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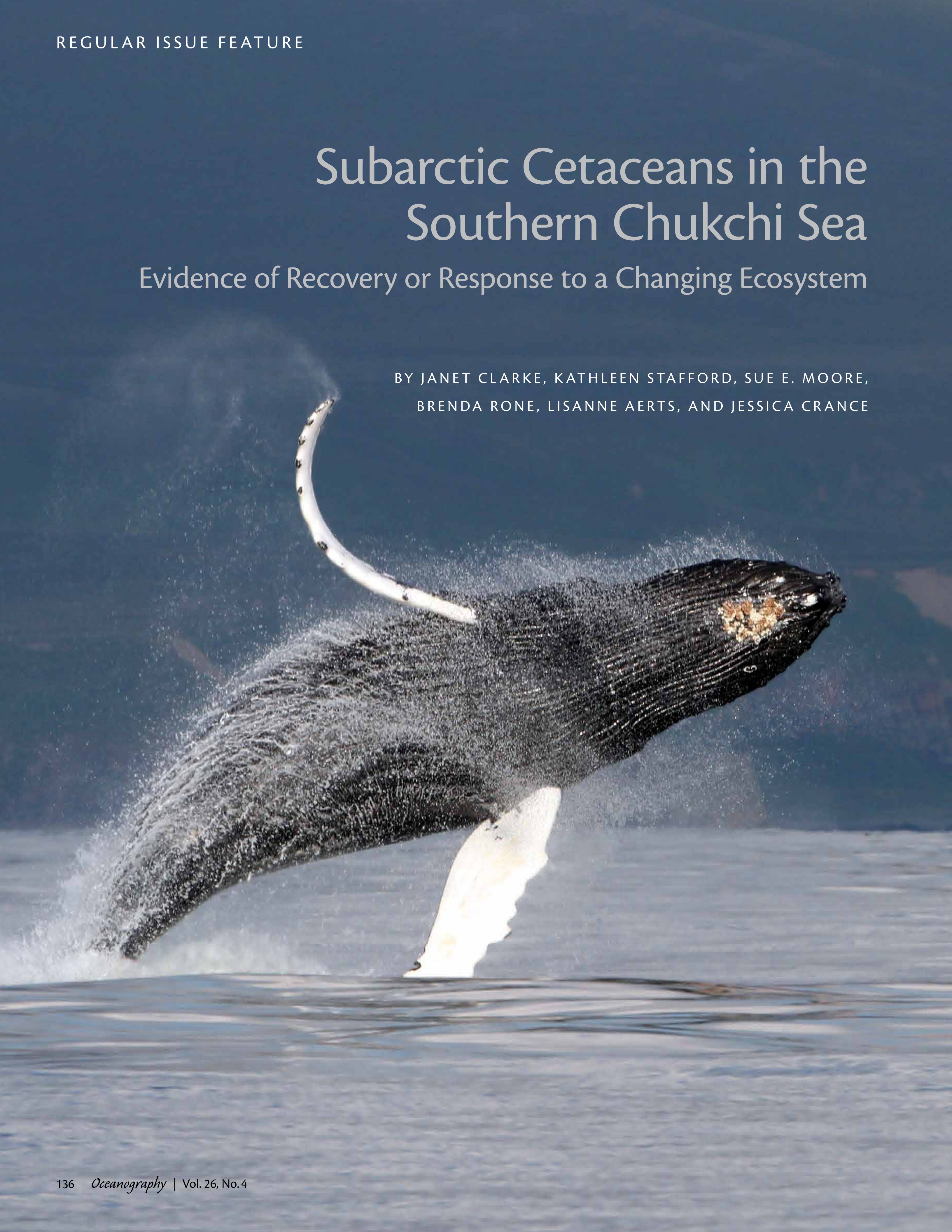
# Subarctic Cetaceans in the Southern Chukchi Sea

## Evidence of Recovery or Response to a Changing Ecosystem

BY JANET CLARKE, KATHLEEN STAFFORD, SUE E. MOORE, BRENDA RONE, LISANNE AERTS, AND JESSICA CRANCE



ABSTRACT. The southern Chukchi Sea is one of the most productive areas in the world ocean. Over the past decade, there have been dramatic changes in this region in sea ice cover and in Bering Strait inflow, and it is now in the path of transpolar shipping and destinational ship traffic, including vessels supporting Arctic offshore oil and gas development and tourism, all of which are anticipated to increase with decreasing seasonal sea ice cover. Little research on cetaceans has been conducted in the southern Chukchi Sea, and most information on the occurrence of subarctic species (humpback whale *Megaptera novaeangliae*, fin whale *Balaenoptera physalus*, minke whale *B. acutorostrata*, and killer whale *Orcinus orca*) comes from the ships' logs of commercial whalers in the mid to late twentieth century and from observers stationed along the Chukotka Peninsula. Information on cetacean seasonal occurrence east of the International Date Line (IDL) in US waters is particularly scarce. To address this information gap, we compiled visual sightings and acoustic detections of subarctic cetaceans in the southern Chukchi Sea during summer and early autumn from 2009 to 2012. Humpback whales were common on both sides of the IDL in August and September. Fin and minke whales were widely distributed east of the IDL from July to September, and killer whales were seen sporadically but were the most widely dispersed of the four species. Comparisons of our results with historical records indicate that the incidence of subarctic cetaceans may be increasing in the southern Chukchi Sea. An increase in occurrence may simply be a post-commercial whaling recovery of whale numbers and seasonal range by each species, or it may reflect responses to ongoing climate change. Understanding current stock identity, spatial and temporal distribution, habitat preference, relative abundance, and potential impacts of climate change on these species will require cetacean-focused research in this region of the Arctic.

## INTRODUCTION

The southern Chukchi Sea is one of the most productive areas in the world ocean (Grebmeier, 2012). Three water masses from the northern Bering Sea enter through the narrow Bering Strait into the shallow (~ 50 m deep) sea (Figure 1): the cold, saline, nutrient-rich Anadyr Water (AW) to the west; the seasonally warm, low-salinity Alaskan Coastal Water (ACW) to the east; and the central Bering Shelf Water (BSW) in between (Weingartner et al., 2005; Woodgate et al., 2005). Although there is high intra- and interannual variability in water properties, current speed, and direction (Woodgate et al., 2012), there is a marked wind-driven seasonal cycle with maximal northward flow through Bering Strait in July and minimum flow in February (Aagaard et al., 1985; Woodgate et al., 2005). Often there is little lateral mixing among the water masses so that fronts defined by pronounced differences in sea surface temperature (SST) can be identified on satellite images (Woodgate et al. 2005), illustrating the heterogeneity of the physical system. Over the past decade, there has been a dramatic lengthening of the sea ice-free season in the southern Chukchi Sea (e.g., Overland and Wang, 2013) and an approximately 50% increase in the inflow of warm freshwater at Bering Strait (Woodgate et al., 2012). Combined, these factors are likely altering the ecosystem of the southern Chukchi Sea, including the availability of prey for baleen whales.

The southern Chukchi Sea is a region of especially high benthic productivity and biodiversity, the result of production from ice algae and phytoplankton not consumed in the pelagic zone that provide the foundation for dense benthic prey assemblages important to seasonally abundant marine mammals (Grebmeier, 2012). Especially high benthic infauna biomass on the western side of the southern Chukchi Sea is likely related to the nutrient-rich AW. Invertebrate prey important to marine mammals, such as epibenthic euphausiids (krill) on which gray whales sometimes feed (Bluhm et al., 2007), can also be advected into the southern Chukchi Sea. Forage fishes, including Pacific herring (*Clupea pallasii)*, capelin (*Mallotus villosus*), and saffron cod (*Eleginus gracilis*), occur in comparatively high densities (Moore et al., in press) associated with specific water masses in the southern Chukchi Sea (Eisner et al., 2013).

Three cetacean species occur seasonally in the southern Chukchi Sea: bowhead whale (*Balaena mysticetus*), beluga (*Delphinapterus leucas*), and gray whale (*Eschrichtius robustus*). Beluga and bowhead whales are Arctic endemic species that migrate through the southern Chukchi Sea during spring and autumn but seldom occur there in summer (Suydam et al., 2001; Quakenbush et al., 2010; Citta et al., 2012). Conversely, gray whales are seasonal Arctic species that may remain in the southern Chukchi Sea in summer to feed on benthic and epibenthic prey (Moore et al., 2003; Bluhm et al., 2007). All three species migrate south in late autumn to wintering areas in the Bering Sea (bowhead whales and belugas) or in the North Pacific as far south as Baja California, Mexico (gray whales). These three species are well known to Chukchi Sea coastal community residents of

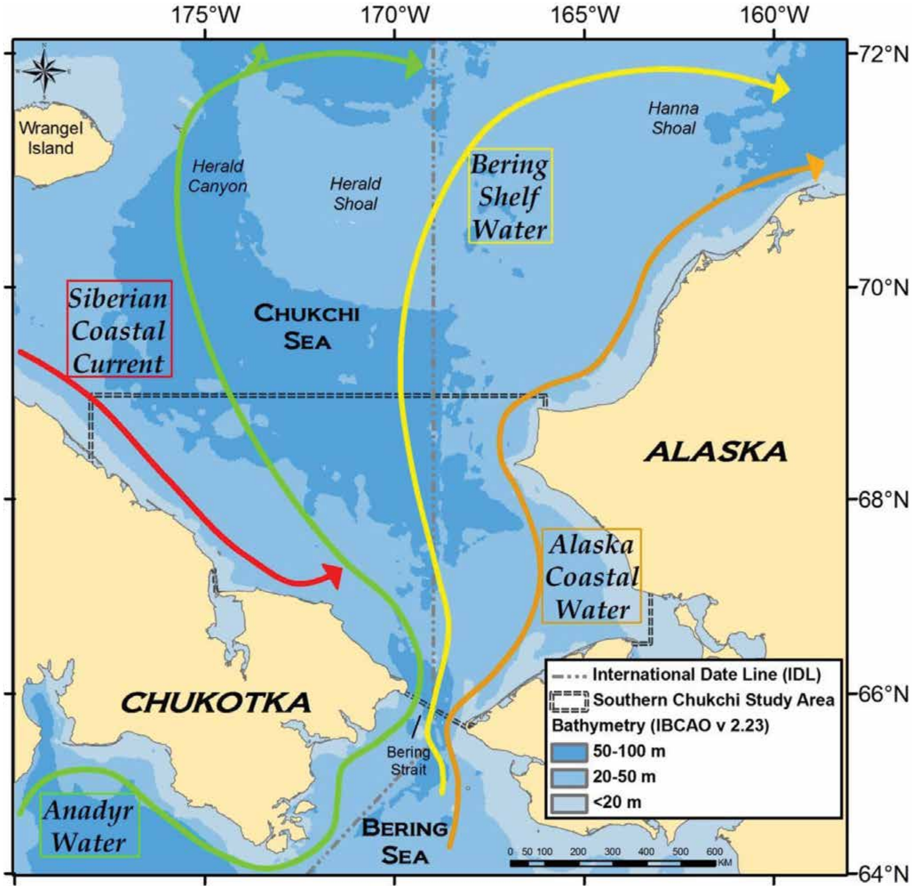



Figure 1. General current patterns and bathymetry in the Pacific Arctic sector, with the southern Chukchi Sea study area indicated.

Wales, Shishmaref, Kotzebue, Kivalina, and Point Hope in Alaska, and Uelen, Neshkan, and Vankarem, Chukotka in Russia, and are often harvested for subsistence purposes (e.g., Borodin et al., 2002; Suydam et al., 2012).

Reports of other cetacean species in the southern Chukchi Sea are less common, especially in US waters. Humpback, minke, and killer whales are common in the southeastern Bering Sea in summer (Moore et al., 2000, 2002; Friday et al., 2012), and fin whales occur there year-round (Stafford et al., 2010). Although there is little historical information on these species in US waters of the southern Chukchi Sea, Soviet scientists and whalers in the late 1930s and early 1940s noted that all four species were found off the Chukotka Peninsula between June and October (Nikulin, 1946). Hundreds of humpback whales were observed in this region, but observations declined from the 1930s to the 1980s (Mel'nikov, 2000), as did observations of fin whales (Nemoto, 1959; Sleptsov, 1961), due to commercial whaling.

Few surveys have been conducted for large whales in the southern Chukchi Sea, in part because other areas have been of higher priority for funding due to oil and gas industry interests. For example, in the northeastern Chukchi and western Beaufort seas, aerial surveys for marine mammals have been conducted since the late 1970s (e.g., Clarke et al., 1993; Moore et al., 1993), and several oceanographic cruises occurred during the 1970s and 1980s (e.g., Feder et al., 1994; Weingartner et al., 2005), but very few sightings of subarctic cetacean species were reported. Recently, research cruises and marine mammal aerial surveys conducted in the southern Chukchi Sea have documented several occurrences of subarctic cetacean species in summer and early autumn. In this paper, we provide a synopsis of the distribution and occurrence of subarctic cetacean species (humpback, fin, minke, and killer whales) in the southern Chukchi Sea from 2009 to 2012 based on visual sightings (vessel and aerial surveys) and acoustic detections (sonobuoys), and we compare these records with historical records and known recent changes in the subarctic and Arctic ecosystems.

## VESSEL AND AERIAL-BASED DATA COLLECTION

We define the southern Chukchi Sea as the area ranging from Bering Strait (approximately 65.5°N) north to 69°N (Figure 1). This region is bordered by the Russian Chukotka Peninsula on the west and the Alaskan Seward Peninsula and Kotzebue Sound on the east. From 2009 to 2012, marine mammal visual sightings and acoustic detections in this region

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were obtained during four research projects: Russian-American Long-term Census of the Arctic (RUSALCA); Chukchi Acoustics, Oceanography and Zooplankton (CHAOZ); Chukchi Sea Environmental Studies Program (CSESP); and Aerial Surveys of Arctic Marine Mammals (ASAMM). Detailed methods for each project are available in the references of this paper.

RUSALCA is a collaborative effort between the National Oceanic and Atmospheric Administration (NOAA) and the Russian Academy of Sciences to investigate long-term physical, chemical, and biological processes in Arctic seas (i.e., northern Bering and Chukchi Seas) that are shared by the two countries (Bluhm et al., 2009). Marine mammal watches were conducted from 2009 to 2012. A single observer conducted marine mammal watches during periods when weather conditions were suitable for 7 × 50 binoculars. Cruises were conducted in September (2009), early August (2010), mid-July (2011), and late August to early September (2012) (http://www.arctic.noaa.gov/aro/russian-american). RUSALCA cruises were unique in providing marine mammal search efforts in the southern Chukchi Sea on both sides of the IDL.

CHAOZ was a multidisciplinary study by the Alaska Fisheries Science Center's National Marine Mammal Laboratory (AFSC-NMML), the Resource Assessment and Conservation Engineering division (AFSC-RACE), and NOAA's Pacific Marine Environmental Laboratory (PMEL). CHAOZ objectives focused on (1) documenting the distribution and relative abundance of whales in the northeastern Chukchi Sea relative to oceanographic conditions, (2) indices of potential prey diversity, and (3) the level of anthropogenic activity in late August to early September from 2010 to 2012 (Berchok et al., 2011, 2012), but data were also collected in the southern Chukchi Sea while transiting to and from the primary study area. Visual observations were conducted during daylight hours by a team of two marine mammal observers using 25× ("bigeyes") and 7 × 50 binoculars (NMML et al., 2010). In addition to gathering visual observations, real-time acoustic surveys were conducted 24 hours a day using AN/SSQ passive acoustic sonobuoys, models 53 D, E, F, 57B, and 77C, manufactured by Sparton or Undersea Systems Inc. (NMML et al., 2010). Sonobuoys are free-floating, expendable hydrophones that transmit signals via VHF radio waves to receivers on a vessel; they can collect data even during inclement weather when visual observations are not possible. In order to ensure nearly continuous coverage as a vessel transited an area, sonobuoys were deployed every three hours, usually in DiFAR (Directional Frequency Analysis and Recording) mode, to obtain directional information about calling animals (Rone et al., 2012). The sonobuoys had an audio frequency range of 10 Hz to 2.5 kHZ (in DiFAR mode) or 24 kHZ (in omnidirectional mode) and a detection range of approximately 27 km. Acoustic signals were monitored in real time using a scrolling spectrogram, and detections were identified to species when possible.

CSESP is a multidisciplinary, ecosystem-based project undertaken by the University of Alaska Fairbanks along with other organizations and focused on northeastern Chukchi Sea ecology. It features the integration of oceanography, plankton, benthos, fish, seabird, and marine mammal studies to establish a baseline for measuring changes. Marine mammal observations in the southern Chukchi Sea were conducted during transits, mostly in August and October (Aerts et al., 2013a); transits were nonrandom, traversing between Cape Prince of Wales and Point Hope. Observations were made from one vessel from 2009 to 2011 and two vessels in 2012, with one observer using 7 × 50 reticle binoculars searching for marine mammals during daylight hours from the bridge or flying bridge of each vessel (Aerts et al., 2013b).

> "THE SUMMARY OF SUBARCTIC CETACEAN RECORDS PRESENTED HERE IS THE MOST COMPREHENSIVE AND RECENT FOR THE SOUTHERN CHUKCHI SEA REGION..."

For ASAMM, AFSC-NMML flew broad-scale systematic aerial surveys from 2009 to 2012 (Clarke et al., 2013) in a continuation of aerial surveys conducted in the Alaskan Arctic since 1979. The study area extended from 68°N to 72°N and 140°W to 169°W, and surveys were conducted from late June or early July through late October each year. The southernmost part of this study area was not surveyed as often as areas farther north, but a few surveys were conducted each year between 68°N and 69°N.

ASAMM surveys were flown in high wing, twin turbine aircraft with bubble windows that allow observers situated on opposite sides of the aircraft a complete view of the trackline.

Data collected during all of these projects included environmental conditions (e.g., visibility, sea state) and sighting information (location, species, group size, calf number, behavior). Only sightings and acoustic detections that were positively identified to species were included in the species synopsis. Effort varied considerably, both temporally and spatially, depending on specific project objectives, observation protocol, weather conditions, and other factors.

## SAMPLING EFFORT

Efforts from the RUSALCA, CHAOZ, CSESP, and ASAMM studies were combined and summarized to provide an estimated number of hours and days per month and year of visual and acoustic observations (Table 1). We used this approach because survey effort among the studies was not directly comparable due to different platforms (aerial vs. vessel; visual vs. acoustic), number of observers (one to two), sampling design (line transect vs. opportunistic marine mammal watch), and other factors. Visual and acoustic efforts were sporadic over the four years, both temporally and spatially. Visual effort was conducted on approximately 20% of the days during July through October 2009–2012. There was less visual effort in October (39 hours in 11 days) compared with July (251 hours in 24 days), August (198 hours in 28 days), and September (294 hours in 33 days) (Table 1). Visual effort also varied among years, with the most effort in 2012 (357 hours in 40 days) and least effort in 2009 (117 hours in 15 days) (Table 1). Passive acoustic data were collected by CHAOZ only, with the greatest effort in 2010 (10 days), and about half as much in both 2011 (5 days) and 2012 (6 days). Most vessel effort occurred in the south-central Chukchi Sea (during transits to and from study areas in the northeastern Chukchi Sea), and aerial effort occurred in the northeast part of the study area between Point Hope and Cape Lisburne east of the IDL.

## RECENT AND HISTORICAL SUBARCTIC CETACEAN RECORDS

### Humpback Whales

From 2009 to 2012, humpback whales were the most commonly observed subarctic cetacean (51 sightings of 108 whales) in the southern Chukchi Sea (Table 2). They were broadly distributed, extending from Bering Strait to 68.5°N, in both nearshore and offshore areas on both sides of the IDL (Figure 2). Most sightings occurred in September (69%) and consisted mainly of adults, although calves (n = 3) and juveniles (n = 3) were also seen. Humpback whales were often observed in close association with fin or gray whales. Several humpback whales were seen feeding, including some using bubble nets (Wiley et al., 2011). Humpback whales were the second most common acoustically detected species, with recordings on 16% of the sonobuoys (Table 2). The majority of acoustic detections (67%) were in August, and humpback whales were heard throughout the central part of the study area from Wales to Cape Lisburne (Figure 3). Although humpback whales were detected in all three years, more were detected in 2012 than in the other two years combined (9 of 15 total detections), even though 2010 had the greatest effort. Only one sonobuoy detected humpback whales in 2011.

Humpback whales winter in subtropical and tropical waters, and most migrate seasonally to higher latitudes to feed on euphausiids and small schooling fishes (Clapham, 2002). In the North Pacific Ocean, humpback whales are known to feed in the Gulf of Alaska and the Bering Sea in summer (Mel'nikov et al., 1999; Moore et al., 2000); these

Table 1. Annual and monthly summary of days of visual and acoustic effort and estimated hours of visual effort in the southern Chukchi Sea, 2009–2012. Acoustic effort is in parenthesis.

| | July | | August | | September | | October | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # hours | # days | # hours | # days | # hours | # days | # hours | # days | # hours | # days |
| 2009 | 0 | 0 | 0 | 0 | 102 | 11 | 15 | 4 | 117 | 15 |
| 2010 | 4 | 2 | 142 | 15 (3) | 4 | 2 (7) | 0 | 0 | 150 | 19 (10) |
| 2011 | 122 | 11 | 8 | 4 (3) | 18 | 4 (2) | 10 | 3 | 158 | 22 (5) |
| 2012 | 125 | 11 | 48 | 9 (6) | 170 | 16 | 14 | 4 | 357 | 40 (6) |
| Total | 251 | 24 | 198 | 28 (12) | 294 | 33 (9) | 39 | 11 | 782 | 96 (21) |

whales likely represent more than one stock (Ohsumi and Masaki, 1975; Allen and Angliss, 2012). Humpback whales were regularly reported near the Chukotka coast between Bering Strait and Capes Serdtse-Kamen and Schmidt (northwest of Vankarem) in the 1930s and 1940s, and as far north as Long Strait (between Wrangel Island and mainland Russia) in 1960 (Mel'nikov et al., 1999). Few were reported during Soviet whaling for gray whales in the 1970s (Votrogov and Ivashin, 1980; Ivashin and Votrogov, 1982), perhaps as a result of previous Soviet commercial whaling pressure in the Bering Sea and the North Pacific Ocean (Ivashchenko et al., 2013). Humpback whales were observed during a research cruise in late September 1980 near Cape Serdtse-Kamen (Miller et al., 1986). Observations from several villages on the Chukotka Peninsula between 1994 and 1996 suggested that humpback whales were re-inhabiting summer feeding areas, and they were regularly seen northwest of Cape Dezhneva in summer (July–September) and, in years when sea ice formation was late, as late as November (Mel'nikov et al., 1999).

Humpback whales were not seen during aerial surveys conducted in the southern and northeastern Chukchi Sea from 1982 to 1991 (Moore and Clarke, 1992). There were scattered sightings in the northeastern Chukchi Sea and westernmost Beaufort Sea in 2007, 2008, and 2012 (Hashagen et al., 2009; Haley et al., 2010; Aerts et al., 2013a; Clarke et al., 2013).

### Fin Whales

Fin whales were less commonly observed (18 sightings of 29 whales) than humpback whales (Table 2) and had a much narrower distribution (Figure 4). A majority of the fin whales (n = 28 whales) were observed from early August to mid-September, with a single sighting in July. Nine fin whales, including one calf, were seen in the south-central Chukchi Sea in September 2011, and five fin whales, including two calves, were seen ~ 75 km south of Point Hope in September 2012. Two of the adults observed in September 2012 were lunge-feeding (Figure 4). Fin whales were not documented west of the IDL. Fin whales were the most common acoustically detected species, with recordings on 18% of all sonobuoys (Table 2), and they were widely distributed throughout the central part of the study area (Figure 3). There were slightly more acoustic detections in August (53%) than in September. More fin whales were acoustically detected in 2010 than in the other two years combined (10 of 17 total detections). The fewest detections were in 2011 (two of 17 total detections).

Fin whales in the Northern Hemisphere feed on a wide variety of organisms, including euphausiids, other planktonic crustaceans, and schooling fishes, including capelin (Aguilar, 2002). Fin whales in the Bering Sea (and southern Chukchi Sea) may be from two migratory stocks (eastern and western North Pacific); stock structure and migratory patterns in the North Pacific are not well understood (Mizroch et al., 2009) although animals from both populations may mingle in the Bering Strait and Chukchi Sea region (Tomilin, 1957). From the 1920s to the 1940s, fin whales were commonly seen in the Chukchi Sea by commercial whalers and were hunted there at least until the early 1950s (Sleptsov, 1961). Nasu (1974) described

Table 2. Annual and monthly summary of cetacean observations (sightings/whales), sighting rates (whales per hour), and acoustic detections (sonobuoys with detections/sonobuoys deployed), in the southern Chukchi Sea, 2009–2012.

| | Sightings/Whales | | | | | Whales/hour | Sonobuoys with Detections/Sonobuoys Deployed | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Humpback | Fin | Minke | Killer | Total | | Humpback | Fin | Minke | Killer | Total |
| Year | | | | | | | | | | | |
| 2009 | 15/51 | 0 | 0 | 0 | 15/51 | 0.437 | na | na | na | na | na |
| 2010 | 14/26 | 2/2 | 8/8 | 3/18 | 27/54 | 0.359 | 5/46 | 10/46 | 1/46 | 1/46 | 17/46 |
| 2011 | 3/3 | 5/9 | 6/8 | 1/7 | 15/27 | 0.171 | 1/18 | 2/18 | 0/18 | 0/18 | 3/18 |
| 2012 | 19/28 | 11/18 | 2/2 | 2/12 | 34/60 | 0.168 | 9/32 | 5/32 | 0/32 | 1/32 | 15/32 |
| Month | | | | | | | | | | | |
| July | 1/1 | 1/1 | 5/5 | 2/14 | 9/21 | 0.0835 | na | na | na | na | na |
| August | 15/28 | 8/13 | 8/8 | 3/18 | 34/67 | 0.3392 | 10/57 | 9/57 | 0/57 | 2/57 | 21/57 |
| September | 35/79 | 9/15 | 2/2 | 1/5 | 47/101 | 0.3440 | 5/39 | 8/39 | 1/39 | 0/39 | 14/39 |
| October | 0 | 0 | 1/3 | 0 | 1/3 | 0.0763 | na | na | na | na | na |
| Total | 51/108 | 18/29 | 16/18 | 6/37 | 91/192 | | 15/96 | 17/96 | 1/96 | 2/96 | 35/96 |

the area between Cape Dezhneva and Neshkan as a whaling ground for fin whales in August 1940 and 1941. Fin whales were heavily hunted in the northeastern Bering Sea by the Soviet whaling fleet in the 1950s and 1960s (Ivashchenko et al., 2013). Sightings in Bering Strait and the Chukchi Sea continued until the late 1970s but not thereafter (Nemoto, 1959; Sleptsov, 1961; Votrogov and Ivashin, 1980). Votrogov and Ivashin (1980) reported that fin whales were occasionally encountered from August to October in coastal areas of the northwestern Chukchi Sea near the Chukotka Peninsula and as far north as Cape Serdtse-Kamen, but the frequency and number of sightings varied from year to year. Few fin whales were seen near the Chukotka Peninsula in the late 1970s (Ivashin and Votrogov, 1982). Fin whales have been well documented in the Bering Sea since 1980 (Moore et al., 2000; Friday et al., 2012), but few fin whales have been seen in the northeastern Chukchi Sea (Clarke et al., 2011). Fin whales were detected acoustically in the northeastern Chukchi Sea in 2007, 2009, and 2010, with large interannual variability (Delarue et al., 2013).

## Minke Whales

Minke whales were the least commonly observed baleen whale (16 sightings of 18 whales) (Table 2). Distribution ranged from Bering Strait north to ~ 68.3°N, with most sightings just north of Bering Strait (Figure 4). With the exception of five whales near Bering Strait in August 2010 and one group of three whales north of Bering Strait in October 2011, minke whale sightings were of single animals and widely scattered. Unlike fin and humpback whales, more minke whales were seen in July (five whales) and August (eight whales) than in September (two whales). Minke whales were the only subarctic cetacean observed during October. Minke whale calls were detected on only one sonobuoy, which was deployed in September 2010 (Table 2, Figure 3).

Minke whales feed on euphausiids, small schooling fishes, and walleye pollock (*Theragra chalcogramma*) (Perrin and Brownell, 2002). Minke whales in the Bering Sea and farther north may be a separate migratory stock from those found elsewhere in the North Pacific (Allen and Angliss, 2012), although acoustic evidence indicates that minke whales in the northeastern Chukchi Sea may be related to minke whales that winter near Hawaii (Delarue et al., 2012). Sleptsov (1961) noted that minke whales were relatively abundant throughout the Chukchi Sea in the 1940s and 1950s. Ivashin and Votrogov (1981a) indicated that minke whale occurrence in the coastal waters of the Chukotka Peninsula was low, and relatively few minke whales were observed during research cruises conducted in the Chukchi Sea in summer and fall from 1979 to 1981 (Miller et al., 1986). In the 1990s, however, Mel'nikov et al. (2001) reported that the waters near the Chukotka Peninsula were an important feeding area for minke whales, particularly in years when the summer pack ice edge was considerably north. Minke whales near Chukotka were more common south of Bering Strait but were observed as far north as 68°N in 1992. They were commonly seen in the central-eastern Bering Sea in summer 1999, particularly along upper slope waters between 100 m and 200 m depth (Moore et al., 2000). During aerial surveys conducted from 1982 to 1991, minke whales were not sighted in the southern and northeastern Chukchi Sea (Moore and Clarke, 1992), but they were observed in the northeastern Chukchi Sea during ASAMM surveys in 2011

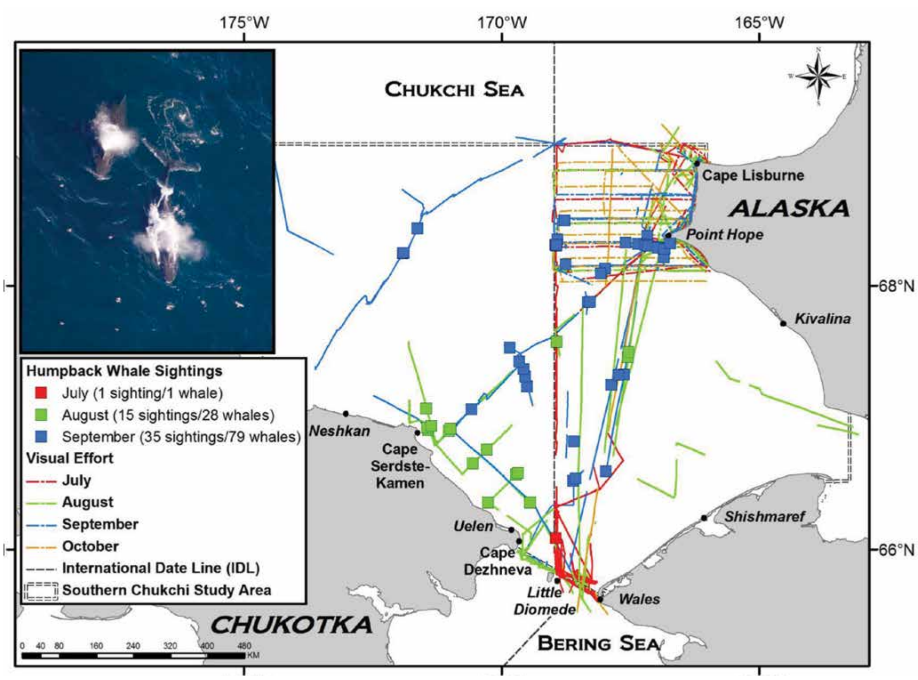


Figure 2. Sightings of humpback whales, by month, from vessel and aerial surveys conducted from July to October 2009–2012. Dotted lines indicate aerial survey effort, and solid lines show vessel effort. Inset: Humpback whales sighted during an ASAMM (Aerial Surveys of Arctic Marine Mammals) survey west of Point Hope, Alaska, in September 2012. *Photo credit: Allison Henry, NMFS*

and 2012 (Clarke et al., 2012, 2013) and during CSESP surveys in 2009, 2011, and 2012 (Aerts et al., 2013a). Additionally, there were four acoustic detections from bottom-mounted hydrophones in the northeastern Chukchi Sea between October 2009 and October 2011 (Delarue et al., 2012).

### Killer Whales

Killer whales in the southern Chukchi Sea were seen in small pods of three to eight whales, with a total of six sightings of 37 whales (Table 2, Figure 5). Most killer whales were observed just north of Bering Strait, with one sighting of five whales (including one calf) west of Point Hope and one sighting of three whales near Cape Serdste-Kamen. Most killer whale sightings occurred in July and August. Killer whale calls were detected on only two sonobuoys, one deployed in August 2010 and the other in August 2012 (Table 2, Figure 3). Photos of killer whales from RUSALCA sightings have been shared with killer whale researchers to try to determine stock identity, and some of the whales were identified as the transient ecotype (C. Matkin, North Gulf Oceanic Society, *pers. comm.*, March 18, 2013).

Killer whale diet depends on ecotype (e.g., fish-eating or mammal-eating), and there is often prey specialization within a stock (Ford, 2002). In the Pacific Arctic, killer whales may be representative of two stocks, the Eastern North Pacific Alaska Resident Stock (fish-eaters) and the Gulf of Alaska, Aleutian Islands, and Bering Sea Stock (mammal-eaters) (Allen and Angliss, 2012). Killer whales were once so common that there was a commercial harvest in the mid-1900s (Sleptsov, 1961). However, Ivashin and Votrogov (1981b) noted that killer whales were relatively scarce in the coastal waters of Chukotka, Ivashin and Votrogov (1982) reported a single sighting of five killer whales near Cape Serdste-Kamen in July 1980, and Miller et al. (1986) reported two sightings of 19 killer whales between Capes Dezhneva and Serdtse-Kamen in late September 1980. Mel'nikov and Zagrebin (2005) documented observations of killer whales from several coastal villages on the Chukotka Peninsula from 1990 to 2000, including several instances of killer whales actively hunting bowhead and gray whales, belugas, and Pacific walruses (*Odobenus rosmarus divergens*). Additional observations of killer whales in the Chukchi and northern Bering Seas also indicate that marine mammals may be their main targeted prey (Ljungblad and Moore, 1983; Lowry et al., 1987; George et al., 1994; Kryukova et al., 2012). Killer whales were not seen during aerial surveys conducted in the southern and northeastern Chukchi Sea from 1982 to 1991 (Moore and Clarke, 1992), but one group of 13 whales, including two calves, was seen near Barrow during aerial surveys in August 2012 (Clarke et al., 2013). One of the males photographed in that group has also been photographed numerous times near False Pass, Unimak Island, in the Aleutian Islands (Clarke et al., 2013). This resight, combined with a single discrete call match between killer whales recorded in the northeastern Chukchi Sea in 2007 and in the Aleutian Islands and off Kamchatka, Russia (J. Delarue, Jasco, *pers. comm.*, November 2013), demonstrates the range of killer whales in the Arctic. In the northeastern Chukchi Sea, pods of killer whales were observed during CSESP surveys in 2011 and 2012, including one group of 30 whales (Aerts et al., 2013a), and calls were recorded in 2009 and 2010 (Hannay

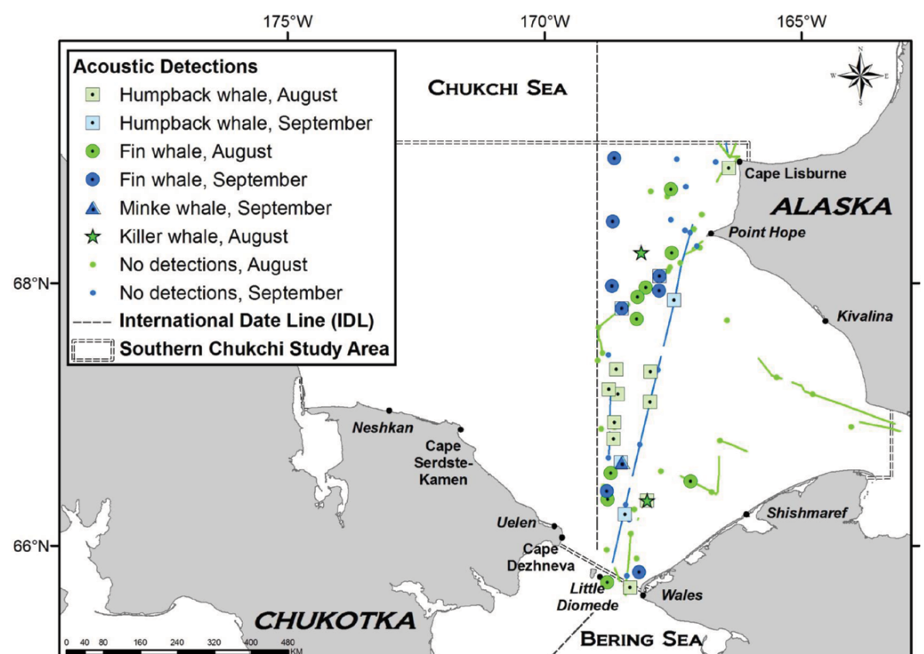


Figure 3. Acoustic detections of humpback, fin, minke, and killer whales from sonobuoys deployed during CHAOZ (Chukchi Acoustic, Oceanographic and Zooplankton) cruises, August to September 2010–2012. Locations are also shown for sonobuoy deployments where cetaceans were not detected. Solid lines denote time periods when visual observations were possible from the vessel. Sonobuoys were deployed even when visual observations were not possible.

et al., 2013). Local hunters also occasionally see killer whales in the Point Barrow region (George et al., 1994).

### Summary

With the exception of 2009, when only humpback whales were sighted, there was no clear pattern to interannual variation in sightings (Table 2). Humpback whales were the most common species seen most years, followed by fin and minke whales. Killer whales were seen every year from 2010 to 2012, but less frequently than baleen whales. Although the highest annual total of humpback, fin, minke, and killer whales combined occurred in 2012, visual sighting rate (# of whales per hour of survey effort) was highest in 2009, followed by 2010 (Table 2). Most whales were seen during August and September, and sighting rates were four times higher during those months compared to July and October (Table 2). The results of acoustic monitoring show that fin whales were detected on a slightly higher percentage of sonobuoys than humpback whales (18% vs. 16%), but both were detected more frequently than either minke or killer whales. Sonobuoys were only deployed in August and September, but in these months, humpback whales were detected on a higher percentage of sonobuoys in August (18% vs. 13%), while fin whales were detected on a higher percentage of sonobuoys in September (21% vs. 16%).

## DISCUSSION

### Significance of Subarctic Cetaceans in the Southern Chukchi Sea

Subarctic cetaceans have been previously documented in the southern Chukchi Sea, but reports were restricted to coastal observations near the Chukotka Peninsula (e.g., Mel'nikov, 2000; Mel'nikov and Zagrebin, 2005; Mel'nikov et al., 1999, 2001) and observations from areas targeted by commercial whalers roughly 40 years ago (e.g., Nikulin, 1946; Sleptsov, 1961). The summary of subarctic cetacean records presented here is the most comprehensive and recent for the southern Chukchi Sea region and represents the only account since the dramatic retreats of Arctic summer sea ice documented over the past decade (Stroeve et al., 2008; Maslanik et al., 2011). This summary also provides insight into subarctic cetacean occurrence in open ocean areas that complements observations made by scientists and villagers in nearshore areas.

There are three nonexclusive possible explanations for recent sightings: (1) an increase in sighting effort, (2) population and range recovery during the post-whaling era with a reoccupation of the southern Chukchi Sea, and/or (3) changes in the environment that have made the southern Chukchi Sea more favorable for subarctic cetaceans. Distinguishing among these three is challenging.

The incidence of subarctic cetaceans observed and acoustically detected in the southern Chukchi Sea from 2009 to 2012 may be due to the recent increase of marine mammal surveys in this area. Humpback, fin, minke, and killer whales occur regularly in polar regions elsewhere, often when sea ice still remains (e.g., Higdon et al., 2012; Laidre and Heide-Jørgensen, 2012). They may have been seasonally present, but with low abundance, in the southern Chukchi Sea and were simply undetected prior to 2009. Minke whales observed during ASAMM surveys in the northeastern and southern Chukchi Sea were very elusive and hard to resight even when survey conditions were good (Clarke et al., 2012); they may be particularly hard to

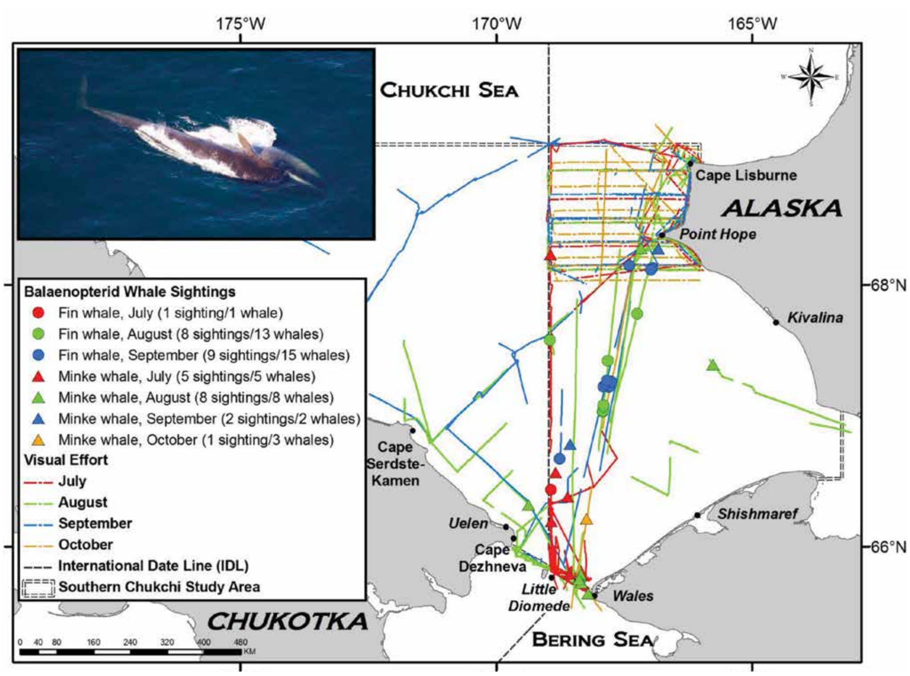


Figure 4. Sightings of fin and minke whales, by month, from vessel and aerial surveys, July to October 2009–2012. Dotted lines depict monthly aerial effort and solid lines, vessel effort. Inset: Feeding fin whale approximately 75 km south of Point Hope, Alaska, September 2012. *Photo credit: Allison Henry, NMFS*

detect if overall abundance is low. Minke and killer whales may also have been underreported historically because they were not species targeted by commercial whalers operating in offshore areas (Mel'nikov et al., 2001).

Subarctic cetacean sightings and acoustic detections from 2009 to 2012 may also be due to resurgence in population sizes and concomitant recovery of range. In the North Pacific, the humpback whale population is currently estimated at greater than 21,000, which is thought to be greater than estimates of pre-whaling abundance (15,000; Carretta et al., 2011), and its growth rate is approximately 8.1% per year (Barlow et al., 2011). Humpback whales were the most commonly sighted and abundant species from 2009 to 2012, and it is thought that they may be reoccupying habitat used prior to intensive (and often illegal) commercial whaling that occurred as recently as the 1970s (Ivashchenko et al., 2013). Unreported whaling may explain why subarctic cetaceans were not encountered during aerial surveys conducted in the southern and northeastern Chukchi Sea from 1982 to 1991.

It is somewhat surprising that fin whales, relatively abundant in the western Chukchi Sea prior to the 1970s, were not seen west of the IDL. This may be due to sparse sampling effort in this region or perhaps due to a shift in distribution or extirpation of local populations. Fin whales detected acoustically on long-term instruments in the northeastern Chukchi Sea produced a unique song type that likely represents only one stock (Delarue et al., 2013), and song type has been used to distinguish among fin whales from different geographic populations (Delarue et al., 2009; Castellote et al., 2012). Fin whales were heard much more often than seen during CSESP (Aerts et al., 2013a; Delarue et al., 2013) and CHAOZ. Use of acoustic data from west of the IDL to examine fin whale song type could be useful in determining whether animals from a different population are heard there (Delarue et al., 2009).

Climate change (e.g., warmer water incursions, earlier and greater loss of summer sea ice) may also be enhancing the ability of subarctic cetaceans to expand further into the Chukchi Sea geographically and seasonally. Soviet scientists reported that commercial whaling for humpback and fin whales in the 1930s to 1950s varied annually and was more successful when ice conditions were favorable (Sleptsov, 1961), and Russian researchers indicated that humpback and minke whales were more likely to occur near the Chukotka coast in years when sea ice re-formed late in autumn than in years when sea ice re-formed in early autumn (Mel'nikov et al., 1999); the southern Chukchi Sea may offer reduced competition for prey for baleen whales compared to the adjacent Bering Sea and increased hunting potential for killer whales (both ecotypes) due to increased productivity and reduced sea ice.

## Association of Baleen Whale Distribution with Water Masses and Potential Prey

The distribution of humpback, fin, and minke whales can be related to a recent summary of water masses and associated pelagic fish and zooplankton species sampled east of the IDL in the southern Chukchi Sea (Eisner et al., 2013). Humpback and fin whale distribution appears to correspond with cold, saline BSW and AW. Sharp temperature and salinity gradients between these two water masses occur between 166°W and 168°W at 67.5°N, with the

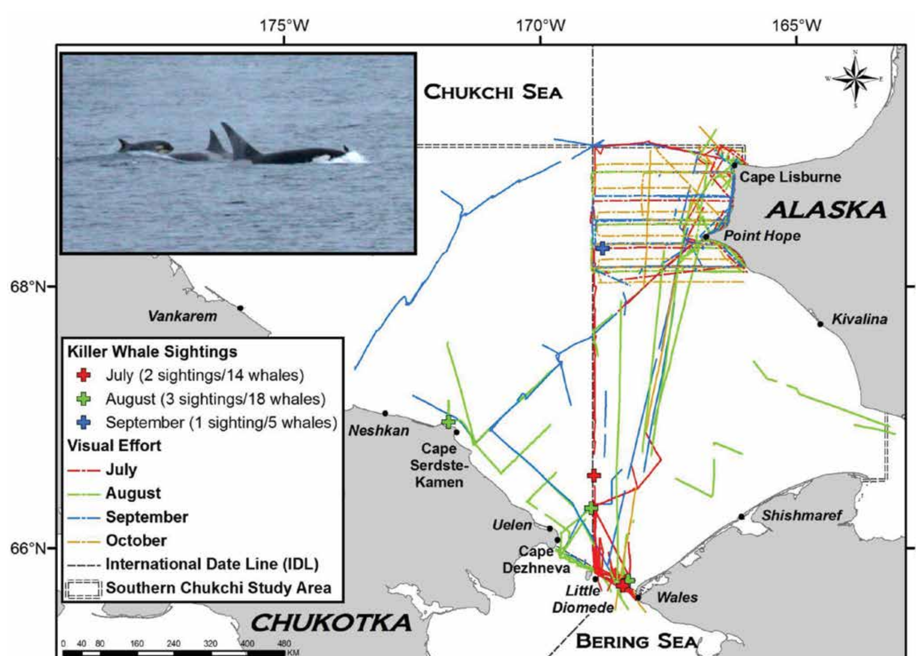


Figure 5. Sightings of killer whales, by month, from vessel and aerial surveys, July to October 2009–2012. Dotted lines indicate monthly aerial effort and solid lines, vessel effort. Inset: Killer whales sighted near Cape Serdste-Kamen, Chukotka, during a RUSALCA (Russian-American Long-term Census of the Arctic) cruise in August 2010. *Photo credit: Kate Stafford, APL*

warm, fresh ACW overriding both east of about 167.5°W (Eisner et al., 2013). Such sharp density gradients can serve to aggregate zooplankton and forage fishes that feed on zooplankton, providing good feeding opportunities to baleen whales. Supporting this contention, Eisner et al. (2013) found large copepods (*Calanus* spp.) and euphausiids (*Thysanoessa raschii*) in greatest abundance south and southwest of Point Hope associated with BSW/Bering Sea Anadyr Water (BSAW) and in ACW/BSAW, respectively (Table 3 and Figure 5 in Eisner et al., 2013). Conversely, highest densities of forage fishes such as sand lance (*Ammodytes hexapterus*), Pacific herring, and saffron cod were found primarily north of Cape Lisburne.

A lack of concurrent oceanographic sampling hampers correlation of hydrographic or prey data to baleen whale distribution. However, it appears that the central southern Chukchi Sea is an advective pathway for euphausiids (Berline et al., 2008). Gray whales have been reported feeding there on dense epibenthic krill assemblages associated with oceanographic fronts (Bluhm et al., 2007). Humpback, fin, and minke whales may also be taking advantage of this krill-prey pathway, benefiting from a ~ 50% increase in transport through Bering Strait between 2001 and 2011 (Woodgate et al., 2012) that is bringing heat, freshwater, and possibly more food into the southern Chukchi Sea. Indeed, there have been so many physical changes to the Arctic system, including sea ice reduction, seawater warming, increased storms, and possibly increased primary production, that the marine ecosystem is considered to be in a "new state" (Jeffries et al., 2013; Overland and Wang, 2013). Whether or not baleen whales are responding to these environmental changes or merely reoccupying range as their populations "recover" from the low numbers caused by commercial whaling is difficult to tease apart.

> "TO UNDERSTAND HOW SHIP TRAFFIC MAY AFFECT CETACEAN ABUNDANCE AND DISTRIBUTION, MORE INTERDISCIPLINARY STUDIES LIKE THOSE DESCRIBED HERE ARE NEEDED TO INVESTIGATE THE DYNAMICS OF THE ECOSYSTEM."

### Future Opportunities

The limited sampling effort (see Table 1) certainly affected the number and distribution of documented cetacean sightings and acoustic detections. Consequently, it is difficult to draw strong conclusions about the seasonal occurrence and habitat selection of subarctic species in the southern Chukchi Sea. Nevertheless, this compilation of records from four recent research projects provides documentation of summertime subarctic cetacean distribution and occurrence.

In addition to the studies reviewed in this paper, new research has been initiated that might shed light on questions of habitat preference, stock structure, and migration timing of subarctic whales in the Pacific Arctic. For example, the interdisciplinary Arctic Whale Ecology Study (ARCWEST) includes passive acoustics, oceanography, satellite tagging, and visual surveys to investigate the influence of prey on cetacean distribution and abundance in the northeastern Chukchi Sea, with a specific focus on large cetaceans, including bowhead, gray, fin, and humpback whales (Friday et al., 2013). Data from this and other studies may provide insight into the cetacean habitat partitioning that has been noted elsewhere in the Arctic (Laidre and Heide-Jørgensen, 2012).

The Arctic marine ecosystem's "new state" requires better understanding of the importance of the southern Chukchi Sea region to all cetaceans. Increased presence of subarctic cetaceans in the southern (and northeastern) Chukchi Sea could affect distribution and abundance patterns of Arctic endemic cetaceans through, for example, competition for preferred prey or increased predation by killer whales. These changes could, in turn, affect the availability of Arctic endemic marine mammals to coastal communities that depend upon them for subsistence. Federal, state, and local agencies tasked with investigating effects of offshore activities (e.g., via oil spill risk analysis) require information pertaining to whale distribution relative to areas of interest for oil and gas exploration and development. Vessel traffic is increasing in Arctic waters, including transpolar shipping, vessel transits related to Arctic oil and gas exploration, recreational cruise and sailing ships, and national defense (US Committee on the Marine Transportation System, 2013). The narrow Bering Strait is the gateway to the Arctic, and, as vessel traffic increases, the probability of ship strikes and disturbance from vessel noise will increase in the southern Chukchi Sea. In 2013, more than 200 ships were expected to sail the Northern Sea Route along the north coast of Russia between Europe and Asia, compared to 46 in 2012 and four in 2011 (Milne, 2013). To understand how ship traffic may affect cetacean abundance and distribution, more interdisciplinary studies like those described here are needed to investigate the dynamics of the ecosystem. Other research within this region, such as the multidisciplinary Distributed Biological Observatory (http://www.arctic.noaa.gov/dbo), could provide a scientific foundation for the integration of data from cetacean-focused studies. Integrating data from various disciplines will enhance our understanding of underlying mechanisms that influence cetacean distribution, abundance, and habitat selection to support informed decisions regarding conservation and management of both Arctic and subarctic cetacean species.

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