Coastal Marine Institute

University of Alaska

Migration of King and Common Eiders Past Point Barrow, Alaska, during Summer/Fall 2002 through Spring 2004: Population Trends and Effects of Wind

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Final Report
OCS Study MMS 2009-036

June 2009

Minerals Management Service
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Abstract

We surveyed King (*Somateria spectabilis*) and Common Eiders (*S. mollissima v-nigra*) at Point Barrow, Alaska, during the summer/fall migrations of 2002 and 2003 and during the spring migrations of 2003 and 2004. King Eiders comprised approximately 85% of the identified eiders during all migrations and Common Eiders comprised most of the rest; only 86 Spectacled (*S. fischeri*) and 20 Steller's Eiders (*Polysticta stelleri*) were identified. In spring, King Eiders migrated past Point Barrow before Common Eiders. During summer/fall migrations, most male and many female King Eiders had migrated out of the Beaufort Sea by early September before they molted, whereas most of the Common Eiders molted flight feathers before they migrated out of the Beaufort Sea in September and October. During the summer/fall migrations, we estimated (estimates ± 95% confidence intervals) that 499,423 ± 70,849 King and 174,063 ± 42,549 Common Eiders passed Point Barrow in 2002, and 365,680 ± 75,699 King and 132,404 ± 18,984 Common Eiders passed Point Barrow in 2003. During the spring migrations, we estimated that 304,966 ± 76,254 King and 114,998 ± 28,566 Common Eiders passed Point Barrow in 2003, and 591,961 ± 172,011 King and 110,561 ± 32,087 Common Eiders passed Point Barrow in 2004. Our estimates suggest that, since 1996, the number of Common Eiders passing Point Barrow has increased and that the number of King Eiders passing has at least remained stable and has possibly increased. Few King Eiders were observed in September and October in 2002 and 2003, suggesting low nesting success in both years. We suggest that future surveys should investigate combining visual and radar methods for assessing population size of eiders passing Point Barrow. Preliminary analyses of passage rates and wind conditions indicate that King and Common Eiders may respond to wind slightly differently. The passage of King Eiders was highest during low-speed tailwinds (<10 km/hr) and lowest for high-speed (>20 km/hr) headwinds. For Common Eiders, passage was also lowest for high-speed headwinds, but passage tended to be higher for high compared to low-speed tailwinds.

Introduction

Populations of all four eider species have apparently declined across the Arctic. Spectacled (*Somateria fischeri*) and Steller's Eiders (*Polysticta stelleri*) have declined in Alaska (Stehn et al. 1993, Kertell 1991, Quakenbush et al. 2002). King Eiders (*Somateria spectabilis*) have declined in both eastern and western North America (Gratto-Trevor et al. 1998, Mosbech and Boertmann 1999, Suydam et al. 2000a), and several populations of Common Eiders (*S. mollissima v-nigra*) have declined in western North America as well (Stehn et al. 1993, Goudie et al. 1994, Robertson and Gilchrist 1998, Suydam et al. 2000a). Reasons for these declines are not known, but may include factors such as habitat changes to wintering, molting, or nesting areas; lead poisoning; hunting; and increased predation on nests, ducklings, and adults. Because reasons for the population declines are not well known, there is a need to continue monitoring eider populations.

In western North America, King and Common Eiders leave wintering areas in the north Pacific and the Bering Sea and migrate north to nesting areas. At the Bering Strait, the migration divides, and some birds move west toward northern Russia and others move east to Alaska and northwestern Canada. Eiders moving east follow a series of leads and polynyas in the sea ice in April, May, and June through the Chukchi Sea off the western coast of Alaska (Woodby and Divoky 1982). At Point Barrow, Alaska, the spring migration passes very close to shore and is sometimes spectacular. For example, on 26 May 1976, Woodby and Divoky (1982) estimated that 113,000 eiders passed in 30 minutes. Various authors have noted the spring passage of eiders at Point Barrow (Murdoch 1885; Bailey 1948; Brueggeman 1980), but the magnitude of the spring migration has been estimated on only a few occasions (Woodby and Divoky 1982; Suydam et al. 1997, 2000b).

The summer/fall migration for both species begins in early July and is mostly complete by October (Cotter et al. 1997; Suydam et al. 1997, 2000b), although some flocks pass as late as November or December (Bent 1925, Bailey et al. 1933, Barry 1986). The westward migration is along a corridor paralleling the northern coast of the Yukon Territory and Alaska (Divoky 1984). At Point Barrow, the migration corridor again passes close to shore as birds leave the Beaufort Sea and fly southwest across the Chukchi Sea (Bailey 1948, Divoky 1984). The size of the summer/fall migrations have been estimated several times (Thompson and Person 1963; Johnson 1971; Suydam et al. 1997, 2000b).

The primary purpose of this study was to examine population trends of King and Common Eiders migrating past Point Barrow. In this paper we: (1) present estimates of the numbers of King and Common eiders passing Point Barrow during the summer/fall of 2002 through the spring of 2004 and compare them to estimates from 1994 and 1996, (2) document the sex ratios of King and Common eiders passing Barrow during spring, (3) document sex-specific migration phenology for both eider species during spring and summer/fall, and (4) investigate possible relationship of passage rates with wind conditions.

Methods

Observations

In general, we used the same methods to collect and analyze data as those used by Suydam et al. (1997). Typically, two observers in spring and 1–2 in summer/fall conducted a counting session during daylight hours that lasted 2 hrs, and the next count session would start 2 hrs after the previous one ended. Several counts did not last for the entire 2 hrs for various reasons, including extreme weather conditions and polar bears near the observation site. We used only completed 2-hr counts for estimating the number of eiders passing. For each counting period, we collected data on weather, including percent cloud cover, the presence of fog and precipitation, air temperature, visibility, wind speed, and wind direction. For each flock sighted, we recorded time, direction of travel, species composition, number sighted, ratio of males to females for each species, and comments on behavior when possible. All observers were trained in species identification and flock enumeration by experienced observers. Two of the observers involved in the 1990 surveys (Suydam et al. 1997, Suydam et al. 2000b), trained observers and participated as observers for these surveys. Experienced observers were paired with less experienced observers during each count session. Observers estimated the size of each flock independently and then arrived at a consensus estimate. Flock size estimates between observers generally were within $\pm$ 10% of each other. Discussion of estimates usually resulted in an explanation for a discrepancy and convergence on a consensus estimate was made. Flocks could often be counted multiple times and if observer estimates were disparate another count was made. Flocks passing contrary to the expected direction of travel were subtracted from the number of eiders flying in the expected direction during each 2-hr period.

Although we often were unable to identify all birds within a flock to species due to distance, we were able to estimate size of eider flocks. In such cases, the flock was categorized as ‘unidentified eiders’. To estimate passage rates by species, we divided the number of unidentified eiders between King and Common eiders based upon the proportion of King and Common Eiders that were identified during each 2-hr survey period.

The spring migration covers the period late April to early June, although the migration does not typically begin in earnest until early May. The summer/fall migration began as early as 1 July for male King Eiders and probably ends in late November for Common Eiders. The summer/fall migration does not typically begin in earnest until mid-July. King and Common Eiders migrate in mixed and conspecific flocks, but both species appear to behave similarly when migrating past Barrow; neither species was seen farther from shore than the other.

During summer and fall 2002 and 2003, we observed migrating eiders from the base of the Point Barrow spit (71° 21’ N, 156° 36’ W). In the spring 2003 and 2004, we observed eiders from a combination of locations on the ice and shore. On 26 April 2003, we established an observation site on an ice pressure ridge on the nearshore lead edge of shorefast sea ice. This site (71° 20.5’ N, 156° 44’ W) was located about 8 km southwest of Point Barrow and was approximately 9 m above sea level (asl). By 27 May, the sea ice was no longer safe, and we moved the observation site (71° 19.5’ N, 156° 14’ W) to a 4-m-high platform situated on the beach. On 28 April 2004, we established an observation site (71° 23’ N, 156° 41’ W) on an ice pressure ridge on the nearshore lead edge of shorefast sea ice. The site was located about 5 km west of Point Barrow and was situated approximately 4 m asl. On 22 May, because of deteriorating ice conditions, we moved to a second site located approximately 3 km southwest of the original observation site. Additionally, two surveys were conducted on 27 May and one on 29 May by one observer from the bluffs (71° 17’ N, 156° 46’ W) near the gravel pits approximately 2 km southwest of the City of Barrow.

Estimation of Sex Ratios

We compared sex ratios for both King and Common Eiders during each observed migration period (i.e., spring and summer/fall) from 2002 through 2004. To examine sex ratios, we either counted the actual number of males for smaller flocks (i.e., less than ~100 birds) or we estimated the proportion of males in each flock. Observed sex ratios were compared with a 50:50 ratio using contingency tables and chi-square tests for goodness of fit with an alpha level of 0.05 and 1 degree of freedom (Zar 1998). We could not visually distinguish adult females from hatch-year eiders for either species while in flight. The only way to identify the proportion of each was to sample the local subsistence harvest.

Estimation of Population Size and Trend

We estimated the total number of eiders passing during each migration season between summer/fall 2002 and spring 2004. Eider migration is quite variable from day to day (Thompson and Person 1963; Johnson 1971; Timson 1976; Woodby and Divoky 1982; Suydam et al. 1997, 2000b; Day et al. 2004). To account for daily variation in our estimate of total population size, we treated our sample as coming from a stratified design, where each day represents a separate stratum. Within each day (d), the average number of eiders passing $(\bar{y}_d)$ is estimated using all 2-hour periods sampled. This average then is multiplied by the total number of 2-hour sampling periods that are possible within each day $(N_d = 12)$. Following Thompson (2002; page 119), the population total thus is defined as the sum of the daily totals:

$$total = \sum_{d=1}^{L} N_d \bar{y}_d ,$$

where L is the total number of days sampled. The variance estimator for the population total accounts for the number of 2-hour periods sampled within each day (n_d), the variance within each day (σ_d^2), and is defined as:

$$\text{var}(total) = \sum_{d=1}^{L} N_d (N_d - n_d) \frac{\sigma_d^2}{n_d} .$$

We estimated the trend in population totals between 1994 through 2004 using an exponential model,

$$N_t = N_0 * e^{rt} ,$$

where N is the population count, r is the rate of increase, and t is the sampling event (i.e., time). When data are log transformed, this model simplifies to a simple linear regression:

$$ln(N_t) = ln(N_0) + rt .$$

We log transformed the count data and estimated separate trends for both King and Common Eiders. To account for error in our estimates of N_t, we weighted our regressions by the inverse variance of N_t. On a log scale, the inverse variance of N_t is equal to:

$$1 \Big/ \left(\left(\frac{1}{N_t} \right)^2 \sigma_{N_t}^2 \right) .$$

In effect, sampling events with high variances have less influence on the trend.

Wind and Passage Rates

We modeled the counts of King and Common Eiders for each two hour observation period as a function of wind direction and speed by using zero-inflated negative binomial models (Lambert 1992, Martin et al. 2005). Count data typically have skewed distributions in that the number of observations with small (or zero) counts far outnumber observations with large counts. Although such data are typically examined via Poisson regression, count data often have properties that the Poisson distribution cannot accommodate. For example, the Poisson distribution restricts the variance to equal the mean, but count data often have variances larger than the mean. Furthermore, count data often include more zero counts than is allowable for analysis using Poisson distribution (e.g., Bohning et al. 1999, Martin et al. 2005, Welsh et al. 1996).

These restrictions have led to the use of distributions that allow for larger variances or large numbers of zero counts (e.g., Lambert 1992; Welsh et al. 1996). The negative binomial distribution often is used to account for extra-Poisson variation (e.g., Welsh et al. 1996; Martin et al. 2005). This distribution is similar to the Poisson distribution but has an extra parameter, θ, which scales the distribution to account for extra variance. As θ approaches zero, the negative binomial distribution converges on the Poisson distribution. Likewise, mixture distributions, also known as "zero-inflated" distributions, commonly are used to account for extra zeros. Such distributions typically combine distributions suitable for binomial and count data. In effect, if a count is zero, it is modeled as a mixture of zeros from the negative-binomial process with additional zeros from a Bernoulli process. If the count is greater than zero, the count is modeled as resulting from a negative-binomial process. Where *p* is the probability that an observation is generated from a negative binomial process, μ is the mean count, *y* is the specific count (i.e., the number of eiders), θ is an over-dispersion parameter, *y*! is the factorial of count *y*, and Γ is the gamma function:

$$\Pr(Y_i = 0) = 1 - p + p\frac{1}{1+\theta\mu}^{1/\theta}, \qquad \text{if } y_i\text{=0, and}$$

$$\Pr(Y_i = y) = p\left(\frac{\Gamma(y+1/\theta)}{y!\Gamma\left(\frac{1}{\theta}\right)}\right)\left(\frac{\theta^y\mu^y}{(1+\theta\mu)^y(1+\theta\mu)^{\frac{1}{\theta}}}\right), \qquad \text{if } y_i\text{>0.}$$

Within this model, covariates for *p* are modeled with a logistic link function and covariates for μ are modeled with a log link function (Martin et al. 2005).

Preliminary analyses indicated that count data were strongly skewed, had a variance larger than Poisson variance, and were zero-inflated, indicating that a zero-inflated negative-binomial regression was most appropriate. Models were optimized in *R* (*R* Development Core Team 2005) using package *pcsl* (Jackman 2005). We selected models using an information-theoretic approach (AIC, Burnham and Anderson 1998) and considered all models within 2 AIC of the best approximating model. Goodness-of-fit (GOF) was used to assess model fit for the most parameterized model using a log-likelihood G-statistic (Sokal and Rolf 1995; White and Bennetts 1996) with an alpha level of 0.05. Where *O* and *E* are observed and expected frequencies, respectively, $G = 2\sum O_i \ln(O_i/E_i)$. The *G*-statistic is approximately chi-square distributed with degrees of freedom equal to the number of categories minus 1 (Sokal and Rolf 1995).

All models assumed that the count varied by species, year, and season; they differed only in how wind direction and speed related to the count. In effect, we wanted to know if wind direction and speed accounted for variation in addition to inherent differences in the average count. We examined multiplicative and additive relationships between individual 2-hr counts and the daily averages for wind direction and wind speed for each species. We focused on eiders flying in the dominant direction; occasionally, groups were observed flying the opposite direction. These groups constituted <1% of the total for both species (King Eiders = 0.56%; Common Eiders = 0.28%) and were subtracted from daily counts. Daily averages for wind direction and speed were recorded by the National Climate Data Center (NCDC) weather station located at the Wiley Post – Will Rodgers Memorial Airport (WBAN: 27502). We assigned wind speed into one of three categories: <10, 10–20, or >20 km/hr. Our classification of three wind categories is somewhat subjective. Thompson and Person (1963) suggested that eiders are insensitive to wind direction when winds are less than 14.5 km/hr. Day et al. (2004) examined migration relative to two categories, 'weak' winds (≤ 16 km/hr) and 'strong' winds (> 16 km/hr). We thought that having three categories would allow for greater resolution and allow us to isolate the effects of very strong (> 20 km/hr) winds, where relationships between wind speed migratory behavior are expected to be the most pronounced. Following Day et al. (2004), we categorized wind direction as headwinds, tailwinds, or neutral winds. In the fall, as eiders migrate west along the coast, the direction of migration is approximately 315º (True); again following Day et al. (2004), we classified winds originating between 270º and 360º (True) as headwinds, between 180º and 90º (True) as tailwinds, and all other winds as neutral. In the spring, the main direction of migration to Point Barrow is approximately 045º (True). For spring, we classified winds originating between 360º and 090º as headwinds, between 180º and 270º (True) as tailwinds, and all other winds as neutral.

Because we used a joint-probability model and cannot interpret the binomial and count portions of the models separately (Cunningham and Lindenmayer 2005), sequential fitting of model parameters may prevent us from converging on the best model structure. To ensure that we converged on the best model structure, we examined all combinations of all parameters, resulting in 36 separate models.

Results

Observation Periods

Summer/fall. We surveyed eiders for a total of 642 and 660 hrs in summer/fall 2002 and 2003, respectively. In 2002, surveys began on 11 July and ended on 17 October (Fig. 1a); in 2003 surveys began on 7 July and ended on 14 October (Fig. 1b). Twenty-four hours of daylight allowed us to survey ≥10 hrs from mid-July to early August. During September and October, the amount of daylight decreased rapidly (10–20 min/day) so that, by late October, we only conducted surveys for about 4 hrs/day (Figs. 1a and 1b).

Spring. We surveyed eiders for a total of 388 hrs in the spring of 2003. Continuous daylight allowed us to conduct surveys throughout the day. In 2003, during the beginning of the spring migration (26 April–1 May) and near the end (1–5 June), we survey for 2–8 hrs/day. During the main migratory period, between 2–31 May, we attempted to survey for 10–12 hrs/day (Fig. 2a). However, high winds and snow, reduced visibility, and unsafe ice conditions occasionally reduced our sampling efforts.

We surveyed eiders for a total of 284 hrs in the spring of 2004. From 1–23 May, we attempted to survey between 8–12 hrs/day. Occasionally, we were unable to maintain this schedule; and poor visibility or unsafe ice conditions reduced our sampling effort on 1, 6, 7, and 21 May. From 24 May–3 June, near the end of spring migration, we surveyed for 4–6 hrs/day (Fig. 2b).

Timing of Migration by Species

Summer/fall 2002. King Eiders were first observed on 11 July (the first day of surveys) and they continued to pass steadily through early September (Fig. 1a). High counts occurred from 17–21 July, 26–29 July, and 19–24 August. After 7 September, large numbers of King Eiders were only observed passing on 12 September. We first saw Common Eiders on 12 July, but only in low numbers until 19 August (Fig. 1a). The highest number of migrating Common

Eiders (~42,000 birds) passed from 9–11 October. Most (64%) of the Common Eiders passed Barrow after 1 October.

King and Common Eiders composed 83% and 17%, respectively, of all the eiders identified migrating past Point Barrow during summer/fall 2002. We did not identify any Spectacled or Steller's Eiders during the summer/fall 2002 survey period.

Summer/fall 2003. King Eiders were first observed on 7 July (the first day of surveys) and they continued to pass steadily through early September (Fig. 1b). High counts occurred on 30 July and 3 August. We observed few King Eiders after 7 September. We also first saw Common Eiders on 7 July (Fig. 1b). A steady passage of Common Eiders continued throughout the migration. The highest numbers of migrating Common Eiders (~15,000 birds) occurred on 20 August and 5 October (Fig. 1b). As in summer/fall 2002, many (33%) Common Eiders passed Barrow after 1 October.

King and Common eiders composed 84% and 16%, respectively of all the eiders identified migrating past Point Barrow during summer/fall 2003. We identified 24 Spectacled and 9 Steller's eiders during the summer/fall 2003 survey period.

Spring 2003. King Eiders were first seen on 1 May. Only small groups were counted until 14 May (Fig. 2a). During a five day interval (14–18 May), ~68% of the King Eiders passed Point Barrow with the peak (103,000) occurring on 15 May. We first saw Common Eiders on 29 April. The highest daily estimate of migrating Common Eiders (~34,000) occurred on 15 May, but their numbers generally were low and varied little throughout May (Fig. 2a). Most (90%) of the Common Eiders passed Barrow from 15 May to 5 June.

King and Common eiders composed 66% and 35%, respectively, of all the eiders identified migrating past Point Barrow during spring 2003. Eight Spectacled Eiders and one Steller's Eider were also observed during the spring 2003 survey period.

Spring 2004. Large numbers of King Eiders were observed 28–29 April, the first two survey days (Fig. 2b). Large passages of King Eiders also occurred on 2, 10–12, and 17–19 May. From 4 to 9 May we recorded more eiders moving southwest than northeast and the daily passages were < 2,000. Roughly 88% of King Eiders observed had passed Barrow by 22 May. We first observed Common Eiders on 28 April, but did not count many until 10 May (Fig. 2b). Pulses of Common Eiders were observed 10–12, 17–20, and on 31 May. Most (68%) Common Eiders had passed Barrow from 15 May to 5 June.

King and Common eiders composed 76% and 24%, respectively, of all eiders identified migrating past Point Barrow during spring 2004; we also recorded 54 Spectacled and 10 Steller's eiders during spring 2004.

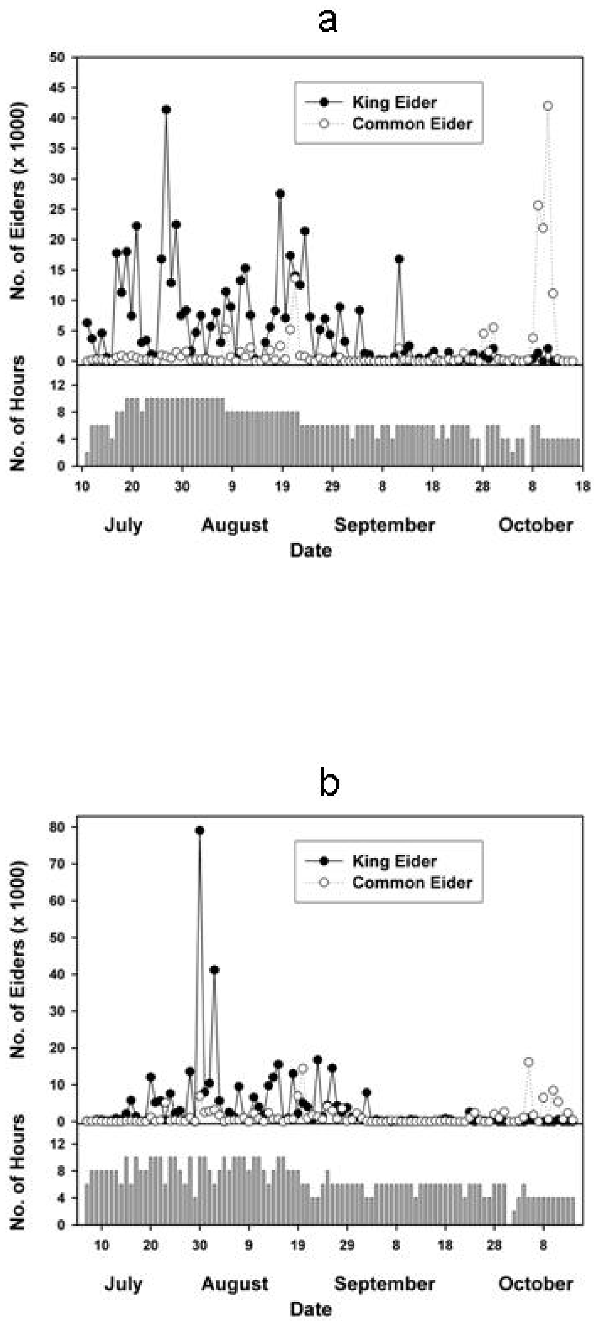
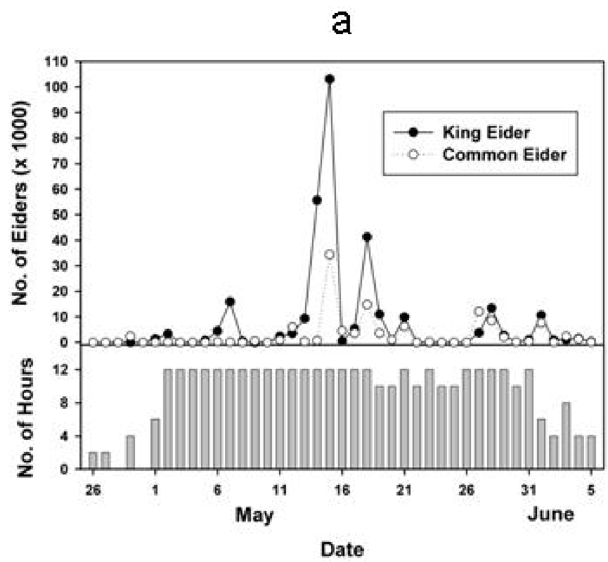


Figure 1. Number of hours of observation per day and projected daily passage of King and Common eiders during summer/fall 2002 (a) and 2003 (b) at Point Barrow, Alaska. Projected passages include unidentified eiders that were assigned to species according to the daily proportions of King and Common eiders that were identified.



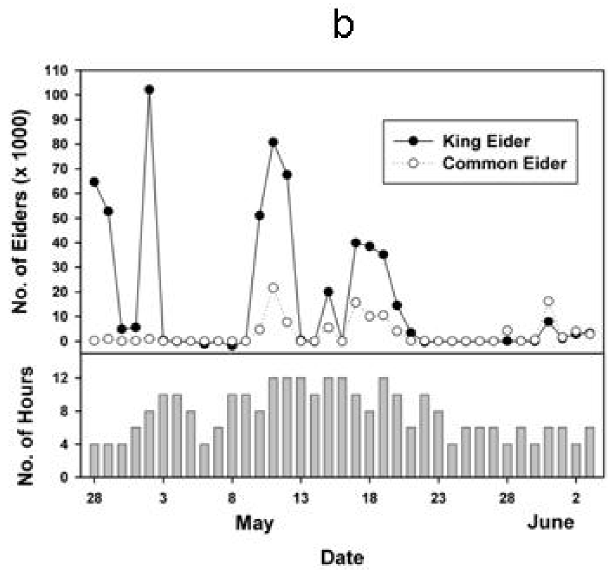


Figure 2. Number of hours of observation per day and projected daily passage of King and Common eiders during spring 2003 (a) and 2004 (b) at Point Barrow, Alaska. Projected passages include unidentified eiders that were assigned to species according to the daily proportions of King and Common eiders that were identified.

Timing of Migration by Sex

In both King and Common eiders, most males migrated before females in summer/fall. In the summer/fall of 2002 and 2003, groups of eiders passing in July and early August were largely composed of males (Figs. 3a and b). Sex composition of groups shifted predominantly to females by late August. In contrast, both sexes apparently migrated together in spring. Flocks observed in spring of 2003 and 2004 were of approximately equal sex ratios (Figs. 4a and b).

Summer/fall. In summer/fall, the daily proportion of male King Eiders varied from 0 to 100%. In both 2002 and 2003, the sex ratio over the entire migration tended to be skewed toward males (Table 1). In summer/fall 2002, the proportion of males was 63% ($\chi^2 = 3{,}025$, $P < 0.01$); in summer/fall 2003, the proportion of males was 85% ($\chi^2 = 20{,}851$, $P < 0.01$).

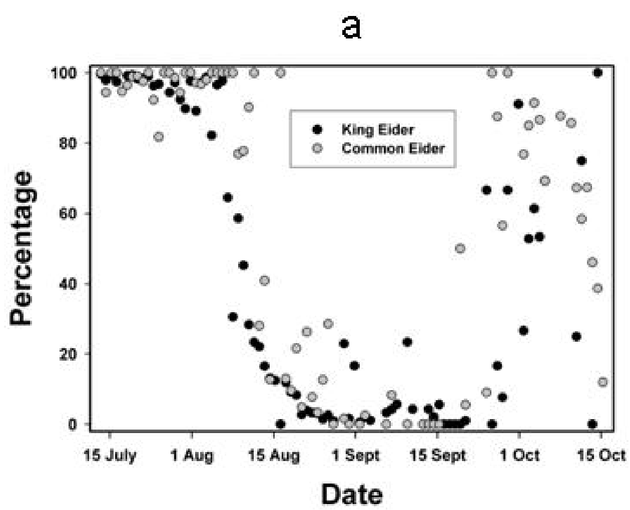
Sex ratios for Common Eiders were similar to ratios described for King Eiders. In summer/fall, the daily proportion of male Common Eiders varied from 0 to 100%. However, in both years, the sex ratio over the entire migration period was also skewed toward males (Table 1). In summer/fall 2002, the proportion of males was 59.5% ($\chi^2 = 333$, $P < 0.01$); in summer/fall 2003, the proportion of males was 77% ($\chi^2 = 2{,}162$, $P < 0.001$).

Table 1. Sex ratios expressed as percent males for King and Common eiders passing Point Barrow.

Species	Year	Season	Daily average (SE)	Season average
King Eider	2002	summer/fall	42.9 (4.4)	63.0
	2003	summer/fall	57.9 (5.0)	85.4
	2003	spring	52.6 (0.5)	52.6
	2004	spring	53.7 (1.5)	51.1
Common Eider	2002	summer/fall	59.8 (4.4)	59.5
	2003	summer/fall	69.5 (4.0)	76.6
	2003	spring	55.0 (2.0)	51.0
	2004	spring	53.3 (0.8)	51.2

The majority of the summer/fall migration of Common Eiders occurred after 1 October in both 2003 and 2004 and consisted of adult males, adult females and young of the year, which are female-like in appearance. Subadult (i.e., nonbreeding male and presumably female) King or Common Eiders are rarely seen during either migration period.

Spring. In spring, the daily percentage of male King Eiders was 48–61% in 2003 and 24–75% in 2004. In both years, the sex ratio over the entire migration was only slightly skewed towards more males (Table 1). In spring 2003, the percentage of males was 53% ($\chi^2 = 56.0$, $P < 0.01$), and in spring 2004, the percentage of males was 54% ($\chi^2 = 20.8$, $P < 0.01$).



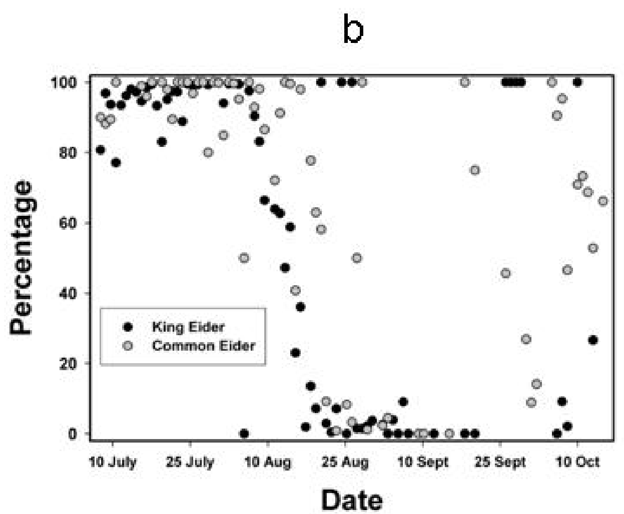
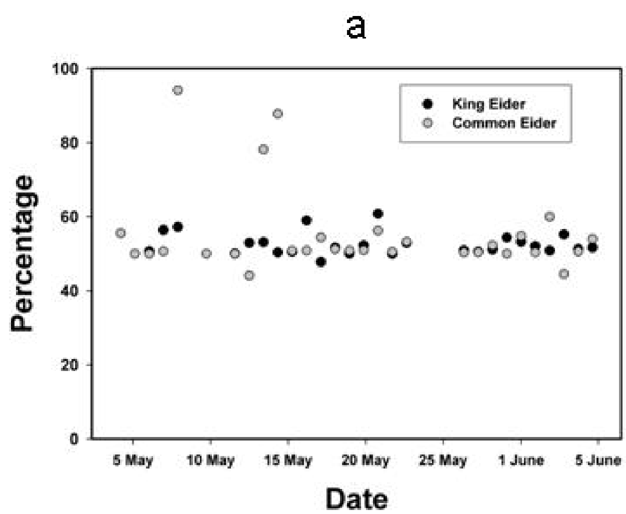


Figure 3. Percentage of males observed in eider flocks during the summer/fall migration at Point Barrow, Alaska, in 2002 (a) and 2003 (b). Percentages near 100 indicate flocks dominated by males, and percentages near 0 indicate flocks dominated by females.



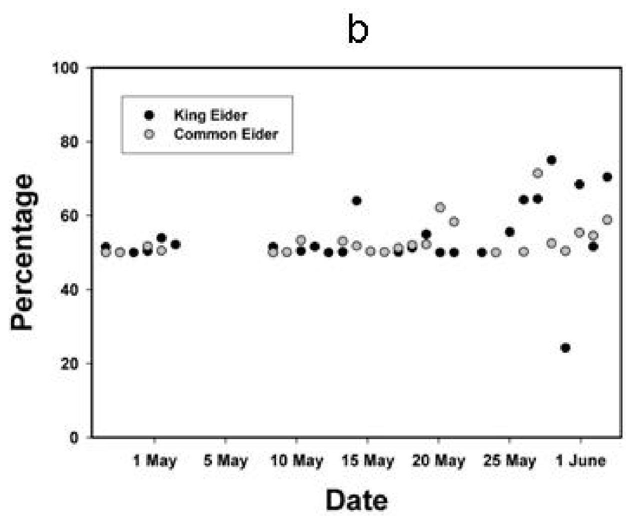


Figure 4. Percentage of males observed in eider flocks during the spring migration at Point Barrow, Alaska, in 2003 (a) and 2004 (b). Percentages near 100 indicate flocks dominated by males, and percentages near 0 indicate flocks dominated by females.

In spring, the daily percentage of male Common Eiders was 44–94% in 2003 and 50–71% in 2004. The flocks that were predominantly males occurred on days with low Common Eider passage. There were four days in 2003 with more than 60% males and on those days less than 325 Common Eiders per day were identified. In 2004, there were only two days with more than 60% males and on those days fewer than 40 Common Eiders were identified. In both years, the sex ratio over the entire migration was only slightly skewed toward more males. In spring 2003, the percentage of males was 55% ($\chi^2 = 7.9$, $P < 0.01$) and in spring 2004, the proportion of males was 53% ($\chi^2 = 7.3$, $P < 0.01$).

Population Size

For summer/fall 2002, we estimated (± 95% Confidence Interval) that 499,423 ± 70,849 and 174,063 ± 42,549 King and Common Eiders, respectively, passed Point Barrow during our survey period from 11 July to17 October (Table 2). In order to compare with previous summer/fall surveys we also estimated that 462,947 ± 65,864 King Eiders passed during 11 July–7 September, the period that was comparable among all surveys (Table 3). We did not calculate a similar estimate for Common Eiders because many adults migrated past Barrow after many of the previous survey efforts had ceased counting. Furthermore, hatch year birds, which resemble females, migrated after early September making it extremely difficult to estimate the number of adult females. Thus comparisons between the numbers of Common Eiders passing in the summer/fall with spring are not useful.

In spring 2003, we estimated that a total of 356,293 ± 75,598 and 114,998 ± 28,566 King and Common Eiders, respectively, passed Point Barrow during 26 April–5 June (Table 2). It was not necessary to calculate different estimates for comparison across spring counts because the survey periods were already comparable (Table 3).

In summer/fall 2003, we estimated that a total of 365,680 ± 75,699 and 132,404 ± 18,984 King and Common eiders, respectively, passed Point Barrow during 7 July–14 October (Table 2). In order to compare with previous summer/fall surveys we also estimated that 356,293 ± 75,598 King Eiders passed during 7 July–7 September, the period that was comparable among surveys (Table 3). We did not calculate a similar estimate for Common Eiders because their summer/fall behavior did not allow for useful comparisons among surveys.

In spring 2004, we estimated that 591,961 ± 172,011 and 110,561 ± 32,087 King and Common Eiders passed Point Barrow during 28 April–3 June (Table 2). It was not necessary to calculate different estimates for comparison in the spring because the survey periods were already comparable (Table 3).

Table 2. Numbers of King, Common, and unidentified eiders seen during summer/fall 2002–spring 2004 migrations, projected total passage, and 95% confidence interval.

Season	King Eider	Common Eider	Eider[1]	TOTAL
Summer/fall 2002[2]				
Number Seen[3]	61,707	13,776	134,728	210,211
Projected Total Passage[4]	499,423	174,063		673,486
95% Confidence Interval	70,849	42,549		
Summer/fall 2003[5]				
Number Seen[3]	52,756	10,609	97,414	160,812
Projected Total Passage[4]	365,680	132,404		498,084
95% Confidence Interval	75,699	18,984		
Spring 2003[6]				
Number Seen[3]	78,500	24,704	101,872	205,085
Projected Total Passage[4]	304,966	114,998		419,994
95% Confidence Interval	76,254	28,566		
Spring 2004[7]				
Number Seen[3]	106,546	23,237	133,932	263,779
Projected Total Passage[4]	591,961	110,561		702,522
95% Confidence Interval	172,011	32,087		

[1] Unidentified eiders.
[2] From 11 July to 17 October.
[3] Net number of birds migrating northeast (spring) or southwest (summer/fall).
[4] Sum of the daily projected passage—number seen expanded for the time not observed. Unidentified eiders were assigned to species according to the daily proportions of King and Common eiders that were identified.
[5] From 7 July to 14 October.
[6] From 26 April to 5 June.
[7] From 28 April to 3 June.

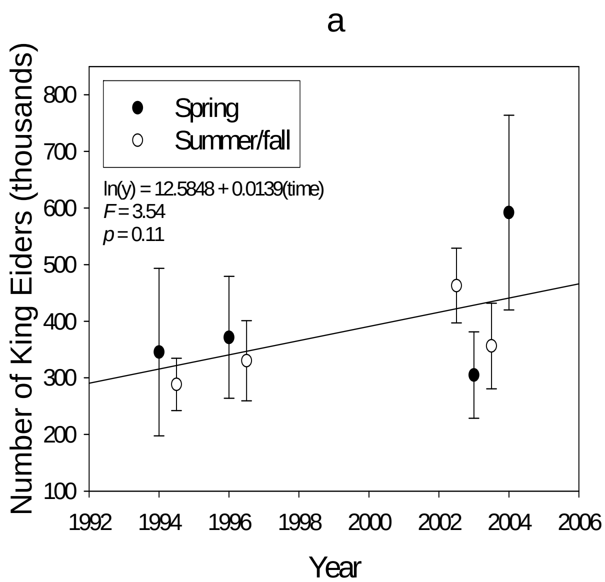
Table 3. Estimated total passage and 95% confidence intervals of King and Common Eiders calculated using comparable time periods in spring 1994, 1996, 2003, and 2004, and in summer/fall 1994, 2002, and 2003. These estimates were used to determine population trends.

Season	King Eider	Common Eider
Spring 1994[1]		
Estimate for Trend Analysis	345,489	74,651
95% Confidence Interval	147,877	22,317
Summer/fall 1994[2]		
Estimate for Trend Analysis	288,362	
95% Confidence Interval	46,229	
Spring 1996[1]		
Estimate for Trend Analysis	330,218	72,606
95% Confidence Interval	70,725	13,606
Summer/fall 1996		
Estimate for Trend Analysis	371,452	
95% Confidence Interval	107,697	
Summer/fall 2002[3]		
Estimate for Trend Analysis	462,947	
95% Confidence Interval	65,864	
Spring 2003[4]		
Estimate for Trend Analysis	356,293	114,998
95% Confidence Interval	75,598	28,566
Summer/fall 2003[5]		
Estimate for Trend Analysis	304,966	
95% Confidence Interval	76,254	
Spring 2004[6]		
Estimate for Trend Analysis	591,961	110,561
95% Confidence Interval	172,011	32,087

[1] From 1 May to 4 June.
[2] From 13 July to 7 September.
[3] From 11 July to 7 September.
[4] From 26 April to 5 June.
[5] From 7 July to 7 September.
[6] From 28 April to 3 June.

Population Trends

King Eider population estimates tended to increase from 1994 through 2004, however trend analysis indicated no strong relationship (F= 3.54, P = 0.11, df=1) in population size over time (Fig. 5). The rate of increase for King Eiders was 0.0139 (95% CI= -0.004–0.0319). The trend analysis for Common Eider population estimates indicated an increase (F= 28.6, P = 0.03, df=1) between 1994 and 2004 (Fig. 5). The rate of increase for Common Eiders was 0.0226 (95% CI= 0.0044–0.0410).



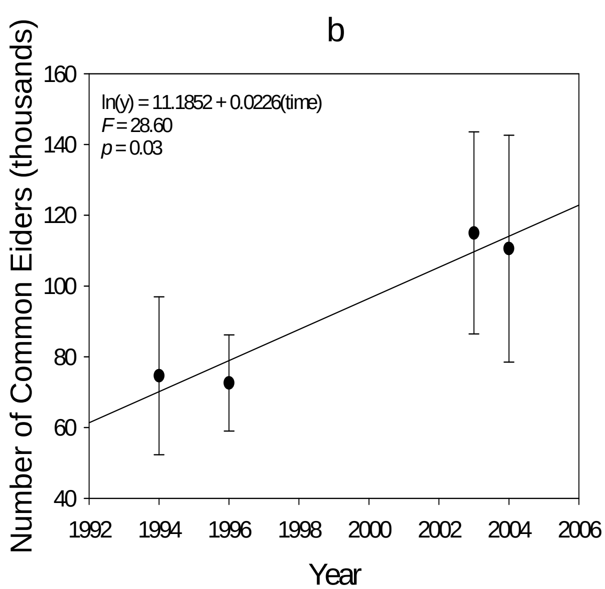


Figure 5. Trend of King Eider (a) and Common Eider (b) populations at Point Barrow, Alaska, 1994–2004. Point estimates and 95% confidence intervals are presented.

Wind Speed and Passage Rates

All models within 2 AIC of the best approximating model supported the effect of wind direction and speed on the number of eiders that passed during each survey period (Table 4). The best approximating model indicated that passage rate was a function of both wind speed and direction, but the relationship differed by species.

Table 4. The best approximating models for eider passage. All models include a species*year*season term to account for baseline differences in eider numbers. Parameters are fit separately for the binomial and count portions of the model. One additional model with no wind effects is presented for comparison. Models > 2 AIC units from the best approximating model were not supported by the data.

Model		# Para.	logLik	AIC	Δ AIC
Binomial portion	**Count portion**				
Direction*Speed	Species*Direction*Speed	41	-9333.69	18749.38	0.00
Direction+Speed	Species*Direction*Speed	37	-9337.70	18749.41	0.03
Species*Direction*Speed	Species*Direction*Speed	49	-9325.75	18749.51	0.13
Direction*Speed	Direction*Speed	29	-9353.39	18764.77	15.39
Direction+Speed	Direction*Speed	29	-9357.55	18773.11	23.73
Species*Direction*Speed	Direction*Speed	41	-9347.95	18777.89	28.51
Direction*Speed	Direction+Speed	25	-9372.95	18795.89	46.52
Direction*Speed	Direction	23	-9375.30	18796.61	47.23
Direction+Speed	Direction	23	-9379.00	18804.00	54.62
Direction+Speed	Direction+Speed	25	-9377.92	18805.85	56.47
		17	-9492.28	19018.55	269.17

Passage rates of King Eiders decreased with increasing wind speed, especially when high-speed winds were headwinds (Fig. 6a). For example, in the fall of 2003, the average passage rate (number of birds/2-hr observation session) when winds were < 10 km/hr was 588 (95% CI = 149–1358) during headwinds and 676 (95% CI = 367–1211) during tailwinds. As wind speed increased, the point estimates for passage rate decreased although the confidence intervals overlapped. For high-speed winds (> 20 km/hr), the decrease was most pronounced for headwinds, where the passage rate dropped to 106 (95% CI = 65–171), than for tailwinds, where the average was 390 (95% CI = 237–621).

The average passage rate of Common Eiders decreased with increasing headwinds. However, in contrast to the pattern seen for King Eiders, the passage rate increased with high-speed tailwinds (Fig. 6b). For example, in the fall of 2003, the average passage rate for Common Eiders when winds were < 10 km/hr was similar for neutral or tail winds (94 birds per sample period; 95% CI = 57–145) and headwinds (134 birds per sample period; 95% CI = 60–296). As wind speed increased (> 20 km/hr), the passage rate increased to an average of 499 (95% CI = 293–779) for tailwinds and decreased to an average of 12 (95% CI = 7–19) for headwinds.

However, the global model did not adequately fit the data ($\chi^2_{0.05, 65} > 30{,}000$; $P < 0.01$). Examination of residuals indicated that the lack of fit was primarily due to variation in daily wind speed and direction being insufficient to fully account for variation in passage rates for large pulses of migrating eiders.

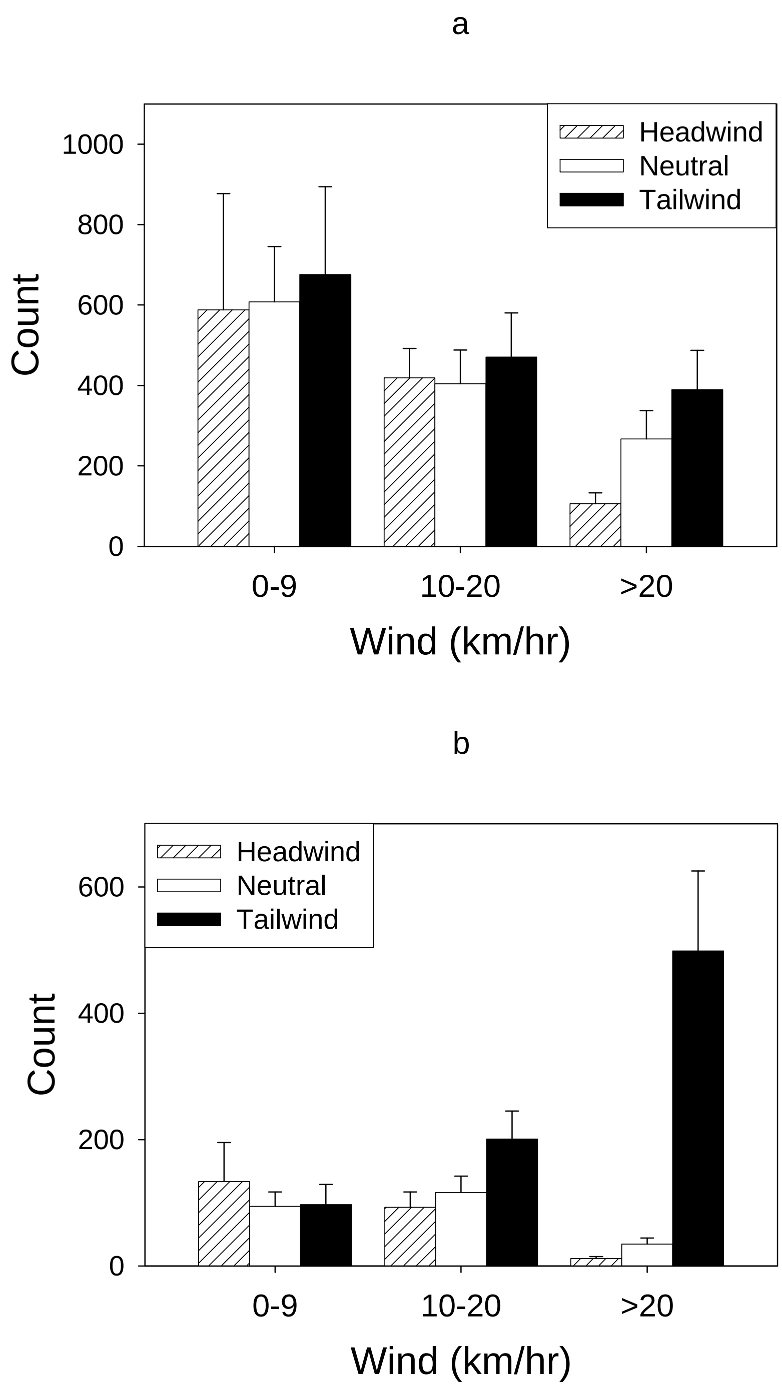


Figure 6. Average count of King Eiders (a) and Common Eiders (b) during 2-hr counts at Point Barrow, Alaska, during summer/fall and spring 2002–2004 categorized by wind speed and direction. The effect of wind was restrained to be constant across years and seasons. Values for fall 2003 are presented; for other years and seasons, the scaling will change but the relationship between the count and winds will be the same. Error bars represent 1 SE.

Discussion

Efficacy of Counting Locations and Periods

Our analyses assumed that a constant proportion of the populations were sampled across years and across seasons for King Eiders. If we violated this assumption or there was a trend in the proportion of birds that we observed across years, our population estimates and trends may have been biased. We know that not all birds fly within visual range; some fly inland and some likely fly farther offshore. If the migratory corridor shifted (i.e., offshore or onshore) closer to the observation points in recent years, we may have detected more eiders and thus, concluded an increasing trend even though the population was actually stable. Unfortunately we were not able to test this assumption. We surveyed migrating eiders using methods as similar as possible to previous studies so that our passage estimates could be used for trend analyses. At least two observers (Suydam and Quakenbush) were instrumental in the surveys in the mid-1990s and the recent ones presented here.

Location of counts. All summer/fall sampling locations were near the base of Point Barrow spit. The presence of an ancient hunting site at this location ("Birnik," now known as "Duck Camp") indicates that the site has been a preferred hunting location for at least 2,000 years (Murdoch 1892). A radar study, which occurred in 1997 and 2000, indicated that nearly all eiders encountered (i.e., those within the range of the radar) passed within 3 km of our survey location at Duck Camp (see Day et al. 2004; Fig. 4). Further evidence that this location seems to be appropriate includes data from King Eiders with satellite transmitters showing that they migrated relatively close (14.8 km) to shore (Phillips 2005). Although Phillips (2005) reported that migrating King Eiders averaged 14.8 km from shore, it appears that individuals in fact migrate much closer to shore in the vicinity of Point Barrow (Fig. 7; see also Day et al. 2004, Fig. 4). We did not consider telemetry locations east of Point Barrow because movements of individual eiders there suggested that they were not migrating (Phillips 2005). Within 55 km west of Point Barrow, King Eiders were located an average of 4.7 km (SE = 0.8 km) from shore (Fig. 8). When we examined these same telemetry locations very near Point Barrow spit, we found that King Eiders migrated even closer to shore ($\bar{x}$ =3.2 km, SE = 0.38). It also appeared that very few of the transmittered eiders passed inland of our observation site (Fig. 7). However, because the transmitters had a 6-day duty cycle, we were unable to determine the exact migratory route where most transmittered eiders passed Point Barrow. Regardless, the telemetry data along with the radar data of Day et al. (2004) suggests the base of Point Barrow spit is the most appropriate location for counting migrating eiders. No satellite-tracking or radar data are available to examine interannual spatial variation in the migratory corridor near Point Barrow.

During spring, eiders tended to migrate along the nearshore edge of the open lead, where all spring counts have occurred, although some flocks migrate along the beach or farther inland. There are no data available to evaluate a trend in interannual variation of migratory corridors used by King and Common eiders during spring.

We conducted the 2002 to 2004 summer/fall and spring counts in locations as similar as possible to previous counts so that passage rates could be compared across years.

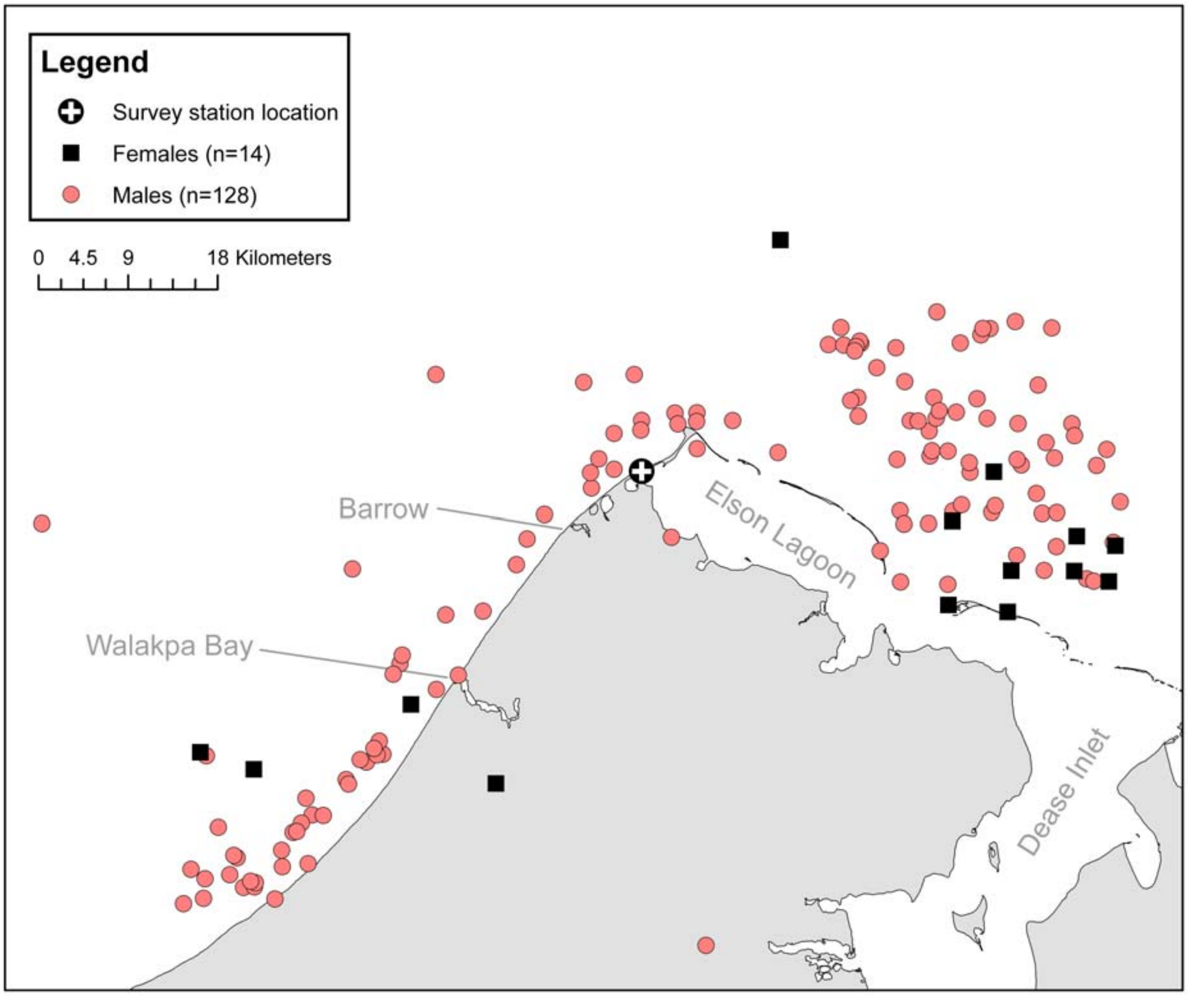


Figure 7. Locations of King Eiders with satellite transmitters in summer/fall (10 June–30 October) within 55 km of the survey location at Point Barrow, Alaska, 2002–2005. Because the duty cycle of the transmitters was 6 days in duration, we do not know what proportion of individuals actually was migrating.

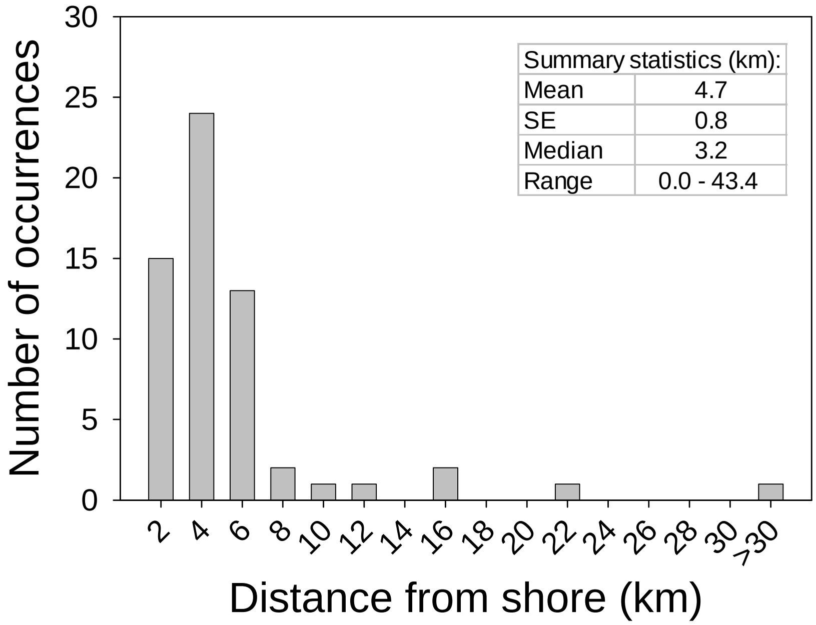


Figure 8. Distance King Eiders with satellite transmitters were located from shore west of Point Barrow, Alaska, in summer/fall 2002–2005. The area used for this calculation was between 156.41° W and 158.29° W and included all locations within 55 km west of Point Barrow.

Timing of counts. We also used satellite telemetry data from Phillips (2005) to determine timing of passage of transmittered King Eiders relative to our surveys (see also Powell et al. 2005a). Based on satellite tracking data, our survey periods were appropriately timed to coincide with migrating female King Eiders; all satellite-tagged female King Eiders passed within our survey periods (Figs. 9 and 10). Although all satellite-tagged male King Eiders passed within our survey period in the spring of 2003 and 2004, ~20% of marked males passed before we began our surveys in summer/fall 2003, and 50% passed before we began our surveys in summer/fall 2002 (Fig. 9). Our ability to make inferences based on these data is limited. Phillips (2005) only marked and tracked eiders that were captured in northern Alaska. Most of the eiders migrating past Point Barrow probably nest in areas farther to the east, especially on Banks and Victoria Islands, Canada (Barry 1986; Dickson et al. 1997). Even though Phillips' (2005) results are useful, the data represent only a small portion, probably less than 5%, of the population that breeds much farther to the west. Phillip's (2005) birds migrated a much shorter distance than most of the population to get to Point Barrow. Hence, although we may have missed 20–50% of Phillips' (2005) tagged sample of King Eiders in the summer/fall, it is likely that we missed a much smaller proportion of the total population of King Eiders that migrate past Point Barrow from Banks and Victoria Islands.

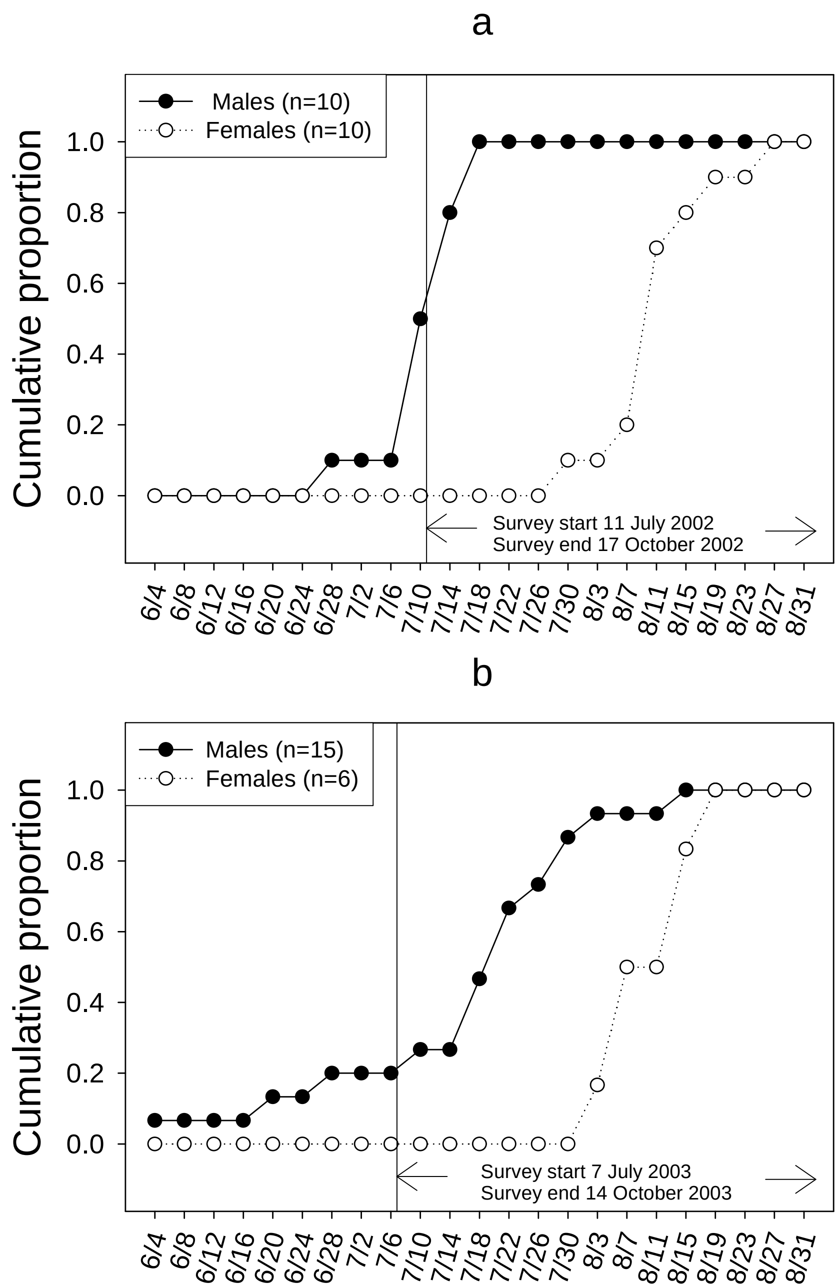


Figure 9. Cumulative proportion of King Eiders with satellite transmitters (see Phillips 2005) that passed Point Barrow during summer/fall migration counts in 2002 (a) and 2003 (b). All female eiders passed during the migration counts, but 50% of male eiders passed before counting began in 2002 and 20% of male eiders passed before counting began in 2003.

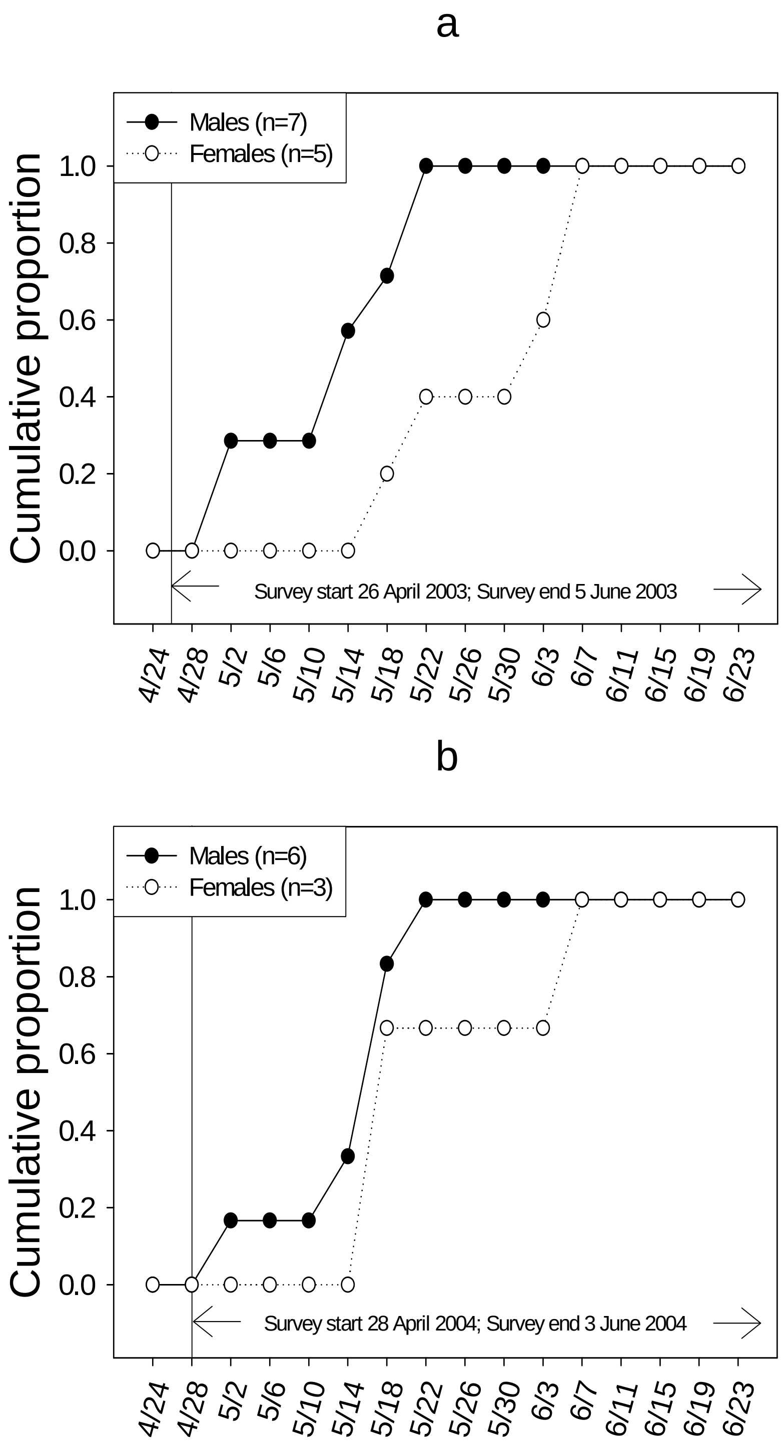


Figure 10. Cumulative proportion of King Eiders with satellite transmitters (see Phillips 2005) that passed Point Barrow during spring migration counts in 2003 (a) and 2004 (b). All male and female eiders passed during the migration counts, indicating that surveys were well timed.

In addition to missing some eiders during summer/fall migration, we missed a large number of eiders during spring migration 2003. Approximately 15,000 eiders were seen northeast of our survey location on 26 April during an aerial survey for bowhead whales, *Balaena mysticetus* (W. Koski, LGL Ltd., pers. comm.). In addition, during preparation of the survey location, two of our observers saw ~20,000 eiders pass during a 2-hr interval on 30 April 2003. Because no systematic surveys were being conducted on 30 April 2003, these birds were not included in our estimate.

We based the timing of our 2003 and 2004 spring migration surveys to overlap the dates of previous eider migration surveys (Woodby and Divoky 1982, Suydam et al. 1997). Observations from the ice edge near Point Barrow showed that spring migrations of eiders did not begin until early to mid-May (Woodby and Divoky 1982, Suydam et al. 1997). During our 2003 and 2004 surveys there appeared to be more open water and reduced ice cover than during previous years. Thus, eider migration may have begun earlier in recent years. This change would have biased our estimates low, especially in spring 2003. Hence, it appears that although we selected an appropriate location for counting migrating eiders, we may have missed large numbers of King Eiders in some years or during some seasons.

Timing of Migration by Species

Summer/fall. In both 2002 and 2003, most King Eiders passed Barrow before 1 September, whereas, the majority of Common Eiders passed after 1 October (Fig. 1). Most King Eiders appear to move to molting areas outside of the Beaufort Sea, including areas near the Chukotsk and Kamchatka peninsulas, Anadyr, Olyutor, and Karagin bays (Russia), near St. Lawrence Island and in Bristol and Kuskokwim bays (Alaska) to complete the wing molt (Powell et al. 2005a; Fig. 5, Phillips and Powell 2006; Fig. 2). We suspect that many Common Eiders remain in the Beaufort Sea to molt their flight feathers prior to migration. In both 1994 and 1996, adult male Common Eiders observed in September and October already had completed their wing molt (Suydam et al. 2000). Molting locations of Common Eiders are largely unknown, although Barry (1986) saw flightless Common Eiders at Cape Parry and Prince of Wales Strait, Canada in 1981 and some may molt near breeding islands along the Beaufort Sea coast.

The timing of migration in 2002 and 2003 was similar to the pattern observed in both 1994 and 1996 (Suydam et al. 1997, 2000b). During the earlier surveys (1994 and 1996), few Common Eiders passed in July and August. In 1994, there was a large pulse of Common Eiders in October, whereas in 1996, there were large pulses in both September and October (see Suydam et al. 2000b; Fig. 2).

Spring. Most King Eiders tend to pass Point Barrow before Common Eiders (this study; Woodby and Divoky 1982; Suydam et al. 1997, 2000b). This earlier migration of King Eiders past Point Barrow is apparently not related to longer migration distances, in that King Eiders passing Barrow nest primarily on Banks and Victoria Islands (Barry 1986; Dickson et al. 1997), whereas Common Eiders tend to migrate farther to the east (Cornish and Dickson 1997). The interspecific difference in timing may be due to differences in preferred nesting habitat and regional differences in when preferred nesting habitat becomes available. King Eiders initiate nests earlier than Common Eiders (Palmer 1976; Cramp and Simmons 1977) and they typically nest at low densities across the tundra (Suydam 2000) or on islands in tundra ponds and lakes (Kellett and Alisauskas 1997, Powell et al. 2005); nesting begins as soon as the snow melts. In contrast, Common Eiders often nest at relatively high densities and may nest in colonies on small marine islands (Cramp and Simmons 1977, Cornish and Dickson 1997, Noel et al. 2005). Because these marine islands are surrounded by water once the sea ice melts, predation by arctic foxes (*Alopex lagopus*) is limited later in the spring (Larson 1960, Barry 1986, but see also Quinlan and Lehnhausen 1982, Stickney 1991, Noel et al. 2005). Because the sea ice often takes longer to melt than does the snow pack or the ice on tundra ponds, Common Eiders probably initiate nesting later than King Eiders, when the risk of fox predation is lower.

We compared our results to eider migration observations during spring in four other years. The majority (> 80%) of eiders passed Point Barrow by 20 May in 2003 and 2004. This is consistent with observations in 1987, 1994 (Suydam et al. 1997), and 1996 (Suydam et al. 2000b). In contrast, in 1976 (Woodby and Divoky 1982), > 90% of the eiders passed after 20 May; however, strong, persistent headwinds likely delayed migration in spring 1976 (Woodby and Divoky 1982).

We suspect that the migration in spring 2003 was earlier than that observed in other years, as we know at least 35,000 eiders were not included in our survey (see above). Because King Eiders migrate earlier than Common Eiders, it is likely that most of those 35,000 eiders were King Eiders. It is possible that favorable wind and sea ice conditions could account for the relatively early migration in spring 2003. Wind conditions are known to affect passage rates of migrating eiders (Thompson and Person 1963, Johnson 1971, Flock 1973, Richardson 1978, Timson 1976, Woodby and Divoky 1982, Day et al. 2004). Based upon the National Climate Data Center (NCDC) database, winds preceding our 2003 survey were not especially favorable for King Eiders; winds within 1 week of the start date were moderate to heavy (> 10 km/hr) and varied from headwinds to tailwinds. Relatively light sea ice conditions and open water may have been a more important influence on the timing of the spring migration in 2003 compared to 2004.

Timing of Migration by Sex

Summer/fall. For both King and Common Eiders, adult males tended to pass Point Barrow earlier than adult females (Fig. 3). In general, flocks observed early in summer/fall consisted primarily of males, and flocks observed later in migration consisted of adult females or mixed flocks of adult females and their offspring (unknown sex). This sex-age specific pattern of migration for both eider species is generally similar to previous work (Johnson 1971, Suydam et al. 1997, 2000b). Data from satellite-transmittered King Eiders (Dickson et al. 2000, Phillips 2005, Powell et al. 2005a) indicate that females left breeding areas adjacent to the Beaufort Sea later than males. This sex-specific pattern in migration behavior is not surprising given that males do not typically remain in breeding areas after incubation begins (see review by Afton and Paulus 1992).

Spring. In spring 1976, Woodby and Divoky (1982) found that male King Eiders migrated past Point Barrow before females. Based on these observations, they suggested that pair-bonds formed at spring staging areas in the Beaufort Sea. In contrast, we found that both sexes generally migrated past Point Barrow together during observations in spring 2003 and 2004, although small flocks of all males were observed occasionally. Our results are comparable to other studies conducted at Point Barrow in 1994 and 1996 (Suydam et al. 1997, 2000b), and with satellite-telemetry data that further suggests male and female King Eiders arrive on the breeding grounds (as pairs) at approximately the same time (Phillips 2005, Powell et al. 2005a, Phillips and Powell 2006).

Sex Ratios

Sex ratios from our surveys for both species in all years were skewed towards males during summer/fall migrations, but close to unity during spring migrations (Table 1). Sex ratios in waterfowl tend to be male-biased (Baldassarre and Bolen 1994) probably caused by female vulnerability to predation during nesting. Eider populations are likely skewed to males. Our skewed sex ratio may also be due to several other factors. During the summer/fall migration it is likely that some females pass Barrow after the survey period for both species of eiders. These females that pass later in the season may be the successful breeders that return later in summer/fall after our survey ends. It may also be possible that we count males and females differently. We may simply estimate greater numbers of the whiter and more visible males. Our skewed estimates of sex ratios in the summer/fall are especially surprising given that hatch year birds, which look very similar to females, are included in the counts. Video taping flocks of eiders and confirming numbers of males and females would help evaluate potential biases in estimates.

The male-biased sex ratio observed in summer/fall was greater in 2003 compared to 2002. During summer/fall 2002, males composed 63% and 59% of all King and Common Eiders, respectively. During summer/fall 2003, the proportion of males was 85% for King Eiders and 77% for Common Eiders. This could mean that more females were successful in 2003 and returned with their broods after our survey ended, however we have no data on productivity to confirm or refute this hypothesis.

Species Composition

King Eiders composed 66–84% of the total eiders we identified during migration. In other studies at Point Barrow, King Eiders composed 81–95% of the migration (Johnson 1971, Woodby and Divoky 1982, Suydam et al. 1997). Although these earlier studies found higher proportions of King Eiders, we suggest this difference probably is due to the fact that the majority of Common Eiders migrate after King Eiders and that many of the previous studies ended before the entire migration had passed Point Barrow. For example, Johnson (1971) likely underestimated the number of Common Eiders and female King Eiders in the migration because counts ended on 7 September. Our study and other studies (e.g., Suydam et al. 1997, 2000b) demonstrated that the majority of Common Eiders migrate in September and October. Hence, there is little evidence to indicate that the ratio of King Eiders to Common Eiders has changed over the past 30 years.

We found no evidence that King and Common Eiders behave differently during migration past Point Barrow at different distances from shore. Large numbers of Common Eiders were seen passing in early October during this study; however some flocks of eiders are known to migrate in November and December in some years (Bent 1925, Bailey et al. 1933, Barry 1986).

Passage Rate and Wind

Poor fit of the wind models to passage rates of eiders was likely due to a lack of model structure and not an inappropriate error distribution. Preliminary analyses indicated that the count data were zero-inflated having larger variances than what is typically accounted for by a Poisson distribution. The best approximating model included most of the available structure, and it is likely that adding more variables would improve model fit. For example, wind effects may be seasonal or may depend upon how many days of unfavorable winds preceded days with favorable winds, as suggested by Woodby and Divoky (1982). We also expect the effect of wind to depend upon how many eiders have already passed in the migration. For example, large counts on days late in migration with favorable winds may not be possible because most of the birds have already passed Barrow. Including covariates that integrate these sources of variation should improve predictive capability, model fit, and our understanding of eider biology. However, we stress that poor model fit does not negate our findings about the importance of wind. The average passage rates are valid, and poor predictive power is manifested as large confidence intervals (Fig. 6).

Numerous studies have documented the effects of wind on passage rates of eiders. Murdoch (1885) reported "warm southwest wind is pretty sure to bring a large flight of eiders" in spring. Thompson and Person (1963) noted that eider passage rates at Point Barrow were unaffected by winds less than 14.5 km/hr and appeared to peak with tailwinds. Johnson (1971) noted that fewer eiders generally migrated when there were unfavorable winds (headwinds or neutral winds >14.5 km/hr). However, Johnson also noted that there was high variation in migratory patterns and that the highest counts of eiders occurred when winds were unfavorable. Johnson concluded that eiders may prefer tailwinds, but will fly without them. Flock (1973) also noted that fewer eiders migrated when there were high velocity headwinds. Timson (1976) also found a strong effect of wind. In Timson's study, eiders avoided headwinds, but more eiders passed during neutral winds than during favorable winds. Woodby and Divoky (1982) documented a higher passage rate for eiders with low winds and with tailwinds. Day et al. (2004) identified eider flocks via radar and found a higher passage rate with "weak winds" (< 16 km/hr) than for "strong" winds (> 16 km/hr) and higher passage rates for tailwinds than for headwinds. Traditional knowledge indicates that eiders tend to fly on days with tailwinds. More hunters are found at "Duck Camp" in the summer/fall migration during east winds, or tailwinds, because more birds are likely flying west on those days. In general, it appears that eiders prefer neutral winds or tailwinds to headwinds. Likewise, fewer eiders generally migrate during strong winds.

Our study is the first to suggest that King and Common Eiders may respond to wind differently. King Eiders tended to move past Point Barrow whenever there are low-speed winds. In contrast, Common Eiders tended to migrate during higher speed tailwinds (Fig. 6). One explanation may be related to the energy requirements of female Common Eiders. Female Common Eiders do not feed while nesting (Parker and Holm 1990) and may lose 35–45% of their body mass during incubation (Korschgen 1977, Parker and Holm 1990, Bolduc and Guillemette 2003); other studies indicate such a loss is costly for females in terms of current immunocompetence and future reproductive success (e.g., Hanssen et al. 2002, 2003). If arriving at nesting areas in prime body condition is paramount for the success of breeding female Common Eiders, then waiting for higher speed tailwinds to migrate in the spring may be important. If replacing energy stores after nesting and molting is important for future reproductive success then conserving energy by waiting for higher speed tailwinds during summer/fall migration may also be important. Common Eiders average ~1 kg heavier than King Eiders (Bellrose 1980) and the energy saved may be substantially greater for these larger birds.

Common Eider nesting areas are available later and they may be better able to wait for favorable wind conditions. However, species comparisons are difficult because the annual energy budgets and potential energetic bottlenecks in either species are not well known. For example, although it is unclear whether or not King Eiders fast during incubation, the time spent feeding is thought to be low (Suydam 2000). Similar to Common Eiders, King Eiders lose a high proportion (~30%; Kellet and Alisauskas 2000) of their pre-incubation body mass during the 22–24 day incubation period. Additional data and analyses are needed to evaluate differences in annual energy budgets for King and Common Eiders in order to determine how individuals of each species might respond to environmental conditions during migration.

Weather conditions in addition to wind and their relationship to migration warrants further investigation. Previous weather or weather far away may be a greater factor on migration rates than local weather.

Numbers and Trends of Eiders

The King Eider population migrating past Point Barrow appears to have at least remained stable and may have increased between 1994 and 2004 (Fig. 5a). The Common Eider population that migrates past Point Barrow increased over the same period (Fig. 5b).

Our King Eider estimates are not in complete agreement. In particular, our 2003 estimates are lower than expected. We know that the spring 2003 estimate is likely low. In late April, before we began surveys, thousands of eiders migrated past Point Barrow. It is likely that the 2003 spring estimate should be considerably higher, giving further support to an increase in the King Eider population.

Our summer/fall 2003 estimate for King Eiders was considerably lower than the spring 2004 estimate and confidence intervals barely overlap. It is possible that the larger estimate for spring 2004 was due to a large recruitment of maturing birds or possibly an influx of subadult birds not previously seen on counts due to changes in sea ice and a northward shift of wintering areas. King Eiders do not breed until ≥ 3 yrs of age (Suydam 2000) and it is believed that subadult King Eiders spend their pre-breeding years offshore in the Bering Sea, but their distribution and movements are poorly understood (Suydam 2000). Subadult male King Eiders, however, are identifiable by their coloration and very few have been identified in all of our survey hours.

A more plausible explanation is that we missed a large number of King Eiders during the summer/fall 2003 survey. We know we initiated surveys too late in the season to catch the entire migration. As described previously, surveys did not begin until after ~50% and ~20% of the satellite-tagged male eiders had passed Point Barrow in fall/summer 2002 and 2003, respectively (Phillips 2005, Powell et al. 2005a). Although our 2002–2004 estimates for King Eiders were not in complete agreement, we conclude that the King Eider population is at least stable and likely increasing (Fig. 5a).

By continuing migration surveys late into the fall, we had hoped to develop an index of breeding success for King Eiders based on the number and proportion of birds with female-like plumage. Females that had successfully reared young pass Point Barrow sometime after early September (Johnson 1971). In 1996, ≥ 100,000 King Eiders were seen during September and

October, whereas few (13,000) King Eiders were observed during the same period in 1994 (Suydam et al. 2000b). Although no productivity data are available for 1994, productivity of King Eiders at one location in Canada was known to be high in 1996 (Kellet and Alisauskas 1997). In 2002 and 2003, few King Eiders passed in September and October, suggesting that nesting success was probably low in both years. Breeding biology studies of King Eiders in northern Alaska found that nesting success was low in 2002 and 2003 (Powell et al. 2005b). We have no information regarding success in Canada in 2002 and 2003.

Common Eiders migrated later than King Eiders regardless of their sex and age affiliation; therefore the use of ratios obtained during the late fall migration does not appear to be a viable index of reproductive success for this species.

Recommendations for Monitoring and Research

King and Common Eider populations remain conservation concerns (USFWS 1999, Goudie et al. 2000, Suydam 2000, SDJV 2003). We suggest that periodic migration surveys be conducted to monitor population trends of King and Common Eiders. Additional surveys are especially important for King Eiders because the population trend was unclear. Counting eiders again on the major breeding areas such as Banks and Victoria Islands may also be warranted (Dickson et al. 1997).

Frequency of surveys. Although periodic assessments of eider populations are necessary, we do not believe that annual migration counts are necessary at this time. Eiders are characterized by high adult survival rates; therefore, we expect declines to be detectable only over long periods. We believe that migration counts conducted once every 3–5 yrs may be sufficient to detect trends; however, we suggest a power analysis of existing data or a simulation (see below) to estimate the level of population change that can be detected over a prescribed period of time. This type of analysis would be informative for planning future surveys.

Although we suggest that conducting eider surveys each migratory season is not necessary, there are advantages to conducting surveys in spring versus summer/fall. Advantages of spring surveys include: (1) the migration typically consists of mostly adult eiders, which makes an analysis of population trend more straightforward, and (2) the migration interval is more contracted, making surveys logistically easier and less expensive. Disadvantages of spring surveys include: (1) confidence intervals tend to be larger because the amplitude of migration pulses tends to be greater compared to summer/fall, (2) it would be difficult to use radar (see below) to verify migratory pathways because transporting the fragile radar equipment over sea ice would be problematic and (3) sea ice is becoming more instable because of climate change making a spring count from the ice edge more dangerous.

Advantages of summer/fall surveys include: 1) confidence intervals tend to be smaller, 2) radar can be used to verify migratory patterns under variable environmental conditions (e.g., fog, snow, wind), and 3) an index to productivity can be estimated for King Eiders. Disadvantages of summer/fall surveys include: 1) calculating an estimate of Common Eiders for long-term trend analysis is difficult because many adults remain in the Beaufort Sea to molt and then migrate with young birds (distinguishing adult females from hatch-year eiders visually is difficult), 2) decreasing day-length from August through October limits observer ability to discriminate species, sex, and age of migrating eiders, and 3) the summer/fall migration period is prolonged making surveys logistically and financially more challenging.

For population trend analysis, we suggest surveying eiders in the spring because a reasonable index can be obtained for both King and Common eiders. As mentioned above, the disadvantage of spring surveys is that the variance, and thus the confidence interval, is larger. Of course, any surveys conducted in the future need to be timed appropriately. Surveys prior to 2002 started about 1 May. Surveys conducted in 2003 appeared to have missed a substantial portion of the migration; less sea ice in 2003 may have allowed eiders to begin migration earlier or a large component of subadult eiders may have passed during our spring observation period in 2003. Hence, future spring surveys should probably start by 20 April. Likewise, future summer/fall surveys should also begin earlier than our counts in 2002 and 2003, preferably by 5 July.

Simulation analyses will likely be useful for assessing alternative sampling designs. The ability of a monitoring program to detect trends in a population depends on the variance in the population estimate, the predicted or hypothetical trend and how frequently population assessments are conducted (Thompson et al. 1998). Computer simulations can be used to assess different sampling designs in the following manner. First, a biologically realistic predicted or hypothetical population trend is derived using the current state of knowledge relative to the species and population in question. Second, count data are selected from a suite of possible distributions that exhibits the hypothetical mean trend with the observed levels of sampling error. For our surveys, we have population estimates and the associated sampling error (i.e., SE) by season and year. Monte Carlo simulations are conducted with > 1,000 test runs and each simulated data series is tested for a trend. The proportion of simulations with statistically significant trends provides an estimate of power. Such an analysis would allow researchers and managers to rank and compare different sampling designs. For example, simulations could be used to determine the statistical power associated with surveys that are conducted once every year versus once every 3 years, or once every 5 years.

Location and method of surveys. We know of no locations other than Barrow that are more appropriate for migration counts for eiders. Both the radar data of Day et al. (2004) and the satellite telemetry data of Phillips (2005) support our assertion that Point Barrow is the best single geographical point for observing migrating eiders. Birds migrate close to shore in both the spring and summer/fall migrations. However, visual survey methods are limited by both how far observers can see and survey conditions. For example, our observers could only detect eiders within ~2 km of the survey location and observers could not detect eiders in fog or low light conditions. Using radar, Day et al. (2004) found that passage rates decreased with poor visibility, but many eiders still migrated, especially at night.

To overcome such limitations, combining the radar methods of Day et al. (2004) with direct visual observations of flock size and composition would be useful for evaluating changes in migration pathways and developing a better understanding of passage rates in the dark or inclement weather. Radar can detect flocks ≥ 3 km and it is relatively insensitive to fog or low light conditions. The main limitation of radar is that the actual number of birds in a flock often cannot be determined. Likewise, radar methods cannot be used to determine the proportion of different eider species or sex ratios within a flock. However, radar data could easily be incorporated with observations of flock size and composition and the data are amenable to statistical analyses with inclusion of environmental covariates relative to passage rates. The total number of flocks, determined via radar, could be adjusted for average flock size or composition, determined via visual observations. Again, treating days as strata, observations within each day

(d) are used to determine the size of n flocks. The average flock size $(\bar{s}_d)$ on day (d) is multiplied by the total number of flocks observed via radar (R_d) on day (d). Again following Thompson (2002; page 119), the population total is thus defined as the sum of the daily totals:

$$total = \sum_{d=1}^{L} R_d \bar{s}_d \ ,$$

where L is the total number of days sampled. The variance estimator for the population total accounts for the number of flocks sampled within each day (n_d), the variance within each day (σ_d^2), and is defined as:

$$\text{var}(total) = \sum_{d=1}^{L} R_d (R_d - n_d) \frac{\sigma_d^2}{n_d} \ .$$

Where y_{di} is the size of flock (i) on day (d):

$$\sigma_d^2 = \frac{1}{R_d - 1} \sum_{i=1}^{L} (y_{di} - \bar{s}_d)^2 \ .$$

This estimator assumes that flocks not observed have the same mean as those observed and that all flocks present are detected with radar. It is important to note that this is just an example of how radar data and direct visual observations could be used together; more efficient and robust estimators may exist.

We also suggest investigating the role of radar placement. Day et al. (2004) indicated that most eiders passed near the base of Barrow Spit. Although the satellite data of Phillips (2005) are difficult to interpret because we do not know actual flight paths of individually marked eiders, the data suggest that eiders may pass farther from shore (Figs. 7 and 8). We suggest this disparity in the two studies warrants further examination.

Using radar in conjunction with future direct visual observations would be helpful in determining the total number of eiders passing Barrow. Future trend analysis could include radar and visual observations which would likely decrease variance, thus increase the power to detect future population change. Radar data might further be useful in the re-analysis of older eider survey data. Information on how eider migration is affected by darkness, wind, or fog could be used to adjust previous estimates of eider passage when counts were not conducted. For example, previous radar data (Day et al. 2004) could be used to estimate how many eiders passed during darkness in previous summer/fall migration counts. This re-analysis would probably result in less biased estimates of eider migration, if the location of migratory pathways near Barrow is truly static.

Wind and eider passage. Our analysis of wind effects is interesting, but incomplete. We suggest combining the data from this study with data collected in 1994 (Suydam et al. 1997) and 1996 (Suydam et al. 2000b). If migration events are predictable and somehow related to wind, then inclusion of additional data and the use of a more comprehensive analysis might further our understanding of migratory behavior and increase accuracy and precision of population estimates. Other weather parameters may also be important to analyze, such as barometric pressure and precipitation.

Summary of Recommendations

1. Conduct periodic migration surveys in spring to detect population trends for King and Common Eiders.
2. Begin spring surveys about 20 April to ensure surveying the early portion of the migration.
3. Use simulation analysis to evaluate statistical power of different intervals between surveys (i.e., 1, 3, or 5-yr intervals).
4. Combine radar and visual observations of flocks to learn more about passage during poor visibility, especially at night.
5. Using various radar sites to investigate how closely eiders travel to shore near Barrow.
6. Once estimates from radar data are available for passage during darkness and fog, re-analyze previous summer/fall migration counts.
7. Use videotapes of flocks to verify observer estimates of numbers of birds, species composition, and sex composition.
8. Use wind and passage rate data from this study and Suydam et al. (1997 and 2000b) to conduct a more comprehensive analysis of passage rates relative to wind.

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Study Products

Presentations

Knoche, M. J. 2003. The Biology of King Eiders: What can their feathers tell us? Barrow Arctic Science Consortium, National Science Foundation, Schoolyard Project, 16 August. Ukpeagvik Inupiat Corporation Science Center, Barrow, AK.

Knoche, M. J. 2003. Isotopes and King and Common Eider migrations past Point Barrow. Alaska Bird Observatory, November 2003. Fairbanks, AK.

Knoche, M. J. 2004. Isotopes and King and Common Eider migrations past Point Barrow. Annual presentation to CMI, February. Fairbanks, AK.

Quakenbush, L. 2004. King and Common Eider migrations past Point Barrow, Alaska. Annual presentation to CMI, February. Fairbanks, AK.

Knoche, M. J. 2004. King Eider molting ecology using stable isotope analyses. Alaska Cooperative Fish and Wildlife Research Unit review, February. Fairbanks, AK.

Quakenbush, L. 2005. King and Common Eider migrations past Point Barrow, Alaska. Annual presentation to CMI, March. Fairbanks, AK.

Suydam, R. 2005. Status of King and Common Eiders migrating past Point Barrow, Alaska. 10th Information Transfer Meeting, Minerals Management Service, 14–16 March 2005, Anchorage, AK.

Suydam, R. S., L. T. Quakenbush, R. Acker, M. Knoche, and J. Citta. 2008. Migration of King and Common Eiders past Point Barrow, Alaska, during summer/fall 2002 through spring 2004: population trends and effects of wind. Alaska Marine Science Symposium, 22-23 January 2008, Anchorage, AK.

Abstracts

Suydam, R., L. Quakenbush, and M. Knoche. 2004. Status of King and Common Eiders Migrating Past Point Barrow, Alaska. 10th Alaska Bird Conference, 14–16 March 2004, Anchorage, AK.

Knoche, M. J., A. N. Powell, M. J. Wooler, P. S. Barboza, and L. Quakenbush. 2004. King Eider wing molt: ecology using stable isotopes. American Ornithologist Union Meeting, 23–28 August 2004. Quebec, Ontario, Canada

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principals of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.