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MONITORING MARINE BIRDS OF CONCERN IN THE EASTERN CHUKCHI NEARSHORE AREA (LOONS)

Final Report

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TABLE OF CONTENTS

EXECUTIVE SUMMARY 8

INTRODUCTION 8

METHODS 10

Satellite Transmitter Deployment 10

Annual Movements 12

Use of the Chukchi Sea 12

RESULTS 14

Satellite Transmitter Deployment 14

Annual Movements 15

DISCUSSION 29

Efficacy of Satellite Telemetry 29

Migratory Connectivity 30

Use of the Chukchi Sea 31

Population Implications 33

LITERATURE CITED 35

LIST OF FIGURES

Figure 1. Satellite telemetry locations of adult red-throated loons (top panel), juvenile red-throated loons (middle panel), and adult yellow-billed loons (bottom panel) throughout their annual migration from breeding grounds on the Arctic Coastal Plain, Alaska, to wintering grounds on the Pacific coasts of Asia and North America. 15

Figure 2. Proportion of weekly locations in the Chukchi Sea from marked adult red-throated loons (top panel), juvenile red-throated loons (middle panel), and adult yellow-billed loons (bottom panel). 19

Figure 3. Locations of adult red-throated loons (red points) at the Colville River Delta during July–August grouped across years 2000, 2002, 2008–2010. 20

Figure 4. Frequency distributions of distances between Chukchi Sea locations and the nearest coastline for adult red-throated loons (top panel), juvenile red-throated loons (middle panel), and adult yellow-billed loons (bottom panel). 21

Figure 5. Locations of adult red-throated loons (red points), juvenile red-throated loons (green points), and adult yellow-billed loons (blue points) in relation to active oil and gas leases in the Chukchi Sea Oil and Gas Lease Sale 193. 22

Figure 6. Frequency distributions of distances between Chukchi Sea locations and the nearest active oil and gas lease block boundary of Lease Sale 193 for adult red-throated loons (top panel), juvenile red-throated loons (middle panel), and adult yellow-billed loons (bottom panel). 23

Figure 7. Locations of adult red-throated loons (red points), juvenile red-throated loons (green points) and adult yellow-billed loons (blue points) with satellite transmitters in the Chukchi Sea during May–June (top panel), July–August (middle panel), and September–November (bottom panel).. 24

Figure 8. Estimated maximum (circles) and minimum (squares) residence times of adult red-throated loons, juvenile red-throated loons, and adult yellow-billed loons marked with PTTs during post-breeding (top panel) and pre-breeding (bottom panel) migration. Error bars indicate 95% confidence intervals. No juvenile red-throated loons were detected during pre-breeding migration. Two adult red-throated loons were detected during pre-breeding migration and both had the same residence time and therefore zero variance. 25

Figure 9. Examples of east-to-west post-breeding migration routes across the Chukchi Sea taken by yellow-billed loons (top panels; PTTs YB09_9529, YB02_32936) and red-throated loons (bottom panels; PTTs RL09_95294, RL00_11009). 26

Fig. 10. Kernel density contours of locations of satellite-marked loons in the Chukchi Sea accumulated across seasons and years of tag deployment (top panel: adult red-throated loons, middle panel: juvenile red-throated loons, bottom panel: adult yellow-billed loons). 27

LIST OF TABLES

Table 1. Numbers of red-throated and yellow-billed loons from the Arctic Coastal Plain, Alaska marked with satellite transmitters (PTTs)……………………………………………………..11

Table 2. Mean and range of post-breeding dispersal dates from breeding habitat, pre-breeding arrival dates at the Chukchi Sea, and minimum/maximum residence times in the Chukchi Sea during pre-breeding and post-breeding migration for red-throated and yellow-billed loons captured on the Arctic Coastal Plain, Alaska. Two adult red-throated loons were detected in the Chukchi Sea during pre-breeding migration with identical migration chronology. No marked juvenile red-throated loons were detected in Alaska during pre-breeding migration……………17

MONITORING MARINE BIRDS OF CONCERN IN THE EASTERN CHUKCHI NEARSHORE AREA (LOONS)

Joel A. Schmutz

EXECUTIVE SUMMARY

To better understand the potential effects of resource development on 2 loon species of conservation concern, we marked red-throated (*Gavia stellata*) and yellow-billed (*G. admasii*), loons from breeding grounds on the Arctic Coastal Plain of Alaska with satellite transmitters. We used locations of marked loons to describe their migratory patterns and use of the Chukchi Sea. We marked totals of 17 adult and 14 juvenile red-throated loons, and 36 adult yellow-billed loons over 6 years. When in the Chukchi Sea, both species were most frequently located in nearshore marine habitat within 25 km of the coastline (≥ 75% of locations) during the open water season (May–October). Pre-breeding migration of marked loons was more synchronous than post-breeding migration, likely due to variation in breeding success and the timing of departure from breeding grounds. Further, juvenile red-throated loons had longer average post-breeding residence periods (average: 31, range: 4–53 days) than adult red-throated loons (average: 16, range: 1–77 days) and yellow-billed loons (average: 14, range: 1–76 days). Spring residence times were short for both species (range: 2–14 days). We also detected marked adult loons in nearshore marine habitat during summer. Summer use of marine habitat was related to the foraging behavior of red-throated loons and the abandonment of breeding habitat by some yellow-billed loons that did not successfully breed. Thus, breeding age adults of both species were located in nearshore marine habitat from the 3rd week of May to the 4th week of October. Yellow-billed loons migrating across the Chukchi Sea from Alaska to wintering grounds in Asia during post-breeding migration came in closest proximity to active oil and gas leases in the northeast Chukchi Sea (minimum distance = 43 km). Marked loons used coastal habitat adjacent to the Lease Sale 193 boundary; however, no marked loons were detected within active leases. Migration routes of marked loons indicate that the Chukchi Sea was used by all marked red-throated and yellow-billed loons from the Arctic Coastal Plain and therefore is likely an important migratory corridor for these breeding populations.

INTRODUCTION

Loons (family Gavidae) are diving birds that spend the majority of their annual cycle on marine habitats, which they only depart during summer to nest and raise young on freshwater lakes. Red-throated loons (*Gavia stellata*) and yellow-billed loons (*G. adamsii*) breed in tundra habitats throughout their circumpolar ranges and have been identified as species of conservation concern in the United States. The red-throated loon was identified as a Bird of Conservation Concern by the U.S. Fish and Wildlife Service (USFWS; 2008) due to unexplained changes in abundance, including a decline of >50% on Alaskan breeding grounds during 1977–1993 (Groves et al. 1996, Mallek and Groves 2009, Larned et al. 2010). The yellow-billed loon was designated a candidate species for listing under the Endangered Species Act (USFWS 2009) due to its small population size, estimated at roughly 3,400 individuals, and discrete nesting range, which lies primarily within the National Petroleum Reserve-Alaska (NPR-A; Earnst et al. 2005).

Numbers of both red-throated and yellow-billed loons on Alaskan breeding grounds are monitored annually during waterfowl surveys conducted by the USFWS (Mallek and Groves 2009, Larned et al. 2010), but information on their use of marine habitat is lacking (McCaffery 2000). Breeding populations in Alaska migrate to wintering grounds along the Pacific coasts of

North America and Asia (Barr et al. 2000, North 1994). Both species occur in the Chukchi Sea during months when open water is present (Lehnhausen and Quinlin 1981, Johnson et al. 1993, Lysne et al. 2004). However, due to the scale and remoteness of the area, little information exists regarding routes of migration, timing of use, or areas of concentrated use. This information gap exists at a time of increased interest in resource extraction on the onshore and offshore habitats used by these species (BLM 2004, MMS 2006) and hinders the ability of managers to assess and mitigate potential impacts of development.

Loons are characterized by slow life history traits (Sæther and Bakke 2000), including high adult survival rates, generally low and variable rates of annual productivity, and a prolonged non-breeding juvenile life stage. This life history type is associated with a low potential rate of recovery following a reduction in numbers, which in combination with their reliance on marine habitat, makes loons highly vulnerable to at-sea oil spills (King and Sanger 1979, Williams et al. 1995). Further, because of the lengthy non-breeding period in loons (3−6 years; Okill 1994, Evers 2004), the juvenile age class composes a large portion of their populations. Around 20% of the yellow-billed loon population on the Arctic Coastal Plain is composed of 1−2 year old birds (Earnst et al. 2005). However, the migratory behavior and habitat use of juveniles is poorly understood. Whether juvenile loons migrate to the breeding grounds or remain on the wintering grounds and whether they use freshwater or marine habitat is unknown. This information is vital to understanding factors that regulate recruitment of juveniles into the breeding population and thus the population dynamics and management of these species.

Red-throated loons differ from other loon species in several important ways. Red-throated loons are the smallest of the loons (body mass 1.3–2.3 kg; Barr et al. 2000), they typically breed on very small lakes (0.1–0.8 ha surface area; Bergman and Derksen 1977), and they feed themselves and provision their young fish captured during foraging trips from their breeding lakes to the ocean (Eberl and Picman 1993, Bergman and Derksen 1977). This unique foraging behavior makes management of coastal marine habitats of particular concern for this species. The red-throated loon population in Alaska is estimated at 16,600 with approximately 3,000 individuals on the Arctic Coastal Plain (Mallek and Groves 2009, Larned et al. 2010). Their population status in Canada is unknown, but their breeding range extends throughout the Arctic Archipelago (Barr et al. 2000). The largest historic declines of red-throated loons in Alaska have occurred in breeding areas south of the Arctic Coastal Plain (Groves et al. 1996); however, aerial surveys conducted since 1992 show a statistically significant decline of 4% per year on the Arctic Coastal Plain (Larned et al. 2010).

Yellow-billed loons are the largest of the loon species (body mass 4.0–6.5 kg; North 1994). On their tundra breeding grounds they nest primarily on large, deep lakes (1.1–1,933 ha; Earnst et al. 2006) and, like most loons, feed themselves and their chicks fish and invertebrates captured from their breeding lakes. In Alaska, yellow-billed loons breed on the Arctic Coastal Plain and Seward Peninsula (Bollinger et al. 2008, Earnst et al. 2005) with nearly 91% of the breeding population occurring on the NPR-A between the Meade and Ikpikpuk rivers (Earnst et al. 2005). Approximately 8,000 yellow-billed loons are thought to occur in Canada, although the species has not been thoroughly surveyed (Fair 2002). The Arctic Coastal Plain population has shown no significant trend since aerial surveys were started in 1986; however, precision around the trend estimate was low (Earnst et al. 2005). Migratory routes of yellow-billed loons occurring along the Arctic Coastal Plain have long been a source of debate (Cooke 1915, Dixon 1916).

We designed the present study to describe the use of the Chukchi Sea by red-throated and yellow-billed loons breeding on the Arctic Coastal Plain. We deployed satellite transmitters during 2008−2010 to delineate broad-scale migration routes, define the timing and duration of use of the Chukchi Sea, and identify areas of concentrated use along the Chukchi Sea coast by adult and juvenile red-throated loons, and adult yellow-billed loons. Data collected during 2008−2010 were added to previously existing data from loons marked during 2000–2003 to compile the most complete data set of locations in the Chukchi Sea available. These data will be valuable to decision-makers conducting environmental risk assessments and other National Environmental Policy Act requirements associated with offshore oil and gas development in the Chukchi Sea.

METHODS

Satellite Transmitter Deployment

We deployed satellite transmitters in loons captured on the Arctic Coastal Plain during the summers of 2008–2010 (Table 1). We captured adult red-throated loons breeding at the Colville River delta (70° 25.5´ N, 150° 24.5´ W), pre-fledging juvenile red-throated loons near the village of Point Lay (69° 44.4´ N, 162° 51.7´), and breeding adult yellow-billed loons in the central NPR-A (70° 24.1´ N, 155° 49.4´). We captured adult loons of both species on nests using bow net traps (Salyer 1962) and juvenile loons with mist nets deployed on the surface of lakes (Okill 1981). Only one adult or juvenile from a single nest or brood was captured. In most instances, we placed artificial eggs in the nest during capture attempts and placed real eggs in a padded, ventilated container to prevent depredation of the unattended nest and damage to the eggs during trapping. We tagged most captured loons with a numerically coded U.S. Geological Survey (USGS) metal band on one leg. However, we had to custom fit bands for loons because of their laterally-flattened tarsal shape (Okill 1981) and in some instances did not have bands that properly fit a captured bird. In these cases, birds were not banded. During transport and post-surgical recovery, we held birds individually in plastic kennels modified with raised mesh floors and foam-padded walls. We could not capture juvenile yellow-billed loons and therefore focused our effort on adults.

Our sample of birds implanted with PTTs (hereafter referred to as “marked”) in 2008–2010 was augmented with data from transmitters deployed in red-throated and yellow-billed loons from the Arctic Coastal Plain during prior studies conducted by the USGS (J. Schmutz, unpublished data; Table 1). Loons marked in 2000–2003 included: 7 adult red-throated loons captured on nests in the Colville River Delta during 2000 and 2002, 1 adult red-throated loon captured on a nest in the NPR-A in 2002, and 12 adult yellow-billed loons captured on nests in the NPR-A during 2002–2003.

We deployed battery-powered satellite transmitters (Platform Transmitting Terminals, PTTs; model PTT-100 implantable version, Microwave Telemetry, Columbia, MD) in captured loons.

Table 1. Numbers of red-throated and yellow-billed loons from the Arctic Coastal Plain, Alaska marked with satellite transmitters (PTTs).

Species	Age	Year	PTTs Deployed
Red-throated Loon	Adult	2000	5
		2002	2
		2008	3
		2009	3
		2010	4
		Total	17
	Juvenile	2008	5
		2009	5
		2010	4
		Total	14
Yellow-billed Loon	Adult	2002	5
		2003	7
		2008	8
		2009	7
		2010	9
		Total	36

Transmitters used for red-throated loons weighed 42 g (2.8% of average body mass). We were able to implant PTTs with larger batteries in yellow-billed loons because of their substantially larger body mass; transmitters used in yellow-billed loons weighed 65 g (1% of average body mass). Wildlife veterinarians surgically implanted transmitters in the lower right coelomic air sac; the antenna of each transmitter exited caudally through the body wall near the right pubic bone and synsacrum (Korschgen et al. 1996, Mulcahy and Esler 1999). Throughout the procedure, an anesthetists administered propofol general anesthesia intravenously, monitored heart rate and body temperature, and maintained respiration using a bag valve attached to a tracheal tube. Surgery times from induction of anesthesia to extubation were 20 minutes on average. Birds were held for observation for at least 1 hour before being released at the site of their capture.

PTTs were programmed to transmit signals intermittently to extend battery life. These on-off cycles (i.e., duty cycles) were programmed to change over the deployment of the transmitter, ranging from 8 hours of transmission every 48 hours to 8 hours of transmission every 110 hours. Duty-cycles were more frequent during the pre- and post-breeding migration periods than during summer and winter. Transmitters were equipped with a sensor that monitored body temperature to detect the loss of internal temperature associated with the death of an individual. Data from the internal temperature sensor, and a sensor monitoring PTT battery voltage, were included in PTT transmissions. Argos data collection systems aboard NOAA polar-orbiting satellites collected PTT transmissions. Location estimates were based on satellite overpass geometry and Doppler shifts in the PTT uplink frequency (Fancy et al. 1988). PTT locations were assigned to an accuracy category based on signal quality. Standard location classes (classes 1, 2, or 3) have an approximate 1 standard deviation error radius of < 1,500 m. Auxiliary location classes (classes 0, A, B, or Z) have an unknown accuracy and are highly variable. We filtered PTT location data to include the single best standard class location from each day of signal reception for each bird. We included all data beginning immediately after release for filtering.

Annual Movements

We plotted filtered locations received from the time of deployment through 20 January 2012 in ArcGIS software (ESRI 2006). We used the National Geospatial-Intelligence Agency's World Vector Shoreline data set (Soluri and Woodson 1990) to determine the geographic position of PTT locations relative to the shorelines of North America, Asia and outlying islands. We plotted all coordinates in the Lambert Equal Area Azimuthal projection. We used the resulting dataset to summarize broad-scale migration patterns of marked loons.

Use of the Chukchi Sea

To examine when loons were present in the Chukchi Sea, we calculated the proportion of telemetry locations in the Chukchi Sea that occurred during each week of the year, summing data across years. These proportions represent the number of detections located in the Chukchi Sea of the total number of locations detected during a given week. Thus a proportion of 1.0 indicates all detections for that week were in the Chukchi Sea, and conversely 0 indicates no detections during that week were in the Chukchi Sea.

We used locations in the Chukchi Sea to calculate distance from shore and distance from active lease blocks in the Lease Sale 193 area in ArcGIS. We calculated distance from shore as the shortest straight-line distance from a loon location to World Vector Shoreline (Soluri and Woodson 1990) polyline shapefile of the Chukchi Sea coastline. We calculated distance to active lease blocks as the shortest straight-line distance from loon locations to a polyline shapefile of active federal oil and gas leases in the Chukchi Sea Outer Continental Shelf planning area through Lease Sale 193 (BOEM 2012).

We defined residence time as the average number of days a marked loon spent in the Chukchi Sea during pre- or post-breeding migration. PTTs transmitted location information intermittently making the exact timing of loon movements and the true duration of residence unknown. We present the uncertainty around residence time resulting from intermittent transmission and detection of PTT signals by providing 2 estimates of Chukchi Sea residence: maximum residence and minimum residence. We defined maximum residence as the interval between the date of the location before the first location in the Chukchi Sea and the date of the location after the last location in the Chukchi Sea. We defined minimum residence as the interval bounded by first and last location dates in the Chukchi Sea. Thus, maximum residence assumes loons were located in the Chukchi Sea during the periods before and after known Chukchi Sea locations, and minimum residence assumes loons were not in the Chukchi Sea during this period; these estimates represent the limits around true residence time. Maximum and minimum residence times in the Chukchi Sea were calculated for pre- and post-breeding migration periods.

We used the date of the first inland location on the breeding grounds to define the end of the pre-breeding migration period. Likewise, we used the data of departure from inland habitat as the start of the post-breeding migration period. Because of their use of marine habitat for foraging, red-throated loons often were located in marine habitat during the summer. Therefore, we defined the start of the post-breeding migration for red-throated loons in a given year as the continued use of marine habitat not followed by a return to inland habitat. Some yellow-billed loons departed inland habitat for the coast during summer and did not return inland; we used these locations to define post-breeding migration. Thus, our definition of post-breeding migration includes all locations following the final departure from inland breeding habitat in a given year.

We identified areas of concentrated use by marked loons in the Chukchi Sea using kernel density estimation (Silverman 1986). Due to our small sample size, we combined Chukchi Sea locations across years and seasons for each species and age class. We used a raster grid size of 10 km and set density contours based on apparent break points in the data for each cohort. Density values indicate the density of locations per square kilometer accumulated over all years of data collection and all marked birds detected in the Chukchi Sea.

Our study design maximized the number of transmitters we deployed in each species given the logistical constraints of capturing a dispersed nesting species in a remote area and the funding constraints associated with PTTs. As a result, the number of birds in each species that we marked is small relative to the size of their populations on the Arctic Coastal Plain. Sample size, therefore, placed important constraints on the conclusions we are able to draw from the data (Lindberg and Walker 2005). As a consequence, we avoided making inferences to populations and focused instead on describing patterns in the data by reporting means with standard deviations (SD). Because some PTTs provided data for > 1 year, observations of the migratory patterns of some individuals occurred in multiple years. In these instances we report the effective sample size as the number of individuals in addition to the total number of observations made across individuals.

We conducted all capture, banding, and transmitter deployment for this study under U.S. Fish and Wildlife Service Scientific Collection permit MB789758, U.S. Geological Survey bird banding permit 20022, State of Alaska Department of Fish and Game scientific permits 08-029, 09-000, 10-006. All animal handling methods were approved by Institutional Animal Care and Use Committees at the University of Alaska Fairbanks (protocol 08-28) and the USGS Alaska Science Center.

RESULTS

Satellite Transmitter Deployment

We deployed 48 PTTs on red-throated and yellow-billed loons during the summers of 2008–2010, 24 PTTs on each of the 2 species (Table 1). Ten PTTs were implanted in adult red-throated loons and 14 in juveniles; all implanted yellow-billed loons were adults. We do not know the sex of marked birds because in loons both sexes incubate the nest, males and females are monomorphic in plumage, and, although males generally are larger than females, there is substantial overlap in size between the sexes (Barr et al. 2000, North 1994). However, because both parents participate in chick rearing until fledge, we do not have *a priori* reason to expect migration patterns to differ dramatically by sex, as occurs in species with uniparental care of young (e.g., ducks, subfamily Anatinae).

We received location data for an average of 365 days from PTTs deployed in adult red-throated loons (range: 159−511 days), and 205 days (range: 62−461 days) from PTTs deployed in juvenile red-throated loons, and 436 days (range 113−827 days) from PTTs deployed in yellow-billed loons. PTTs in yellow-billed loons functioned longer than those in red-throated loons because they had larger batteries that extended transmitter life. Two PTTs deployed in yellow-billed loons during 2010 were still transmitting as of January 2012. Transmitter life permitted documenting movements over multiple years in 2 adult red-throated loons and 17 yellow-billed loons.

From July 2008 to January 2012, we received a total of 4,923 daily high quality (i.e., standard class) locations: 868 locations from adult red-throated loons, 821 locations from juvenile red-throated loons, and 3,237 locations from yellow-billed loons. Locations from PTTs deployed during 2000–2003 added an additional 366 locations from adult red-throated loons and 2,146 locations from yellow-billed loons. The final dataset used to describe loon distributions included 17 adult red-throated loons, 14 juvenile red-throated loons, and 36 adult yellow-billed loons captured from breeding sites on the Arctic Coastal Plain during 2000, 2002–2003, and 2008–2010.

Rates of known mortalities (individuals detected dead per total individuals implanted with PTTs) during the study were 12% and 36% for adult and juvenile red-throated loons, respectively, and 11% for adult yellow-billed loons. Average mortality rates during the first year following transmitter deployment were 11% for adult red-throated loons, 35% for juvenile red-throated loons, and 10% adult yellow-billed loons. These mortalities were inferred from the loss of body temperature as measured by the implanted transmitters. The average duration of time between PTT deployment and the time of mortality was 123 days (SD=130 days, range: 4 to 392 days). Only one mortality, a juvenile red-throated loon marked in 2009, occurred within 14 days of PTT deployment while the bird was still on its natal lake. We were not able to search for carcasses and therefore do not have information on what may have caused mortalities.

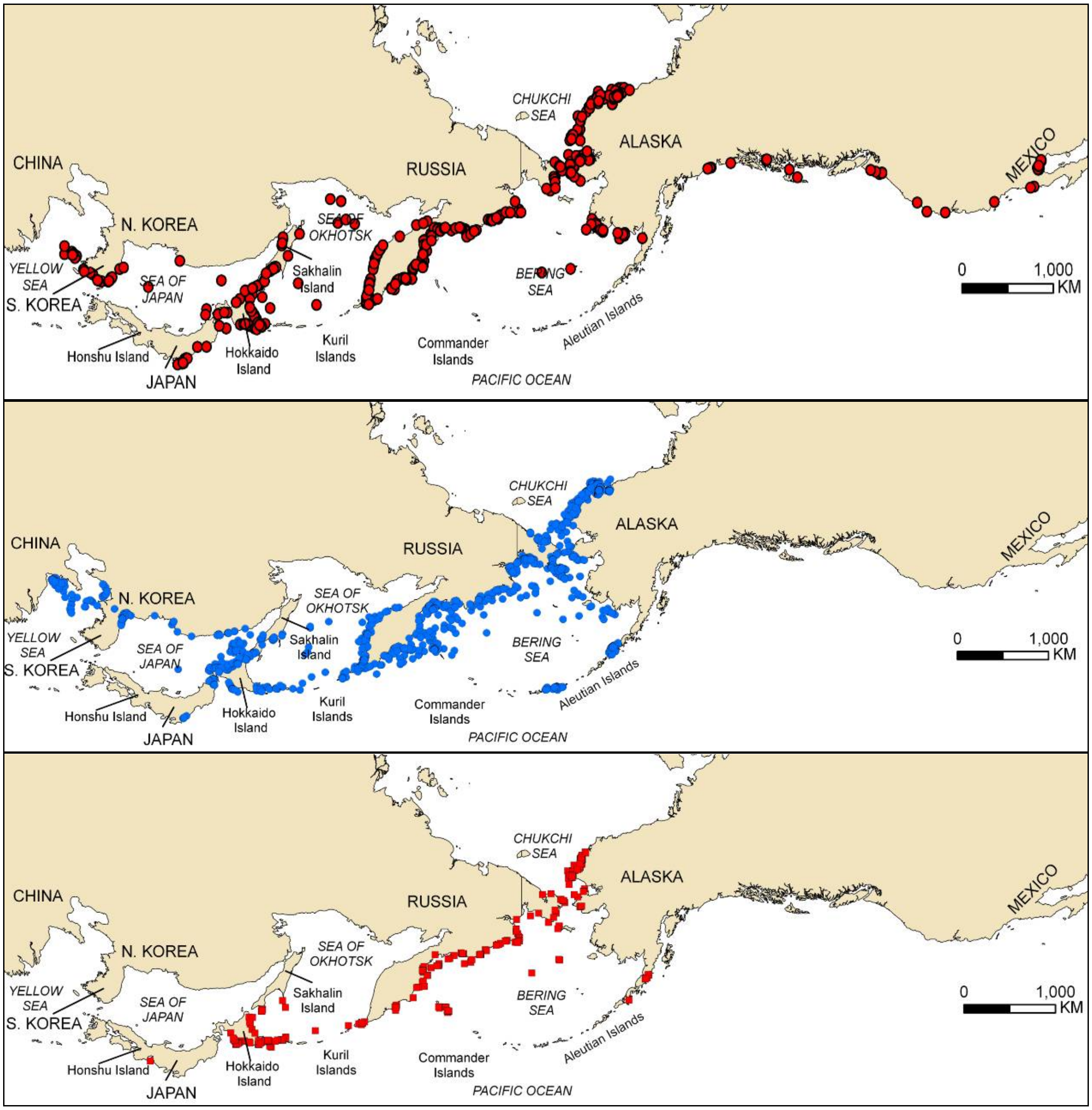

Figure 1. Satellite telemetry locations of adult red-throated loons (top panel), juvenile red-throated loons (middle panel), and adult yellow-billed loons (bottom panel) throughout their annual migration from breeding grounds on the Arctic Coastal Plain, Alaska, to wintering grounds on the Pacific coasts of Asia and North America.

Annual Movements

Our sample of red-throated and yellow-billed loons from the Arctic Coastal Plain showed strong migratory connectivity to wintering grounds in East Asia (Fig. 1). Strong migratory connectivity occurs when most individuals from one breeding area migrate to the same nonbreeding area (Webster et al. 2002). Of 61 loons that provided data migration on their migration, only 4 migrated to wintering sites in North America: 1 adult red-throated loon, 1 juvenile red-throated loon, and 2 adult yellow-billed loons. All other marked loons either wintered in Asia, or followed migration routes to Asia, but had signals that were lost during winter and so we do not know their exact wintering sites. All marked loons from the Arctic Coastal Plain traveled along coastlines during pre-breeding and post-breeding migrations, we found no evidence of long-distance travel over land. Direct migration distance between breeding and wintering sites ranged from 2,600 km (NPR-A to Aleutian Islands) to 7,300 km (NPR-A to the Yellow Sea coast of China).

Wintering sites used by adult red-throated loons included 3 sites in Asia and 1 in North America. Sites in Asia included the Pacific coast of Honshu Island, Japan (n=3), the Sea of Japan coast of North Korea (n=3), and the Yellow Sea coast of North Korea (n=1). In North America, 1 adult red-throated loon migrated to the Gulf of California, Mexico. We did not obtain migration data from 3 loons that either died (2 birds) or had transmitters that failed (1 bird) prior to post-breeding migration. We did not receive locations from 6 loons during the winter; however, all moved west to Asia during post-breeding migration and we regained signals from 3 in May as they migrated east towards the breeding grounds.

Juvenile red-throated loons had post-breeding movements similar to adults. Twelve juvenile red-throated loons of the 14 marked survived to post-breeding migration: 11 migrated west to Asia and 1 migrated to the Alaska Peninsula before it died at the start of its first winter. Wintering sites were confirmed for 4 loons: 3 wintered in the area of Hokkaido Island, Japan, and southern Kuril Islands, Russia, and 1 wintered in the Commander Islands, Russia. We received location data from 1 juvenile through its first summer; this bird remained at Hokkaido Island where it had spent the preceding winter.

Most marked adult yellow-billed loons from the Arctic Coastal Plain migrated to wintering sites in East Asia. One marked yellow-billed loon died on the breeding grounds before post-breeding migration. Of 35 loons that departed the breeding grounds, 2 wintered in the Aleutian Islands (at Amlia Island and Unimak Island). The remaining 33 migrated west to Asia. Winter locations were received from 15 birds and identified wintering sites at the Commander Islands (n=1), southern Kuril Islands (n=2), Hokkaido (n=6) and Honshu (n=1) islands, the Sea of Japan and Yellow Sea coasts of North Korea (n=4), and the Yellow Sea coast of China (n=1). Some of the individuals detected in the Japan Archipelago may have made undetected movements farther west during winter. Transmitter signals from remaining 17 loons were lost during winter, although the signals of 11 were regained during pre-breeding migration as they moved east toward Alaska.

The lack of signal reception during winter suggests a problem with signal interference in the western portion of the winter range. We had no winter signal loss with PTTs deployed in 2000 and 2002–2003, which documented movements as far west as the Yellow Sea coast of China. Among transmitters deployed on loons during 2008–2010, the pattern of PTT signal loss during winter and reappearance during spring was associated with an absence of locations west of Japan and suggests migration to wintering sites that we were not able to identify. Signal reception was adequate to describe the portion of the migration route east of Japan for both species. Along this migration route, we detected locations in the Chukchi Sea from all marked red-throated loons and 85% of yellow-billed loons.

Table 2. Mean and range of post-breeding dispersal dates from breeding habitat, pre-breeding arrival dates at the Chukchi Sea, and minimum/maximum residence times in the Chukchi Sea during pre-breeding and post-breeding migration for red-throated and yellow-billed loons captured on the Arctic Coastal Plain, Alaska. Two adult red-throated loons were detected in the Chukchi Sea during pre-breeding migration with identical migration chronology. No marked juvenile red-throated loons were detected in Alaska during pre-breeding migration.

Species	Age	Post-breeding dispersal (n)	Range	Min/Max post-breeding residence (n)	Range	Pre-breeding arrival (n)	Range	Min/Max pre-breeding residence (n)	Range
Red-throated loon	Adult	30 Aug (15)	09 Aug–12 Sept	9/16 (15)	1–77	13 June (2)	NA[1]	2/6 (2)	2–6
	Juvenile	30 Aug (12)	24 Aug–8 Sept	25/31 (12)	4–53	ND[2]		ND	
Yellow-billed loon	Adult	20 Sept (33)	13 June–30 Sept	8/14 (29)	1–76	29 May (15)	22 May–12 June	13-Mar	1–13

[1] NA: Not applicable, no variation in the data.

[2] ND: No data, no juveniles were detected in the Chukchi Sea during pre-breeding migration.

Use of the Chukchi Sea

We detected red-throated and yellow-billed loons from breeding sites in the central Arctic Coastal Plain in the Chukchi Sea primarily during pre- and post-breeding migrations (Table 2). Juvenile red-throated loons from Point Lay were detected in the Chukchi Sea only during their first post-breeding migration after fledging from their natal lakes (Fig. 2). Adult red-throated and yellow-billed loons were most frequently detected in the Chukchi Sea during the post-breeding migration; in contrast, there were few pre-breeding Chukchi Sea locations, likely due to sample size attrition as PTTs stopped functioning and also shorter pre-breeding residence time as birds advanced rapidly to occupy breeding territories.

We detected yellow-billed loons known to be breeding age adults in the Chukchi Sea during summer; 18% (n=33) of marked yellow-billed loons from the NPR-A had moved to the Chukchi Sea as early as the 4th week of June (Fig. 2). These individuals had been located previously on inland breeding habitat. We did not monitor the nests of marked birds following PTT deployment and do not know their breeding success; however, assuming the postnatal period of yellow-billed loons is similar to that of common loons (Evers 2004), chicks require a minimum of 9 weeks to fledge. Thus, breeding adults would not be done rearing broods until late-September, at the earliest. Therefore, individuals that departed breeding habitat for the coast before late-September could not have successfully bred and were either failed breeders or individuals that did not attempt to breed.

We did not detect marked adult red-throated loons from the Colville River Delta in the Chukchi Sea during summer. Adult red-throated loons remained in the area of their breeding territories until at least August. We did not monitor the breeding status of birds after marking and do not know their reproductive success. However, marked red-throated loon chicks at Point Lay fledged in late August. Only 1 adult red-throated loon from the Colville River Delta departed inland habitat for the ocean prior to the last week of August. Individuals that remained on the Colville River Delta either successfully fledged chicks, or remained on breeding habitat after breeding failure. Red-throated loons are known to use marine habitat throughout the summer when commuting between inland breeding habitat and foraging habitat in the ocean (Bergman and Derksen 1977, Eberl and Picman 1993). Consistent with this foraging behavior, we detected marked red-throated loons from the Colville River Delta in both inland and marine habitat throughout during summer months (Fig. 3).

Most locations of marked loons in the Chukchi Sea were in nearshore habitat (Fig. 4). Marine locations within 25 km of the coastline accounted for 78% of adult and 90% of juvenile red-throated loon locations in the Chukchi Sea. Locations > 50 km from the coastline accounted for 6% and 3% of adult and juvenile red-throated loon locations in the Chukchi Sea, respectively. The farthest offshore detection of an adult red-throated loon in the Chukchi Sea was 130 km due south of Point Hope. The farthest offshore detection of a juvenile red-throated loon was 86 km offshore from Point Hope as it traveled to Uelen Lagoon on northeast Chukotka Peninsula, Russia. We also detected yellow-billed loons most frequently nearshore; 75% of Chukchi Sea detections were within 25 km of the coastline. However, yellow-billed loons were also detected offshore; 15% of detections were > 50 km from shore. The farthest offshore detection of a

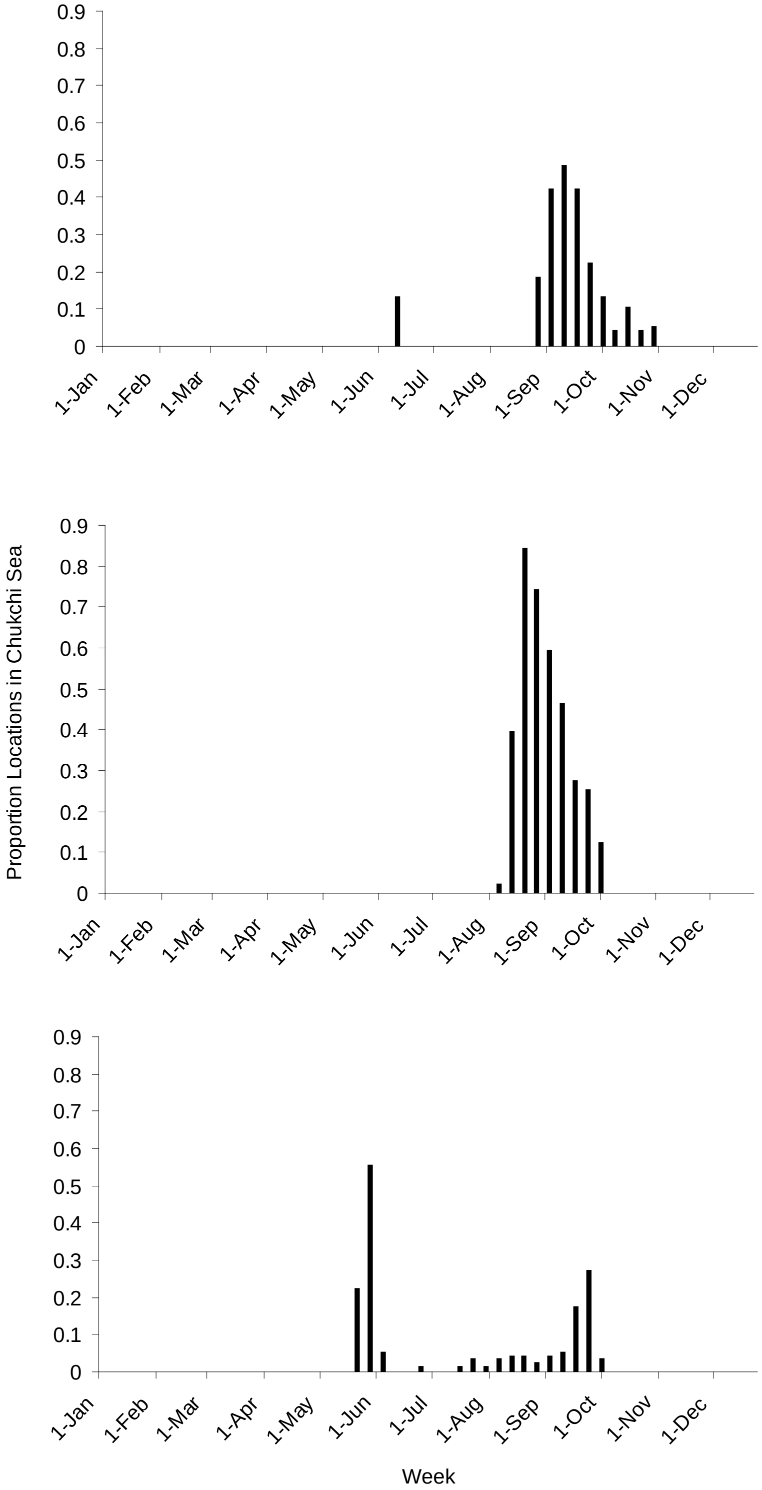

Figure 2. Proportion of weekly locations in the Chukchi Sea from marked adult red-throated loons (top panel), juvenile red-throated loons (middle panel), and adult yellow-billed loons (bottom panel).

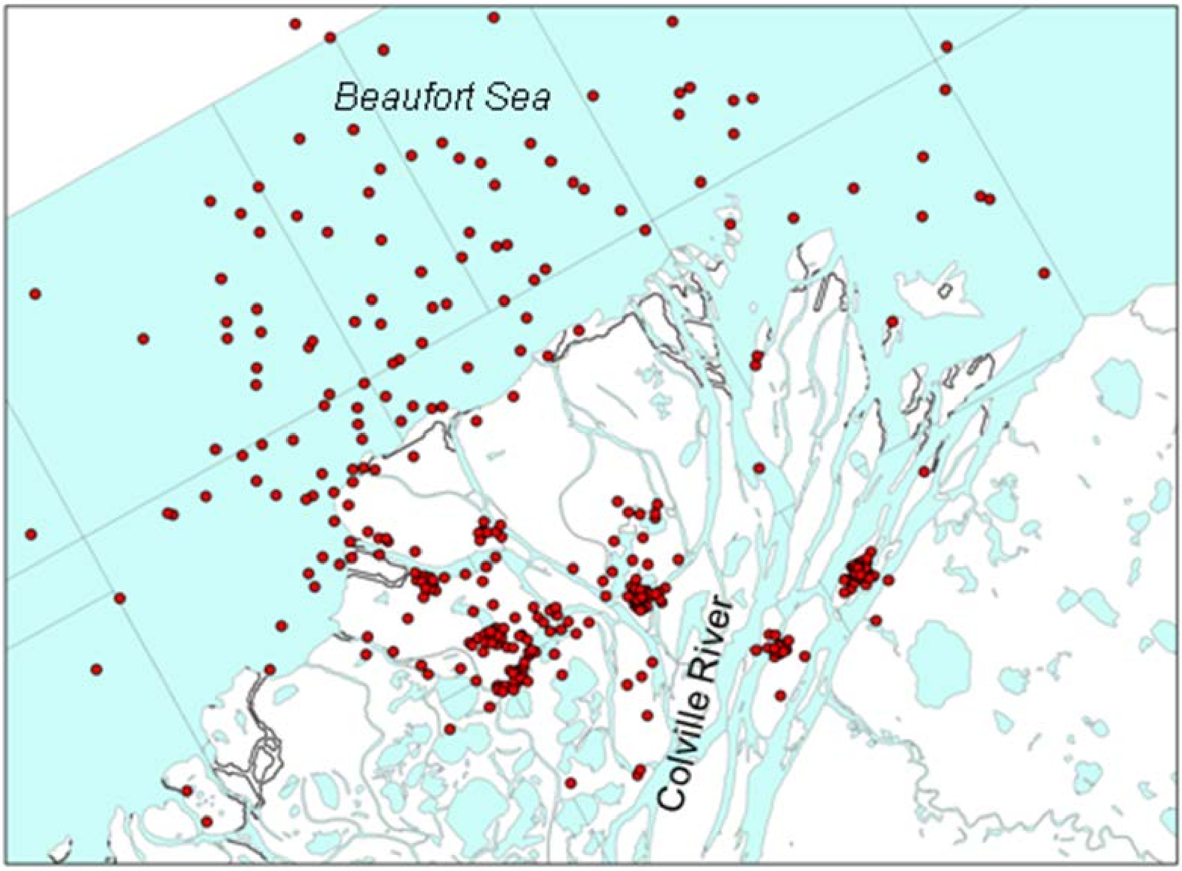

Figure 3. Locations of adult red-throated loons (red points) at the Colville River Delta during July–August grouped across years 2000, 2002, 2008–2010.

yellow-billed loon in the Chukchi Sea was 165 km west of Point Hope during post-breeding migration.

We detected both red-throated and yellow-billed loons between the coast and the BOEM Chukchi Sea Oil and Gas Lease Sale 193 area; however, no marked loon was detected directly within active leases (Fig. 5, 6). The nearest a marked adult red-throated loon was detected to the active leases was 71 km during post-breeding migration; 7.9% of adult red-throated loon detections were within 100 km of active leases. Marked juvenile red-throated loons from Point Lay, a breeding site southeast of the lease sale area, and did not move toward the lease sale area after fledging from their natal lakes. The nearest we detected a juvenile red-throated loon to active lease blocks was 84 km. For yellow-billed loons, 2.4% of Chukchi Sea locations were within 50 km of leased blocks and 33% of detections were within 100 km. The closest we detected a yellow-billed loon to active leases was 43 km during the post-breeding migration.

Over all years, we received 75 locations from 15 adult red-throated loons, 137 locations from 12 juvenile red-throated loons, and 139 locations from 29 adult yellow-billed loons in the Chukchi Sea during post-breeding migration (Fig. 7). Individuals with no locations in the Chukchi Sea likely migrated through the area given subsequent locations in the Bering Sea, but were not

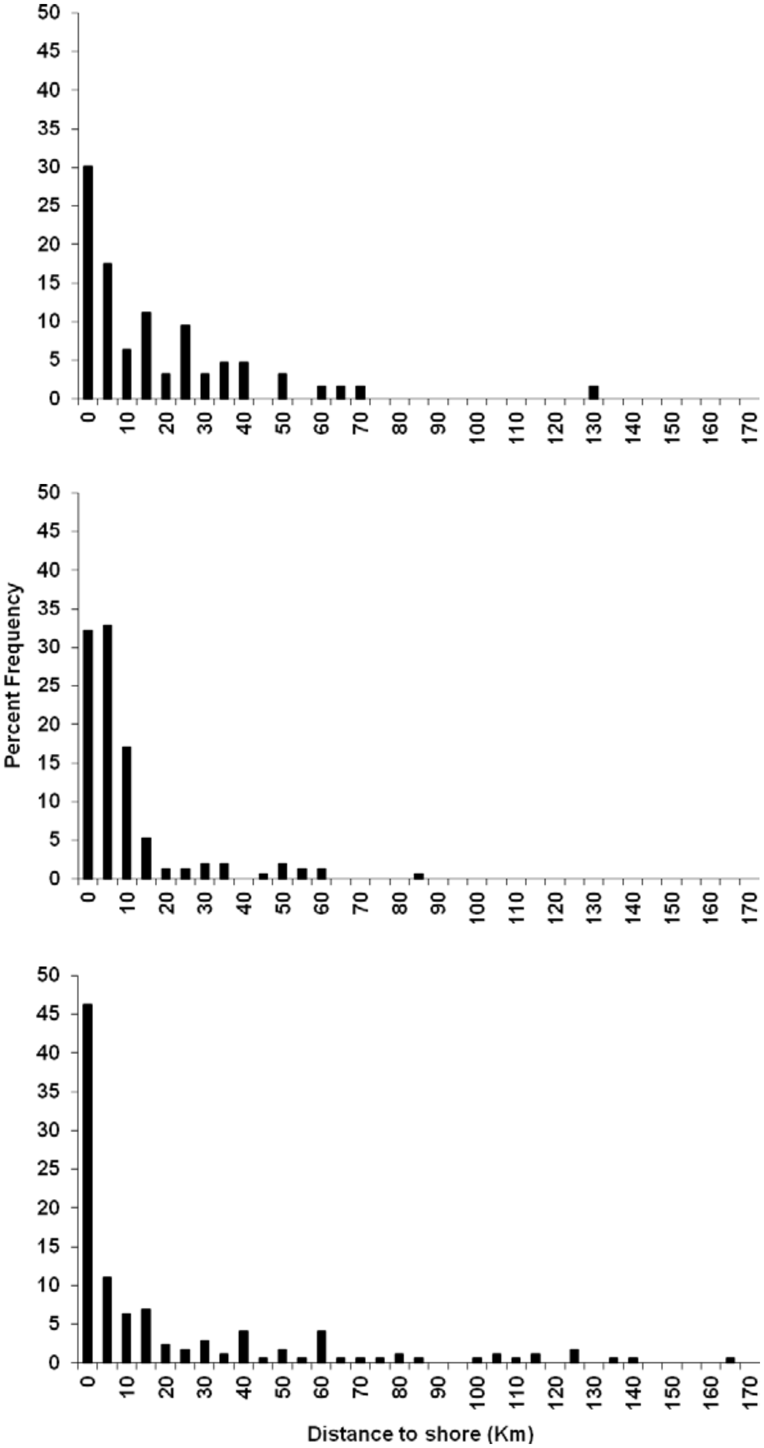

Figure 4. Frequency distributions of distances between Chukchi Sea locations and the nearest coastline for adult red-throated loons (top panel), juvenile red-throated loons (middle panel), and adult yellow-billed loons (bottom panel).

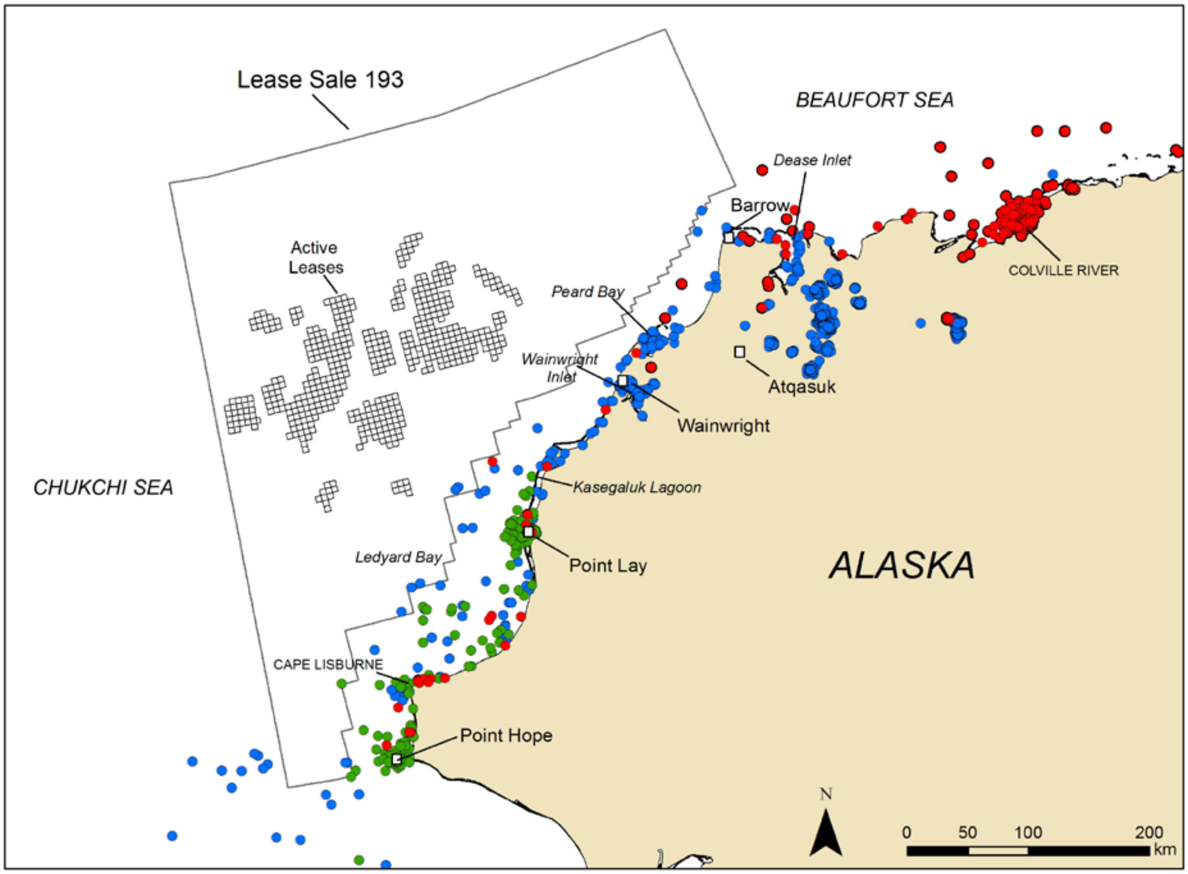

Figure 5. Locations of adult red-throated loons (red points), juvenile red-throated loons (green points), and adult yellow-billed loons (blue points) in relation to active oil and gas leases in the Chukchi Sea Oil and Gas Lease Sale 193.

detected due to the intermittent duty cycle of transmitters and the filtering of auxiliary quality class locations.

Adult red-throated loons breeding at the Colville River Delta departed breeding habitat between 09 August and 12 September (average departure date: 30 August, SD=7 days, n=15). Estimated average minimum and average maximum Chukchi Sea residence times for adult red-throated loons were 9.0 days (SD=16 days, range: 1–68 days, n=15) and 16.0 days (SD=17 days, range: 7–77 days, n=15), respectively (Table 2, Fig. 8**)**. Juvenile red-throated loons departed their natal lakes between 24 August and 8 September (average departure date: 30 August, n=12). Juvenile red-throated loons had longer post-breeding residence times than adults with an estimated minimum residence time of 25.4 days (SD=15 days, range: 4–50 days, n=12) and estimated maximum residence of 30.6 days (SD=14 days, range: 10–53 days, n=12; (Table 2, Fig. 8; difference between means inferred from 95% confidence intervals). Yellow-billed loons from the NPR-A departed breeding habitat between 13 June and 30 September (average departure date: 9 September, SD=27 days, n=33 birds that made 54 departures). However, the distribution of yellow-billed loon departures dates was skewed due to early departures by some individuals and thus the median better describes the central tendency of the data (median departure date=20 September). Average minimum and maximum residence times of yellow-billed loons in the Chukchi Sea were 8.5 days (SD=14 days, range: 1–66 days, n=29 birds with 45 residence

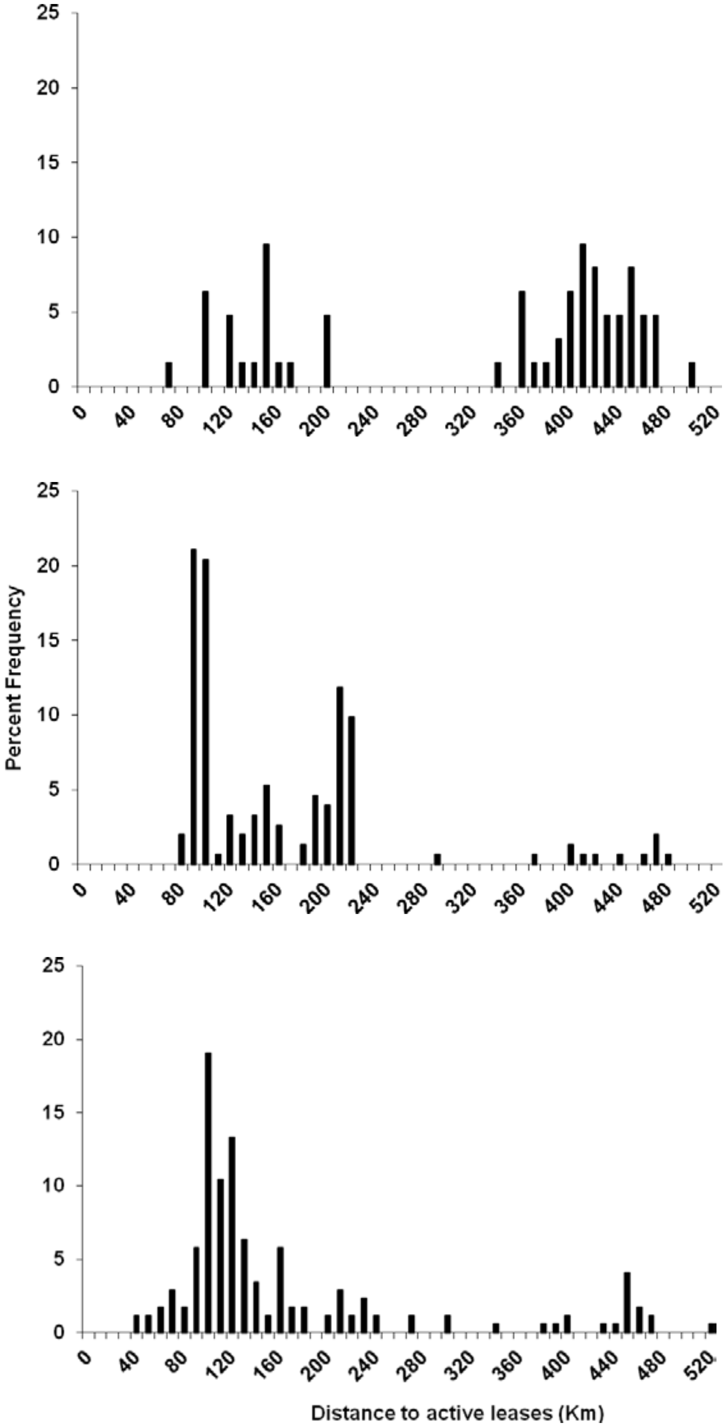

Figure 6. Frequency distributions of distances between Chukchi Sea locations and the nearest active oil and gas lease block boundary of Lease Sale 193 for adult red-throated loons (top panel), juvenile red-throated loons (middle panel), and adult yellow-billed loons (bottom panel).

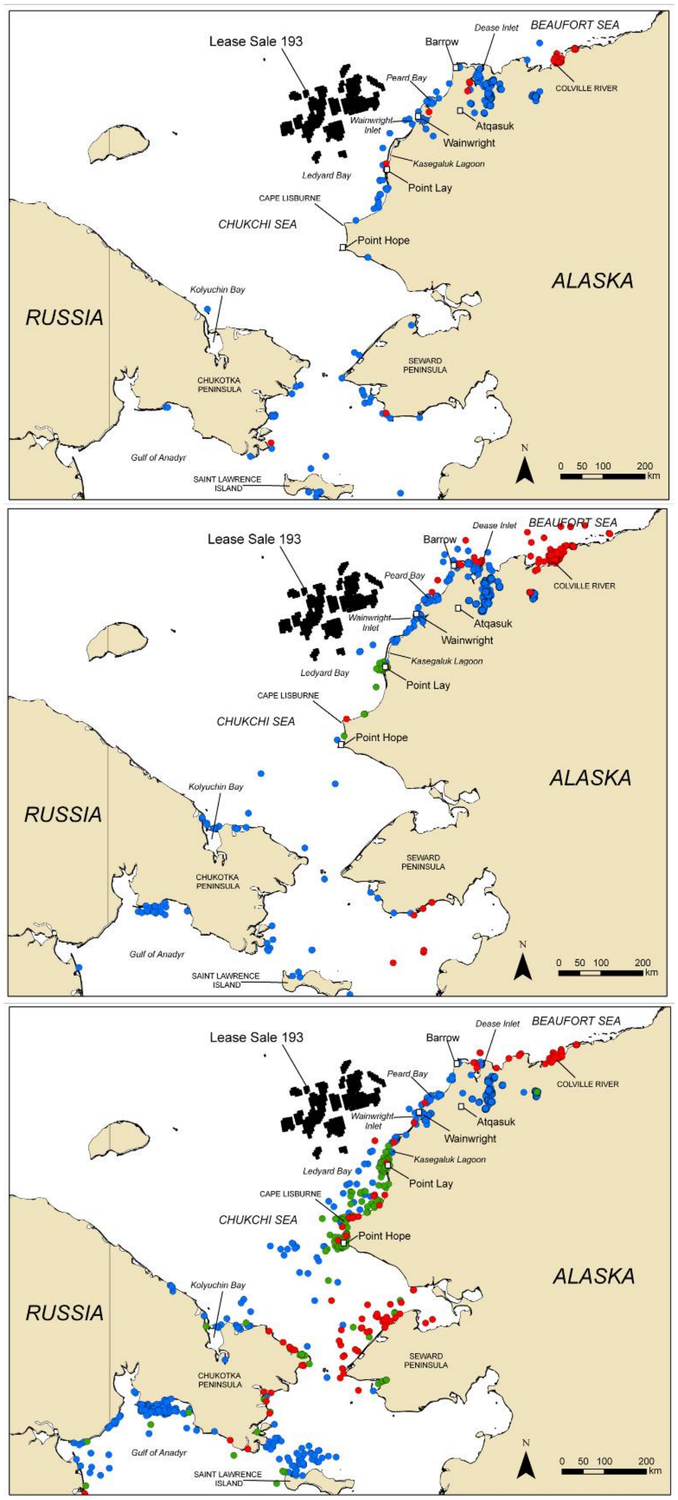

Figure 7. Locations of adult red-throated loons (red points), juvenile red-throated loons (green points) and adult yellow-billed loons (blue points) with satellite transmitters in the Chukchi Sea during May–June (top panel), July–August (middle panel), and September–November (bottom panel).

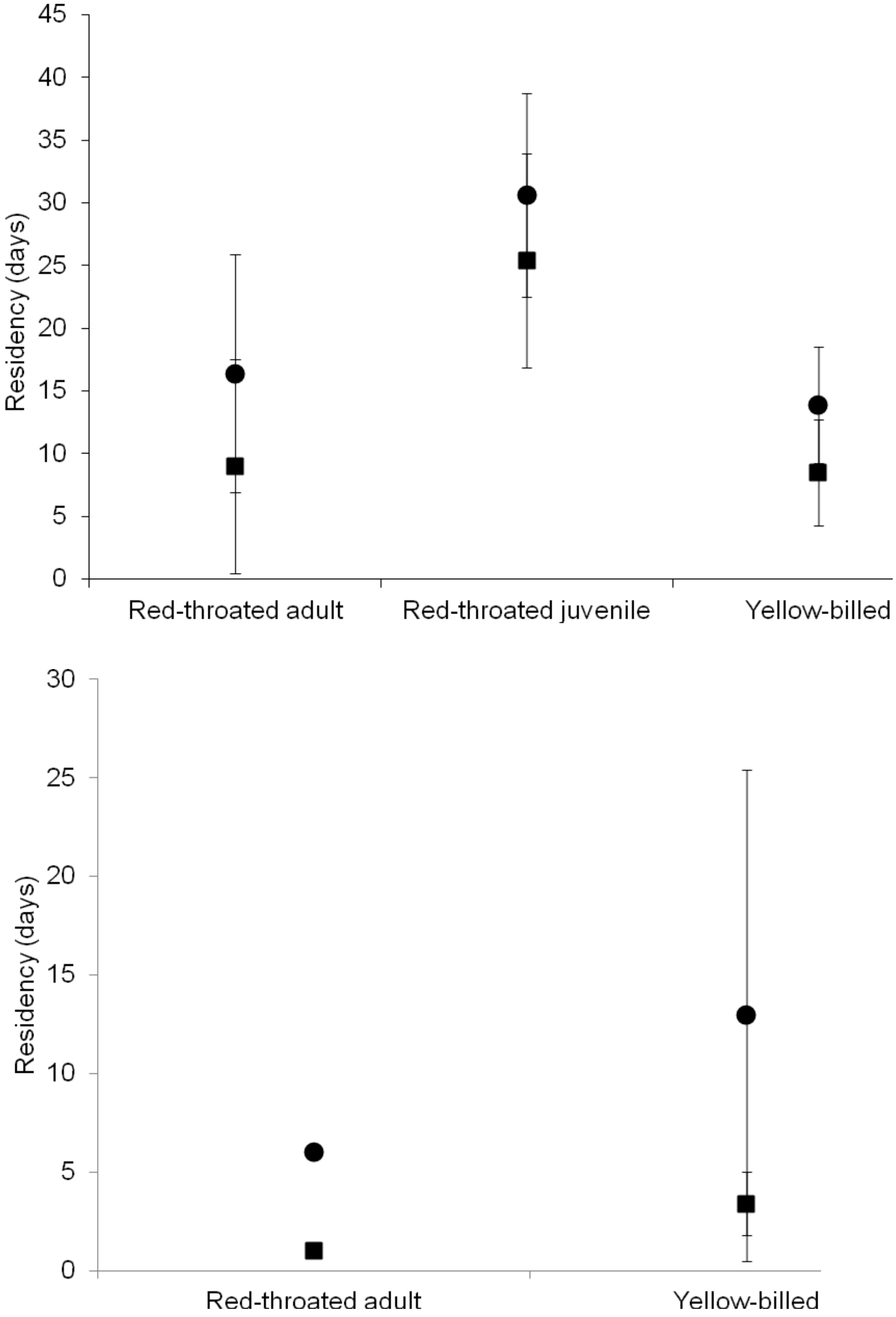

Figure 8. Estimated maximum (circles) and minimum (squares) residence times of adult red-throated loons, juvenile red-throated loons, and adult yellow-billed loons marked with PTTs during post-breeding (top panel) and pre-breeding (bottom panel) migration. Error bars indicate 95% confidence intervals. No juvenile red-throated loons were detected during pre-breeding migration. Two adult red-throated loons were detected during pre-breeding migration and both had the same residence time and therefore zero variance.

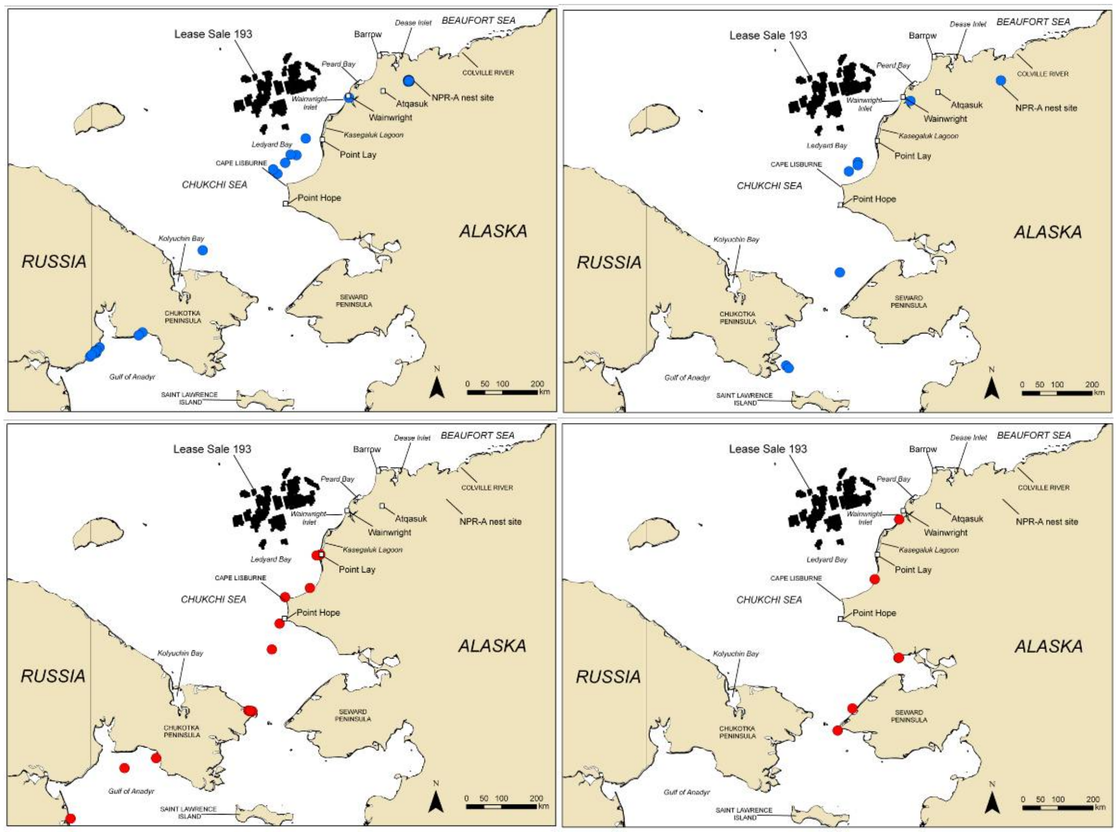

Figure 9. Examples of east-to-west post-breeding migration routes across the Chukchi Sea taken by yellow-billed loons (top panels; PTTs YB09_9529, YB02_32936) and red-throated loons (bottom panels; PTTs RL09_95294, RL00_11009).

periods) and 13.9 days (15 SD, range: 3–76 days, n=29 birds with 45 residence periods; (Table 2, Fig. 8).

Marked red-throated loons crossed the Chukchi Sea from North America to Asia during post-breeding migration along several routes (Fig. 9**)**. Detections on the north coast of the Chukotka Peninsula suggest use of a route north of the Bering Strait. This route traveled southwest from the Lisburne Peninsula in Alaska to East Cape on the Chukotka Peninsula. Alternatively, some individuals apparently traveled to the Seward Peninsula and crossed the Chukchi Sea at the Bering Strait. Equal numbers of marked loons migrated by each of these 2 routes. A third less common route traveled south along the Chukchi Sea and Bering Sea coasts of Alaska and then west to Asia. Two individuals followed this general route, 1 traveling west via St. Matthew Island and the other via the Pribilof Islands.

Marked yellow-billed loons similarly followed 2 post-breeding migration routes between North America and Asia (Fig. 9**)**. Detections offshore from Kasegaluk Lagoon and in Ledyard Bay, in combination with detections on the Chukchi Sea coast of the Chukotka Peninsula around Kolyushin Bay, indicate an offshore route located north of the Bering Strait. Alternatively, detections in the area of the Bering Strait and Saint Lawrence Island indicate a route crossing east to west in the Bering Strait region. The 2 yellow-billed loons that wintered in the Aleutian

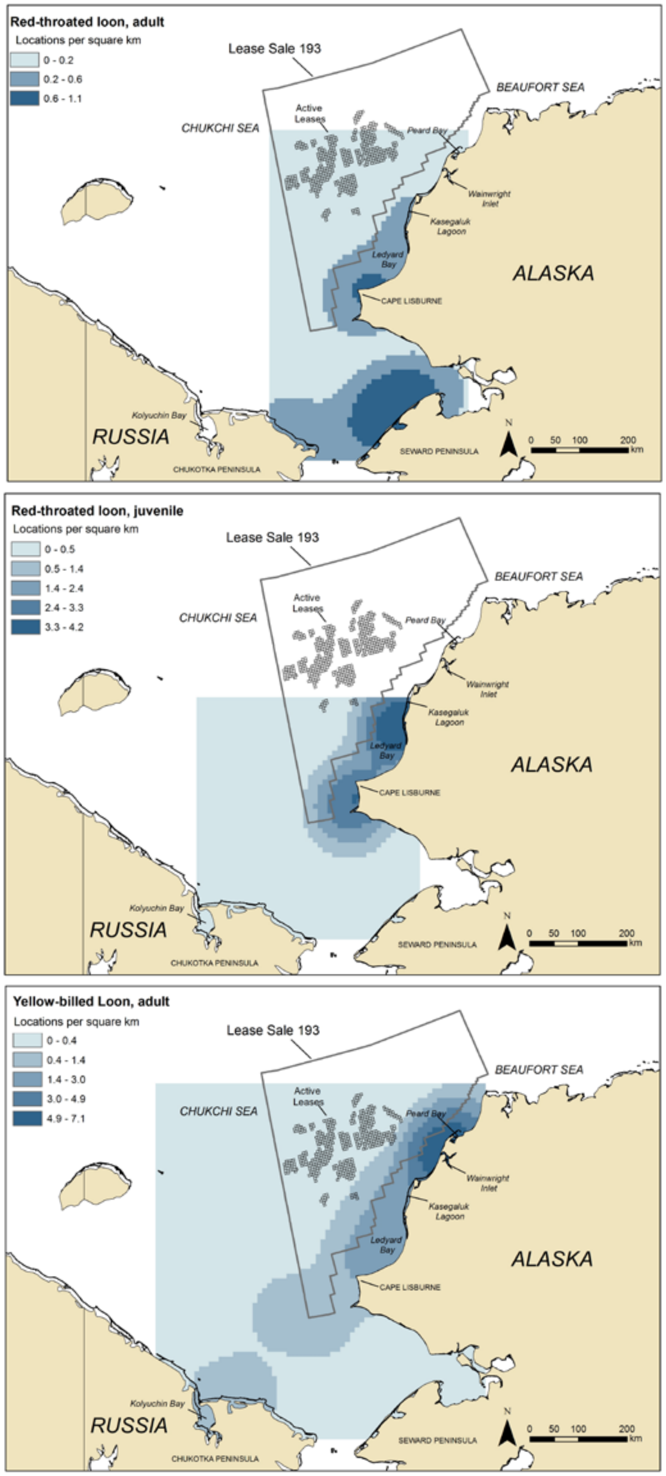

Fig. 10. Kernel density contours of locations of satellite-marked loons in the Chukchi Sea accumulated across seasons and years of tag deployment (top panel: adult red-throated loons, middle panel: juvenile red-throated loons, bottom panel: adult yellow-billed loons).

Islands took very different migration routes. The individual that wintered on Unimak Island traveled south from Saint Lawrence Island, while the individual that wintered at Amlia Island first traveled to the Chukotka Peninsula and then moved south.

Pre-breeding migration by marked loons was characterized by fewer detections than the post-breeding migration (Fig. 7). Location sample size was reduced by the expiration of PTT batteries, mortalities, and less-frequent transmissions of duty cycles. Over all years, we received 2 locations from 2 adult red-throated loons and 34 locations from 14 adult yellow-billed loons in the Chukchi Sea during pre-breeding migration. No juvenile red-throated loons were detected in the Chukchi Sea during pre-breeding migration or during their first summer following transmitter deployment.

Locations from 4 adult red-throated loons showed first eastward movements away from wintering sites occurred between 23 March and 11 May (average departure date=13 April, SD=22 days, n=4 birds). We detected 2 adult red-throated loons in the Chukchi on 13 June, and first detections on breeding habitat occurred between 12–23 June (average date=17 June, SD=3.9 days, n=2 birds). The 2 adult red-throated loons detected in the Chukchi Sea during pre-breeding migration both had estimated minimum and maximum residence times of 2 and 6 days, respectively (Table 2, Fig. 8). Detections during pre-breeding migration were too sparse to delineate migration routes.

Adult yellow-billed loons departed wintering sites between March and June (average departure date=3 May, SD=12 days, n=12 birds that made 18 departures). First pre-breeding locations in the Chukchi Sea occurred between 22 May and 12 June (average=29 May, SD=5.6 days, n=15 birds with 20 first locations). Average minimum and maximum pre-breeding residence times were 3.4 days (SD=3.6 days, range: 1–13 days, n=14 birds with 20 residence periods) and 12.9 days (SD=6.2 days, range: 5–33 days, n=14 birds with 20 residence periods; (Table 2, Fig. 8). Yellow-billed loons arrived on breeding habitat between 26 May and 02 June (average date=29 May, SD=5.6 days, n=22 birds that made 30 arrivals). During pre-breeding migration, most yellow-billed loon detections were in the vicinity of Saint Lawrence Island and the Bering Strait; only 1 individual showed evidence of crossing the Chukchi Sea via the northern, offshore route during spring.

Across years and seasons, we received locations in the Chukchi Sea from 15 adult red-throated loons (77 locations), 12 juvenile red-throated loons (137 locations), and 29 adult yellow-billed loons (173 locations). The highest densities of adult red-throated loon locations were at Cape Lisburne, the northwest coast of the Seward Peninsula (1.1–0.6 locations · km^2), and Ledyard Bay (0.2–0.6 locations · km^2; Fig. 10). Locations from juvenile red-throated loons were concentrated offshore from their natal area near Point Lay (3.3–4.2 locations · km^2), as well as at Ledyard Bay, Cape Lisburne, and Point Hope (2.4–3.3 locations · km^2; Fig. 10). Yellow-billed loon locations were concentrated at Wainwright Inlet and Peard Bay (4.9–7.1 locations · km^2), Kasegaluk Lagoon, and Ledyard Bay (1.4–3.0 locations · km^2; Fig. 10).

DISCUSSION

Efficacy of Satellite Telemetry

Implanted satellite transmitters effectively documented loon movements throughout their annual cycle. Loons implanted with PTTs provided information on migration routes in remote areas that would not otherwise be possible to obtain. However, it is important to consider potential effects of transmitters on the survival and behavior of marked birds when evaluating these data. Across species, the effects of implanted transmitters on birds have varied. Acute responses have been observed in some species. Western grebes (*Aechmophorus occidentalis*) implanted with transmitters suffered 100% mortality with a median postoperative survival time of only 4 days after being released into the wild; however, birds held in captivity all survived a 9-day postoperative period (Gaydos et al. 2011). Implanted transmitters in common murres (*Uria aalge*) and thick-billed murres (*U. lomvia*) caused breeding failure in the year birds were marked as well as in the year following marking when birds remained offshore and did not return to the breeding colony (Meyers et al. 2000).

In contrast, implanted PTTs had no effect on behavior, fecundity or survival during the first year following marking, and only a small effect on migration timing in Canada geese (*Branta canadensis*; Hupp et al. 2003, 2006). Recapture rates of harlequin ducks (*Histrionicus histrionicus*) with and without implanted transmitters were similar, suggesting that transmitters did not affect survival (Esler et al. 2000). However, survival of Canada geese 2–3 years after transmitter deployment was less than that of controls; this difference was not statistically significant, but suggested potential long-term consequences of transmitter implantation (Hupp et al. 2006). Sub-acute effects of implanted transmitters on diving behavior were observed in captive common eiders (*Somateria mollissima*; Latty et al. 2010); however, all marked birds were able to maintain body mass under captive conditions (Latty 2008).

We found no evidence of acute effects of implanted transmitters in loons. Loons implanted with transmitters had mortality rates within the range expected for species with a long life-span, low fecundity life history (Sæther and Bakke 2000), and were similar to natural mortality rates of common loons. No survival estimates are available for loon species that breed in the Arctic; however, estimates of common loon vital rates are available. Apparent annual survival probability in adult common loons, estimated from mark-resight studies of color-banded individuals, was 0.87 (Mitro et al. 2008, Piper et al. 2012). Survival of juvenile common loons ranged from 0.70 for 1 year-olds (estimated from band recoveries; Mitro et al. 2008) to an average annual apparent survival of 0.77 for 1–3 years olds (estimated from mark-resight data; Piper et al. 2012).

Survival rates of marked loons during the first year following transmitter deployment (calculated as 1-proportion of individuals known to have died in a given year, averaged across years) were 0.89 for adult red-throated loons, 0.65 for juvenile red-throated loons, and 0.90 for adult yellow-billed loons. These estimates include only known mortalities and do not include marked individuals that had unknown fates (i.e., PTTs that stopped transmitting data without a corresponding decrease in body temperature indicative of mortality, or a decrease in transmitter voltage indicative of battery failure) and thus likely represent maximal estimates. Marked birds with unknown fates make more rigorous calculations of survival from these data problematic.

We were not able to retrieve the carcasses of known mortalities for necropsy; determining the cause of death in free-ranging birds is often impossible due to carcass degradation and consumption by predators and scavengers (Franson and Cliplef 1992), especially if carcass recovery is not immediate. The number of known mortalities of marked loons was within the range of natural mortality and most occurred well after transmitter deployment (> 100 days on average). These results are not consistent with an acute transmitter effect in loons. We have no information on possible sub-acute effects because it was not possible to observe birds after release; however, any potential sub-lethal effects did not prevent birds from migrating throughout the extent of the annual distributions for these species. Further, previously documented effects of implanted transmitters on migration chronology have been small (1–2 days), and found only when migration conditions were poor (Hupp et al. 2006).

Migratory Connectivity

Strong migratory connectivity between breeding grounds on the Arctic Coastal Plain and wintering grounds in Asia shown by marked loons has important implications to their populations. Individuals from a breeding area that migrate to the same non-breeding area encounter the same environmental conditions and mortality risks (Webster et al. 2002). Thus, poor environmental conditions or disturbances during the nonbreeding season have the potential to impact a large portion of the population in populations showing strong migratory connectivity. The strong migratory connectivity of marked loons from the Arctic Coastal Plain contrasts weak migratory connectivity of marked king eiders (*Somateria spectabilis*) from the same breeding area which wintered at sites in Asia and Alaska with similar frequency (Philips et al. 2006). Although marked loons showed strong migratory connectivity at a broad spatial scale, the strength of connectivity was weaker at a finer scale; within their East Asian nonbreeding grounds, loons used more than a single site and were dispersed from the Archipelago of Japan to the Korean Peninsula.

Migration routes to Asia followed the coastlines of the Arctic Coastal Plain, and the Chukotka and Kamchatka peninsulas. Migration is an energetically demanding period of the annual cycle and requires sufficient resources to meet the cost of movement during the migration period (Alerstam et al. 2003). Thus, sites along this migration route provide important habitat for meeting this energy requirement. The few loons that we tracked to North American wintering sites also migrated through the Chukchi Sea, indicating the importance of the Chukchi Sea as a migratory corridor for loons breeding on the Arctic Coastal Plain regardless of which side of the Pacific Ocean their wintering grounds lie. Coastal migration through the Chukchi Sea provides the most direct route between breeding grounds on the Arctic Coastal Plain and wintering grounds in the Aleutian Islands and Asia. Although loons are capable of overland migration (Sherony et al. 2000, Kenow et al. 2002), we found no evidence of long distance overland movements by marked loons. Instead, marked loons relied exclusively on coastal marine habitat during the nonbreeding period of their annual cycle.

Juvenile red-throated loons marked as chicks did not return to Alaska the summer after their hatch year. The 1 juvenile we received locations from over a full year remained on the nonbreeding grounds during its first summer. This result contrasts with red-throated loons nesting at the Shetland Islands, UK where 25% of birds banded as chicks and recovered during their first summer were in their natal area (Okill 1994). The reason for this apparent difference may be due to ecological differences between sites, or the limitations of the small sample size of juveniles we tracked. The Shetland Islands population is at the southern edge of the breeding range and has a small-scale annual distribution compared to loons from the Arctic Coastal Plain; most of the Shetland Islands population remains in the British Isles during winter (Okill 1994), making a return migration to the breeding grounds less time- and energy-demanding. Comparison with the Okill (1994) study, however, is difficult due to differences in methodology. The results of Okill (1994) are based on band recoveries from a 15 year banding program that marked > 1,800 chicks. Our data, although based on a small sample of marked birds, demonstrate that some juvenile red-throated loons from the Arctic Coastal Plain remain on the nonbreeding grounds during their first summer.

Use of the Chukchi Sea

The presence of satellite-tracked loons in the Chukchi Sea coincides with the annual period of open water. The earliest locations in the Chukchi Sea occurred during late-May when the proportion of open water is low, but rapidly increasing (Douglas 2010). Thus, migrating loons use open leads in the sea ice during pre-breeding migration. Most loons departed the Chukchi Sea by October, well before the loss of open water due to sea ice advance (Douglas 2010). Thus, post-breeding migration chronology apparently is unrelated to sea ice formation; however, fall freeze-up of freshwater lakes in September and October (Morris et al. 1995) likely places a severe time constraint on breeding loons, especially for red-throated loons which use very small lakes for breeding (Bergman and Derksen 1977).

In the Chukchi Sea, we most frequently detected marked loons within 20 km of shore. Locations at this distance lie within the 20 m isobath (Gratto 1980). Little is known about the dive capacity of loons, particularly regarding the depth to which they are capable of diving in marine habitats. However, based on an allometric equation developed for diving birds (Schreer and Kovacs 1997), much of the water column within the 20 m isobath is predicted to be within the dive capacity of loons. The shallow bathymetry of the Chukchi Sea likely makes most of the water column accessible to diving yellow-billed loons, given their large body mass, even at offshore locations. Thus, bathymetry likely does not directly determine suitable marine foraging habitat for loons in the Chukchi Sea south of the deeper water of the Barrow Canyon.

The distribution of prey strongly influences the distribution of marine birds. Distributions of marine prey are associated with oceanographic conditions that vary spatially and temporally. In the Chukchi Sea, water temperature limits fish abundance in cold, offshore Anadyr Water (Grebmeier et al. 2006). Nearshore-flowing Alaska Coastal Water is a warmer water mass that provides more suitable conditions for forage fish species on which loons and other piscivorous marine birds feed (Springer et al. 1984). Nesting seabirds at Cape Thompson and Cape Lisburne foraged more frequently in inshore waters, where fish densities where higher, than offshore waters (Piatt et al. 1989). Further, changes in seabird productivity at these colonies correlated with the extent and duration of sea ice cover and consequent effects on the Alaska Coastal Current system (Springer et al. 1984). Piscivorous loons likely respond similarly to oceanographic conditions in the Chukchi Sea which influence forage fish distribution.

Juvenile red-throated loon residence in the Chukchi Sea during post-breeding migration exceeded adult residence by an average of 2 weeks. Age-related differences in the timing of migration are common in birds and may be related to a number of ecological factors (Woodrey and Chandler 1997). Sites of capture of adults and juveniles were 480 km apart; however, this difference likely does not account for the difference in residence times between age classes we observed given the rapid movement rate afforded by flight. Also confounding is the amount of time between transmitter deployment and the end of the breeding season. Chicks at Point Lay were captured during late-August, 6 weeks after adults at the Colville River. Thus, adults had longer to recover from potential effects of the surgery to implant transmitters prior to migration than juveniles. It is possible that recovery from transmitter deployment may have prolonged juvenile residence in the Chukchi Sea. However, marked chicks fledged from lakes shortly after transmitter deployment, which suggests that transmitters did not interfere with juveniles gaining the ability to fly despite the added mass of the implanted transmitter. Alternatively, juveniles may prolong their residence to complete their growth before undertaking migration, a constraint not faced by adults. Red-throated loon chicks fledge before reaching adult body mass and flight feather length (Ball 2004). If juveniles remain close to their natal sites to complete growth, conditions at these sites are likely important for juvenile survival. However, we cannot disentangle the effects of the timing of transmitter deployment and a requirement for post-fledging growth in chicks.

Adult yellow-billed loons departed breeding habitat for coastal habitat as early as the 4th week of June. This indicates that these loons did not successfully breed and departed their territorial lakes for coastal habitat. We do not know the breeding success of the individuals we tracked and thus birds that remained on their summer lakes into August and September also may have been failed breeders. Loons are highly territorial (Sperry 1987) and compete for access to suitable breeding habitat (Piper et al. 1999), thus there is selective pressure to maintain territorial residence even if a breeding attempt fails. Individuals that depart lakes early may have been displaced from their territories by conspecifics (Piper et al. 1999) or may have come from lakes with insufficient resources to support continued residence (Gringas and Paszkowski 1999). Regardless of the cause, early departures from breeding habitat indicate that some portion of the breeding population is present in coastal habitat during summer months.

Red-throated loons, both failed and successful breeders, rely exclusively on marine habitat to obtain food. PTTs deployed on breeding red-throated loons at Cape Espenberg on the Seward Peninsula exhibited a similar pattern of alternating marine and inland locations indicative of foraging trips to the Chukchi Sea (J. Schmutz, U.S. Geological Survey, unpublished data). We also observed adult red-throated loons breeding near Point Lay flying to Kasegaluk Lagoon and the Chukchi Sea to feed and provision their chicks (J. Schmutz, U.S. Geological Survey, unpublished data). Strict reliance on marine resources makes red-throated loons particularly sensitive to changes, anthropogenic and natural, in the nearshore marine habitat.

Variation in the timing of post-breeding departure from lakes was evident for red-throated and yellow-billed loons. Differences among individuals in the timing of nest initiation and breeding success likely explain this variation. The consequence of this variation is an asynchronous post-breeding migration. Although individuals remained in the Chukchi Sea for post-breeding residence times as brief as 1 or 2 days, individual residence periods were spread out over 10 weeks because of variation in the timing of departure from breeding habitat. Post-breeding Chukchi Sea residence was more synchronous in our sample of juvenile red-throated loons because we selected similarly aged chicks to implant with PTTs which consequently had similar fledging dates. In contrast to post-breeding migration, arrival to breeding habitat in the spring was fairly synchronous in our sample of birds, likely due strong selection for early arrival to breeding territories (North and Ryan 1988).

Although we did not detect any individuals within active leases in BOEM Chukchi Sea Oil and Gas Lease Sale 193, we did frequently detect both red-throated and yellow-billed loons along the coastline east of the lease sale area during spring, summer, and fall. Some marked yellow-billed loons crossed the Chukchi Sea during migration to Asia north of the Bering Strait. However, not all marked yellow-billed loons for which we had Chukchi Sea detections crossed the Chukchi Sea via this offshore route. What factors influence individual decisions on the route of migration across the Chukchi Sea, whether physiological or environmental, are unknown and can only be identified with a larger sample of migrating individuals with more frequent detections in the Chukchi Sea. Yellow-billed loons crossing the Chukchi Sea following the offshore route are most likely to pass near the active oil and gas lease sale area. However, activities associated with oil and gas development in Lease Sale 193, such as vessel and air traffic, will not be limited to the active lease blocks or the general lease sale area. Loons using coastal habitat in the vicinity of Lease Sale 193 may be disturbed or displaced by such activity. Further, accidental releases of oil into the Chukchi Sea have the potential to contaminate or displace migrating red-throated and yellow-billed loons and breeding red-throated loons that forage in coastal marine habitat.

Population Implications

The Arctic Coastal Plain in Alaska is breeding habitat for an estimated 2,200 breeding yellow-billed loons (Earnst et al. 2005), and a population of red-throated loons indexed at a minimum of 3,200 (Larned et al. 2010). Our sample of implanted loons represents a fraction of the total populations breeding on the Arctic Coastal Plain and thus inferences from the data to these populations must be made cautiously (Lindberg and Walker 2007). Such caution is particularly justified with regard to the timing and duration of use of the Chukchi Sea, which are likely to vary with geographic distance between the Chukchi Sea and breeding sites, especially those located farther east along the Beaufort Sea coast and Arctic Archipelago. Marked yellow-billed loons from Victoria Island and interior North West Territories, Canada migrated to wintering sites via a coastal route through the Beaufort and Chukchi seas (J. Schmutz, U.S. Geological Survey, unpublished data). A strategy of a sustained PTT deployment effort over time provides the best approach for quantifying loon movements and habitat use over large, remote areas, such as the Beaufort and Chukchi seas.

The available data indicate that the Chukchi Sea is an important migratory corridor for populations of red-throated and yellow-billed loons breeding on the Arctic Coastal Plain. Red-throated loon breeding grounds are widely distributed throughout coastal tundra habitat in Alaska. In contrast, yellow-billed loon breeding habitat in the U.S. is concentrated in the central Arctic Coastal Plain. Therefore, if the migration patterns of this population are similar to those of the individuals we marked, the majority of breeding yellow-billed loons in the U.S. likely migrate through the northeast Chukchi.

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