The Auk 116(4):1009–1020, 1999

AT-SEA DISTRIBUTION OF SPECTACLED EIDERS: A 120-YEAR-OLD MYSTERY RESOLVED

MARGARET R. PETERSEN,[1,3] WILLIAM W. LARNED,[2] AND DAVID C. DOUGLAS[1]

[1]*U.S. Geological Survey, Biological Resources Division, Alaska Biological Science Center, 1011 East Tudor Road, Anchorage, Alaska 99503, USA; and*

[2]*U.S. Fish and Wildlife Service, Migratory Bird Management, Soldotna, Alaska 99669, USA*

ABSTRACT.—The at-sea distribution of the threatened Spectacled Eider (*Somateria fischeri*) has remained largely undocumented. We identified migration corridors, staging and molting areas, and wintering areas of adult Spectacled Eiders using implanted satellite transmitters in birds from each of the three extant breeding grounds (North Slope and Yukon-Kuskokwim Delta in Alaska and arctic Russia). Based on transmitter locations, we conducted aerial surveys to provide visual confirmation of eider flocks and to estimate numbers of birds. We identified two principal molting and staging areas off coastal Alaska (Ledyard Bay and eastern Norton Sound) and two off coastal Russia (Mechigmenskiy Bay on the eastern Chukotka Peninsula, and the area between the Indigirka and Kolyma deltas in the Republic of Sakha). We estimated that >10,000 birds molt and stage in monospecific flocks at Mechigmenskiy and Ledyard bays, and several thousand molt and stage in eastern Norton Sound. We further identified eastern Norton Sound as the principal molting and staging area for females nesting on the Yukon-Kuskokwim Delta, and Ledyard Bay and Mechigmenskiy Bay as the principal molting and staging areas for females nesting on the North Slope. Males marked at all three breeding grounds molt and stage in Mechigmenskiy Bay, Ledyard Bay, and the Indigirka-Kolyma delta region. Males from the Yukon-Kuskokwim Delta molt and stage mainly at Mechigmenskiy Bay. Equal numbers of males from the North Slope molt and stage at all three areas, and most males from arctic Russia molt and stage at the Indigirka-Kolyma delta region. Postbreeding migration corridors were offshore in the Bering, Chukchi, and Beaufort seas. In winter, eiders were in the Bering Sea south of St. Lawrence Island. Our estimates from surveys in late winter and early spring suggest that at least 333,000 birds winter in single-species flocks in the pack ice in the Bering Sea. *Received 14 August 1998, accepted 10 February 1999.*

THE DISTRIBUTION and ecology of many marine birds at sea are poorly known because of the large distances birds travel and the great expense of such studies. Seaducks (tribe Mergini) may spend one to four months on land during the nesting period and the remainder of the year at sea. In general, these marine locales are in northern latitudes where sea ice is common. The at-sea molting and wintering areas of the Spectacled Eider (*Somateria fischeri*) have remained largely undocumented since the discovery of the species. One speculation was that Spectacled Eiders wintered somewhere in the Bering Sea, probably along the ice edge (Conover 1926, Dement'ev and Gladkov 1952). Dau and Kistchinski (1977) also speculated that this species molted in the Bering Strait and wintered in polynyas south of the Chukotka Peninsula and south of St. Lawrence, Nunivak, and St. Matthew islands. These speculations remained unconfirmed because of high costs and safety issues associated with conducting surveys in the Bering Sea.

The need for better information about the species became urgent when analyses of population trends suggested that the population of Spectacled Eiders nesting on the Yukon-Kuskokwim Delta (Y-K Delta) in Alaska declined by 96% from the 1970s to the early 1990s (Stehn et al. 1993, Ely et al. 1994). In addition, no data were available from other Alaskan and Russian breeding grounds, but anecdotal information suggested that the species had declined in those areas as well (U.S. Fish and Wildlife Service 1996). Consequently, all Spectacled Eider breeding populations were listed as threatened in 1993. Because it was thought that little change had occurred on the nesting grounds in the Sakha Republic and northern Magadan Region (arctic Russia), the North Slope of Alaska, and the Y-K Delta, environmental changes on

[3] E-mail: margaret_petersen@usgs.gov

TABLE 1. Year, location, and number of satellite transmitters deployed on Spectacled Eiders.

Year	Paired males	Failed females	Females with broods
	Arctic Russia		
1995	10[a]	0	0
	North Slope, Alaska		
1995	0	0	10
1996	12	2[b]	8[c]
	Yukon-Kuskokwim Delta, Alaska		
1993	5[c]	5	4
1994	11	11[c]	0
1995	0	2	8[c]

[a] Includes one bird shot on the nesting area by a local hunter (no location data).
[b] Includes one bird whose death on the nesting grounds was complicated by lead poisoning (no location data).
[c] Includes one bird with no location data.

the molting and wintering grounds were suspected in contributing to the decline (U.S. Fish and Wildlife Service 1996). The locations of principal molting and wintering areas of Spectacled Eiders were unknown, so no assessment could be made of habitat conditions and threats to the species while at sea.

Here, we describe the distribution of Spectacled Eiders during the migration, staging, molting, and wintering periods derived from locations of birds that were implanted with satellite transmitters in each of the three major breeding areas. We describe migration patterns between sexes and among breeding locations as well as variations in the use of principal molting and wintering areas. In addition, we provide estimates of abundance of birds in principal molting, staging, and wintering areas based on aerial surveys.

METHODS

Satellite tracking.—All birds were marked with satellite platform transmitting terminal (PTT) transmitters (Telemetry 2000, Columbia, Maryland). Each transmitter weighed 36 g and measured 3.6 × 5.6 × 0.8 cm exclusive of the external antenna. Transmitters were programmed to transmit with a 60-s pulse rate for 6 h every 72 h ($n = 86$) or for 6 h every 120 h ($n = 2$) and were designed to last 6 to 8 months (Petersen et al. 1995).

Transmitters were deployed using an implant technique developed by Korschgen et al. (1996). Capturing and handling procedures were described in Petersen et al. (1995). We marked 88 adult breeders between 1993 and 1996 (Table 1) from each of the three major nesting areas: arctic Russia (Indigirka River Delta, Sakha Republic), North Slope (Prudhoe Bay region, Alaska), and Y-K Delta (Kashunuk or Manokinak rivers, Alaska). Males were considered paired if captured while flying with a female, flying in a flock with an equal sex ratio, or attempting to chase another pair from a wetland. Adult females were captured in spring when paired with adult males, during egg laying, within the first 10 days of incubation, or with a brood of ducklings about 30 days of age. Failed-breeding females abandoned nests after surgery, failed to hatch eggs, or joined flocks of females during the breeding season. Females with broods rejoined their brood after surgery and probably remained with their brood through the remainder of the 45-to-55 day brood-rearing season.

Data from 82 of the 88 transmitters were received through the Argos Data Collection and Location System in Landover, Maryland. From a total of 6,595 satellite overpass events that collected one or more PTT transmissions, 3,888 locations were calculated for 82 individuals whose transmitters provided location data on a regular basis (Table 1). Both standard and auxiliary location processing services (Service Argos 1996) were used in this study. Only 1,165 (30.0%) locations were accepted for analysis as independent and biologically plausible using decision criteria detailed in Petersen et al. (1995). Multiple locations recorded within a single 6-h transmission period were not considered independent, so one location was selected for each individual during each transmission period to describe the location of that individual. Among multiple locations, the location with the highest Argos precision index was selected. If several locations with similar precision occurred, the central-most location was selected. Single locations during a transmission period that were indexed with poor precision were rejected if not corroborated by locations on previous or subsequent days. For locations at sea, offshore distances were calculated to the nearest land mass represented in a 1:1,000,000-scale digital chart of the world using ARC/INFO geographic information system software. No transmitter provided acceptable location data every three days throughout the lifetime of its batteries. Thus, sample sizes vary for estimates of arrival and departure times and numbers of birds at molting areas. Seven transmitters malfunctioned without providing locations beyond the breeding grounds. In addition, three birds on the Y-K Delta died 16 to 34 days after surgery. This is consistent with the level of mortality from lead poisoning in the population at that time (Franson et al. 1995, Flint and Grand 1997, Flint et al. 1997, Franson et al. 1998); however, the cause of death of each individual was not determined.

Data were pooled among years within locations. Departure dates among years for males and females were consistent with those observed during other years on the Y-K Delta (P. Flint pers. comm.) and with those from birds marked with conventional transmitters during the same years birds were marked with PTTs on the North Slope (D. Troy pers. comm.). However, sample sizes often were insufficient for annual comparisons of departure and arrival dates (Table 1).

Aerial surveys.—Transect lines for aerial surveys were established based on the most recent PTT locations for that region. The survey was centered on those locations and then expanded in all directions in an attempt to find other flocks. Survey design was similar to that described by Pihl and Frikke (1992) for open-water areas. Two observers recorded species, flock size, and sex ratio of flocks. Data were then integrated with position coordinates derived using GPSTRAK (Anthony and Stehn 1994) to provide location information for each flock. Aerial photographs were taken of a nonrandom sample of flocks to determine sex ratios after the survey was completed. During some surveys, all flocks in the survey area were photographed and the abundance estimate determined from a count of individuals in all flocks.

Movement data.—A bird was considered migrating when it remained in an area less than one week and sequential locations indicated movement in a single direction. Birds were identified as molting if they remained within a restricted area and moved less than 1.5 km/h for up to three weeks. Staging areas were identified from clusters of locations from several individuals. A bird was considered staging if it remained in an area for at least 10 days or with movements exceeding 1.5 km/h during the period from 1 June to 1 November. Wintering areas were identified from clusters of locations from several individuals during the period 1 October to 20 November (early winter), 21 November to 31 January (mid-winter), and 1 February to 31 March (late winter).

Because locations of individuals were calculated at three-day intervals, the precise date that an individual left an area or arrived at an area could not be determined. An individual migrating to an area was recorded as arriving by the first date that a location was determined; an individual leaving an area was considered to have departed on the date of the last location from the area.

Statistical analysis.—Differences among arrival and departure dates and among distances birds were offshore were analyzed using Kruskal-Wallis tests on ranked data. For the purposes of these analyses, all locations from individuals offshore were pooled and treated as independent samples. However, if all locations for a particular analysis were from a single individual, samples were considered insufficient for statistical comparisons with other birds. Data on dates and distances offshore are presented as medians, interquartile ranges, and numbers of locations. We used Bonferroni tests of ranked data to determine similarities and differences among groups when Kruskal-Wallis tests were significant.

Methods of estimating abundance varied among surveys. Abundance estimates from 11 of 15 (73.3%) surveys were based on uncorrected ocular estimates of the number of birds in flocks. Because ocular estimates of dense flocks with large numbers of birds may be low (Follestad et al. 1988), our abundance estimates should be considered minimal. All flocks located on the water during two late-winter surveys (1995 and 1997) and two surveys of eastern Norton Sound were photographed. An estimate for each survey was calculated from counting the number of males in all photographs and multiplying by the mean ratio of total birds per male derived from a subsample of slides. To each of those products we added our ocular estimate of the number of birds in flying flocks, which gave us the annual point estimate for the survey.

Methods of estimating sex ratios also varied among the 15 surveys. No sex-ratio data were collected on four surveys, ocular estimates were made on six, and counts of birds in photos on five. In the five surveys with photographs of flocks, a sex ratio was calculated for each flock. Variance of this ratio was calculated following Cochran (1977) for cluster sampling of proportions, with each slide treated as a sampling unit. Photographs taken for estimating sex ratios were a nonrandom sample of flocks, because most photographs were taken of large flocks that appeared to contain the highest concentration of birds.

RESULTS

Timing of postbreeding dispersal.—Adult males left the breeding grounds in June, but departure dates varied significantly ($\chi^2 = 14.10$, df = 2, $P = 0.001$), with males departing from arctic Russia and the North Slope almost three weeks later than from the Y-K Delta (Table 2). The departure of females varied according to nesting area and the outcome of the breeding attempt. Females that raised broods departed the breeding grounds about the same time ($P > 0.05$) in late August (Table 2). Females whose breeding attempts failed left the Y-K Delta almost seven weeks before successful females ($\chi^2 = 10.73$, df = 1, $P = 0.001$; Table 2). Furthermore, among failed females on the Y-K Delta, departure dates differed ($\chi^2 = 27.0$, df = 2, $P < 0.001$) between females whose eggs failed to hatch (median = 10 July; interquartile range 3 to 17 July, $n = 10$) and those who lost their broods soon after hatching (median = 2 August, interquartile range 28 July to 7 August, $n = 5$).

Molting areas.—We identified four main molting areas for Spectacled Eiders (Fig. 1). Arrival dates to molting areas varied significantly only

TABLE 2. Departure dates of Spectacled Eiders from nesting areas. Values are median date and interquartile range of dates, with n in parentheses.

Paired males	Failed females	Females with broods
	Arctic Russia	
25 Jun, 19–30 Jun (8)	No data	No data
	North Slope, Alaska	
22 Jun, 19–29 Jun (12)	21 Jul (1)	30 Aug, 26 Aug–4 Sep (15)
	Yukon-Kuskokwim Delta, Alaska	
3 June, 28 May–15 Jun (12)	12 Jul, 30 Jun–31 Jul (15)	29 Aug, 18 Aug–1 Sep (5)

for females that bred successfully ($\chi^2 = 7.14$, df $= 2$, $P = 0.03$). Successful females arrived later at Mechigmenskiy Bay ($P = 0.02$) than at eastern Norton Sound and Ledyard Bay, which had similar arrival dates ($P = 1.00$; Table 3). One successful female that nested on the North Slope arrived off eastern St. Lawrence Island on 21 September. Unsuccessful females from the Y-K Delta arrived in eastern Norton Sound in early August (Table 3). Arrival dates of males at molting areas did not differ significantly (Table 3) among breeding areas ($\chi^2 = 1.44$, df $= 2$, $P > 0.05$) or among molting areas ($\chi^2 = 1.36$, df $= 2$, $P > 0.05$).

Departure dates from molting areas differed among males, successful females, and unsuccessful females ($\chi^2 = 11.65$, df $= 2$, $P = 0.003$). Males left molting areas the earliest, followed by failed females and then successful females (Table 3). Arrival dates to the wintering area also differed in a similar pattern ($\chi^2 = 9.65$, df $= 2$, $P = 0.008$), with males and unsuccessful females arriving first ($P > 0.05$), followed by successful females ($P < 0.001$).

Birds en route from breeding areas to molting areas and from molting areas to wintering areas remained primarily offshore (Fig. 1), except for two adult males from the North Slope

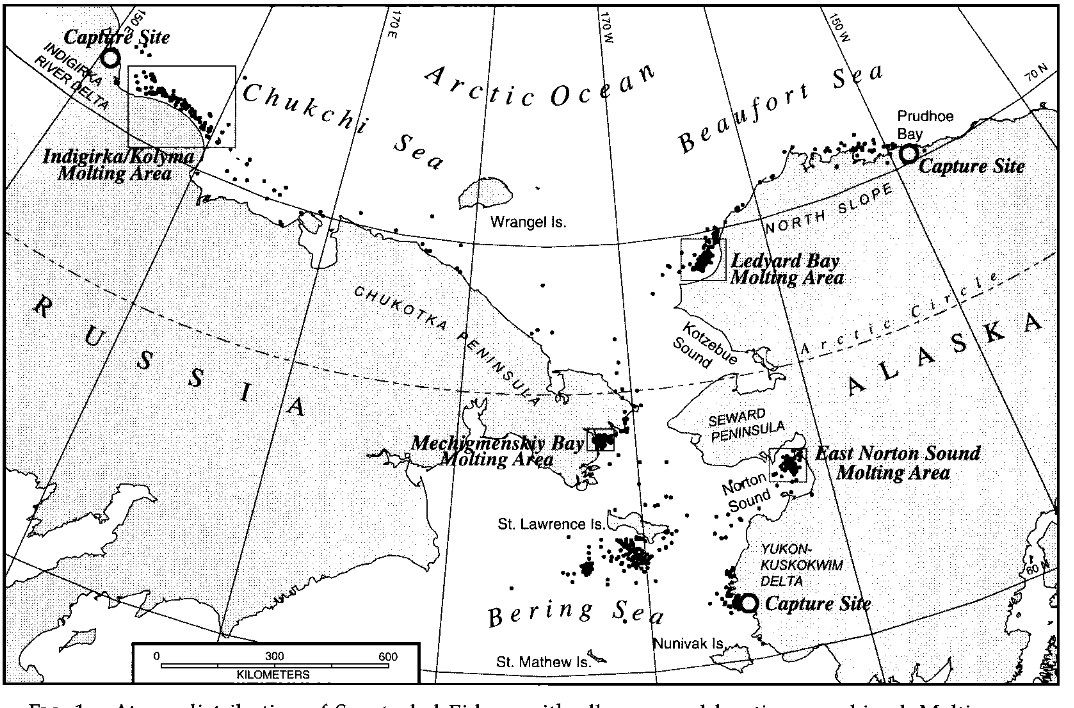

FIG. 1. At-sea distribution of Spectacled Eiders, with all years and locations combined. Molting areas: Indigirka/Kolyma river delta, Ledyard Bay, Mechigmenskiy Bay, and eastern Norton Sound.

TABLE 3. Arrival and departure dates of Spectacled Eiders. Values are median date and interquartile range of dates, with n in parentheses.

Location	Paired males	Failed females	Females with broods
	Arrival dates to molting areas		
Indigirka-Kolyma	17 Jul, 6–24 Jul (9)	None	None
Ledyard Bay	6 Jul, 25 Jun–26 Jul (6)	None	8 Sep, 7–11 Sep (9)
Norton Sound	None	3 Aug, 20 Jul–10 Aug (13)	8 Sep, 4–16 Sep (5)
Mechigmenskiy Bay	25 Jul, 12 Jul–10 Aug (14)	None	21 Sep, 17–21 Sep (4)
	Departure dates from molting areas		
Indigirka-Kolyma	5 Oct, 21 Sep–11 Oct (5)	None	None
Ledyard Bay	19 Sep, 26 Aug–19 Oct (4)	None	18 Oct, 6–25 Oct (9)
Norton Sound	None	28 Sep, 17 Sep–10 Oct (5)	21 Oct, 2–29 Oct (5)
Mechigmenskiy Bay	5 Oct, 25 Sep–12 Oct (8)	None	1 Nov (2)
	Arrival dates to wintering area		
St. Lawrence I.	22 Oct, 28 Sep–2 Nov (8)	17 Oct, 12–22 Oct (4)	7 Nov, 1–11 Nov (9)

that went onshore at Teshekpuk Lake, Alaska. When migrating through the Beaufort Sea, males flew almost 10 km closer to shore than did females ($\chi^2 = 8.94$, df = 1, $P = 0.003$); however, the tendency to migrate offshore did not differ between the sexes when moving along the Chukchi or Bering Sea coasts ($P > 0.05$; Table 4).

Males and females used different molting areas ($\chi^2 = 35.31$, df = 3, $P < 0.001$). At least one male from each breeding area molted and/or staged at each of three locations: Mechigmenskiy Bay, Indigirka/Kolyma river delta, and Ledyard Bay (Fig. 2A). Females nesting on the Y-K Delta were found molting only in eastern Norton Sound. Females nesting on the North Slope molted at Ledyard Bay ($n = 10$), Mechigmenskiy Bay ($n = 3$), near Bukhoto Puoten ($n = 1$), and off eastern St. Lawrence Island ($n = 1$). No marked females from Y-K Delta or North Slope went to the Indigirka/Kolyma River delta region (Fig. 2B).

The distances that females molted and staged offshore varied among locations ($\chi^2 = 63.66$, df = 1, $P < 0.001$). Females were more than 10 km closer to shore at eastern Norton Sound than at Ledyard Bay (Table 4). The numbers of locations for females at other sites were too small for meaningful statistical comparisons.

The distances that males molted and staged offshore at their three main molting areas (Ledyard Bay, Mechigmenskiy Bay, and Indigirka/Kolyma river deltas) also varied ($\chi^2 = 162.09$, df = 2, $P < 0.001$). Males were recorded farthest offshore at Ledyard Bay ($P < 0.001$), closer to shore in the Indigirka/Kolyma river delta ($P < 0.001$), and closest to shore at Mechigmen-

TABLE 4. Distances (km) Spectacled Eiders were offshore when at sea. Values are median distance and interquartile range of distances, with n in parentheses.

Location	Males	Females	Both sexes
	Molt migration		
Beaufort Sea	6.6, 2.7–13.8 (24)	16.5, 8.4–24.8 (24)	
Chukchi Sea	34.7, 23.1–48.2 (69)	59.6, 21.2–93.4 (4)	34.9, 20.8–48.9 (73)
Bering Sea	12.6, 9.3–38.8 (55)	26.2, 14.4–44.4 (31)	15.3, 0.1–30.6 (86)
	Molting areas		
Indigirka-Kolyma	16.9, 10.5–23.3 (103)		
Ledyard Bay	34.5, 30.9–38.1 (75)	37.9, 33.8–42.0 (93)	
Norton Sound		26.7, 21.7–30.9 (107)	
Mechigmenskiy Bay	6.9, 4.3–9.6 (122)	9.3, 5.8–12.7 (6)	7.1, 4.9–12.5 (128)
	Winter (St. Lawrence Island)		
Early winter			52.0, 32.1–71.9 (119)
Mid-winter			108.2, 90.8–125.5 (19)

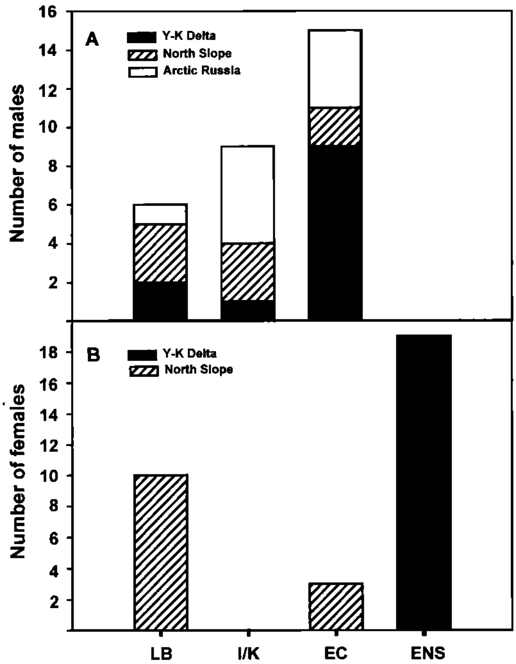

FIG. 2. Molting areas used by marked adult Spectacled Eiders. LB = Ledyard Bay; I/K = Indigirka/Kolyma coast; EC = eastern Chukotka Peninsula (including Mechigmenskiy Bay and Bukhoto Puoten); ENS = eastern Norton Sound. (A) Molting areas used by males; (B) molting areas used by females.

skiy Bay ($P < 0.001$; Table 4). Both males and females marked with PTTs molted in Ledyard Bay and Mechigmenskiy Bay. However, only at Ledyard Bay were samples for males and females sufficient for meaningful comparisons. The distance that birds were offshore at Ledyard Bay differed between males and females ($\chi^2 = 6.23$, df = 1, $P = 0.01$; Table 4).

Observations of birds during aerial surveys at Mechigmenskiy Bay (Fig. 3A), eastern Norton Sound (Fig. 3B), and Ledyard Bay (Fig. 3C) suggested that PTT locations provided accurate data on the location and extent of molting and staging areas used by eiders.

Winter locations.—All marked eiders wintered south and southwest of St. Lawrence Island (Figs. 4A–D). Areas used by eiders appeared to change from early to mid-winter, but use of these areas was similar among years. An aerial survey conducted in March 1996 corroborated evidence from PTT locations suggesting that eiders were absent from the portion of the area that they used in early winter (Fig. 4C). Aerial surveys conducted in late winter/early spring suggested that in spring some areas were used repeatedly (Figs. 4C and 4D), whereas others were used only periodically (Figs. 4B and 4C).

The distances that birds were located offshore varied between early winter and mid-winter ($\chi^2 = 13.91$, df = 1, $P < 0.001$). By mid-winter, the median distance from shore was twice that of early winter (Table 4). The maximum distance eiders were found offshore in winter was 206 km.

Abundance.—Our largest estimate of Spectacled Eider numbers (ca. 363,000 birds; 95% CI 333,526 to 392,532) came from aerial surveys of the Bering Sea in late winter 1996–1997 (Table 5). Estimates of the number of birds in each molting area varied among and within years. We found males and females at all molting and wintering areas surveyed (Table 5). Our survey data indicate that fewer eiders used eastern Norton Sound than Ledyard Bay and Mechigmenskiy Bay. Our best estimates of the number

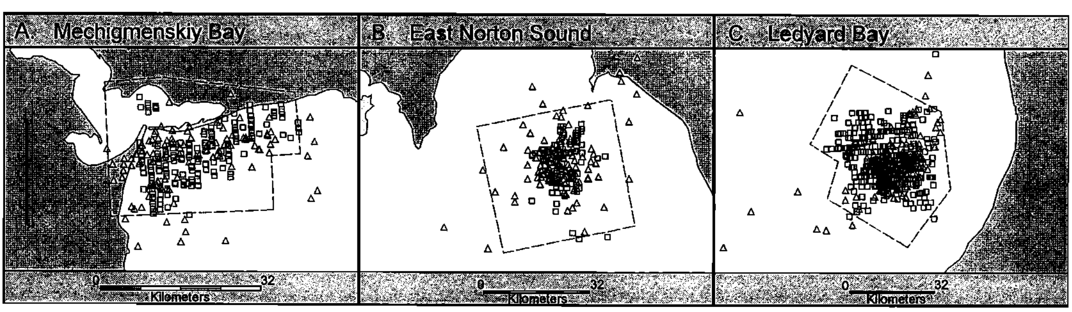

FIG. 3. PTT locations and survey areas of Spectacled Eiders on staging and molting areas at (A) Mechigmenskiy Bay, (B) eastern Norton Sound, and (C) Ledyard Bay. Squares = locations of flocks recorded during aerial surveys and triangles = PTT locations. Aerial survey areas are delineated by dashed lines.

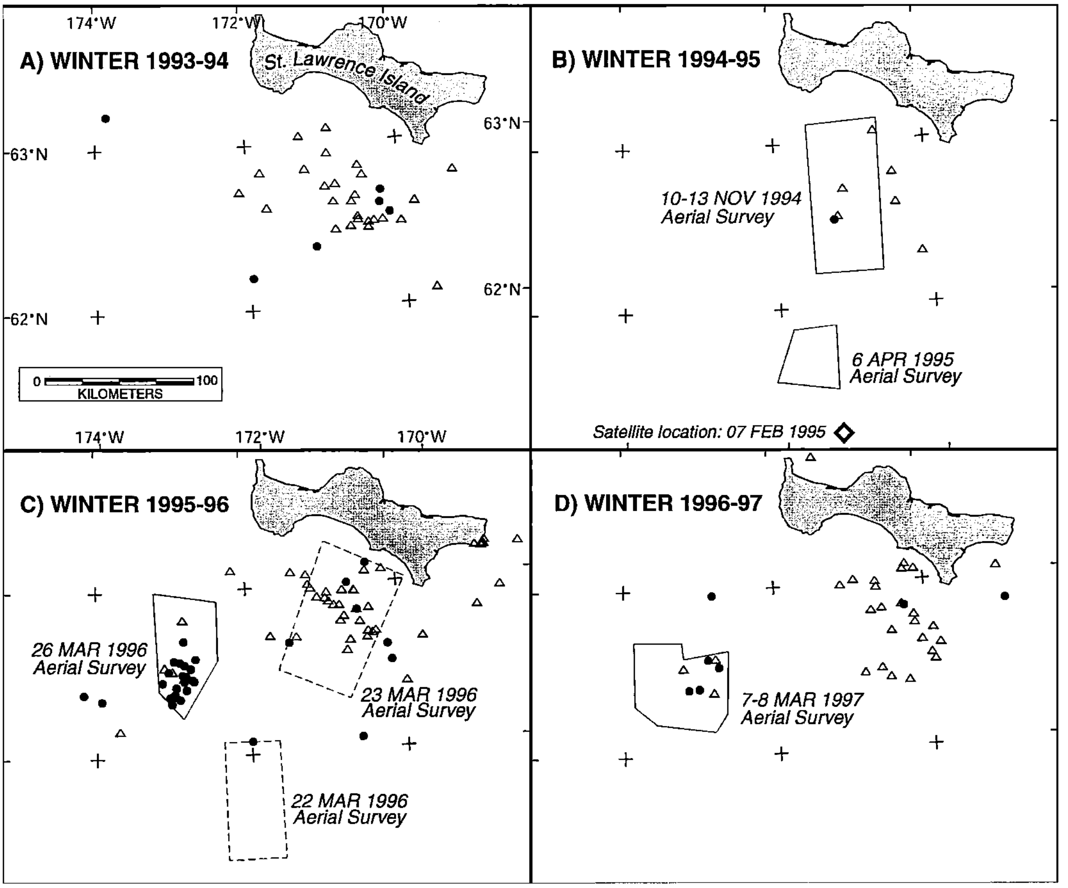

FIG. 4. PTT locations and survey areas of Spectacled Eiders in the Bering Sea during (A) winter 1993-1994, (B) winter 1994–1995, (C) winter 1995–1996, and (D) winter 1996–1997. Triangles = locations of marked birds from 1 October to 20 November, circles = locations of marked birds from 21 November to 31 December, and diamond is the location of a marked bird on 7 February 1995. Survey areas are delineated by solid lines. Reconnaissance areas (no birds located) are marked by dashed lines. See Table 5 for survey totals corresponding to survey dates.

of birds in each area, however, varied substantially among years. Survey conditions varied among years, and timing of surveys often was suboptimal owing to extended bad weather; thus, the number of birds likely was underestimated during some surveys. Because no surveys were conducted in the Indigirka/Kolyma delta area, near Bukhoto Puoten, or in eastern St. Lawrence Island, the relative importance of these areas for molting and staging birds remains undetermined.

DISCUSSION

The at-sea distribution of Spectacled Eiders in winter, as proposed by Conover (1926), Dement'ev and Gladkov (1967), and Dau and Kistchinski (1977), was partly substantiated by our satellite telemetry data. The molting areas, however, were more restricted in location than envisioned by Dau and Kistchinski (1977) and were in near-shore waters. It is understandable that the relatively small and localized molting areas were previously undocumented because birds generally were too far offshore to be seen during incidental flights or aircraft surveys along the coast. In addition, most birds migrated far enough offshore that ground-based observers would have been unable to detect large numbers of birds moving from breeding areas to molting areas.

Distribution.—Eastern Norton Sound was the

TABLE 5. Estimated numbers of Spectacled Eiders at molting and winter locations.

Location	Survey date	Estimate	Proportion male[a]
		Molting areas	
Norton Sound	31 Aug 1993	551[b]	10.7 ± 3.2 (8 flocks[c])
	23 Aug 1994	1,460[b]	No data
	6 Sep 1994	4,030[b]	16.0 ± 1.3 (23 flocks[c])
	18 Aug 1996	3,303[d]	No data
	28 Sep 1996	2,793[d]	14.4 ± 4.3 (6 photos)
Ledyard Bay	18 Aug 1994	202[e]	0 (2 flocks, 100 F, 1 F)
	21 Sep 1995	33,192[b]	85.3 ± 2.5 (28 photos)
	1 Oct 1996	14,116[e]	62.0 ± 2.7 (212 flocks[c])
Mechigmenskiy Bay	21 Aug 1994	37,397[b]	No data
	22 Aug 1994	41,209[b]	49.8 ± 4.0 (8 flocks[e])
	5 Sep 1995	55,731[b]	28.4 ± 9.1 (11 photos)
		Bering Sea	
Early winter	10–13 Nov 1994	32,698[e,f]	56.7 ± 1.7 (70 flocks[c])
Late winter	26 Mar 1996	226,810[b]	No data
	7–8 Mar 1997	363,030[g]	54.4 ± 2.3 (13 photos)
Spring	6 Apr 1995	148,059[g]	56.7 ± 3.6 (15 photos)

[a] "Females" may include hatching year males and subadult females of all ages and unknown proportions; values are $\bar{x}$ ± SE.
[b] Ocular estimate of all birds in survey area.
[c] Ocular estimate of percent in male plumage.
[d] Photo estimates.
[e] Ocular estimate extrapolated to include area between survey lines.
[f] Incomplete survey.
[g] Ocular and photo estimates combined.

primary molting area for females that nested on the Y-K Delta. Our maximum estimate of females in eastern Norton Sound (3,385) corresponds relatively well with the recent estimate of 3,000 or fewer nesting females on the Y-K Delta (U.S. Fish and Wildlife Service 1996). If females from other breeding areas currently molt in eastern Norton Sound, they are probably few in number.

Based on the large numbers of eiders estimated during aerial surveys at Ledyard and Mechigmenskiy bays, we conclude that these are important molting areas for females that breed on the North Slope and for males from all areas. Our data suggest that the area offshore from the Indigirka/Kolyma deltas is an important molting area for males, because a high proportion of males from the Indigirka Delta molted there, as did some males from the Y-K Delta and the North Slope breeding areas. However, the numbers and sex ratios of birds molting offshore from the Indigirka/Kolyma river deltas were not determined because aerial surveys in the area could not be conducted. Females from arctic Russia may molt there. It is unlikely, however, that the area off the Indigirka-Kolyma river deltas is consistently used by large numbers of successfully breeding females as a molting area because the area can be half-covered to completely covered with ice by October (Gloersen et al. 1992).

Differences in the distances birds were offshore among the different molting areas perhaps reflects the biotic and abiotic variability among these areas. For instance, the widths of the relatively shallow shelves of the Ledyard Bay, Mechigmenskiy Bay, and Indigirka-Kolyma delta areas appear to vary, and distance from shore and depths are probably highly correlated. Thus, if molting birds are limited by factors correlated with water depth (such as preferred foods), the distance from shore they are found will differ among molting areas. Similarly, the distance ice is from shore along the Beaufort Sea during molt migration may be correlated with difference distances that males and successful females were found offshore in the Beaufort Sea.

Postbreeding dispersal.—The differences in timing of molt migration between male and female Spectacled Eiders in our study are consistent with those found in other species of sea ducks (Weller 1964) and with previous observations of Spectacled Eiders (Johnsgard 1964, Kistchinski and Flint 1974, Dau and Kistchinski 1977). Similarly, it was not surprising that males in the two northernmost nesting grounds (North Slope and arctic Russia) departed the nesting grounds later than males from the more southern Y-K Delta, because nesting chronology is later at the more northern areas (North Slope median nest initiation 15 June [D. Troy pers. comm.]; arctic Russia nest initiation 17 June to 2 July [Kondratev and Zadorina 1992]) than at the Y-K Delta (median nest initiation 27 May [Grand and Flint 1997]). This conclusion differs from Dau and Kistchinski (1977), who suggested that departure dates were similar from Y-K Delta and Indigirka Delta (arctic Russia), but is consistent with Johnson and Herter (1989) for the Beaufort Sea coast. The tendency for males from all nesting areas to arrive at molting areas at about the same time suggests that molt is synchronous among males. The date a male leaves the breeding area may be a consequence of timing and nesting success of the female with which he is paired. However, migration may be either prolonged or relatively rapid such that most males arrive at molting areas and begin to molt at about the same time.

Failed and nonbreeding females have been reported to leave the Indigirka Delta by 30 July (Kistchinski and Flint 1974), which is within the range of dates that unsuccessful females left the Y-K Delta in our study (26 June to 9 August). Our data for females on the Y-K Delta suggest that the timing of reproductive failure further influences timing of molt migration. This is likely true for females nesting in arctic Russia and the North Slope, but too few unsuccessful females at the North Slope were marked.

Our observations of eiders migrating offshore when leaving the nesting grounds are similar to previous observations (Dau and Kistchinski 1977, Johnson and Herter 1989). Males began postbreeding migration in summer (June to July) and staged or migrated in offshore waters. Subadult and unsuccessful females left their nesting areas later in the summer. Our observations, as well as those summarized by Dau and Kistchinski (1977), showed that successful females left the nesting grounds in late August to September and moved to offshore waters. None of the females we captured with broods was flightless or had recently undergone molt of body or wing feathers. This is contrary to Nelson's suggestion (*in* Bent 1925) that successful females molt in summer on the breeding grounds while raising their broods.

Except for the two males located at Teshekpuk Lake, Alaska, molt migration and fall migration occurred in offshore waters. This is consistent with incidental observations reported in Palmer (1976), Dau and Kistchinski (1977), and Johnson and Herter (1989). We found no evidence that eiders nesting on the North Slope migrated over the coastal plain or near the Brooks Range, as suggested in Johnson and Herter (1989).

Our observation that males often took several weeks to migrate through the Beaufort, Chukchi, and Bering seas suggests that these areas are important staging and/or feeding areas during molt migration. However, the physiological condition of birds when they depart the breeding grounds and arrive at molting areas is unknown, as are the type, quality, and quantity of foods available to eiders during molt migration and staging. The importance of these areas relative to the timing of molt, survival during the molting period, and condition after molting is unknown. However, the availability and quality of key resources in those areas during the prolonged migration period ultimately may influence the survival of Spectacled Eiders.

Winter range.—The wintering area south of St. Lawrence Island that we identified for Spectacled Eiders includes some of the waters proposed by Dau and Kistchinski (1977) as a possible wintering area. We found, however, that Spectacled Eiders were not restricted to polynyas, but instead used areas that may, in some years, have >60% ice coverage, especially in late winter and early spring (Gloersen et al. 1992). Because we surveyed only the areas where marked birds were located, we did not consider other potential wintering areas. No surveys were conducted in areas identified by Dau and Kistchinski (1977), such as south of St. Matthew and Nunivak islands and Chukotka Peninsula, or in areas identified by Alexei Mikhailovich Trukhin (F. H. Fay pers. comm.) in the northern Kurils and southeast Kamchatka.

Observers conducting aerial surveys for large marine mammals in the Bering Sea in spring have reported "eiders" and "large ducks" among the sea ice (J. Brueggeman and G. Garner pers. comm.), but the identity of the species was unknown. At 62°00'N, 176°26'W in the Bering Sea aboard the U.S. Coast Guard cutter *Polar Star,* F. H. Fay (pers. comm.) noted flocks of Spectacled Eiders flying eastward on 17 May 1980 over the ice "at which time they were just about on a straight-line course between Cape Navarin and the Yukon Delta."

Abundance.—Aerial survey data provided minimum estimates of birds that used three of the four main molting areas. Breeding males and females arrived at and molted in these areas at different times of the year. Males arrived at molting areas almost two months earlier than successful females and began leaving the molting areas as successful females arrived. Thus, a comprehensive estimate of the number of males and females molting in each area would require at least two surveys, one each for males and females. We do not know what proportion of subadult Spectacled Eiders molts in these areas, or whether they molt primarily in other areas. Thus, a worldwide population estimate from surveys of the molting grounds would be difficult to obtain. Except for perhaps Y-K Delta birds in eastern Norton Sound, it is unlikely that estimates of molting birds in other areas would provide a breeding-population estimate for arctic Russia or the North Slope of Alaska.

Our minimum population estimate of about 333,000 birds in 1997 suggests that the number of Spectacled Eiders has increased since 1977, when Dau and Kistchinski (1977) proposed a world population of 200,000 breeding birds. Dau and Kistchinski's (1977) estimate was extrapolated from provisional estimates based on small portions of the breeding area (C. Dau pers. comm.). In addition, their estimate did not include nonbreeding or subadult birds. Thus, the total population size can only be considered not to have changed dramatically during the period of rapid decline (a 96% decrease; Stehn et al. 1993) of the Y-K Delta breeding population. Based on data from aerial surveys, a substantial population increase appears to have occurred between 1995 and 1997 (Table 5). Aerial surveys at sea in winter were limited by short daylight periods, chronically bad weather, and fuel restrictions of survey aircraft. Surveys rarely were continued beyond areas where birds were no longer seen. Thus, survey estimates represent the best minimum estimates for the conditions during a particular survey, but no trend data can be inferred with so few years of data.

Conclusions.—Here, we provide a basis to begin more comprehensive studies of eider distribution relative to physical and biological characteristics and potential population effects due to changes in human use of the Beaufort, Chukchi, and Bering seas. With the identification of eastern Norton Sound, Ledyard Bay, Mechimeginskiy Bay, and the Indigirka-Kolyma deltas as important molting areas, studies can be designed that focus on the ecology of Spectacled Eiders during molt. The delineation of the wintering area south of St. Lawrence Island provides a basis to initiate more detailed studies of population dynamics and ecology of wintering birds. Biotic and abiotic factors that probably influence the distribution of Spectacled Eiders within and among winters include sea ice conditions, benthic invertebrate communities, ocean depth, and behavioral characteristics of eiders. Once the wintering area is defined more clearly, hypotheses regarding factors that occur in winter that may limit recovery of the population can be addressed.

The tendency for Spectacled Eiders to clump into discrete areas during molting (and perhaps in winter) leaves them vulnerable to natural and human-caused environmental perturbations. During molt, eiders are particularly vulnerable to contact with petroleum products and to becoming entangled in fishing gear or other floating objects. Because they cannot fly during molt, hazing them away from such areas would be difficult. There is strong evidence that most female Spectacled Eiders nesting on the Yukon-Kuskokwim Delta use eastern Norton Sound as their principal molting area. Thus, perturbations such as new trawl fisheries, fuel spills, or other disruptions to birds and/or their habitat could have a major effect on this breeding population, which has already experienced a major decline. Similarly, wintering Spectacled Eiders appear to use a relatively restricted area in the Bering Sea. Major disruptions of food resources, other habitat changes, or direct threats to birds could have major influences on the worldwide population.

Postbreeding migration routes of Spectacled Eiders tend to be offshore where birds normally would not be at risk to death or injury. However, because petroleum development occurs in these offshore areas, eiders may have an increased risk of flying into fixed structures or supply vessels and being exposed to petroleum products that may spill or accumulate in areas of open water.

A more comprehensive analysis to statistically define high-use areas and habitat characteristics that may help identify critical habitats for molting, migrating, and wintering eiders is needed. This analysis will be important for evaluating proposed activities such as a shipping port for petroleum products in Ledyard Bay; exploration, development, and shipping of petroleum products in the Beaufort Sea; and expanded fisheries in eastern Norton Sound.

Acknowledgments

This project would not have been possible without the surgical expertise of Dan Mulcahy, Kathy Burek, and Pam Tuomi. Many people assisted with the surgery, particularly Mark Cunningham, Kim Mills, Todd O'Hare, Abby Parks, and John Pearce. Kevin Kenow and Carl Korschgen taught us the surgical technique. Declan Troy, Paul Flint, Barry Grand, Joel Schmutz, John Pearce, and Andre Degteyerev allowed us to mark birds on their study areas, and they and their crews were instrumental in capturing birds. Paul Howey was particularly responsive to our phone calls from the field to modify the implant transmitter. Gregory Balogh, Bill Eldridge, Jack Hodges, Karen Laing, Brian McCaffery, Robert Platte, and Tim Tiplady assisted with aerial surveys. J. Brueggeman, F. H. Fay, Paul Flint, Gerald Garner, and Declan Troy allowed us to use their unpublished data. In-kind support was provided by British Petroleum-Exploration (AK) Inc. on behalf of Prudhoe Bay Unit owners, North Slope Borough, Yakutsk Institute of Biology, and Yukon Delta National Wildlife Refuge. This project was funded by the U.S. National Biological Service, Alaska Science Center (now U.S. Geological Survey, Biological Resources Division, Alaska Biological Science Center); U.S. Fish and Wildlife Service, Region 7, Migratory Bird Management; and U.S. Fish and Wildlife Service, Region 7, Ecological Services. We thank T. W. Arnold, D. V. Derksen, D. Esler, J. B. Grand, R. E. Gill, Jr., R. Oates, C. Smith, and two anonymous reviewers for comments on various drafts of the manuscript.

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Associate Editor: T. W. Arnold