Use of the Beaufort Sea by King Eiders Breeding on the North Slope of Alaska

LAURA M. PHILLIPS,[1,2] *Department of Biology and Wildlife, University of Alaska, Fairbanks, AK 99775, USA*

ABBY N. POWELL, *United States Geological Survey Alaska Cooperative Fish and Wildlife Research Unit, and Institute of Arctic Biology, University of Alaska, Fairbanks, AK 99775, USA*

ERIC J. TAYLOR, *United States Fish and Wildlife Service, 1101 E. Tudor Road, Anchorage, AK 99503, USA*

ERIC A. REXSTAD, *Institute of Arctic Biology, Department of Biology and Wildlife, University of Alaska, Fairbanks, AK 99775, USA*

ABSTRACT We estimated areas used by king eiders (*Somateria spectabilis*) in the Alaskan Beaufort Sea, how distributions of used areas varied, and characteristics that explained variation in the number of days spent at sea, to provide regulatory agencies with baseline data needed to minimize impacts of potential offshore oil development. We implanted sixty king eiders with satellite transmitters at nesting areas on the North Slope of Alaska, USA, in 2002–2004. More than 80% of marked eiders spent >2 weeks staging offshore prior to beginning a postbreeding molt migration. During postbreeding staging and migration, male king eiders had much broader distributions in the Alaskan Beaufort Sea than female eiders, which were concentrated in Harrison and Smith Bays. Distribution did not vary by sex during spring migration in the year after marking. Shorter residence times of eiders and deeper water at locations used during spring migration suggest the Alaskan Beaufort Sea might not be as critical a staging area for king eiders during prebreeding as it is postbreeding. Residence time in the Beaufort Sea varied by sex, with female king eiders spending more days at sea than males in spring and during postbreeding. We conclude the Alaskan Beaufort Sea is an important staging area for king eiders during postbreeding, and eider distribution should be considered by managers when mitigating for future offshore development. We recommend future studies examine the importance of spring staging areas outside the Alaskan Beaufort Sea. (JOURNAL OF WILDLIFE MANAGEMENT 71(6):1892–1898; 2007)

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KEY WORDS Alaska, Beaufort Sea, distribution, king eider, migration, satellite telemetry, *Somateria spectabilis.*

In the summer of 1968, a large deposit of oil was discovered beneath the arctic coastal plain of Alaska, USA. Since then, there has been extensive industrial development at Prudhoe Bay, Alaska, and exploration and development of smaller surrounding fields. Thirty-one exploratory wells have been drilled on the Beaufort Sea outer continental shelf of Alaska since 1981 (Minerals Management Service 2004) and the first offshore development project in the region to use a subsea pipeline to transport oil under pack ice began oil production in 2001.

Development of offshore oil resources on natural and artificial islands in the Beaufort Sea has important implications for hundreds of thousands of birds that use the sea as a flyway, staging, or molting area. Of these birds, king eiders are some of the most abundant (Fischer and Larned 2004). In spring, they migrate from the Bering Sea, around Point Barrow into the Beaufort Sea, and to breeding areas on the coastal plain of Alaska and western Canada (Suydam 2000). Woodby and Divoky (1982) counted >100,000 king eiders passing Point Barrow within a 30-minute period during spring migration in 1976. After breeding, eiders move back into the Beaufort Sea to stage prior to migrating to molting sites in the Bering Sea (Thomson and Person 1963, Woodby and Divoky 1982, Suydam et al. 2000). Migrating king eiders can fly only a few meters above ground level, making them susceptible to collisions with man-made structures (Suydam 2000). In addition, disturbance from boats and helicopters supporting oil infrastructure could disrupt or displace eiders from foraging areas (Frimer 1994, Mosbech and Boertmann 1999). Potential impacts from oil spills might include displacement of eiders from foraging habitat, contamination of food resources, and mortality from oiling (Flint et al. 1999; Stehn and Platte, United States Fish and Wildlife Service, unpublished data).

Studies of king eider use of the Beaufort Sea have been limited to coastal migration surveys (Thomson and Person 1963, Johnson and Richardson 1982, Suydam et al. 2000) and aerial transect surveys within 60 km of shore (Fischer and Larned 2004). These methods are limited in their scope, with little information gathered about residence time of individual birds or use of sites outside observation areas. Baseline data about the distribution of king eiders are critical to model potential consequences of oil spills and provide regulatory agencies with opportunities to modify proposed developments and associated activities to minimize impacts. Declining numbers of eiders during migration surveys (Suydam et al. 2000) and low capacity for population growth might extend the time necessary for king eider populations to recover from mortality events or cumulative effects (Suydam 2000).

Satellite telemetry is a useful tool to gather location data about an individual's use of specific areas. Coupled with a large sample size of locations, satellite telemetry can provide insights into the distribution of a population. We deployed 60 satellite transmitters over 3 years to monitor king eiders in the Alaskan Beaufort Sea. Our objectives were to 1) document locations of North Slope-breeding king eiders

[1] *E-mail: laura_phillips@nps.gov*
[2] *Present address: Center for Resources, Science, and Learning, Denali National Park and Preserve, P.O. Box 9, Denali Park, AK 99755, USA*

during prebreeding migration, postbreeding staging, and postbreeding migration in the Alaskan Beaufort Sea; 2) determine whether use areas and location characteristics differed by sex or season; and 3) determine the residence time of king eiders captured on the North Slope of Alaska in the Beaufort Sea and characteristics that explained variation in residence time.

STUDY AREA

Capture Locations

We trapped king eiders in early to mid-June 2002, 2003, and 2004 at Kuparuk (70°20′N, 149°45′W) and in 2004 at Teshekpuk Lake (70°26′N, 153°08′W). The Kuparuk study site was located between the Colville and Kuparuk rivers on the North Slope of Alaska. The Teshekpuk Lake study site was located about 80 km west of the Kuparuk study area and 10 km inland from the southeast shore of Teshekpuk Lake.

Beaufort Sea

During the postbreeding period (late Jun through mid-Sep), Alaskan-breeding king eiders move into the Beaufort Sea where they stage or begin migration to molting locations. The Beaufort Sea is part of the Arctic Ocean that lies north of Alaska from Point Barrow eastward to Banks Island north of the Yukon and Northwest Territories of Canada. We constrained our analysis to king eider use-areas in the Alaskan portion of the sea. It has a narrow continental shelf that extends an average of 55 km offshore to the 200 m bathymetric contours (Soluri and Woodson 1990). Sea ice generally covers the entire sea for 9–10 months each year. Primary productivity is low and food webs are relatively simple with secondary biological productivity peaking during the ice-free summer months of June through October (Norton and Weller 1984).

METHODS

Capture and Telemetry

We used mist net arrays and decoys to capture king eiders on nesting areas. Once captured, we placed eiders in a secure, dark kennel and transported them to an indoor facility or tent equipped for surgery. We surgically implanted a 40-g satellite platform transmitting terminal (PTT) transmitter (Microwave Telemetry, Inc., Columbia, MD) into the abdominal cavity of each eider following the techniques of Korschgen et al. (1996). Satellite transmitters were <3% of the average body mass of birds marked in this study. We fit eiders with a United States Fish and Wildlife Service band while they were still under anesthesia. We held birds until fully awake and recovered from anesthesia (2–3 hr) and then released them at their capture sites. We did not determine nest fate for any of the female eiders with transmitters. We obtained approval for all methods and handling of birds from the University of Alaska Institutional Animal Care and Use Committee (IACUC no. 02-10).

Transmitters broadcast signals for 6 hours every 1) 48 hours from June through September, 2) 84 hours from October through December, 3) 168 hours from January through March, and 4) 84 hours from April until the end of the battery life. Satellite transmitters used during the first 2 years of this study had an average lifespan of 385 $\pm$ 15 (SE) days (n = 31, range = 99–519 d). We received location data from Service Argos, Inc. (2001). We filtered location data for accuracy using the Douglas Argos-filter V5.1 (Douglas 2006). The filtering program removed implausible locations based on location redundancy and tracking paths. We used the best location after filtering per transmission period for our analyses and based this on location class. Argos categorizes the quality of a location using location class indices ranging from 0 to 3 with 3 being the highest-quality location (Harris et al. 1990). We plotted locations using ArcView Geographic Information System (GIS) Version 3.3, 1998.

We focused on the prebreeding and postbreeding seasons of a sample of king eiders while they were in the Alaskan Beaufort Sea. We defined the prebreeding season as the first location of an individual in the Beaufort Sea after it moved east past Point Barrow until the last location at sea before it moved on land or into Canadian waters. We defined postbreeding migration as the first location at sea after an individual had been on land or as it moved west from the Canadian Beaufort Sea until the last location before it moved west past Point Barrow. Prebreeding locations occurred between April and June in the year after marking, whereas postbreeding locations occurred between June and August in the year of marking.

Due to the variation in the number of locations obtained per individual in the Alaskan Beaufort Sea (prebreeding: $\bar{x} = 3$, SE = 0.5, $n = 12$, range = 1–6; postbreeding: $\bar{x} = 11$, SE = 0.8, n = 60, range = 1–44), we used $\leq$6 prebreeding locations and randomly selected 10 postbreeding locations per individual to create 2 subsets of eider locations for use in analyses of distribution and location characteristics. We created all random subsets using Random Point Generator 1.27 extension (Jennes 2003) in ArcView GIS.

Data Analysis

Distribution and use areas.—We examined differences in distributions of king eider locations in the Beaufort Sea using multi-response permutation procedures (MRPP) in BLOSSOM (Cade and Richards 2001). We examined differences by sex within season (prebreeding vs. postbreeding). Due to small annual samples, we combined data across years to examine sex-related differences in seasonal distributions. We acknowledge that distributions could differ among years.

We estimated king eider distributions in the Alaskan Beaufort Sea using fixed kernel analysis (Seaman et al. 1998) to delineate 95% utilization distributions and concentrated areas of use. We defined concentrated use areas as the kernel contour that included eider locations with greater than average density (Seaman et al. 1998).

Location characteristics.—We used 2-way analysis of variance on ranked data to test for differences by sex and season in water depth and distance from shore of eider locations. We calculated water depth using a bathymetric shapefile with 10-m contour intervals compiled by the Alaska Science Center (1997). We calculated distance from

Table 1. Number of king eiders marked with satellite transmitters and locations obtained by sex, year, and season, in the Alaskan Beaufort Sea, USA, 2002–2004. Prebreeding location occurred between April and June in the year after marking, whereas postbreeding locations occurred between June and August in the year of marking.

	Yr					
	2002		2003		2004	
Season	No. of eiders marked	No. of locations used	No. of eiders marked	No. of locations used	No. of eiders marked	No. of locations used
Postbreeding						
M	11	89	9	104	14	112
F	10	168	3	34	13	155
Prebreeding						
M			4	13	2	5
F			4	16	2	7

shore using ArcView GIS as the shortest straight-line distance from an eider location to a 1:250,000 polyline shapefile of the Alaskan coastline (Soluri and Woodson 1990).

Residence time.—We used multiple regression to examine variation in the number of days an eider spent in the Alaskan Beaufort Sea. Residence time of a king eider was the number of days from the first day an eider entered the sea until the date of the last location within the sea. Explanatory variables included sex, season (prebreeding vs. postbreeding), year, standardized date of an individual's first location within Beaufort Sea, and an index of high (>75%) ice cover present within 100 km of shore when an eider entered the sea. We examined collinearity among variables to exclude highly correlated variables from analyses. Ice cover and standardized date of entry were significantly and negatively correlated ($r_s = -0.36$, $P = 0.001$), therefore we chose to exclude ice cover from further analysis. We standardized julian date of an eider's first location within the sea to allow season to be included in the analysis as a class variable. We calculated standardized date as the difference between the julian day of an individual's first location within the Beaufort Sea and the julian day the first marked eider arrived in the sea each season. We included the first order interaction terms sex with season, year, and standardized date. We performed all statistical analyses using SAS Version 8, 2001.

RESULTS

Marked Individuals

At Kuparuk, we surgically implanted transmitters into 21 (10 F, 11 M) king eiders in 2002, 12 (3 F, 9 M) in 2003, and 15 (8 F, 7 M) in 2004. We fitted 12 (5 F, 7 M) king eiders with transmitters at Teshekpuk in 2004. All 60 transmitters provided location information during postbreeding (Table 1). Eight transmitters deployed in 2002 and 4 transmitters deployed in 2003 provided location information in the Beaufort Sea during the prebreeding seasons in 2003 and 2004; data collection terminated prior to the 2005 prebreeding season. Temperature sensors in the transmitters indicated 2 eiders died during the course of the study. The remaining transmitters either failed prior to return of eiders to the Beaufort Sea in the spring after marking, or eiders migrated to an alternate breeding location and did not pass through the Beaufort Sea. All marked eiders entering the Beaufort Sea during prebreeding or postbreeding seasons survived with operational transmitters while in the sea.

Distribution and Use Areas

Distributions of king eider locations in the Alaskan Beaufort Sea differed by sex during the postbreeding period ($\delta_{516} = -26.38$, $P < 0.001$) but not during prebreeding ($\delta_{41} = -1.67$, $P = 0.068$). King eiders tended to move west into the Beaufort Sea during postbreeding, which is the direction of molt migration to the Bering Sea. Female locations, although widely distributed, tended to be more concentrated than male locations in Harrison Bay at the Colville River delta and upper Smith Bay along Pitt Point during postbreeding. Postbreeding male locations were very dispersed from Oliktok Point to Point Barrow and from the coast to >40 km offshore (Fig. 1). Prebreeding locations were scattered from Point Barrow to the Canadian border with over 40% of the locations found >20 km offshore (Fig. 2).

Location Characteristics

Water depth at king eider locations differed by sex ($F_{1,548} = 16.68$, $P < 0.001$) and season ($F_{1,548} = 20.12$, $P < 0.001$) with a significant interaction between the main effects ($F_{1,548} = 42.65$, $P < 0.001$). Distance from shore differed by sex ($F_{1,560} = 9.96$, $P = 0.002$) but not by season ($F_{1,560} = 0.9$, $P = 0.34$), with a significant interaction between sex and season ($F_{1,560} = 24.37$, $P < 0.001$). During prebreeding, female locations were on average farther from shore ($\bar{x} = 26.5$, SE = 3.6 km) in deeper water ($\bar{x} = 28.8$, SE = 3.1 m) than male locations ($\bar{x}$ distance from shore = 12.0, SE = 3.5 km; $\bar{x}$ water depth = 11.1, SE = 1.8 m), whereas during the postbreeding period, females were closer to shore ($\bar{x} = 12.8$, SE = 0.6 km) in shallower water ($\bar{x} = 11.7$, SE = 0.8 m) than males ($\bar{x}$ distance from shore = 14.8, SE = 0.6 km; $\bar{x}$ water depth = 12.6, SE = 0.4 m).

Residence Time

The parameters in our overall model described residence time of marked king eiders within the Alaskan Beaufort Sea

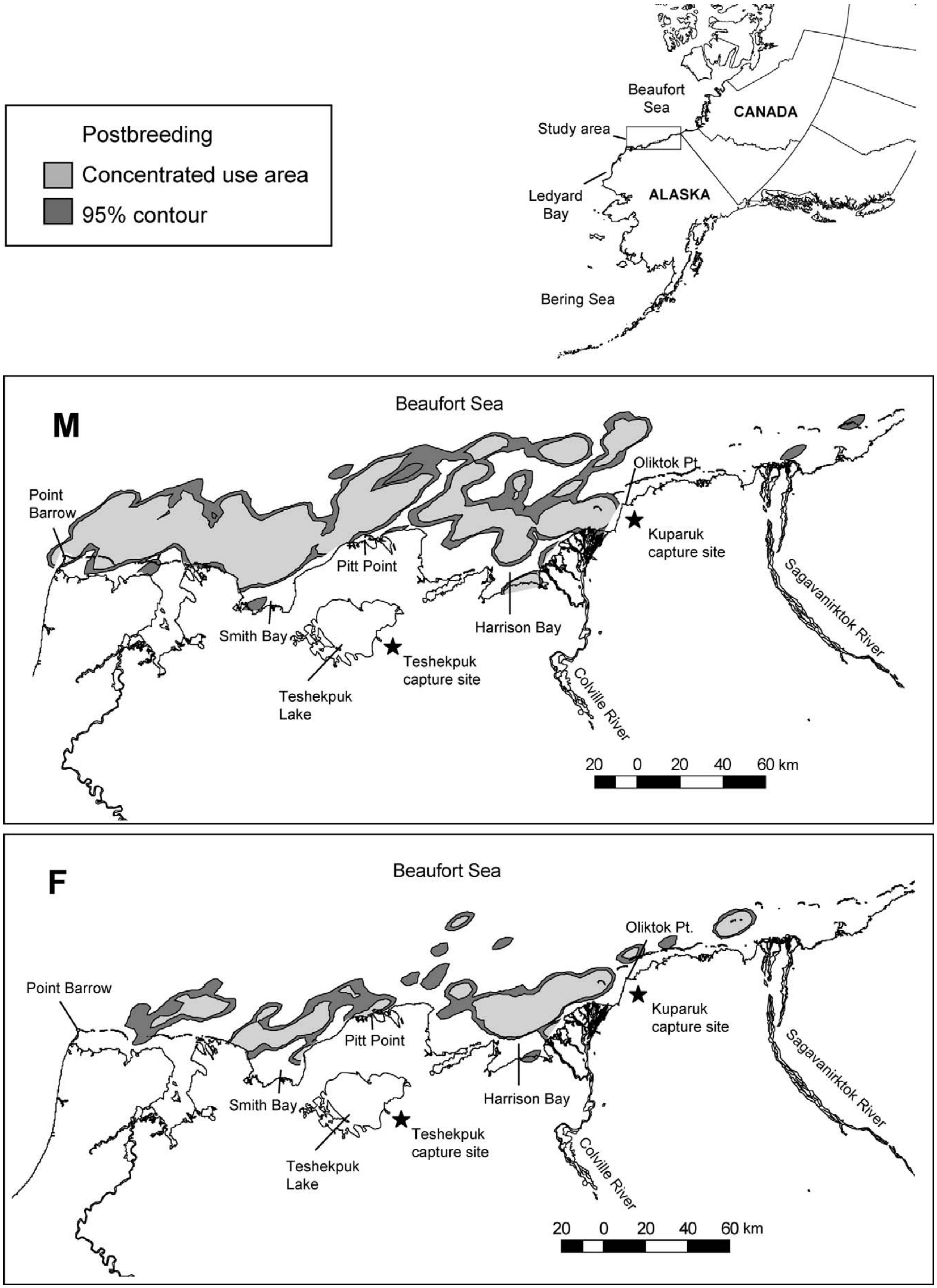

Figure 1. Postbreeding (Jun–Aug) distributions of 34 male and 26 female satellite-tagged king eiders within the Alaskan Beaufort Sea, 2002–2004.

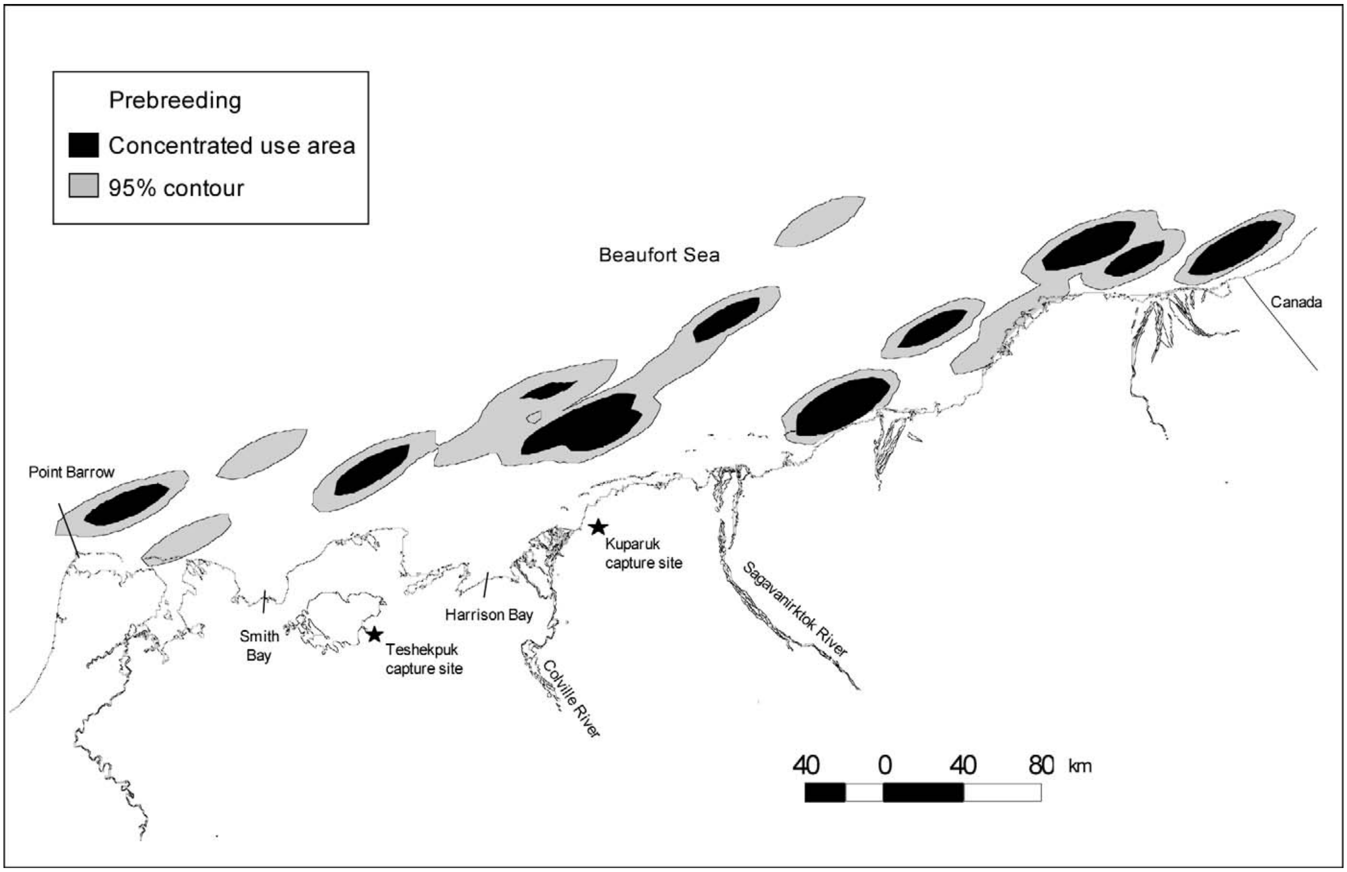

Figure 2. Prebreeding distributions of satellite-tagged king eiders ($n = 12$) in the Alaskan Beaufort Sea, June 2002–September 2004.

($F_{7,70} = 8.12$, $P = <0.001$, $n = 70$, $r^2 = 0.47$). Sex, season, and standardized date of first location within the sea explained variation in the number of days eiders spent in the sea (Fig. 3), but year, sex × year, sex × season, and sex × standardized date explained little variation in residence times (Table 2). On average, females moved into the Beaufort Sea almost 2 weeks later than males during prebreeding and 20 days later than males during postbreeding periods (Fig. 4). They spent almost twice as many days on average in the sea than males in spring and more than a week longer than males during postbreeding (Fig. 4).

DISCUSSION

More than 80% of our marked king eiders spent >2 weeks in the Beaufort Sea before continuing molt migration, suggesting that the sea is an important migration flyway and staging area for this species during postbreeding. Concentrated use areas in Harrison Bay and Smith Bay delineated by this study were consistent with the findings of Fischer and Larned (2004). During postbreeding aerial surveys of the central Beaufort Sea, Fischer and Larned (2004) recorded the highest densities of king eiders in deep water (>10 m) areas of Harrison Bay in July. Harrison and Smith Bays might also be postbreeding staging areas for king eiders from Victoria Island, Northwest Territories and Prudhoe Bay, Alaska (D. L. Dickson, Canadian Wildlife Service, unpublished data).

Smith Bay was used more heavily by postbreeding female eiders than male eiders. Severe ice conditions in early summer might have reduced the amount of time male king eiders spent in Smith Bay. Shore-fast ice in the Beaufort Sea generally begins to move offshore in early July, creating open water habitat nearshore (Craig et al. 1984). The broad distribution of male locations in the sea after breeding could reflect high (>75%) ice cover in June, which forces male king eiders to dispersed pockets of open water during postbreeding.

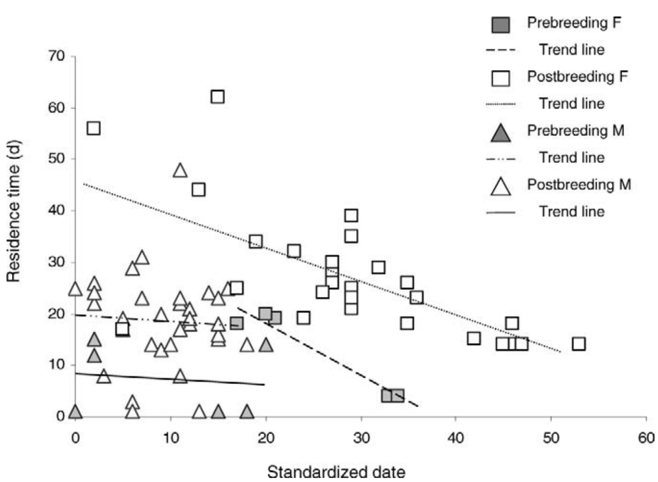

Figure 3. Plot of residence time and standardized date of arrival within the Alaskan Beaufort Sea of satellite-tagged male and female king eiders during postbreeding (M, $n = 34$; F, $n = 26$) and prebreeding (M, $n = 6$; F, $n = 5$).

Table 2. Results of multiple regression analysis examining the influence of individual parameters and interactions on the number of days 60 king eiders spent in the Alaskan Beaufort Sea during prebreeding and postbreeding seasons, 2002–2004.

Parameter	Estimate	SE	*t*	*P*
Sex	−21.5	7.3	−2.95	0.004
Yr	−0.6	1.8	−0.35	0.727
Season	17.2	4.7	3.68	<0.001
Standardized date	−0.7	0.1	−4.92	<0.001
Sex × yr	−0.29	2.7	−0.11	0.916
Sex × season	−5.4	6.4	−0.84	0.402
Sex × standardized date	0.6	0.3	1.84	0.071

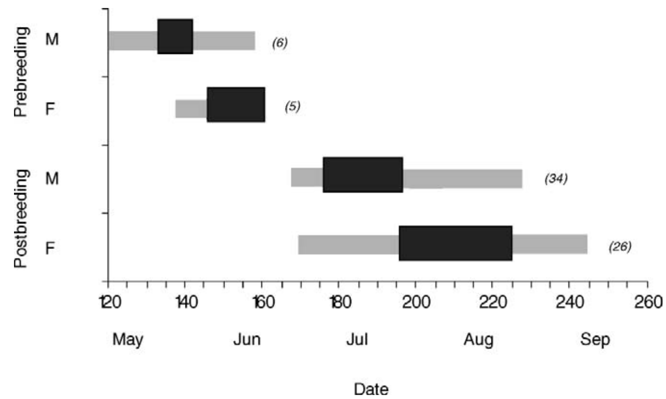

Figure 4. Mean residence time (d, black bar) and range (gray bars) of satellite-tagged king eiders located within the Alaskan Beaufort Sea during prebreeding and postbreeding periods. Sample sizes for each category are listed to the right of each bar.

Short residence times and deep water at prebreeding locations suggest that king eiders might be using the Alaskan Beaufort Sea as a migration corridor rather than as a staging area during this period. In this study, female king eiders exhibited fidelity to nesting areas by returning to sites near where they were captured, whereas male king eiders migrated to Russia, Alaska, and Canada in the spring (Phillips and Powell 2006). During spring migration, king eiders that returned to breed in Alaska and western Canada did not appear to stage within the Alaskan Beaufort Sea. Prebreeding staging areas for king eiders in this study were located in the Chukchi Sea and Canadian Beaufort Sea (L. M. Phillips, University of Alaska, unpublished data). King eiders returning to the arctic coastal plain of Alaska and Canada in spring staged for 18 days on average in Ledyard Bay in the Chukchi Sea prior to entering the Beaufort Sea. Ledyard Bay might be a more critical spring staging site for migrating king eiders, and we recommend evaluating the importance of this area to king eiders prior to any future resource development in that part of the Chukchi Sea.

We found that residence time of female king eiders in the Beaufort Sea during prebreeding and postbreeding was longer than that of males and decreased with date of arrival in the Beaufort Sea. Timing of female staging and migration in the Beaufort Sea might be constrained by subsequent life history events. In spring, early arrival on breeding grounds may provide reproductive advantages to nesting female waterfowl (Johnson et al. 1992), and a short breeding season on Alaska's North Slope might constrain breeding female king eiders to a narrow time period for nest initiation. During postbreeding, female ducks with longer or later reproductive periods might have limited time to replenish diminished fat stores before beginning molt migration, especially in the high arctic where advancing winter weather could reduce forage quality or entrap flightless birds in advancing ice at wing molt sites (Salomonsen 1968, Hohman et al. 1992).

Although we did not determine breeding success of female eiders in this study, we did locate females on nests after they had undergone surgery. Female king eiders might need to remain in the Beaufort Sea longer than males prior to molt migration to replenish fat stores depleted during egg-laying and incubation. Female eiders rely on endogenous reserves for egg-laying and forage very little while incubating (Korschgen 1977, Kellett and Alisauskas 2000). King eiders nesting at Karrak Lake, Northwest Territories lost 30% of their pre-incubation body mass during incubation (Kellett and Alisauskas 2000). More research on postbreeding use of the Beaufort Sea by females that successfully reared broods and by juvenile king eiders is necessary to fully understand potential impacts of future development in the sea.

Timing of male molt migration appears to be highly synchronized in most waterfowl (Hohman et al. 1992), and this is supported by the behavior of our satellite-tagged male eiders after breeding (Phillips et al. 2006). The earlier postbreeding movements of male king eiders into the Beaufort Sea relative to females are similar to movement patterns in spectacled eiders (*Somateria fischeri*; Petersen et al. 1999). Male king eiders disperse from breeding grounds at the onset of incubation, whereas female timing is probably dependent on breeding success.

MANAGEMENT IMPLICATIONS

There are currently 64 active leases within federal waters of the Alaskan Beaufort Sea (Minerals Management Service 2004), and 47% overlap with the postbreeding distribution of our satellite-tagged king eiders. Additional development projects in the Beaufort Sea increase the chance of an oil spill occurring; a large spill could have significant adverse impacts on king eider populations if it occurred in high-use areas such as the Colville River delta in Harrison Bay and upper Smith Bay during the 3–5 months eiders were present within the Beaufort Sea. The Colville River delta could be especially important to king eiders in late June and early July when ice cover could restrict use of alternate staging locations in the Beaufort Sea. Future oil spill models should account for the different timing and spatial distribution of male and female eiders within the Beaufort Sea during postbreeding. Impacts might disproportionately affect female king eiders whose concentrated use and longer residence times than males in these areas suggest they might be less likely to disperse from spill areas to other sites.

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