Figure 27).

COMPARISION WITH HISTORICAL DATA

The NPPSD contains data from 15 historical research cruises that overlap geographically with the AKMAP study area (Figure 5). A total of 1,321 transects were surveyed within the AKMAP study area between 1 August and 15 October 1975–2009

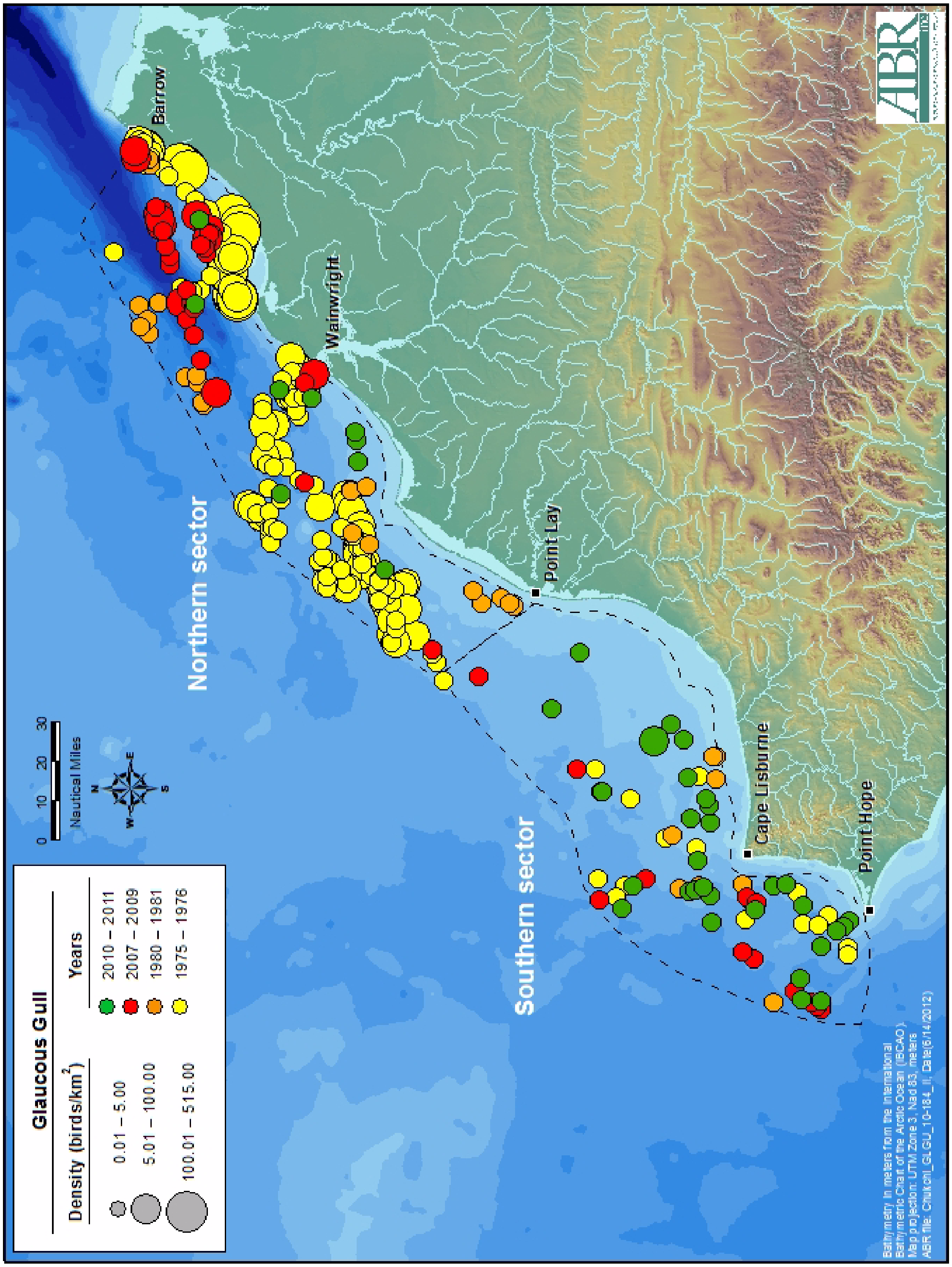

Figure 17. Distribution of Glaucous Gulls in the AKMAP study area, 1975–2011.

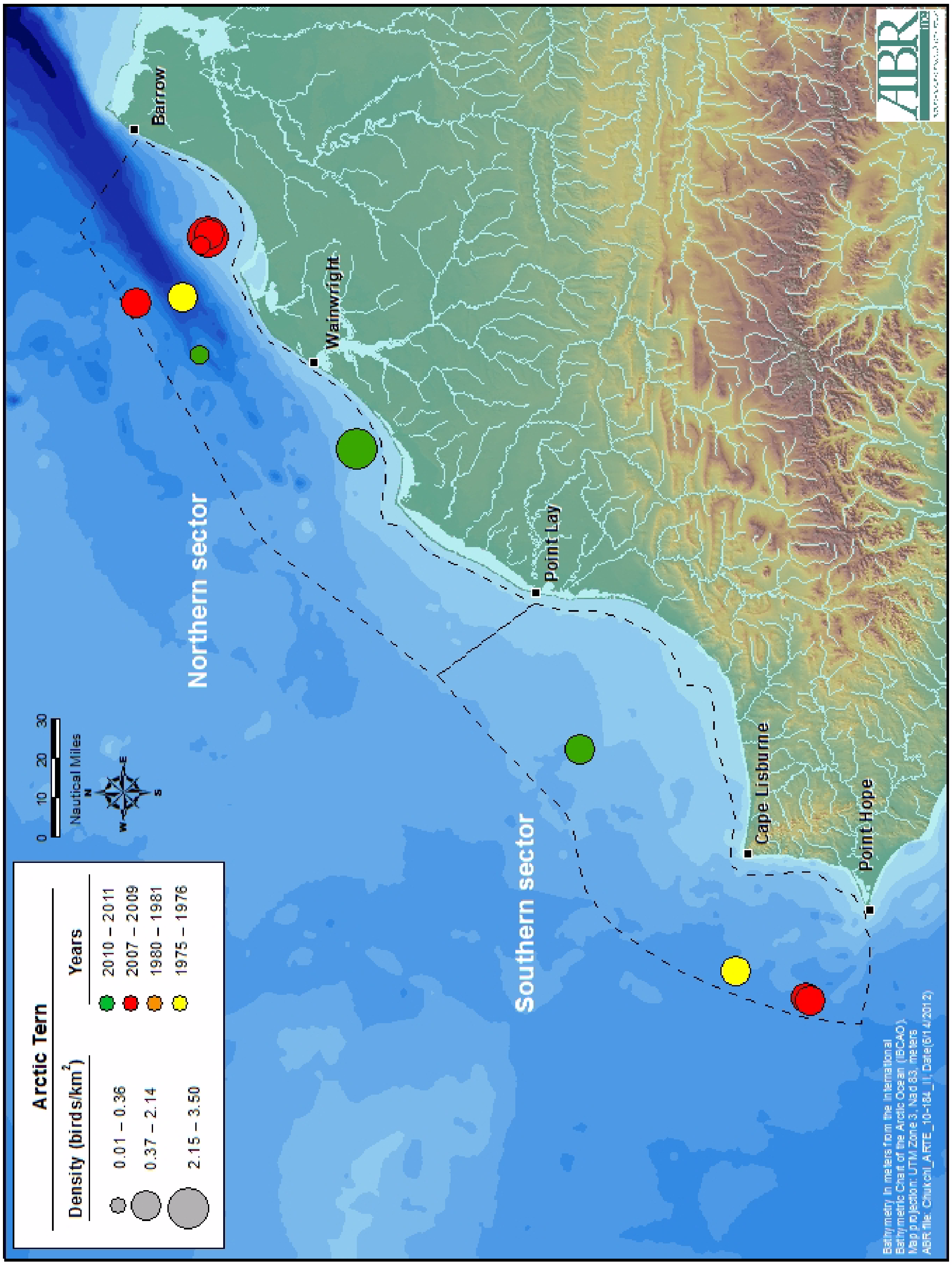

Figure 18. Distribution of Arctic Terns in the AKMAP study area, 1975–2011.

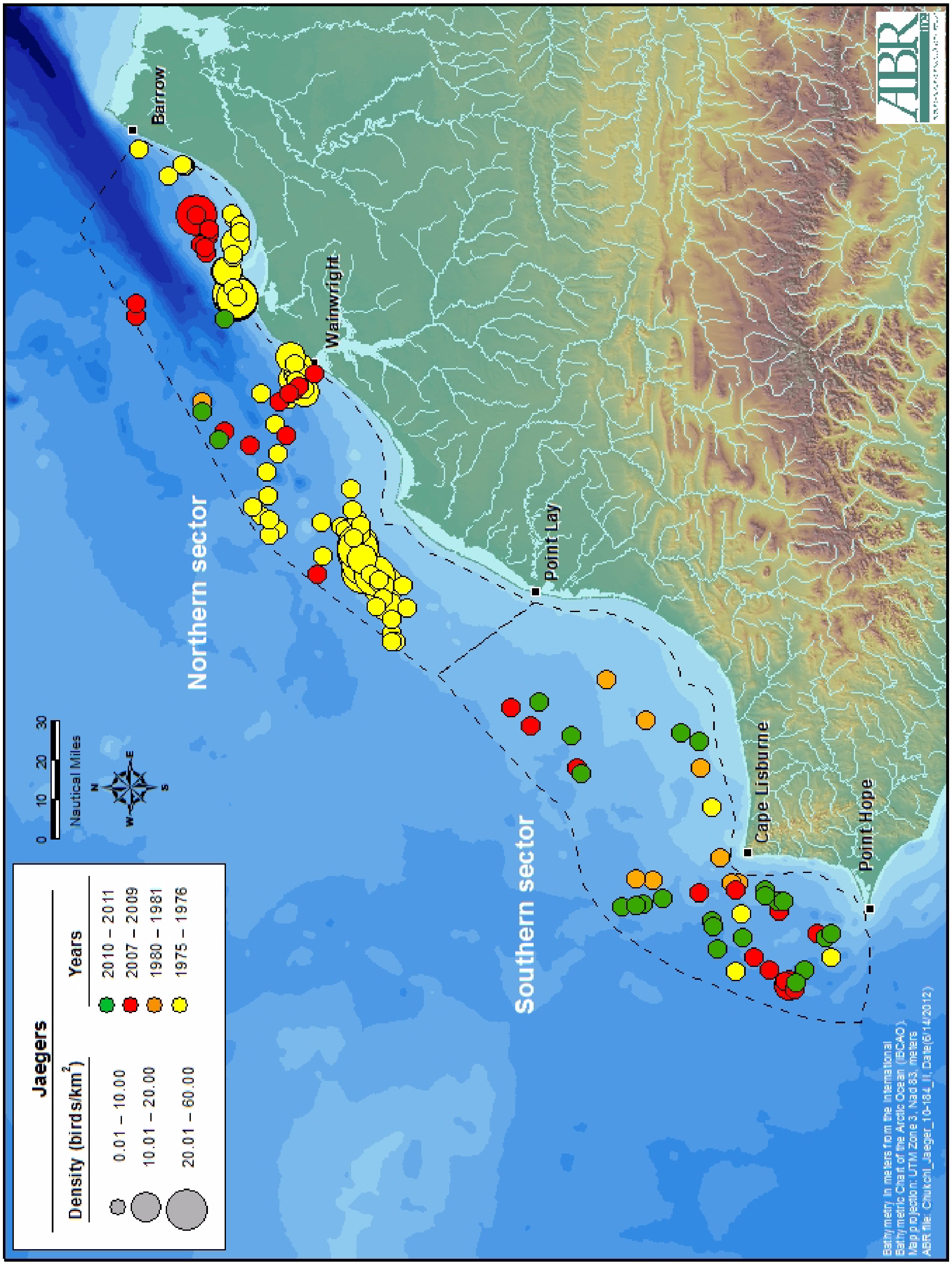

Figure 19. Distribution of jaegers in the AKMAP study area, 1975–2011.

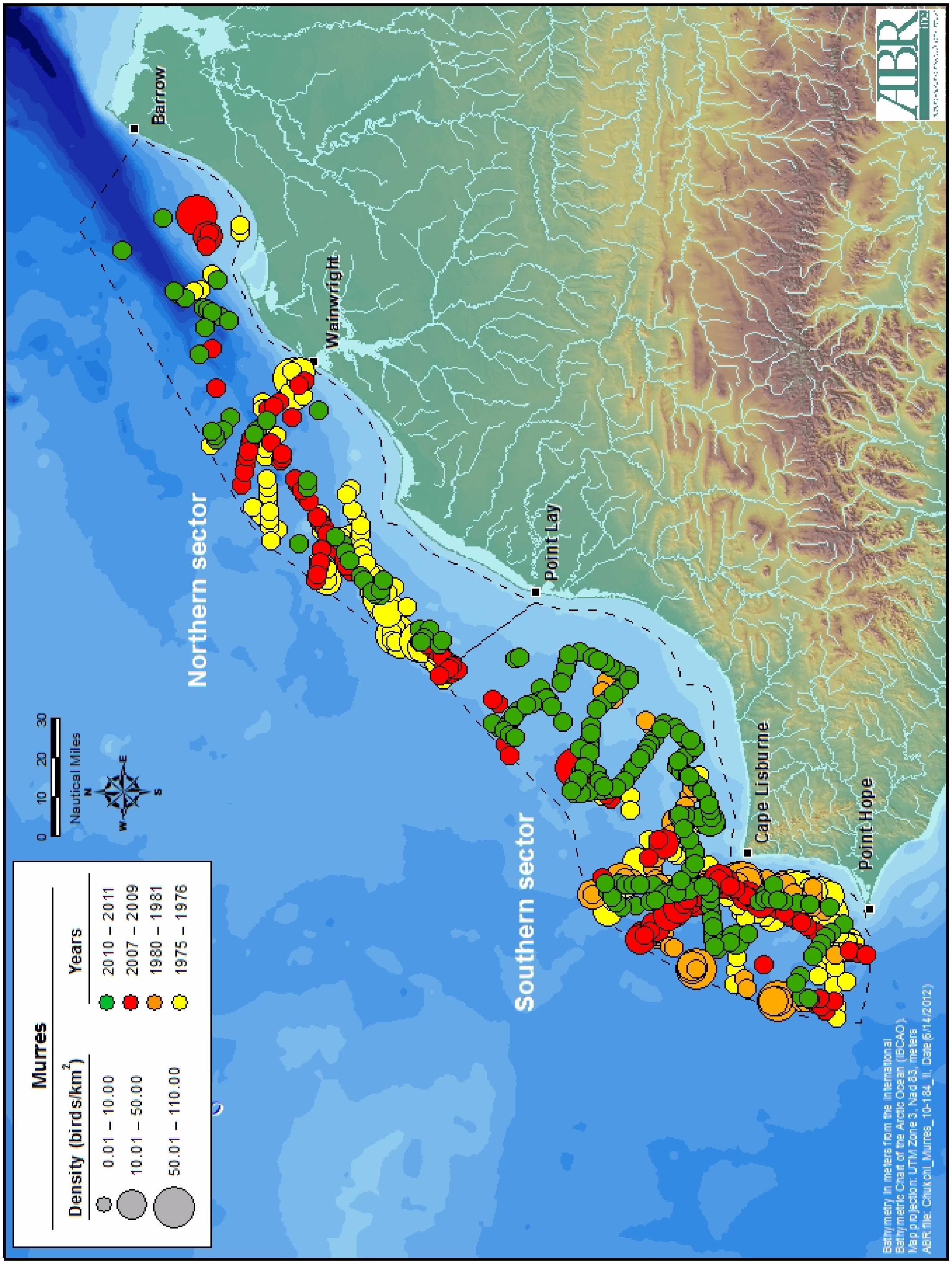

Figure 20. Distribution of murres in the AKMAP study area, 1975–2011.

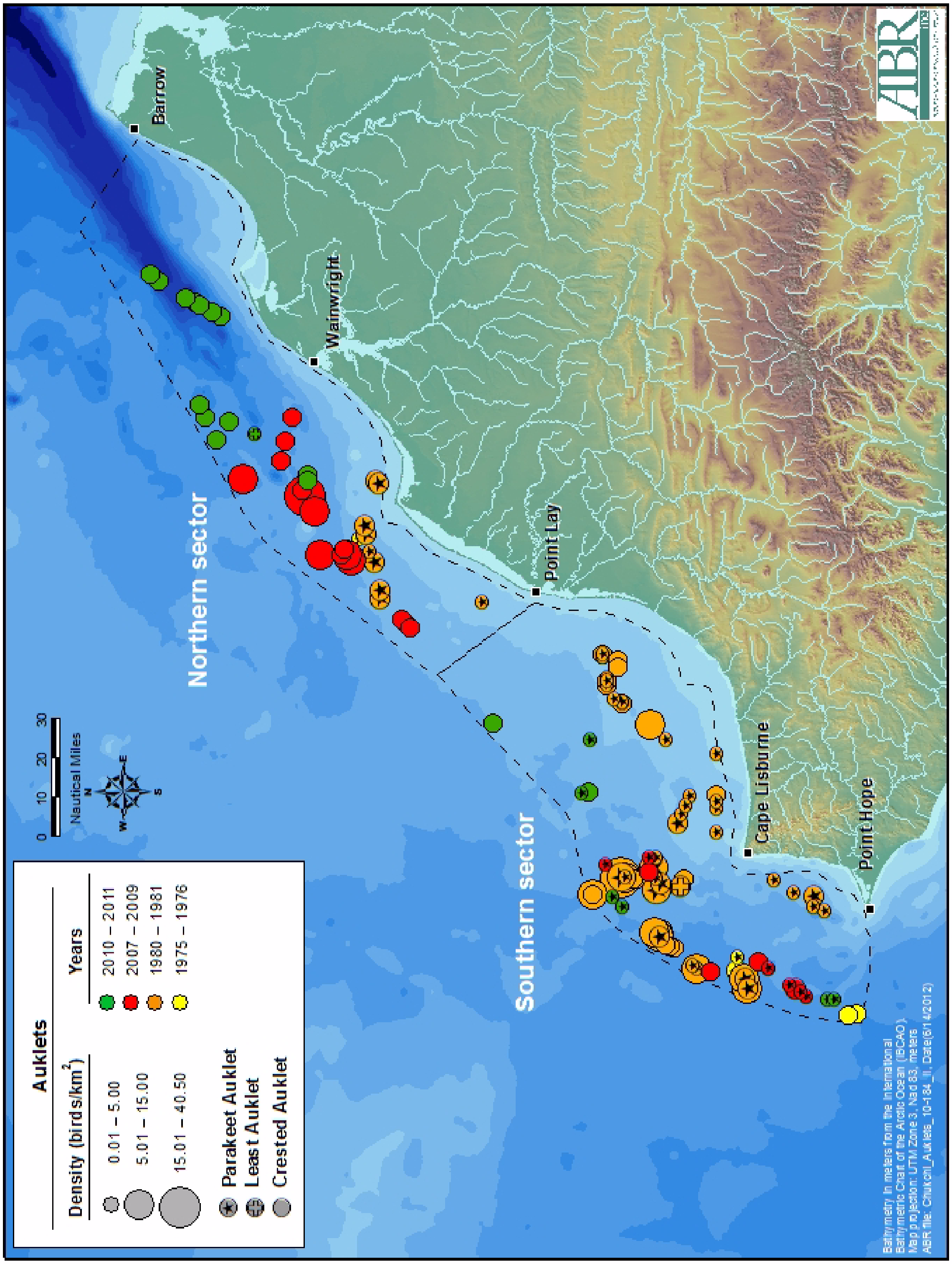

Figure 21. Distribution of auklets in the AKMAP study area, 1975–2011.

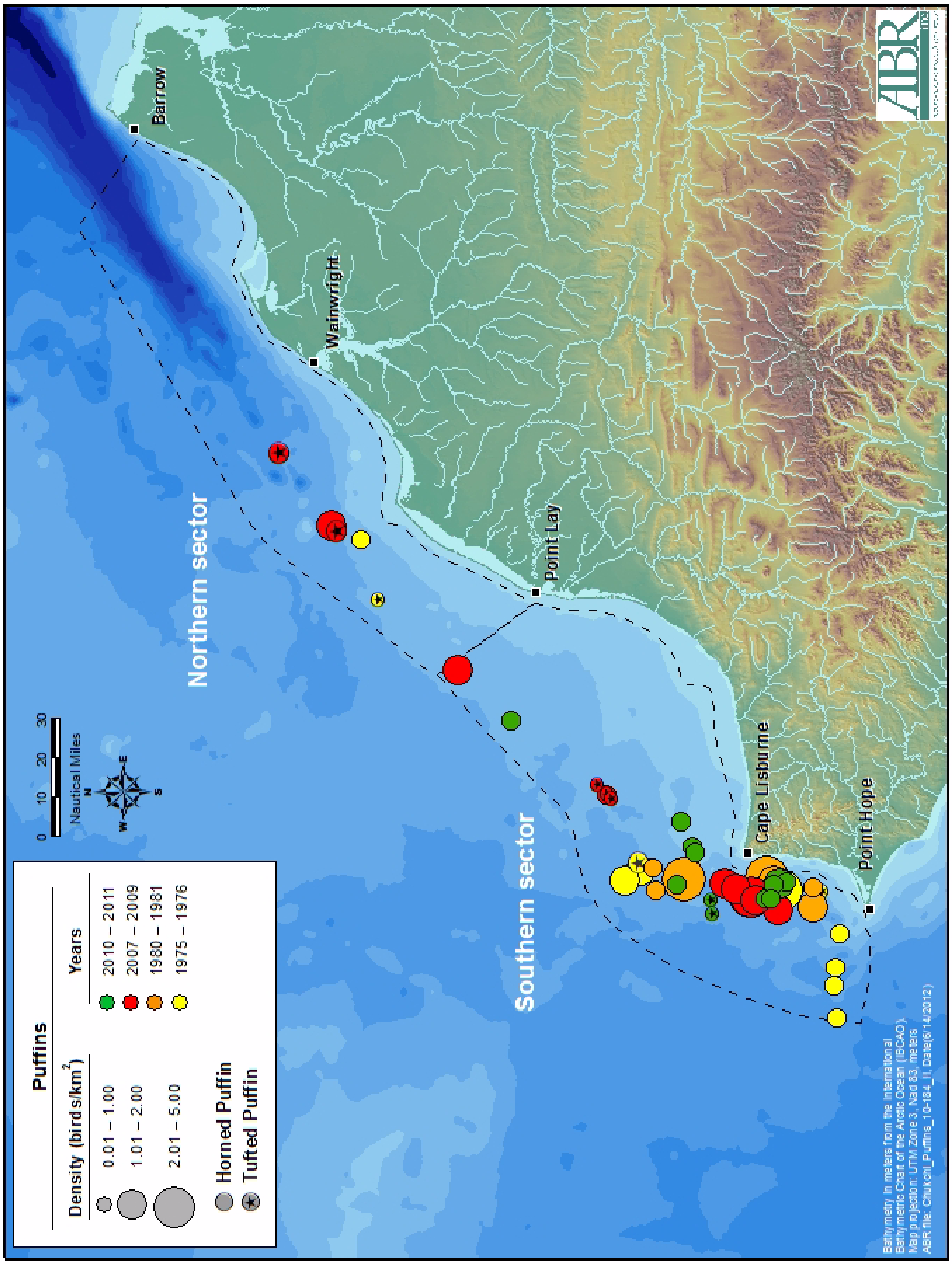

Figure 22. Distribution of puffins in the AKMAP study area, 1975–2011.

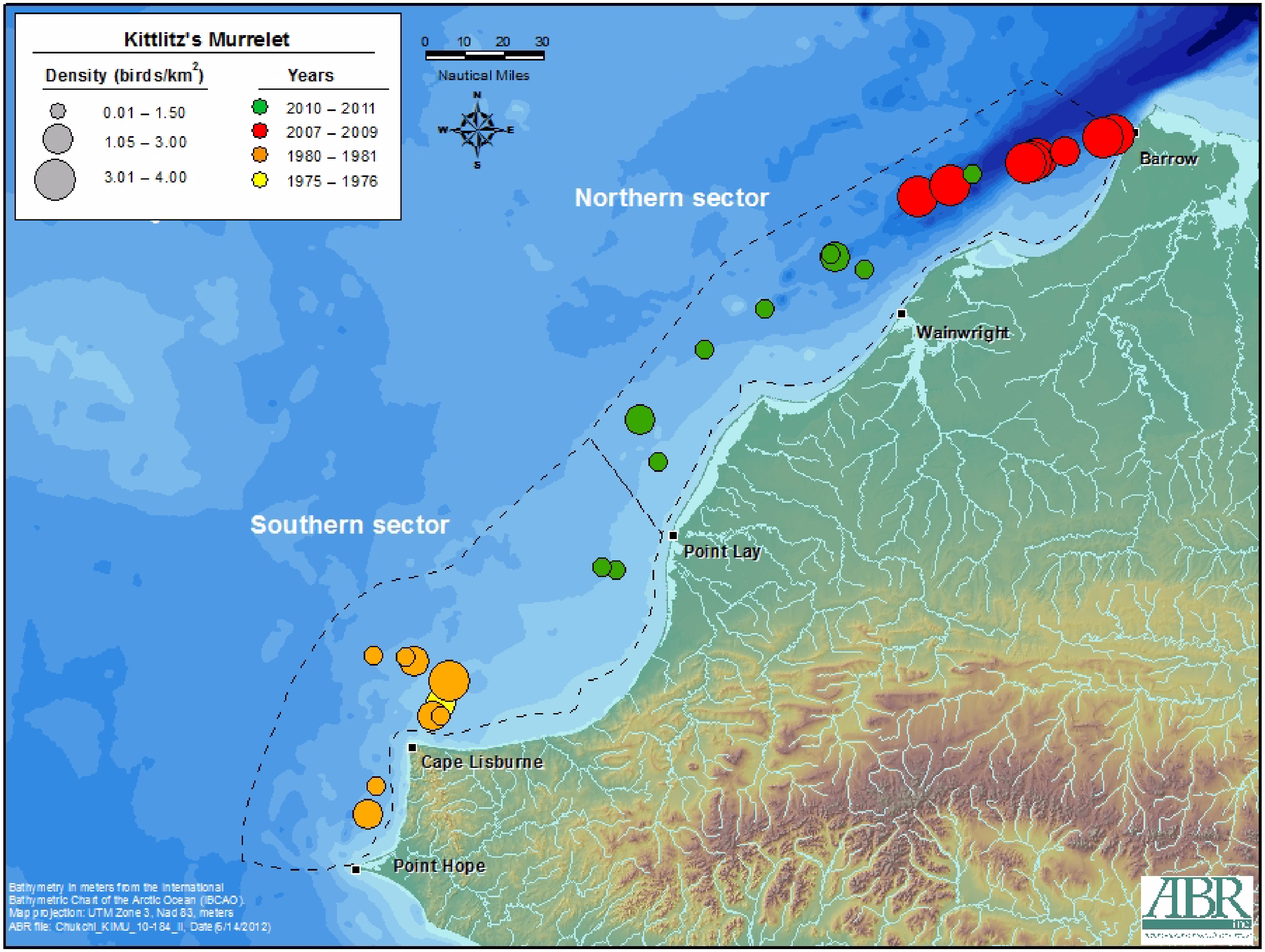

Figure 23. Distribution of Kittlitz's Murrelets in the AKMAP study area, 1975–2011. This figure also includes locations of Kittlitz's Murrelets seen off-transect.

Table 6. Seabird density estimates for the AKMAP study area during 4 study periods: 1970–1979, 1980–1989, 2000–2009 and 2010–2011. Only birds observed on-transect are included in density estimates. Values in parentheses are 95% confidence intervals.

Common name	Density (birds/km^2) by period				Conservation status
	1970–1979	1980–1989	2000–2009	2010–2011	
WATERFOWL					
Brant	0.3 (0.03–0.03)	0	0	0	none
Spectacled Eider	0	9.71 (9.33–10.11)	0.06 (0.06–0.07)	0.01 (0.01–0.01)	threatened[a]
King Eider	0			0.06 (0.06–0.07)	none
Common Eider	0.30 (0.28–0.32)	9.75 (9.37–10.15)	0.56 (0.52–0.60)	0.23 (0.21–0.25)0	none
Unidentified eider	2.17 (2.03–2.32)	0.23 (0.21–0.25)	0.04 (0.04–0.05)	0.67 (0.63–0.72)	none
White-winged Scoter	0	0.15 (0.14–0.16)		0	none
Black Scoter	0	4.28 (3.96–4.62)		0	none
Long-tailed Duck	0.28 (0.26–0.30)	3.25 (3.00–3.51)	0.10 (0.10–0.11)	0.07 (0.07–0.08)	none
LOONS					
Red-throated Loon	0.01 (<0.01–0.01)	0	0	<0.01 (<0.01)	none
Arctic Loon	0.18 (0.16–0.19)	1.86 (1.71–2.02)	0	0[b]	none
Pacific Loon	0	0	0.08 (0.07–0.08)	0.23 (0.21–0.24)	none
Yellow-billed Loon	0.01 (0.01–0.01)	0	0	<0.01 (<0.01)	candidate[a]
Unidentified loon	0.32 (0.30–0.34)	0.21 (0.19–0.23)	0.03 (0.02–0.03)	<0.01 (<0.01)	none
TUEBENOSES					
Northern Fulmar	0.02 (0.02–0.02	0.02 (0.02–0.04)	1.14 (1.32–1.51)	0.104 (0.07–0.11)	none
Short-tailed Shearwater	0.09 (0.09–0.10)	9.39 (8.72–10.11)	0.38 (0.35–0.41)	14.90 (14.38–15.42)	none
SHOREBIRDS					
Red-necked Phalarope	0	0	0.26 (0.24–0.28)	0	none
Red Phalarope	0.34 (0.31–0.37)	2.23 (2.12–2.34)	0.05 (0.04–0.05)	0	none
Unidentified phalarope	0.14 (0.13–0.15)	0.64 (0.58–0.70)	0.68 (0.63–0.72)	0.17 (0.15–0.18)[c]	none
Unidentified shorebird	0	0	9.07 (8.69–9.47)	0.04 (0.03–0.04)	none
GULLS/TERNS/JAEGERS					
Black-legged Kittiwake	9.81 (9.38–10.25)	3.03 (2.80–3.28)	3.78 (3.55–1.01)	0.70 (0.66–0.75)	none
Ross's Gull	0.05 (0.04–0.05)	0.01 (0.01–0.01)	0.04 (0.03–0.04)	0	none
Ivory Gull	0	0.01 (0.01–0.01)	0	0	none
Sabine's Gull	0.20 (0.19–0.22)	0.09 (0.08–0.10)	0.03 (0.02–0.03)	<0.01 (<0.01)	none

Table 6. Continued.

Common name	Density (birds/km^2) by period 1970–1979	1980–1989	2000–2009	2010–2011	Conservation status
Herring Gull	0.01 (0.01–0.01)	0	0.01 (0.01–0.01)	<0.01 (<0.01)	none
Thayer’s Gull	<0.01 (<0.01)	0	0	0	none
Glaucous-winged Gull	0	0.04 (0.04–0.04)	0.75 (0.70–0.81)	0	none
Glaucous Gull	8.57 (8.25–8.91)	0.27 (0.25–0.30)	0	0.23 (0.21–0.24)	none
Arctic Tern	0.50 (0.47–0.54)	0	0.08 (0.07–0.08)	0.05 (0.05–0.05)	none
Pomarine Jaeger	1.07 (1.01–1.15)	0.04 (0.04–0.04)	0.23 (0.21–0.24)	0.06 (0.05–0.06)	none
Parasitic Jaeger	0.20 (0.18–0.21)	0.03 (0.03–0.04)	0.04 (0.04–0.05)	0.02 (0.07–0.02)	none
Long-tailed Jaeger	0.06 (0.05–0.06)	0.03 (0.02–0.03)	0.02 (0.02–0.02)	<0.01 (<0.01)	none
ALCIDS					
Dovekie	0	0.03 (0.02–0.03)	0	0	none
Common Murre	0.08 (0.07–0.09)	0.31 (0.28–0.34)	0.43 (0.40–0.46)	0.21 (0.20–0.23)	none
Thick-billed Murre	1.25 (1.16–1.34)	2.22 (2.05–2.40)	1.23 (1.15–1.31)	0.31 (0.29–0.33)	none
Unidentified murre	3.91 (3.67–4.17)	1.26 (1.16–1.36)	2.48 (2.33–2.65)	1.96 (1.83–2.10)	none
Black Guillemot	0.12 (0.11–0.13)	0.17 (0.15–0.18)	0.04 (0.03–0.04)	0	none
Pigeon Guillemot	0	0	<0.01 (<0.01–0.01)	0	none
Ancient Murrelet	0	0	0	<0.01(<0.01)	none
Kittlitz's Murrelet	0.01 (0.01–0.01)	0.12 (0.11–0.13)	0.34 (0.31–0.36)	0.06 (0.06–0.07)	candidate[a]
Parakeet Auklet	0.02 (0.02–0.03)	1.71 (1.63–1.37)	0.07 (0.06–0.08)	0.03 (0.03–0.03)	none
Least Auklet	0	0.03 (0.03–0.04)	0	<0.01 (<0.01)	none
Crested Auklet	0.01 (<0.01–0.01)	0.50 (0.46–0.55)	0.30 (0.28–0.32)	0.06 (0.06–0.06)	none
Horned Puffin	0.05 (0.04–0.05)	0.08 (0.08–0.09)	0.05 (0.04–0.05)	0.04 (0.03–0.04)	none
Tufted Puffin	0.01 (0.01–0.01)	0	0.03 (0.02–0.03)	<0.01 (<0.01)	none
Unidentified alcid	0.03 (0.03–0.04	0.03 (0.02–0.03)	0.14 (0.13–0.15)	0.02 (0.02–0.02)	none

[a] USFWS 2010.
[b.]Common name changed from Arctic Loon to Pacific Loon in 1998.
[c.]In 2010 and 2011 phalaropes were not identified to the species level, but likely included both Red and Red-necked phalaropes.

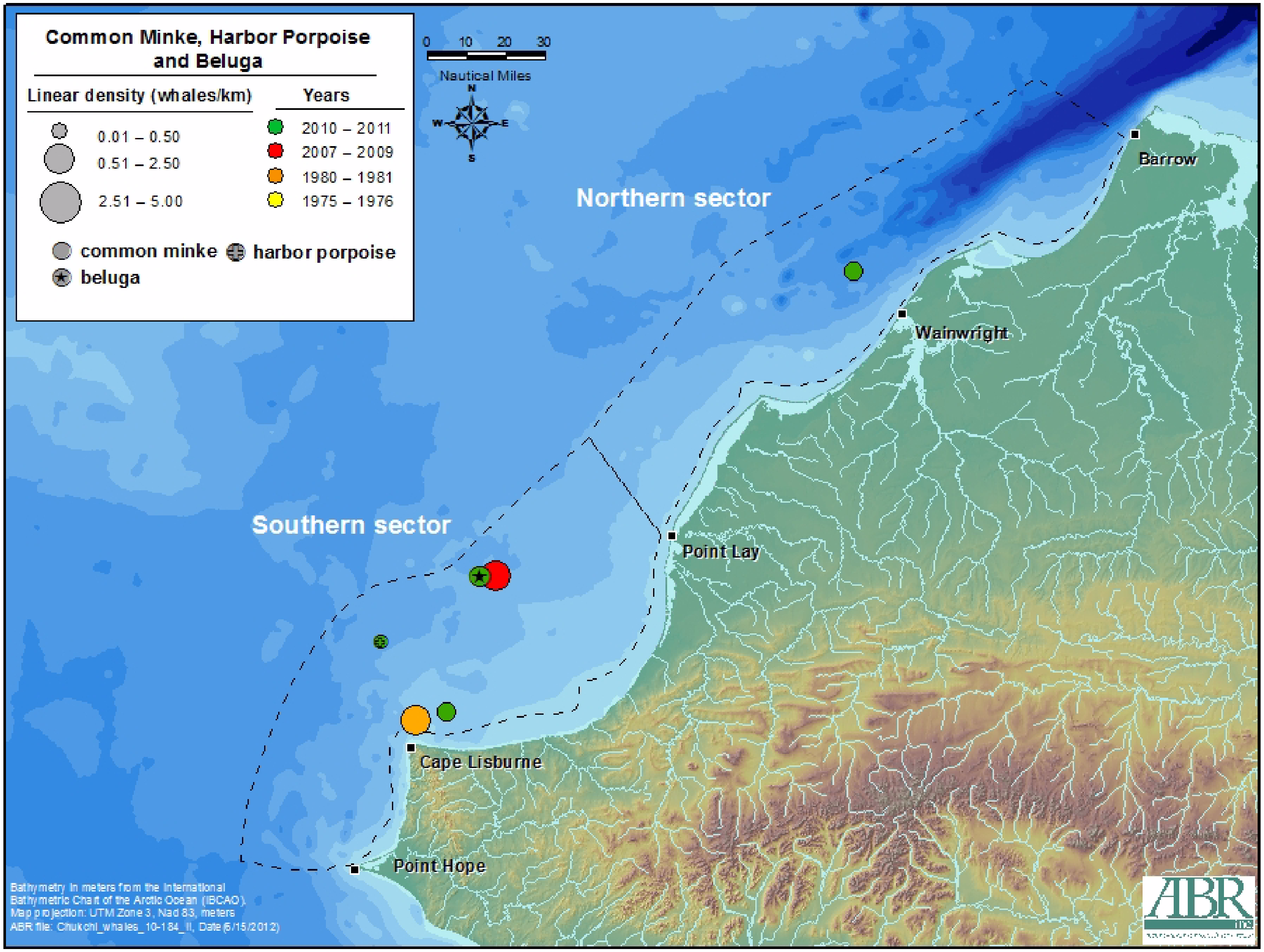

Figure 24. Distribution of pelagic-feeding whales in the AKMAP study area, 1975–2011. Historical data are from the NPPSD and probably represent only opportunistic observations.

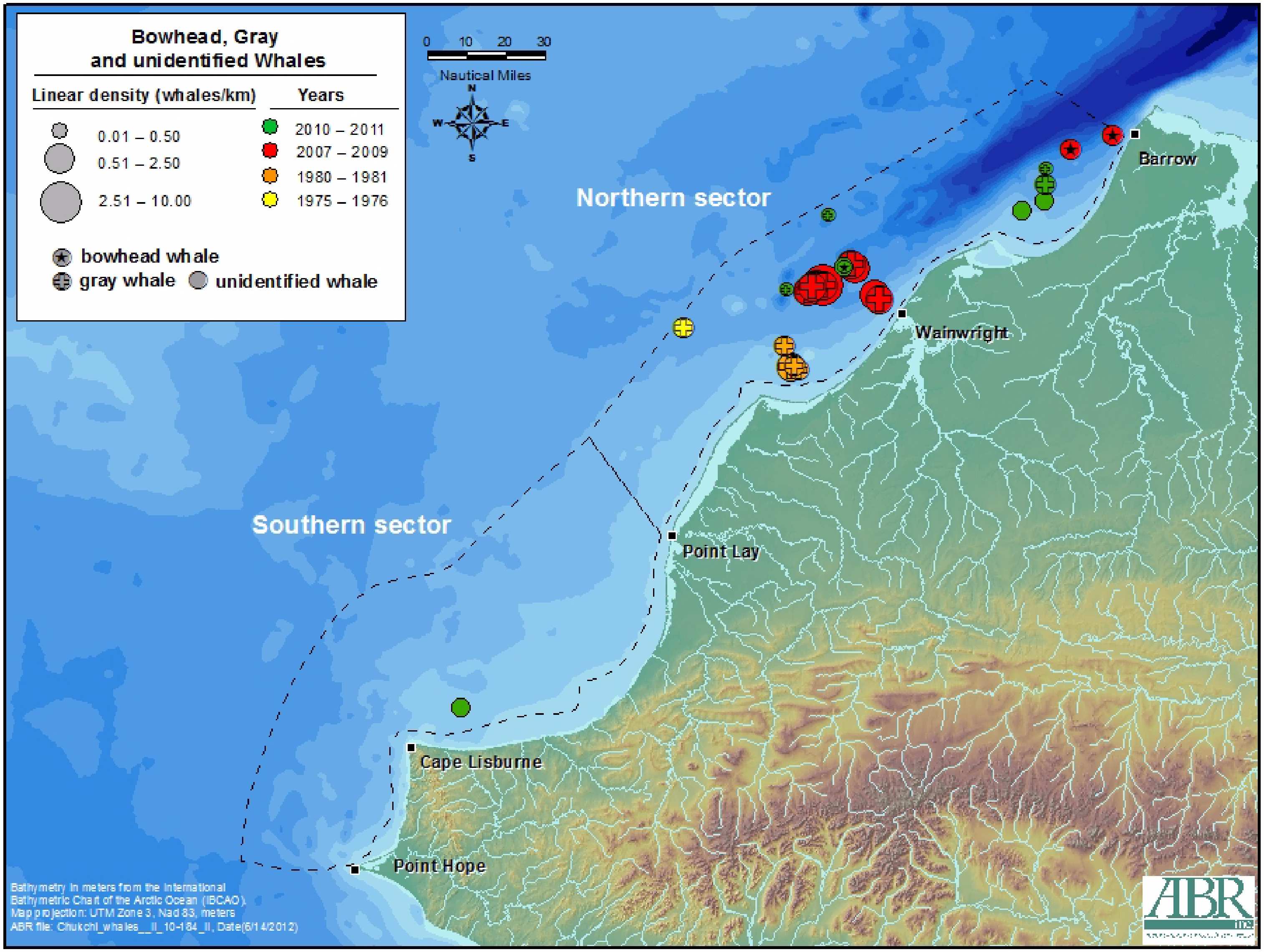

Figure 25. Distribution of benthic-feeding whales in the AKMAP study area, 1975–2011. Historical data are from the NPPSD and probably represent only opportunistic observations.

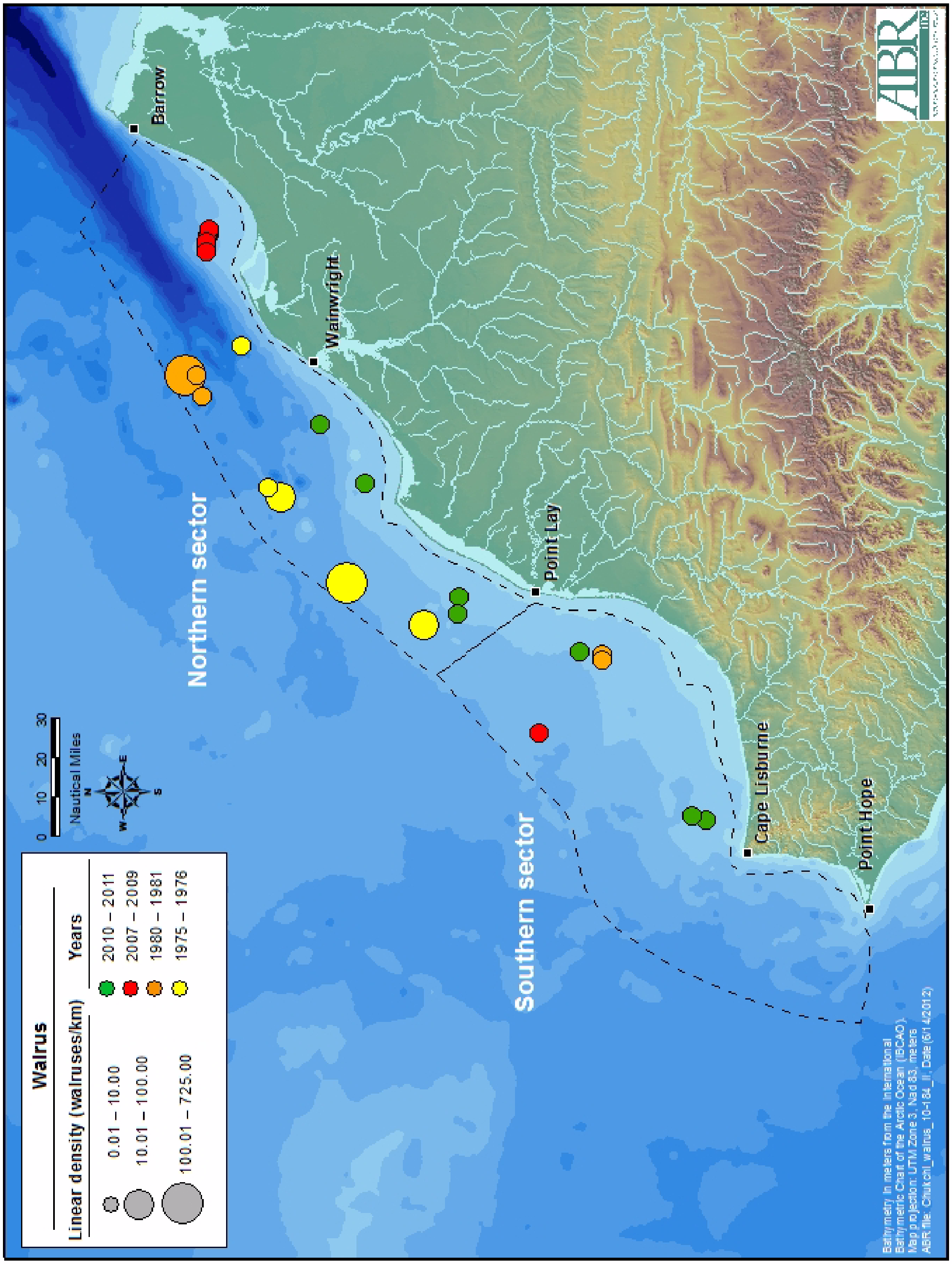

Figure 26. Distribution of walruses in the AKMAP study area, 1975–2011. Historical data are from the NPPSD and probably represent only opportunistic observations.

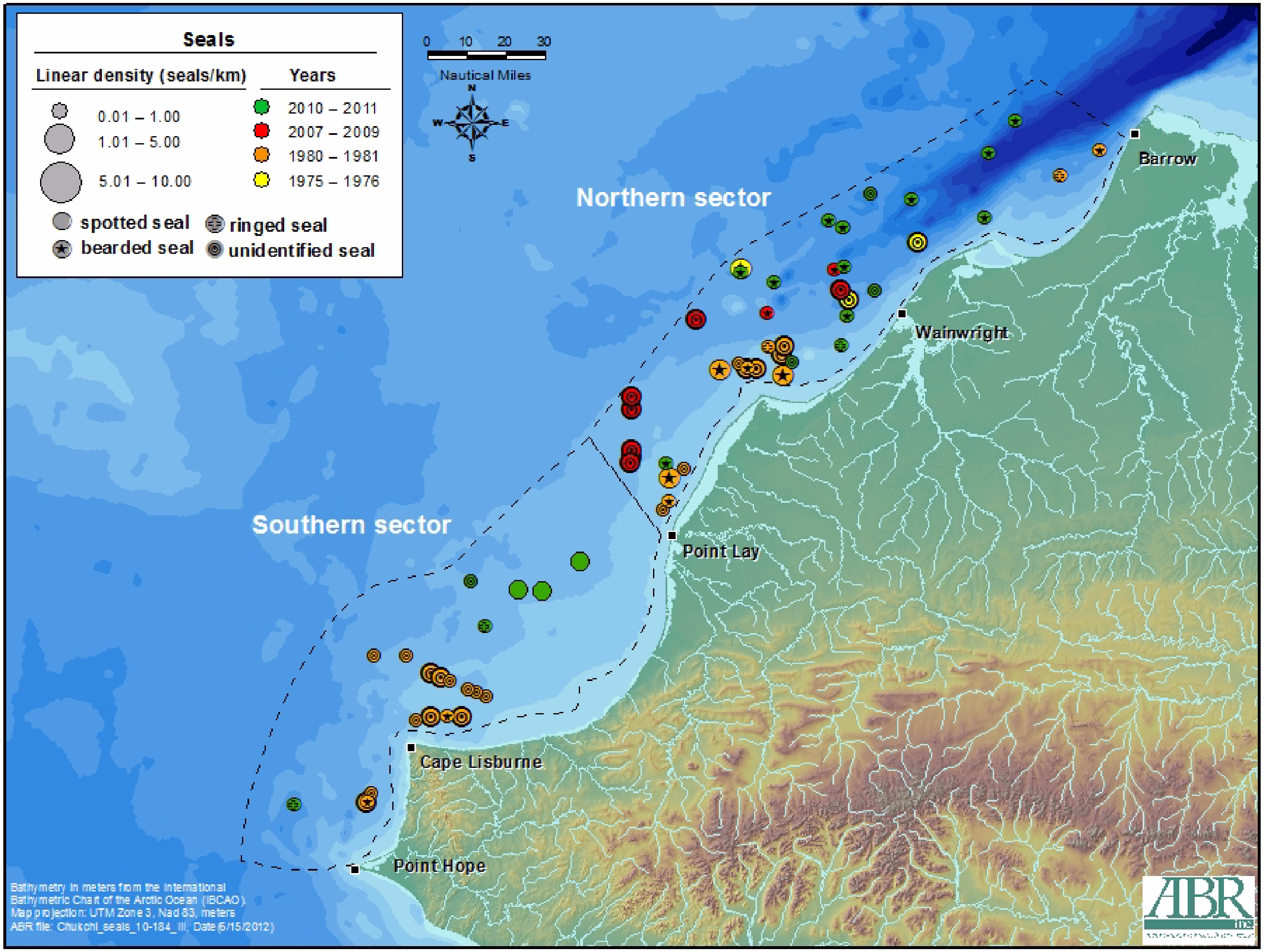

Figure 27. Distribution of seals in the AKMAP study area, 1975–2011. Historical data are from the NPPSD and probably represent only opportunistic observations.

(Figure 6). Historical cruises in most years partially overlapped temporally with the AKMAP study (Figure 6). However, cruises in 2007 extended into the middle of October. The 2007 surveys were more likely to detect species that moved into the Chukchi Sea in late fall, such as Kittlitz's Murrelets, which were detected in high densities near Barrow Canyon in October 2007. Surveys during 1975, 1976, 2008, and 2009 largely targeted the late-summer community, which would consist of early migrants and summer residents, such as migrating eiders and breeding Black-legged Kittiwakes and murres. Surveys conducted in 1980 and 1981 entirely overlapped with the AKMAP time period.

COMMUNITY COMPOSITION

Seabirds

Thirty-eight bird species were recorded within the AKMAP study area between 1975 and 2009. Species richness was highest in 1980 and lowest in 2008. Species recorded during historical surveys but not in the present study included White-winged Scoter, Black Scoter, Ross's Gull, Ivory Gull, Thayer's Gull, Glaucous-winged Gull, Dovekie, Black Guillemot, and Pigeon Guillemot (Table 6). Ancient Murrelets were detected during the AKMAP study but not during historical surveys.

Species composition of the seabird community differed among sectors (Figure 8) and years (Figure 28). Surveys in 1970–1979 and 2000–2011 recorded fewer waterfowl than studies in 1980–1989 did, and the lowest proportion of tubenoses was recorded in the period 1970–1979 (Figure 28). The proportion of waterfowl was low during the AKMAP study, whereas the proportion of tubenoses (mostly Short-tailed Shearwater) was higher than in previous decades.

Marine Mammals

There were 66 historical records of marine mammals available in the NPPSD. These observations probably reflect data collected opportunistically during seabird surveys. Hence, they should not be taken to represent the distribution and abundance of marine mammals in this area during the respective time periods. These data are, however, useful for obtaining a general idea of species composition and identifying areas where marine mammals occurred historically.

Between 1975 and 2009, the southern sector was dominated numerically by seals (Figure 9). In contrast, 92% of the individuals recorded in the northern sector between 1975 and 2009 were walruses (Figure 9). Gray whales historically were the second most abundant species in the northern AKMAP sectors.

The numerically dominant species for both of the sectors was reversed from that of historical studies (Figure 9). During the present study, the southern sector was numerically dominated with walruses, and the northern sector was numerically dominated by seals (predominately bearded seals).

DISTRIBUTION AND ABUNDANCE

We produced maps of uncorrected transect densities for each species detected on-transect in the AKMAP study area. Overall density estimates for each study period are presented in Table 6. Although tracklines and data-collection methodologies differed among studies, we can describe patterns in distribution and abundance over time for the common seabirds.

Waterfowl

Waterfowl densities recorded in the AKMAP study area have been highly variable during the last 36 years, with the highest densities recorded in 1980. Three species of eiders have been recorded within the AKMAP study area: Common, King, and Spectacled eiders. In both 2010 and 2011, we recorded low densities of eiders, similar to densities recorded in 2007–2009. In 2011, we recorded similar densities of eiders as in 2010, but we also recorded Long-tailed Duck densities similar to those seen in 1975–1979 and 2007–2009 (Figure 11, Table 6).

Loons

Arctic Loons were recorded in 1975 and 1980, whereas Pacific Loons were recorded in 2007, 2010, and 2011. In 1998, the American Ornithologist Union split the Arctic Loon into the Palearctic Arctic Loon (*Gavia arctica*) and the Nearctic Pacific Loon (*G. pacifica*; AOU 1998), so the difference in species recorded between the two periods probably reflects this taxonomic change (i.e., we believe that all of the records are of Pacific Loons). Pacific Loons were the most abundant

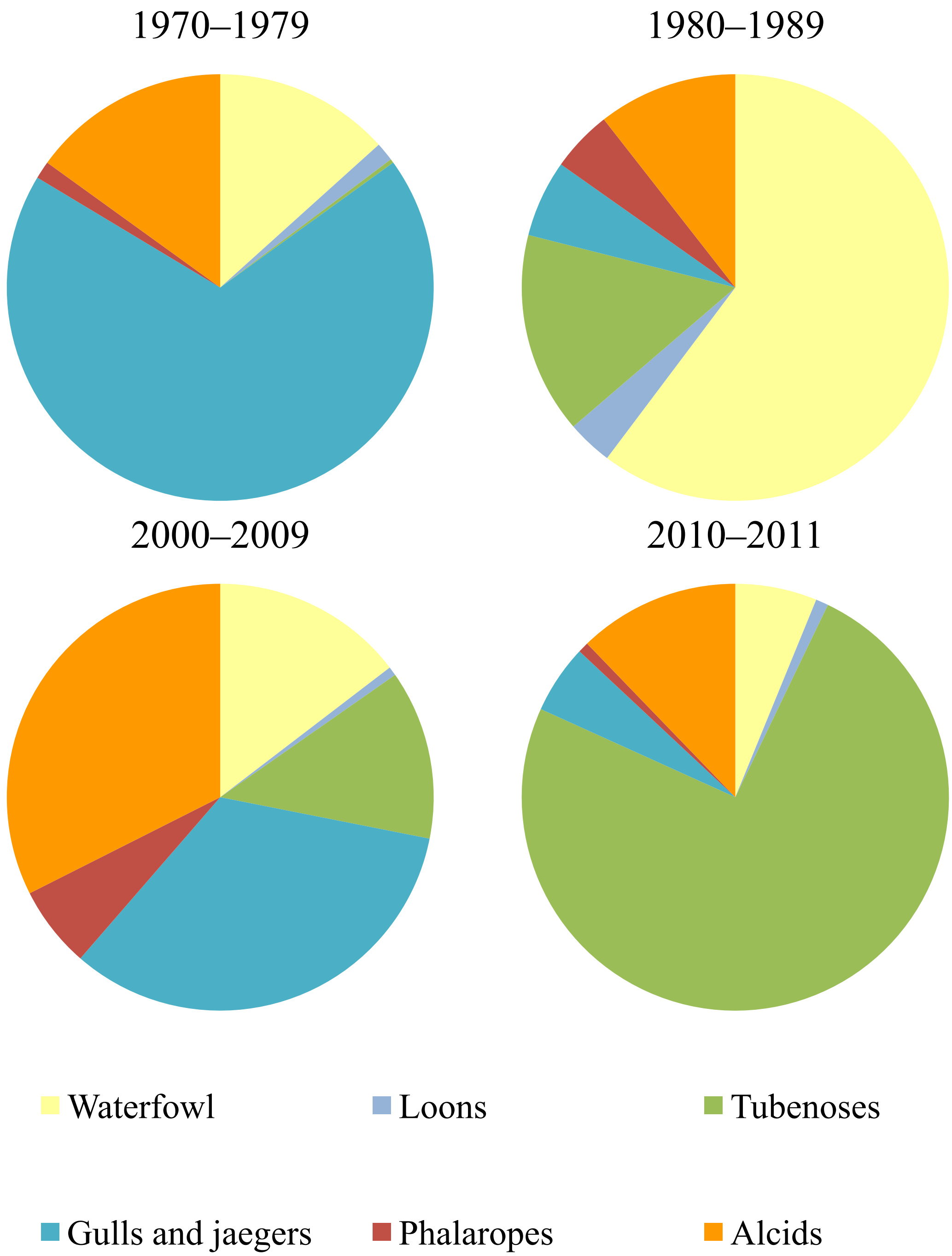

Figure 28. Marine-bird species-composition in the AKMAP study area, 1975–2011.

loon species (Figure 12). Several Common Loons were recorded off-transect in 1980; however, this species should be considered extremely rare in the Chukchi Sea (Bailey 1948; Swartz 1966, 1967; Divoky 1987), and it has not been recorded in the Chukchi Sea in the NPPSD database. We suspect that most of these records are misidentifications of Yellow-billed Loons or possibly Pacific Loons. Overall loon density was highest during the period 1980–1989 and lowest during the period 2000–2009.

Tubenoses

Short-tailed Shearwaters density was higher during the AKMAP study than during historical studies, although Short-tailed Shearwater densities also were high during the period 1980–1989 (Table 6). Their spatial distribution was highly variable among years, with no clearly identifiable or consistent “hot spots” of occurrence (Figure 13). Northern Fulmars were observed throughout both sectors in most years, with the highest densities occurring in 2007–2009 (Figure 14, Table 6).

Phalaropes

Phalaropes were recorded in all years, primarily between the 25-m and 45-m isobaths west of Cape Lisburne; This is an area with strong thermal gradients and fronts that are generated as the Alaska Coastal Current passes the Lisburne Peninsula. Phalaropes generally occur in spatially clumped large flocks, resulting in spatially sporadic high densities (Figure 15).

Gulls, terns, and jaegers

Both Black-legged Kittiwakes and Glaucous Gulls were recorded in all years. Black-legged Kittiwakes were widely distributed and recorded in high densities (Figure 16), although their densities during the AKMAP study were generally lower than those recorded during historical studies (Table 6). Glaucous Gulls were widely distributed (Figure 17); the highest density was recorded during the period 1970–1979.

Arctic Terns were recorded in 1976, 2007, 2010, and 2011. During historical surveys, they were recorded near Point Hope and the mouth of Barrow Canyon (Figure 18). During this study, we recorded them closer to known breeding locations near Point Lay and Icy Cape; however, they were recorded in low densities in all studies (Table 6).

Both Pomarine and Parasitic jaegers were recorded in all periods but not all years, with Pomarine Jaegers consistently recorded in higher densities than Parasitic Jaegers (Figure 19, Table 6). Long-tailed Jaegers were recorded in low densities in all periods (Table 6)

Alcids

In all periods, murres had the highest densities of all alcids, although their distribution and abundance differed among periods (Figure 20). We recorded lower densities of Thick-billed Murres in 2010–2011 than previous studies; however, we recorded densities of Common Murre as similar to those in previous studies (Table 7). Murre distribution in the southern AKMAP sector was concentrated farther to the north than had been recorded in previous years, whereas the distribution in the northern sector largely matched the pattern recorded during historical studies.

Crested Auklet densities were highest during the 1980–1989 period followed by the 2007–2009 period (Figure 21, Table 6). Parakeet Auklets were recorded in all periods, but densities were low in all years (Table 6); they occurred primarily in waters >35 m deep (Figure 21).

In all years, the highest densities of Horned Puffins were recorded within 25 km of known breeding colonies, which occur as far north as Cape Lisburne; they infrequently were seen beyond that range. Tufted Puffins showed a distribution similar to that of Horned Puffins but occurred in lower densities than those of Horned Puffins (Figure 22).

The highest densities of Kittlitz’s Murrelets were recorded in early October 2007 along the edge of Barrow Canyon. During the present study, we recorded the highest density of Kittlitz’s Murrelet in the northern AKMAP sector (Figure 23), with low densities recorded near Barrow Canyon.

DISCUSSION

COMMUNITY COMPOSITION

SEABIRDS

The Chukchi Sea nearshore zone has a shifting assemblage of at least 38 species of seabirds that migrate through or breed in it. During this study, the bird community was dominated numerically by planktivorous Short-tailed Shearwaters, which are near-surface-feeders that use the Chukchi Sea for foraging during their non-breeding season. (They breed in the Southern Hemisphere.) Their presence in the AKMAP study area suggests high abundance of zooplankton, especially euphausiids, near the water's surface (Hunt et al. 1996).

Alcids, gulls, and waterfowl also were present in the AKMAP study area, but their densities were considerably lower than those of shearwaters. Many alcid and gull species, such as murres, puffins, and kittiwakes breed along the shoreline bordering the AKMAP study area as far north as Cape Lisburne; nesting cliffs disappear farther north of those colonies. These species generally use Chukchi Sea nearshore waters during the breeding season, but numbers in the AKMAP study area may fluctuate coincident with the timing of migration and possibly breeding success (i.e., failed-breeders and non-breeders can range father than can birds that are tied to breeding colonies). The timing of both our 2010 and 2011 surveys occurred post-fledging for the majority of species known to breed in this area. Thus, the community composition captured during this study reflects the transition from breeding populations to transient species.

MARINE-MAMMALS

During this study, we recorded 8 species of marine mammals commonly encountered in the northeastern Chukchi Sea in the summer and fall. Belugas, bowheads, spotted seals, and walruses are common in this region during the fall (Johnson et al. 1967; Fay 1982; Frost et al. 1983; Huntington et al. 1999; Christman et al. 2011), whereas harbor porpoises, gray whales, and common minke whales typically summer in the Chukchi Sea and migrate south prior to the arrival of more ice-adapted species (Johnson et al. 1967). The timing of our research cruises coincided with this seasonal shift in the marine-mammal community of the Chukchi Sea nearshore zone, a shift that reflects the timing of seasonal changes in the environment. In the Chukchi Sea, the most prominent environmental change in the summer and fall is the timing of formation of sea ice, which pushes summering species southward and influences the timing of arrival of ice-adapted species. During the August 2010 surveys, we recorded primarily summering species in the Chukchi Sea. In contrast, during the September 2011surveys, we recorded a greater proportion of fall and ice-related species. Hence, it appears that the later timing of the 2011 surveys enabled us to capture a slightly later stage of the seasonal shift in marine-mammal community composition.

SPECIES OF CONSERVATION CONCERN

Several seabird species of conservation concern inhabit the Chukchi Sea nearshore zone for some portion of the year (Johnson et al. 1993; Petersen et al. 1999; Day et al. 2011); three of them were recorded during this study. The three species of conservation concern are from three separate taxa, exhibit different foraging behaviors, and forage on different prey resources. Understanding the relationships between each species' distribution and habitat characteristics in the Chukchi Sea nearshore zone will be important for making good management decisions about these species.

Ledyard Bay is considered Critical Habitat for Spectacled Eiders (Federal Register 2001), which we recorded in low numbers during this study both within (off-transect) and outside of Ledyard Bay (on-transect). Steller's Eiders presumably also use the AKMAP study area during their southward migration from breeding grounds (Quakenbush et al. 2002; OASIS 2008) but were not recorded during this study.

Kittlitz's Murrelets have also been recorded in the Chukchi Sea nearshore zone (Day et al. 2011). The temporal and spatial variation in Kittlitz's Murrelet distribution in the Chukchi Sea nearshore zone makes it difficult to ascertain key components of the ecosystem that may be important to this species. We recorded much higher densities of Kittlitz's Murrelets in 2011 than in 2010; this difference may reflect annual, spatial, and/or seasonal differences in abundance.

In addition to Kittlitz's Murrelets and Spectacled Eiders, we also recorded several Yellow-billed Loons. Bailey (1948) recorded large numbers of Yellow-billed Loons along the Chukchi Sea coastline, Johnson et al. (1993) recorded low densities of them in Kasegaluk Lagoon, and they regularly are seen in summer in Wainwright

Lagoon (Day, pers.obs.); however, this species has not been recorded within the study area during recent boat-based surveys.

DISTRIBUTION AND ABUNDANCE

The greatest diversity of seabird species was found near Cape Lisburne, indicating that this area is important through the early fall for several species of breeding and migrating birds. Large colonies of breeding Common and Thick-billed murres are found at and near Cape Lisburne. These colonies have been part of the Alaska Seabird Monitoring Program for several decades and continue to support some of the largest murre populations in Alaska (Dragoo et al. 2008). During the last 10 years, the number of breeding murres at Cape Lisburne has increased, whereas colonies farther south at Cape Thompson have decreased (Dragoo et al. 2008). Fadely et al. (1989) recorded a difference in foraging directions for murre colonies at Cape Lisburne and Cape Thompson that may be associated with these differences in population trends and productivity between the two colonies (Hatch et al. 2000). Fadely et al. (1989) also found a positive association between murre foraging locations in this area and fish biomass at depths of 10–20 m. The relationship between murre densities and fish biomass described by Fadely probably is influenced by water-column structure, in that both murre density and fish biomass were highest in areas with low vertical temperature and salinity gradients (i.e., weak stratification). As murres spread out from foraging areas near Cape Lisburne, other environmental characteristics may influence their foraging distribution. In this study, we found Common Murres in highest abundance in areas of warm SST and more Thick-billed Murre in areas where the horizontal gradients in SST were highest. Warm SSTs are characteristic of ACW, whereas a strong thermal gradient in SST may indicate a front between the warm ACW and the colder, more productive BSW. The difference in distribution between these two species may reflect differences in foraging techniques as well as preferred prey items. Although similar ecologically, Common and Thick-billed murres often forage on different resources. Common Murre are detected in large and sometimes mixed foraging groups more frequently than Thick-billed Murres are (Sealy 1973; Hoffman et al. 1981; Hunt et al. 1988) and prey on pelagic schooling fish. In contrast, Thick-billed Murres target demersal prey such as crustaceans and sculpins more frequently than Common Murres do (Dragoo et al. 2012).

Black-legged Kittiwakes and Glaucous Gulls are common breeders along the Chukchi Sea coast, with the former concentrating at cliffs near the Cape Lisburne complex and the latter nesting in low numbers and in a variety of habitats throughout the region (Swartz 1966, 1967; Johnson et al. 1993; Dragoo et al. 2012). At the time of the 2010 surveys, Black-legged Kittiwakes were still rearing young. Breeding Black-legged Kittiwakes near Cape Lisburne tend to forage close to their breeding colonies, where zooplankton and forage fishes such as arctic cod concentrate (Bradstreet 1982; Fadely et al. 1989).

Black-legged Kittiwake abundance near Cape Thompson was positively associated with strong thermohaline gradients (Fadely 1989), suggesting that Black-legged Kittiwakes rely on pycnoclines to concentrate food resources in the upper portion of the water column. Similarly we found the highest abundance of Black-legged Kittiwakes in areas where the depth of the upper mixed layer (distance to the top of the pycnocline) was 7–20 m. Pycnoclines occurring at these depths may concentrate small prey items, allowing access to higher densities of prey than would be accessible if they were distributed throughout the water-column.

Glaucous Gulls are omnivores that take a wide spectrum of prey, including birds, bird eggs, and rodents from land and fishes and zooplankton at sea (Gilchrist 2001). When foraging at sea, they typically are solitary, except when they detect large prey concentrations (Gilchrist 2001). On two occasions, we recorded large numbers of Glaucous Gulls near concentrations of Black-legged Kittiwakes, suggesting that high densities of prey were available for both species at these locations. Despite the fact that both Black-legged Kittiwakes and Glaucous Gulls are surface-feeders, their difference in diet may influence associations with environmental gradients. Glaucous Gulls did not show the same positive association with pycnoclines as Black-legged Kittiwakes did and instead were negatively associated with horizontal

SST gradients (i.e., oceanographic fonts). Hence Glaucous Gulls apparently prefer to forage within areas of mixed water or within a single water-mass.

Short-tailed Shearwaters, phalaropes, and Northern Fulmars are surface- or near-surface-feeders that target oceanographic fronts and areas of upwelling (Harrison et al. 1990; Day 1992). Of these three taxa, phalaropes and Northern Fulmars are limited to foraging at the water's surface, so they are closely tied to microscale divergent (upwelling) fronts that bring small prey items to the surface or convergent fronts that concentrate small prey there. In contrast, shearwaters may dive for their food (Burger 2001; Shaffer et al. 2006), so they can use mesoscale fronts that extend to the ocean bottom and concentrate prey in upper water layers (Hatch and Nettleship 1998; Rubega et al. 2000; Tracy et al. 2002). Divoky and Springer (1988) found Short-tailed Shearwaters where ACW and BSW waters abutted, and suspected upwelling was concentrating zooplankton near the surface, whereas we found Short-tailed Shearwaters to be most abundant where the depth to the pycnocline was 5–15 m. Short-tailed Shearwaters can plunge into the water-column to retrieve prey concentrated at these depths (Burger 2001; Shaffer et al. 2006).

COMPARISON WITH HISTORICAL DATA

Comparisons between the present study and historical data provided an interesting look at changes in abundance and species composition in the Chukchi Sea nearshore zone; however, there are a few caveats to consider when drawing conclusions from these comparisons. Seabird populations naturally are stochastic and vary spatially and temporally within and among years. In addition, the timing of migration can strongly influence the number of individuals observed within a given time period (e.g., a short research cruise), as can temporally and spatially changing foraging conditions. Without standardizing timing, sampling effort, and survey methodology, it can be difficult to conclude with confidence apparent temporal changes in abundance and density from natural variability in the ecosystem; thus, results need to be interpreted cautiously.

COMMUNITY COMPOSITION

Between historical studies in 1975−1981 and recent studies in 2007−2011, the avian community in the Chukchi Sea nearshore zone shifted from a largely waterfowl-dominated system to a system dominated by planktivorous Short-tailed Shearwaters: we recorded a much greater percent composition of Short-tailed Shearwaters in both years of this study than previous studies had. Overall, this shift is apparent in a greater percent composition of Short-tailed Shearwaters in 1980–1989, 2000–2009, and the present study than in 1970–1979. The pattern of decline in percent composition of waterfowl in the Chukchi Sea nearshore zone shows greater variability between studies and years than that of shearwaters. However, the shift in community composition that we observed parallels changes observed farther offshore in the northeastern Chukchi over a similar period; that area also has switched to a planktivore-dominated system that consists primarily of shearwaters and auklets (Gall and Day 2011).

Another reason for this change in species composition in the Chukchi Sea nearshore zone may be because the abundance of seaducks, and especially eiders, has changed. Suydam et al. (2000) reported >50% declines in numbers of King and Common eiders migrating past Barrow, Alaska, between 1975 and 1996, and Dau and Bollinger (2009) recorded lower breeding numbers of Common Eiders at Kasegaluk Lagoon in recent years than on historical surveys.

DISTRIBUTION AND ABUNDANCE

During historical surveys in 1970, eiders and Long-tailed Ducks occurred in large flocks near Barrow, Wainwright, and Point Lay and in smaller flocks near Cape Lisburne during late fall (Watson and Divky 1970). Since then, waterfowl densities recorded in the AKMAP study area have been highly variable, with the highest eider densities recorded in 1980 and the highest Long-tailed Duck densities recorded in 1981. We recorded low densities of eiders in 2010 and did not record any other ducks, resulting in low overall densities of waterfowl in the AKMAP study area that year. In 2011, we recorded both eiders and Long-tailed Ducks. Because the timing of arrival and departure of eiders in the area can vary from year to year

(Petersen and Flint 2002; Oppel et al. 2008), this difference in density may reflect seasonal, annual, or long-term changes in abundance. When surveys are conducted over varying time frames, as in our comparison to historical studies, seasonal patterns of use may confound apparent changes in species composition; however, because eider population numbers in northern Alaska have declined in recent years (Suydam et al. 2000; Quakenbush et al. 2002; Dau et al. 2009), the low densities observed during this study likely reflect at least the overall decline in the number of eiders using this area for molting and staging.

Murre species can be difficult to distinguish at sea, so it can be difficult to ascertain species-specific population trends for Common and Thick-billed murres; however, Thick-billed Murres are overwhelmingly the more abundant species in the Chukchi Sea. During this study, Thick-billed Murre densities were lower than densities recorded historically; however we also must consider unidentified murres in this comparison. The density of unidentified murres in the AKMAP study area in 2010–2011 also was lower than the density reported for 1975–2009. Low density estimates for both Thick-billed and unidentified murres would suggest a decline in Thick-billed Murres in the Chukchi Sea nearshore zone. This decline seen in the Chukchi Sea is consistent with a decline in Thick-billed Murre populations in the Bering Sea (Dragoo et al. 2012).

The two most common gull species in the Chukchi Sea nearshore zone are Black-legged Kittiwake and Glaucous Gull both of which had lower densities in 2010–2011 than 1975–2009. Lower densities may reflect seasonal shifts in abundance and/or changes in population numbers. Black-legged Kittiwake populations have shown steady breeding population numbers in the Chukchi Sea through 2009 (Dragoo et al. 2012). Lower at-sea densities recorded during this study than in historical studies may reflect the timing of research cruises coinciding with seasonal movements, a shift in foraging location, and/or recent declines in population numbers. In the Pribilofs, surface-feeders such as kittiwakes showed a negative response to oceanographic changes before species that forage deeper in the water column (Byrd et al. 2008). Similar oceanographic changes in the Chukchi Sea may influence abundance and spatial distribution of Black-legged Kittiwakes in the Chukchi Sea nearshore zone.

Short-tailed Shearwaters were much more widely distributed during this study than in previous studies, which recorded a largely patchy distribution of shearwaters. The distribution of predators can reflect the distribution and abundance of prey resources, so the more extensive distribution of Short-tailed Shearwaters during this study than in previous surveys suggests that substantial densities of zooplankton were widely distributed over the entire AKMAP study area.

REGIONAL PERSPECTIVE

In the winters of 1977 and 1989, the North Pacific Ocean (including the Bering and Chukchi seas) underwent a regime shift (Hare and Mantua 2000). Associated with changes in physical oceanography were shifts in apex-predator communities (Anderson and Piatt 1999; Benson and Trites 2002). In the Gulf of Alaska, walleye pollock (*Theragra chalcogramma*) replaced fishes with higher fat content in the diet of seabirds during the 1980s, resulting in a reduction in populations of piscivorous seabirds (Piatt and Anderson 1996). In the Bering Sea, the abundance of zooplankton and some demersal fishes also decreased after the 1989 regime shift (Hare and Mantua 2000). Planktivorous seabirds were more common in the Chukchi Sea offshore zone in 2008–2010 than during historical studies (Gall and Day 2011), an increase that parallels a similar increase in the nearshore waters. In the Chukchi Sea nearshore zone, species composition was dominated numerically by waterfowl in 1975–1981, whereas shearwaters and murres dominated numerically in 2000–2009 and 2010–2011. Short-tailed Shearwaters are planktivorous, and murres forage extensively on euphausiids at times (Roseneau et al. 2000). Hence, the presence of plankton-feeding shearwaters in high numbers in recent years suggests a shift in the prey community composition for this area on either a seasonal or larger scale.

CONCLUSIONS

The Chukchi Sea nearshore zone supports a diverse assemblage of migrating and breeding birds and mammals during late summer to early fall. The suite of species that make up this assemblage is consistently composed of Common and Thick-billed murres, Horned Puffins, Black-legged Kittiwakes, and Glaucous Gulls, all of which breed in the area. Transient birds such as Short-tailed Shearwaters show more interannual variability than breeding birds do, possibly reflecting differences in the timing of migration and/or responses to oceanographic conditions. The shifts in community composition and abundance that we observed in the AKMAP study area parallel changes in community composition and abundance in other parts of the northeastern Chukchi Sea.

The Chukchi Sea nearshore zone is of particular importance for several species of conservation concern. Of these species, walruses use the area during migration and increasingly have been observed hauled out on land between Icy Cape and Cape Lisburne. We also recorded both Kittlitz's Murrelets and Yellow-billed Loons during this study, highlighting the need for further exploration of the temporal and spatial habitat use of these species in the Chukchi Sea nearshore zone. Spectacled Eiders were recorded in low numbers, which we attribute to a shift in community composition in the Chukchi Sea nearshore zone and, at least in part, to an overall decline in eider populations in northern Alaska and a shift in community composition in the Chukchi Sea nearshore zone.

LITERATURE CITED

Aerts, L.A.M., A. Kirk, C. Schudel, K. Lomac-Macnair, A. McFarland, P. Seiser and B. Watts. 2010. Marine mammal distribution and abundance in the northeastern Chukchi Sea, July–October 2010. Report prepared for ConocoPhillips Company, Anchorage, AK, Shell Exploration and Production Company, Anchorage, AK, and Statoil USA E & P, Inc., Anchorage, AK, by OASIS Environmental, Inc., Anchorage, AK. 74 pp.

Allen, B. M., and R. P. Angliss. 2010. Alaska marine mammal stock assessments, 2009. National Marine Mammal Laboratory, Seattle, WA. 276 pp.

Anderson, P. J., and J. F. Piatt. 1999. Community reorganization in the Gulf of Alaska following ocean climate regime shift. Marine Ecology Progress Series 189: 117–123.

Bailey, A. M. 1948. Birds of Arctic Alaska. Colorado Museum of Natural History, Denver, CO. Popular Series, No. 8. 317 pp.

Bengtson, J. L., L. M. Hiruki-Raring, M. A. Simpkins, and P. L. Boveng. 2005. Ringed and bearded seal densities in the eastern Chukchi Sea, 1999-2000. Polar Biology 28: 833-845.

Benson, A. J., and A. W. Trites. 2002. Ecological effects of regime shifts in the Bering Sea and eastern North Pacific Ocean. Fish and Fisheries 3: 95–113.

Bockstoce, J. R., and D.B. Botkin. 1982. The harvest of Pacific walrus by the pelagic whaling industry, 1848 to 1914. Arctic and Alpine Research 14: 183–188.

Bockstoce, J. R., and D. B. Botkin. 1983. The historical status and reduction of the Western Arctic bowhead whale (*Balaena mysticetus*) population by the pelagic whaling industry, 1848–1914. International Whaling Committee, Special Issue 5: 107–141.

Bockstoce, J. R., and J. J. Burns. 1993. Commercial whaling in the North Pacific sector. Pp. 563–577 *in* J. J. Burns, J. J. Montague, and C. J. Cowles, editors. The bowhead whale. Society of Marine Mammalogists, Special Publication No. 2.

Bockstoce, J. R., D. B. Botkin, A. Philp, B.W. Collins, and J. C. George. 2005. The geographic distribution of bowhead whales (*Balaena mysticetus*) in the Bering, Chukchi, and Beaufort seas: evidence from whaleship records 1849–1914. Marine Fisheries Review 67: 1–43.

Bradstreet, M. S. W., and W. Cross. 1982. Trophic relationships at high arctic ice edges. Arctic 35: 1–13.

Braham, H. W., M. A. Fraker, and B. D. Krogman. 1980. Spring migration of the Western Arctic population of bowhead whales. Marine Fisheries Review 42: 36–46.

Braham, H. W., J. J. Burns, G. A. Fedoseev, and B. D. Krogman. 1984a. Habitat partitioning by ice-associated pinnipeds: distribution and density of seals and walruses in the Bering Sea, April 1976. Pp. 25–47 *in* F. H. Fay and G. A. Fedoseev, editors. Soviet–American cooperative research on marine mammals. Volume 1: Pinnipeds. NOAA Technical Report NMFS 12.

Braham, H. W., B. D. Krogman, and G. M. Carroll. 1984b. Bowhead and white whale migration, distribution, and abundance in the Bering, Chukchi, and Beaufort seas, 1975–1978. NOAA Technical Report NMFS SSRF-778. 48 pp.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press, Oxford, United Kingdom. 432 pp.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2004. Advanced distance sampling: estimating abundance of biological populations. Oxford University Press, Oxford, United Kingdom. 416 pp.

Burger, A. E. 2001. Diving depths of shearwaters. Auk 118: 755–759.

Burn, M. D., M. S. Udevitz, S. G. Speckman, and R. B. Benter. 2009. An improved procedure for detection and enumeration of walrus signatures in airborne thermal imagery. International Journal of Applied Earth Observation and Geoinformation 11: 324–333.

Burns, J. J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi seas. Journal of Mammalogy 51: 445–454.

Burns, J. J. 1981. Ribbon Seal—*Phoca fasciata*. Pp. 89–109 *in* S. H. Ridgeway and R. J. Harrison, editors. Handbook of marine mammals. Volume 2: Seals. Academic Press, New York.

Burns, J. J., and G. A. Seaman. 1985. Investigations of belukha whales in the coastal waters of western and northern Alaska. II: Biology and ecology. Final report prepared for National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program (NOAA/OCSEAP), Anchorage, AK , by Alaska Department of Fish and Game, Fairbanks, AK. 129 pp.

Byrd, G. V., W. J. Sydeman, H. M. Renner, and S. Minobe. 2008. Responses of piscivorous seabirds at the Pribilof Islands to ocean climate. Deep-Sea Research (Part II) 55: 1856–1867.

Christman, C., M. Ferguson, G. Friedrichsen, B. Rone, and J. Clarke. 2010. Pacific walrus sightings documented by COMIDA aerial surveys of the northeastern Chukchi Sea in 2009. Poster presented at Alaska Marine Science Symposium, Anchorage, AK, January 2010.

Christman, C. M., A. Brower, M. Ferguson. S. Grassia, and J. Clarke. 2011. Pacific walrus sightings documented by COMIDA aerial surveys of the northeastern Chukchi Sea in 2010. Poster presented at Alaska Marine Science Symposium, Anchorage, AK, January 2011.

Clarke, J., M. Ferguson, L. Morse, F. Friedrichsen, B. Rone, and C. Christman. 2010. Aerial surveys for marine mammals in the northeastern Chukchi Sea: 2009. Poster presented at Alaska Marine Science Symposium, Anchorage, AK, Jan 2010.

Coachman, L. K., K. Aagaard, and R. B. Tripp. 1975. Bering Strait: the regional physical oceanography. University of Washington Press, Seattle, WA. 172 pp.

Comiso J. C., C. L. Parkinson, R. Gersten, and L. Stock. 2008. Accelerated decline in the arctic sea ice cover. Geophysical Research Letters 35: L01703. doi: 01710.01029/02007GL031972.

Dau, C. P., and K. S. Bollinger. 2009. Aerial population survey of Common Eiders and other waterbirds in near shore waters and along barrier islands of the Arctic Coastal Plain of Alaska, 1–5 July 2009. Unpublished report prepared by U.S. Fish and Wildlife Service, Anchorage, AK. 20 pp.

Day, R. H. 1992. Seabirds at sea in relation to oceanography. Ph.D. Thesis, University of Alaska, Fairbanks, AK. 135 pp.

Day, R. H., A. E. Gall, A. K. Prichard, G. J. Divoky, and N. A. Rojek. 2011. The status and distribution of Kittlitz's Murrelet (*Brachyramphus brevirostris*) in northern Alaska. Marine Ornithology 39: 47–57.

Delarue, J., B. Martin, X. Mouy, J. MacDonnell, D. Hannay, and N. E. Chorney. 2011. Chukchi Sea joint acoustics monitoring program 2009–2010. Report prepared for ConocoPhillips Company, Anchorage, AK, Shell Exploration and Production Company, Anchorage, AK, and Statoil USA E & P, Inc., Anchorage, AK, by JASCO Applied Sciences, Dartmouth, Canada. 222 pp.

Devlin, C. M., A. Diamond, S. W. Kress, C. S. Hall, and L. Welch. 2008. Breeding dispersal and survival of Arctic Terns (*Sterna paradisaea*) nesting in the Gulf of Maine. Auk 125: 850–858.

Divoky, G. J. 1981. Birds and the ice-edge ecosystem in the Bering Sea. Pp. 799–804 *in* D. W. Hood and J. A. Calder, editors. The eastern Bering Sea shelf: oceanography and resources. Volume 2. University of Washington Press, Seattle, WA.

Divoky, G. J. 1987. The distribution and abundance of birds in the eastern Chukchi Sea in late summer and early fall. Final report prepared for National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program (NOAA/OCSEAP), Anchorage, AK, by College of the Atlantic, Bar Harbor, ME. 96 pp.

Divoky, G. J., A. E. Good, T. L. McElroy, and L. E. Stenzel. 1980. The distribution, abundance, and feeding ecology of birds associated with pack ice. Environmental Assessment of the Alaskan Continental Shelf, Final Reports 1: 110–141. U.S. Department of Commerce, NOAA, Anchorage, AK.

Divoky, G. J., and A. M. Springer. 1988. Pelagic and coastal birds. Pp. 69–83 *in* M. J. Hameedi and A. S. Naidu, editors. The environment and resources of the southeastern Chukchi Sea. National Oceanic and Atmospheric Administration, Anchorage, AK.

Divoky, G. J., G. A. Sanger, S. A. Hatch, and J. C. Haney. 1988. Fall migration of Ross' Gull (*Rhodostethia rosea*) in Alaska('s?) [sic] Chukchi and Beaufort seas. Unpublished report prepared by U.S. Fish and Wildlife Service, Anchorage, AK. OCS Study No. MMS 88–0023. 120 pp.

Douglas, D. C. 2010. Arctic sea ice decline: projected changes in timing and extent of sea-ice in the Bering and Chukchi seas. U.S. U.S. Geological Survey, Reston, VA. Report No. 2010-1176. 32 pp.

Dragoo, D. E., H. M. Renner, and D. B. Irons. 2012. Breeding status, population trends, and diet of seabirds in Alaska, 2009. U.S. Fish and Wildlife Service, Homer, AK. Report No. AMNWR 2012/01. 108 pp.

Dragoo, D. E., J. C. Schneeweis, and D. W. Kuehn. 2011. Biological monitoring at Cape Lisburne, Alaska in 2011. U.S. Fish and Wildlife Service, Homer, AK. Report No. AMNWR 2011/13. 24 pp.

Dunton, H. K., J. L. Goodall, S. V. Schonberg, J. M. Grebmeier, and D. R. Maidment. 2005. Multi-decadal synthesis of benthic–pelagic coupling in the western Arctic: role of cross-shelf advection processes. Deep-Sea Research (Part II) 52: 3462–3477.

Egevang, C., and M. Frederiksen. 2011. Fluctuating breeding of Arctic Terns (*Sterna paradisaea*) in arctic and high-arctic colonies in Greenland. Waterbirds 34: 107–111.

Elphick, C. S., and G. L. Hunt, Jr. 1993. Variation in the distribution of marine birds with water masses in the northern Bering Sea. Condor 95: 33–44.

Fadely, B. S., J. F. Piatt, S. A. Hatch and D. G. Roseneau. 1989. Populations, productivity, and feeding habits of seabirds at Cape Thompson, Alaska. Final report prepared for Minerals Management Service, Anchorage, AK, by U.S. Fish and Wildlife Service, Anchorage, AK. Report No. MMS 89–0014. 429 pp.

Fay, F. H. 1982. Ecology and biology of the Pacific walrus, *Odobenus rosmarus divergens* Illiger. North American Fauna 74. 279 pp.

Fay, F. H., and G. A. Fedoseev, editors. 1984. Soviet–American cooperative research on marine mammals. Volume 1: Pinnipeds. NOAA Technical Report NMFS 12. 104 pp.

Feder, H. M., A. S. Naidu, S. C. Jewett, J. M. Hameedi, W. R. Johnson, and T. E. Whitledge. 1994. The northeastern Chukchi Sea: benthos-environmental interactions. Marine Ecology Progress Series 111: 171-190.

Frost, K. J., L. F. Lowry, and G. Carroll. 1993. Beluga whale and spotted seal use of a coastal lagoon system in the northeastern Chukchi Sea. Arctic 46: 8–16.

Gall, A. E., and R. H. Day. 2011. Distribution and abundance of seabirds in the northeastern Chukchi Sea, 2008–2010. Unpublished report prepared for ConocoPhillips Company, Anchorage, AK, Shell Exploration and Production Company, Anchorage, AK, and Statoil USA E & P, Inc., Anchorage, AK, by ABR, Inc.—Environmental Research & Services, Fairbanks, AK. 78 pp.

Garlich-Miller, J., J. G. MacCracken, J. Snyder, R. Meehan, M. Myers, J. M. Wilder, E. Lance, and A. Matz. 2011. Status review of the Pacific walrus (*Odobenus rosmarus divergens*). U.S. Fish and Wildlife Service, Anchorage, AK. 155 pp.

Gilchrist, H. G. 2001. Glaucous Gull (*Larus hyperboreus*). *In* A. Poole, editor. The birds of North America, No. 573. Birds of North America, Inc., Philadelphia, PA. 32 pp.

Gould, P. J., and D. J. Forsell. 1989. Techniques for shipboard surveys of marine birds. U.S. Fish and Wildlife Service, Technical Report No. 25. 22 pp.

Gradinger, R. 2008. Sea ice. Pp. 24–32 *in* R. Hopcroft, B. Bluhm, and R. Gradinger, editors. Arctic Ocean synthesis: analysis of climate change impacts in the Chukchi and Beaufort seas, with strategies for future research. Unpublished report prepared for North Pacific Research Board, Anchorage, AK, by University of Alaska, Fairbanks, AK.

Grebmeier, J. M., and L. W. Cooper. 1995. Influence of the St. Lawrence Island polynya upon the Bering Sea benthos. Journal of Geophysical Research 100: 4439–4460.

Grebmeier, J. M., L. W. Cooper, H. M. Feder, and B. I. Sirenko. 2006. Ecosystem dynamics of the Pacific-influenced northern Bering and Chukchi seas in the Amerasian Arctic. Progress in Oceanography 71: 331–361.

Hare, S. R., and N. J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography 47: 103–145.

Harrison, N. M., G. L. Hunt, Jr., and R. T. Cooney. 1990. Front affecting the distribution of seabirds in the northern Bering Sea. Polar Research 8: 29–31.

Hatch, S. A., and D. N. Nettleship. 1998. Northern Fulmar (*Fulmarus glacialis*). *In* A. Poole, editor. The birds of North America, No. 361. Birds of North America, Inc., Philadelphia, PA. 32 pp.

Hatch, S. A., P. M. Meyers, D. M. Mulcahy, and D. C. Douglas. 2000. Seasonal movements and pelagic habitat use of murres and puffins determined by satellite telemetry. Condor 102: 145–154.

Hobson, K. A., J. F. Piatt, and J. Pitocchelli. 1994. Using stable isotopes to determine seabird trophic relationships. Journal of Animal Ecology 63: 786–798.

Hoffman, W., D. Heinemann, and J. A. Wiens. 1981. The ecology of seabird foraging flocks in Alaska. Auk 98: 437–456.

Hopcroft, R., B. Bluhm, and R. Gradinger. 2008. Arctic Ocean synthesis: analysis of climate change impacts in the Chukchi and Beaufort seas with strategies for future research. Unpublished report prepared for North Pacific Research Board, Anchorage, AK, by University of Alaska, Fairbanks, AK. 184 pp.

Hunt, G. L., Jr., and D. C. Schneider. 1987. Scale-dependent processes in the physical and biological environment of seabirds. Pp. 7–41 *in* J. P. Croxall, editor. The feeding ecology of seabirds and their role in marine ecosystems. Cambridge University Press, Cambridge, United Kingdom.

Hunt, G. L., Jr., N. M. Harrison, W. M. Habber and B. S. Obst. 1988. Observations of a mixed-species flock of birds foraging on euphausiids near St. Matthew Island, Bering Sea. Auk 105: 345–349.

Huntington, H. P., the communities of Buckland, Elim Koyuk, Point Lay, and Shaktoolik. 1999. Traditional knowledge of the ecology of beluga whales (*Delphinapterus leucas*) in the eastern Chukchi and northern Bering seas, Alaska. Arctic 52: 49–61.

Huntington, H. P., and L. T. Quakenbush. 2009. Traditional knowledge of bowhead whale migratory patterns near Kaktovik and Barrow, Alaska. Unpublished report prepared for the Barrow and Kaktovik Whaling Captains Association, Barrow and Kaktovik, AK, and the Alaska Eskimo Whaling Commission, Barrow, AK. 13 pp.

Johnson, M. L., C. H. Fiscus, B. T. Ostenson, and M. L. Barbour. 1967. Marine mammals. Pp. 877–926 *in* N. J. Wilimovsky and J. N. Wolfe, editors. Environment of the Cape Thompson region. U.S. Atomic Energy Commission, Oak Ridge, TN.

Johnson, S. R., D. A. Wiggins, and P. F. Wainwright. 1993. Late-summer abundance and distribution of marine birds in Kasegaluk Lagoon, Chukchi Sea, Alaska. Arctic 46: 212–227.

Laidre, K. L., I. Stirling, L. F. Lowry, Ø. Wiig, M. P. Heide-Jørgensen, and S. H. Ferguson. 2008. Quantifying the sensitivity of arctic marine mammals to climate-induced habitat change. Ecological Applications 18 (Supplement): S97–S125.

Ladd, C., and J. E. Overland. 2009. Retrospective analysis of sea surface temperature in the northern Bering and Chukchi seas. Pacific Marine Environmental Laboratory, Seattle, WA. NOAA Technical Memorandum OAR PMEL–145. 17 pp.

Larned, W. W., and G. R. Balogh. 1997. Eider breeding population survey, Arctic Coastal Plain, Alaska, 1992–96. Unpublished report prepared by U.S. Fish and Wildlife Service, Anchorage, AK. 51 pp.

Lentfer, J. W., editor. 1988. Selected marine mammals of Alaska. U.S. Marine Mammal Commission, Washington, DC. 175 pp.

Lowry, L. F., K. J. Frost, and J. J. Burns. 1983. Trophic relationships among ice-inhabiting phocid seals and functionally related marine mammals in the Chukchi Sea. Environmental Assessment of the Alaskan Continental Shelf, Final Reports 19: 179–230. U.S. Department of Commerce, NOAA, Juneau, AK.

Magurran, A. E. and B. J. McGill. 2011. Biological diversity: frontiers in measurement and assessment. Oxford University Press, NY. 345 pp.

McLaren, I. A. 1958.The biology of the ringed seal (*Phoca hispida* Schreber) in the eastern Canadian Arctic. Fisheries Research Board of Canada Bulletin 137. 30 pp.

Moore, S. E. 2008. Marine mammals as ecosystem sentinels. Journal of Mammalogy 89: 534–540.

Moore, S. E., and R. R. Reeves. 1993. Distribution and movement. Pp. 313–386 *in* J. J. Burns, J. J. Montague, and C. J. Cowles, editors. The bowhead whale. Society for Marine Mammals, Special Publication No. 2.

Moore, S. E., K. M. Stafford, D. K. Mellinger, and J. A. Hilderbrand. 2006. Listening for large whales in the offshore waters of Alaska. BioScience 56: 49–55.

Moore, S. E., and H. P. Huntington. 2008. Arctic marine mammals and climate change: impacts and resilience. Ecological Applications 18: 157–165.

Moore, S. E., J. C. Sheffield, G., Bacon, and C. J. Ashijian. 2010. Bowhead whale distribution and feeding in the western Alaskan Beaufort Sea during late summer, 2005–2006. Arctic 63: 196–205.

OASIS 2008. Spectacled and Steller's Eider ground-based nest surveys and avian inventory at six U.S. Air Force radar sites in northern Alaska. Unpublished report prepared for U.S. Air Force, Elmendorf AFB, Alaska, by OASIS Environmental, Inc., Anchorage, AK. 58 pp.

Oppel, S., A. N. Powell, and D. L. Dickson. 2008. Timing and distance of King Eider migration and winter movements. Condor 110: 296–305.

Oppel, S., D. L. Dickson, and A. N. Powell. 2009. International importance of the eastern Chukchi Sea as a staging area for migrating King Eiders. Polar Biology 32: 775–783.

Piatt, J. F., J. L. Wells, A. MacCharles, and B. Fadely. 1990. The distribution of seabirds and their prey in relation to ocean currents in the southeastern Chukchi Sea. Canadian Wildlife Service, Occasional Papers No. 68: 21–31.

Piatt, J. F., and P. Anderson. 1996. Response of Common Murres to the *Exxon Valdez* oil spill and long-term changes in the Gulf of Alaska marine ecosystem. P. 720–737 *in* S. D. Rice, R. B. Spies, D. A. Wolfe, and B. A. Wright, editors. Proceedings of the *Exxon Valdez* oil spill symposium. American Fisheries Society Symposium 18.

Piatt, J. F., and W. J. Sydeman. 2007. Seabirds as indicators of marine ecosystems. Marine Ecology Progress Series 352: 199–204.

Petersen, M. R. 2009. Multiple spring migration strategies in a population of Pacific Common Eiders. Condor 111: 59–70.

Petersen, M. R., and P. L. Flint. 2002. Population structure of Pacific Common Eiders breeding in Alaska. Condor 104: 780–787.

Petersen, M. R., W. W. Larned, and D. C. Douglas. 1999. At–sea distribution of Spectacled Eiders (*Somateria fischeri*): 120-year-old mystery resolved. Auk 116: 1009–1020.

Powell A. N., A. R. Taylor, R. B. Lanctot. 2010. Pre-migratory ecology and physiology of shorebirds staging on Alaska's North Slope. Final report prepared for Bureau of Oceans, Minerals, and Resource Management (BOEMRE) Anchorage, AK, by Coastal Marine Institute, School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks, AK. 194 pp.

Prentki, R. 2009. Seabird and marine mammal observations during COMIDA CAB, July 24–August 12, 2009 Chukchi Sea cruise. Unpublished report prepared by Minerals Management Service, Anchorage, AK. 5 pp.

Quakenbush, L. T., R. H. Day, B. A. Anderson, F. A. Pitelka, and B. J. McCaffery. 2002. Historical and present breeding season distribution of Steller's Eiders in Alaska. Western Birds 33: 99–120.

Roseneau, D. G., A. M. Springer, E. C. Murphy, and M. I. Springer. 1985 Population and trophic studies of seabirds in the northern Bering and eastern Chukchi seas. Environmental Assessment of the Alaskan Continental Shelf, Final Reports 30: 1–58. U.S. Department of Commerce, NOAA, Anchorage, AK.

Roseneau, D. G., M. F. Chance, P. F. Chance, and G. V. Byrd. 2000. Monitoring seabird populations in areas of oil and gas development on the Alaskan continental shelf: Cape Lisburne and Cape Thompson seabird studies, 1995–1997. Unpublished report prepared for U.S. Geological Survey, Seattle, WA, by Alaska Maritime National Wildlife Refuge, Homer, AK. Report No. USGS/BRD/CR-1999-0002 (OCS Study MMS 99-0011). 147 pp.

Rubega, M. A., D. Schamel, and D. M. Tracy. 2000. Red-necked Phalarope (*Phalaropus lobatus*). *In* A. Poole, editor. The birds of North America, No. 538. Birds of North America, Inc., Philadelphia, PA. 28 pp.

Rugh, D. J., and J. C. Cubbage. 1980. Migration of bowhead whales past Cape Lisburne, Alaska. Marine Fisheries Review 42: 46–51.

Seaman, G. A., K. J. Frost, and L. F. Lowry. 1986. Investigations of belukha whales in coastal waters of western and northern Alaska, I: Distribution, abundance, and movements. Environmental Assessment of the Alaskan Continental Shelf, Final Reports 56: 153–391. U.S. Department of Commerce, NOAA, Anchorage, AK.

Schick, R. S., and D. L. Urban. 2000. Spatial components of bowhead whale (*Balaena mysticetus*) distribution in the Alaska Beaufort Sea. Canadian Journal of Fisheries and Aquatic Science 57: 2193–2200.

Shaffer, S. A., Y. Tremblay, H. Weimerskirch, D. Scott, D. R. Thompson, P. M. Sagar, H. Moller, G. A. Taylor, D. G. Foley, B. A. Block, and D. P. Costa. 2006. Migratory shearwaters integrate oceanic resources across the Pacific Ocean in an endless summer. Proceedings of the National Academy of Sciences 103: 12799–12802.

Springer, A. M., D. G. Roseneau, and M. I. Springer. 1984. Environmental controls of marine food webs: food habits of seabirds in the eastern Chukchi Sea. Canadian Journal of Aquatic Science 41: 1202–1215.

Springer, A. M., D. G. Roseneau, B. A. Cooper, S. Cooper, P. Martin, A. D. McGuire, E. C. Murphy, and G. van Vliet. 1985. Population and trophic studies of seabirds in the northern Bering and eastern Chukchi seas. Environmental Assessment of the Alaskan Continental Shelf, Final Reports 30: 243–306. U.S. Department of Commerce, NOAA, Anchorage, AK.

Springer, A. M., J. F. Piatt, and G. B. van Vliet. 1996. Seabirds as proxies of marine habitats in the western Aleutians. Arctic Fisheries and Oceanography 5: 45–55.

Stringer, W. J., and J. E. Groves. 1991. Location and areal extent of polynyas in the Bering and Chukchi seas. Arctic 44: 164–171.

Suddaby, D., and N. Ratcliffe. 1997. The effects of fluctuating food availability on breeding Arctic Terns (*Sterna paradisaea*). Auk 114: 524–530.

Suydam, R. S., D. L. Dickson, J. B. Fadely, and L. T. Quakenbush. 2000. Population declines of King and Common eiders of the Beaufort Sea. Condor 102: 219–222.

Suydam, R. S., L. F. Lowry, and K. J. Frost. 2005. Distribution and movements of beluga whales from the eastern Chukchi Sea stock during summer and early autumn. Unpublished report prepared for the Bureau of Ocean Energy Management, Regulation and Enforcement, Washington, DC., by North Slope Borough Department of Wildlife Management, Barrow, AK, and Institute of Marine Science, University of Alaska, Fairbanks, AK. OCS Study MMS 2005-035. 39 pp.

Swartz, L. G. 1966. Sea-cliff birds. Pp. 611–678 *in* N. J. Wilimovsky and J. N. Wolfe, editors. Environment of the Cape Thompson region. U.S. Atomic Energy Commission, Oak Ridge, TN.

Swartz, L. G. 1967. Distribution and movement of birds in the Bering and Chukchi seas. Pacific Science 21: 332–347.

Tasker, M. L., P. H. Jones, T. J. Dixon, and B. F. Blake.1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. Auk 101: 567–577.

Taylor, A. R. R. B. Lanctot, A. N. Powell, and F. Huettman. 2010. Distribution and community characteristics of staging shorebirds on the northern coast of Alaska. Arctic 63: 451–467.

Thomas, L., S. T. Buckland, E. A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. A. Marques, and K. P. Burnham. 2010a. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5–14.

Thomas, L., J. L. Laake, S. Strindberg, F. F. C. Marques, S. T. Buckland, D. L. Borchers, D. R. Anderson, K. P. Burnham, S. L. Hedley, J. H. Pollard, J. R. B. Bishop, and T. A. Marques. 2010b. Distance, Version 6.0 (Release 2). Research Unit for Wildlife Population Assessment, University of St. Andrews, St. Andrews, United Kingdom. [Date of use: 1 March 2010. http://www.ruwpa.st-and.ac.uk/distance/]

Thomas, T. A., W. R. Koski, D. S. Ireland, D. W. Funk, M. Laurinolli, and A. M. Macrander. 2009. Pacific walrus movements and use of terrestrial haul-out sites along the Alaska Chukchi Sea coast in 2007. Poster presented at the Society for Marine Mammalogy Annual Meeting, Québec City, RQ, Canada, 12–16 October 2009.

Tracy, D. M., D. Schamel, and J. Dale. 2002. Red Phalarope (*Phalaropus fulicarius*). *In* A. Poole, editor. The birds of North America, No. 698. Birds of North America, Inc., Philadelphia, PA. 32 pp.

USFWS (U.S. Fish and Wildlife Service). 2001. Endangered and threatened wildlife and plants; Final determination of critical habitat for the Spectacled Eider. Federal Register 66:9146–9185.

USFWS. 2010. Endangered, threatened, proposed, candidate, and delisted species in Alaska, January 2010. U.S. Fish and Wildlife Service, Anchorage, AK. 2 pp.

Watson, G. E., and G. J. Divoky. 1970. Pelagic bird and mammal surveys in the eastern Chukchi Sea, early fall 1970. U.S. Coast Guard Oceanographic Report 50:111−172.

Zuur, A. F., E. N. Ieno, N. J. Walker, A. A. Saveliev, and G. M. Smith. 2009. Pp. 261–294 *in* M. Gail, K. Krickenberg, J. M. Samet, A. Tsiatis, and W. Wong, editors. Mixed effects models and extensions in ecology with R. Springer Science and Business Media LLC, New York, NY.

Appendix A. Common and scientific names of birds and mammals mentioned in this report.

Species-group/common name	Scientific name
WATERFOWL	
Brant	*Branta bernicla*
Spectacled Eider	*Somateria fischeri*
King Eider	*S. spectabilis*
Common Eider	*S. mollissima*
Unidentified eider	*Polysticta stelleri* or *Somateria* spp.
Surf Scoter	*Melanitta perspicillata*
White-winged Scoter	*M. fusca*
Black Scoter	*M. nigra*
Long-tailed Duck	*Clangula hyemalis*
LOONS/GEBES	
Red-throated Loon	*Gavia stellata*
Arctic Loon	*G. arctica*
Pacific Loon	*G. pacifica*
Yellow-billed Loon	*G. adamsii*
Unidentified loon	*Gavia* spp.
TUEBENOSES	
Northern Fulmar	*Fulmarus glacialis*
Short-tailed Shearwater	*Puffinus tenuirostris*
SHOREBIRDS	
Red-necked Phalarope	*Phalaropus lobatus*
Red Phalarope	*P. fulicarius*
Unidentified phalarope	*Phalaropus* spp.
Unidentified shorebird	
GULLS/TERNS/JAEGERS	
Black-legged Kittiwake	*Rissa tridactyla*
Ross's Gull	*Rhodostethia rosea*
Ivory Gull	*Pagophila eburnea*
Sabine's Gull	*Xema sabini*
Herring Gull	*Larus argentatus*
Thayer's Gull	*L. thayeri*
Glaucous-winged Gull	*L. glaucescens*
Glaucous Gull	*L. hyperboreus*
Arctic Tern	*Sterna paradisaea*
Pomarine Jaeger	*Stercorarius pomarinus*
Parasitic Jaeger	*S. parasiticus*
Long-tailed Jaeger	*S. longicaudus*
Unidentified jaeger	*Stercorarius* spp.
ALCIDS	
Dovekie	*Alle alle*
Common Murre	*Uria aalge*
Thick-billed Murre	*U. lomvia*

Appendix A. Continued.

Species-group/common name	Scientific name
Unidentified murre	*Uria* spp.
Black Guillemot	*Cepphus grylle*
Pigeon Guillemot	*Cepphus columba*
Ancient Murrelet	*Synthliboramphus antiquus*
Kittlitz's Murrelet	*Brachyramphus brevirostris*
Parakeet Auklet	*Aethia psittacula*
Least Auklet	*Aethia pusilla*
Crested Auklet	*Aethia cristatella*
Horned Puffin	*Fratercula corniculata*
Tufted Puffin	*Fratercula cirrhata*
Unidentified alcid	
MARINE MAMMALS	
Walrus	*Odobenus rosmarus*
Northern fur seal	*Callorhinus ursinus*
Bearded seal	*Erignathus barbatus*
Ribbon seal	*Phoca fasciata*
Ringed seal	*Phoca hispida*
Spotted seal	*Phoca largha*
Unidentified seal	*Erignathus barbatus* or *Phoca* spp.
Unidentified pinniped	
Polar bear	*Ursus maritimus*
Bowhead whale	*Balaena mysticetus*
Common minke whale	*Balaenoptera acutorostrata*
Fin whale	*Balaenoptera physalus*
Humpback whale	*Megaptera novaeangliae*
Gray whale	*Eschrichtius robustus*
Killer whale	*Orcinus orca*
Beluga	*Delphinapterus leucas*
Harbor porpoise	*Phocoena phocoena*
Unidentified cetacean	