SPATIAL-TEMPORAL VARIATION IN REPRODUCTION AND SITE FIDELITY OF SPECTACLED EIDERS ON THE YUKON-KUSKOKWIM DELTA, ALASKA

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SPATIAL-TEMPORAL VARIATION IN REPRODUCTION AND SITE FIDELITY OF SPECTACLED EIDERS ON THE YUKON-KUSKOKWIM DELTA, ALASKA

A

THESIS

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ABSTRACT

In response to a recent decline, we compared migration and nesting chronology, nest success, and clutch size of spectacled eiders nesting at Kigigak Island with those nesting on Kashunuk River to better understand regulation of the spectacled eider breeding population on Y-K Delta. We also examined and compared subpopulation relationships between nest site fidelity and breeding performance. We examined the relationship between female age and distance moved between consecutive year nest sites. Clutch sizes were comparable between the two sites and declined seasonally with older females laying earlier and larger clutches. Mayfield nest success was higher due to lower predation and females moved shorter distances between nest sites at Kigigak Island. Breeding performance measures were not related to distance moved within study areas. Among study areas, successful females moved shorter distances. High adult survival, nest success, and probably different site fidelity at Kigigak Island have resulted in an increasing population, in contrast to Kashunuk River.

TABLE OF CONTENTS

LIST OF FIGURES

Figure

LIST OF TABLES

Table

ACKNOWLEDGMENTS

This Master of Science thesis consists of two chapters, both of which are written in journal format. Both are intended for submission to the *Journal of Wildlife Management*. Although this thesis is single authored, co-authors for each manuscript are listed in the first page of each chapter. In each manuscript, "we" refers to all authors listed.

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INTRODUCTION

Reproduction in sea ducks is poorly studied except for cavity nesters. Spectacled eiders are typical of other sea ducks in that they delay reproduction until 2-3 years of age, have low recruitment rates, and high annual survival (Brown and Brown 1981, Kehoe et al. 1994, Elliot 1997, Krementz et al. 1997, Grand et al. 1998). Spectacled eiders like other northern sea ducks, also must contend with extreme and variable environmental conditions and annual variation in timing and length of a short breeding season (Goudie et al. 1994). The timing of snow melt and break up along migrational routes and on breeding grounds can vary from 1-3 weeks annually and may result in delayed availability of nesting habitat, reduced clutch sizes and non-breeding (Barry 1960, Cooch 1965, Ryder 1967, Kistchinski and Flint 1974).

For waterfowl in general, clutch size varies with female age and body condition, nest initiation date, and geographical location (Drent and Daan 1980, Baillie and Milne 1982, Afton 1984, Rowher 1992). Hypotheses to explain clutch size variation include young females having less experience and poorer body condition (Krapu and Doty 1979, Afton 1984, Baillie and Milne 1982, Dow and Fredga 1984, Rowher 1992). Alternatively, fewer young females may survive to reproduce in subsequent years, so increased performance with age may be caused by the differential mortality of ineffectual breeding females (Rowher 1992). Seasonal decline of clutch size is common in most waterfowl (Dau 1976, Swennen 1983, Afton 1984, Grand and Flint 1997, Pearce et al.

1998). Age may again play a role because young females generally lay smaller clutches and nest later (Baillie and Milne 1982). Other factors, including poor body condition, irrespective of age, may also influence nest initiation date and clutch size (Esler and Grand 1994).

Spectacled eider females, like most waterfowl, are philopatric to breeding areas (Dau 1974). Understanding philopatry is essential because fidelity of individuals to natal and breeding areas affects the distribution and size of populations and has implications for their genetic structure (Dow and Fredga 1983, Rockwell and Barrowclough 1987, Gauthier 1990, Anderson et al. 1992, Cooke et al. 1995, Lindberg et al. 1998).

Philopatry is associated with habitat quality and benefits of local familiarity (Greenwood 1980). Benefits of local familiarity with a high quality breeding area include increased feeding efficiency, improved survival and nest success, and higher brood rearing success (Hinde 1956, Greenwood 1980, Askenmo 1984, Belesky and Orians 1987, Pärt and Gustafsson 1989, Bensch and Hasselquist 1991, Pärt 1994). Site familiarity primarily benefits female spectacled eiders because males do not assist with nest site selection, incubation, or brood rearing.

In several avian species, successful individuals return to previous nest locations at a higher rate than unsuccessful individuals. Those that return to the same site or breeding area have higher nest success (Harvey et al. 1979, Newton and Marquiss 1982, Gratto et al. 1985, Drilling and Thompson 1988, Gavin Bollinger 1988, Haas 1998). Site faithful females also initiate nests earlier and lay more eggs (Gauthier 1990).

Nest site fidelity may also be influenced by age, with younger females having greater probability of moving than older females (Hepp and Kennamer 1992). Benefits of local familiarity increases with age as the amount of local experience accumulates. Age may also be associated with density which could affect dispersal patterns (Fretwell 1972). Density may exert an important influence on animal location and nest site selection. Skeel (1983) reported in whimbrels that return rates were higher in high density areas because these areas were probably better nesting habitat, which in turn was linked to high longevity and high nest success. In lower density areas, lower return rates suggested a less stable or low quality area. Poor quality birds, usually young females, may be relegated to less preferred areas (Coulson 1968).

Interest in the reproductive biology of spectacled eiders has increased owing to a decline in the North American breeding population between the 1970's and 1990's (Dau 1974, Stehn et al. 1993, Ely et al. 1994). Since the early 1970's, the Yukon-Kuskokwim (Y-K) Delta population declined approximately 95%. In 1993, the species was listed as threatened under the Endangered Species Act. Dau (1974) provided some of the first data on breeding biology for spectacled eiders on Yukon Delta National Wildlife Refuge (YDNWR) in the early 1970's, however, more life history information was needed to help develop strategies for population management. This need prompted the initiation of studies of spectacled eider nesting ecology including this study and Flint and Grand (1997) at Kashunuk River on the Y-K Delta.

CHAPTER 1. SPATIAL-TEMPORAL VARIATION IN REPRODUCTION BY SPECTACLED EIDERS ON KIGIGAK ISLAND, YUKON-KUSKOKWIM DELTA, ALASKA.[1]

INTRODUCTION

Nesting biology of sea ducks (Tribe Mergini) is relatively poorly known except for cavity nesters (*Bucephala spp.*). Typical of other sea ducks, spectacled eiders (*Somateria fischeri*) delay reproduction until 2-3 years of age, have low recruitment rates, and high survival (Brown and Brown 1981, Kehoe et al. 1994, Elliot 1997, Krementz et al. 1997, Grand et al. 1998). Like other northern sea ducks, they also must contend with extreme and variable environmental conditions which produce annual variation in timing and length of a short breeding season (Goudie et al. 1994). Timing of snow melt and break up of seasonal ice in marine water along migration routes and in freshwater ponds on breeding areas can vary by 1-3 weeks annually, and may result in delayed availability of nesting habitat, reduced clutch sizes, and non-breeding (Barry 1960, Cooch 1965, Ryder 1967, Kistchinski and Flint 1974).

For waterfowl in general, clutch size may vary with age, nest initiation date, body condition, and geographical location (Drent and Daan 1980, Baillie and Milne 1982, Afton 1984, Rowher 1992). Hypotheses explaining clutch size variation include young

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females having less experience and poorer body condition (Krapu and Doty 1979, Afton 1984, Baillie and Milne 1982, Dow and Fredga 1984, Rowher 1992). Also, fewer young "poor quality" breeding females may survive to reproduce in subsequent years, so increased performance with age may be caused by the removal of ineffectual breeding females (Rohwer 1992). Seasonal decline of clutch size is common in most waterfowl (Dau 1976, Swennen 1983, Afton 1984, Grand and Flint 1997, Pearce et al. 1998). Age may again play a role because young females generally lay smaller clutches and nest later (Baillie and Milne 1982), however, seasonal declines in clutch size are also seen within young and older age classes (Rohwer 1992). Factors including, poor body condition irrespective of age, may influence nest initiation date and clutch size (Esler and Grand 1994).

Interest in spectacled eider reproductive biology has increased owing to a decline in the North American breeding population from levels in the 1970's (Dau 1974, Stehn et al. 1993, Ely et al. 1994). Demographic parameters used in current spectacled eider population model (Grand and Flint pers. comm.) to calculate expected population growth rate and projected population size include: nesting population size, breeding propensity, nest success, duckling survival, clutch size, and adult survival. The model does not include age related demographic variation in reproductive output which generally occurs in waterfowl (Baillie and Milne 1982, Afton 1984, Dow and Fredga 1984, and Rowher 1992). From 1992-1997, we studied spectacled eider nesting ecology on Kigigak Island, YDNWR, Alaska. We compare our nest success results to Grand and Flint (1997) study of spectacled eiders on the Kashunuk River study area on theY-K Delta to better understand spatial, temporal, and age variation in reproductive parameters.

STUDY AREA

Kigigak Island (165°50' W, 60° 50' N) encompasses 32.5 km^2 and is located on the west coast of Yukon Delta National Wildlife Refuge (YDNWR) near the mouth of Baird Inlet (Fig. 1-1). Habitat is predominately coastal graminoid meadows dominated by *Carex ramenskii*, interspersed by numerous shallow ponds (≤3 m wide), lakes (>3 m wide), and a network of tidal sloughs. About 20% of terrestrial habitat is upland tundra vegetation comprised of *Empetrum nigrum*, *Salix spp.*, *Betula spp.*, lichen, and *Sphagnum spp.* overlaying permafrost (Kincheloe and Stehn 1991).

The island supports several nesting waterfowl species, including relatively high densities of Pacific black brant (*Branta bernicla nigricans)*, cackling Canada geese (*B. canadensis minima*), and common (*S. mollissima*) and spectacled eiders. Predators include glaucous gulls (*Larus hyperboreus*), mew gulls (*L. canus*), parasitic jaegers (*Stercorarius parasiticus*), and arctic fox (*Alopex lagopus*). More than 250 pairs of glaucous gulls nest on the island in colonies varying in size from 4 to 30 pairs. The number of arctic fox was maintained at 1 pair or less during each nesting season by killing 2 animals in 1992 and 1 each in 1994 and 1996.

Kigigak Island nest success results were compared with those from the Kashunuk River study area (61°20'N, 165°35'W) (Grand and Flint 1997), located on the mainland approximately 56 km north of Kigigak Island. This study area is described in detail by

Grand et al. (1997) and consists of graminoid and sedge meadows and contains numerous ponds, lakes, sloughs, and the Kashunuk River. In contrast to Kigigak Island, the area is mainly on old estuarine deposits, elevations are extremely low, and high storm tides flood nearly the entire area (Grand and Flint 1997). This area supports similar nesting waterfowl species to those on Kigigak Island, except, in lower concentrations, and has a similar suite of predators.

METHODS

To document spring arrival of spectacled eiders, we daily monitored the island's coast until eiders first arrived. Subsequent daily observations occurred in historically high nest density areas and numbers of pairs landing or flying were recorded.

We searched for spectacled eider nests on 22, 0.33 km^2 randomly chosen plots in 1992. In 1993, we stratified the island for "suitable or unsuitable" spectacled eider nesting habitat based on 1992 results, and selected 29 plots to maximize the number of spectacled eider nests found. In 1994-1997, we reduced plot size to 0.17 km^2 (Fig.1-2) so all plot boundaries were contained within the stratified area. We searched 33, 35, 34 and 49 plots, in these years respectively. We further stratified the "suitable" spectacled eider nesting habitat into high (30 plots), medium (12 plots) and low (7 plots) density strata

Nest searches began as soon as egg laying was detected (mid-May to early June) and continued until eggs began hatching (early to mid-June). We searched plots in 10 (1992 -1996) and 7 day (1997) cycles and all active nests were revisited during these searches. A 7 day cycle was possible due to increased personnel. In addition to study plots, we searched random plots from an eider/goose production survey (Bowman et al. 1999) during the latter half of incubation each year, including 5 (0.33 km^2), 5 (0.33 km^2), 1 (0.33 km^2), 4 (0.45 km^2), 2 (0.36 km^2), and 2 (0.33 km^2) plots in each of the study years, respectively. Some of these additional plots partially overlapped study plots. Nests found on these plots and incidentally were treated the same as those found on study plots. Overall, we searched 60-90% of the stratified spectacled eider nesting habitat totaling 11 km^2 each year.

We used bownet traps (Sayler 1962) to trap females on their nests 1-5 days before hatch. We marked each female with a U.S. Fish and Wildlife Service metal leg band (left leg), an alphanumerically coded, yellow plastic nasal disk, and an alphanumerically coded yellow plastic tarsal band (right leg).

We collected nesting data using Kashunuk River study protocol (Grand and Flint 1997). Each nest was mapped on an aerial photo (1:30 K) and marked with a white flag placed 10 m north of the nest to reduce fox depredation. Eggs were individually numbered to monitor partial depredation and candled (Weller 1956) and floated (Westerkov 1950) to monitor incubation and predict hatch date. Data recorded when each nest was found included: date, nest number, number of eggs, egg length and width, male presence, marker code, incubation stage, down abundance, nest condition (laying, incubating, hatched, flooded, abandoned, or depredated), and nest site. Nest sites included sloughbank, shoreline, peninsula, island, mudflat, displaced island (displanted tundra), or grassflat (meadow > 10 m from a water body). During each revisit, data recorded included: date, female status (present, flushed, absent), male presence, incubation stage, nest condition, and number of eggs present, and number of new and missing eggs. Nest loss to arctic fox was indicated by disappearance of an entire clutch or presence of tracks near the nest (Stickney 1989). Avian depredation was indicated by the presence of egg shells or eggs with holes pecked in them, or large egg shell fragments with peck marks (Strang 1976, Quinlan and Lehnhausen 1982).

Statistical Analyses

We only used nests that survived to incubation to calculate clutch sizes. Clutch size was defined as the total number of documented eggs laid. Successful nests were those for which at least one egg hatched. Egg laying dates, float angle and candling data, assuming a 24-day incubation period (Dau 1974) were used to predict hatch dates. Assuming 1 egg was laid each day, we calculated nest initiation date by backdating from egg laying dates, known hatch dates, or float angle and candling data. All means are reported $\pm$ SE and statistical tests were conducted with SPSS+ (ver. 7.0). We assigned plots to nest density strata as follows: low- less than 2 nests, medium- 3 to 4 nests, or high- 5 or more nests.

We used analysis of variance (ANOVA): (1) to test for differences in nest initiation date among years within marked and unmarked populations, (2) to examine the relationship between nest initiation and marked status (marked or unmarked), and (3) to examine variation in nest initiation date with nest density. We contrasted marked and unmarked females because marked females were assumed older and this allowed an examination of age effect. Assuming marked females were older was a reasonable assumption because: (1) fidelity of marked females was high and (2) by the 5th year of the study 60% females in the breeding population were marked (Moran unpubl. 1996), suggesting that most unmarked females were new recruits replacing adult mortalities because estimated annual survival is 0.78 (Grand et al. 1998).

To calculate relative initiation dates for each year, we subtracted median nest initiation date each year from calculated nest initiation dates. We used analysis of covariance (ANCOVA) with year and marked status as main effects and adjusted nest initiation dates as a covariate to examine effects of female age and initiation date on clutch size. We used ANCOVA with year and density as main effects and nest initiation date as a covariate to examine variation in clutch size among nest densities and years. We calculated repeatability estimates for relative nest initiation date and clutch size following Lessells and Boag (1987). We also examined variation in egg size among years using ANCOVA with adjusted nest initiation date as a covariate. Egg size data for 1996 were not included due to measurement error.

Mayfield nest success estimates were calculated using a modified Mayfield approach (Grand and Flint 1993) using mean of bootstrapped estimates (Manly 1997) and bootstrap estimates of SE (Grand and Flint unpubl.data) The model included nest age, nest initiation date and the interaction nest age x nest initiation date to calculate Mayfield nest success estimates and 95% confidence intervals (Mayfield 1961, 1975). In analyses of nest success, we examined annual variation using only data from nests with known fates. The program and data entry procedure were modified to accommodate successful nests visited after hatch. When the exact hatch date was unknown, probable exposure of the final interval was set to 50% of that interval (Grand and Flint 1997). Daily mortality was assumed constant. Overall exposure period for successful nests calculated from median clutch size and incubation period was 29 days (Harwood and Moran 1993).

RESULTS

During the study, spectacled eiders first arrived at Kigigak Island 4-24 May, with peak arrival occurring 5 to 12 days later (Fig. 1-3). Groups were usually observed staging in Hazen Bay approximately two days before they were observed on the island. Snow cover when eiders first arrived was approximately 60% in most years and meltwater was present on 20% of the ponds. Peak arrival occurred when meltwater was present on 90% of the ponds. Delayed snow melt in 1992 resulted in later first and peak arrival dates than subsequent years. Spectacled eiders arrived singly or more commonly in small groups of 2-4 pairs. While arrival occurred within 3 days of one another 15-18 May, every year except 1992, first arrival occurred over a 9 day range, 4-12 May, during this period. As first arrival occurred earlier, there was a greater number of days until peak arrival compared to when first arrival occurred after day 130.

Initiation dates of first nests ranged from 10-26 May during 1992-1997 with peak nest initiation ranging from 19-31 May (Fig. 1-4). The nest initiation period within years ranged from 20-30 days between 1992 and 1997 ($\bar{x} = 26.5 \pm 1.75$ days). Nest initiation dates of marked females were significantly earlier than nest initiation dates of unmarked females ($F_{1, 500}$ = 33.89, P < 0.01) (Table 1-1). Statistically significant among year variation in nest initiation dates occurred for unmarked females ($F_{5, 236}$ = 49.99, P < 0.01) but not for marked females ($F_{4, 101}$ = 1.29, P =0.28). The range of days from first arrival to first nest initiation was 2-7 days. As first arrival occurred earlier, the number of days to the first nest initiated became larger. It appeared that with earlier peak arrival there was a greater number of days to peak nest initiation. Repeatability of adjusted nest initiation dates of individual females was 0.134. The time from peak arrival to peak nesting was 1-3 days for 4 of 6 years of study.

Clutch size ranged from 2-7 eggs. Median clutch sizes ranged from 5-6 eggs among years. After controlling for nest initiation date, clutch size varied among years ($F_{5, 438}$ = 7.148, P < 0.001). Clutch size was larger for marked females than unmarked females ($F_{1, 368}$ = 4.48, P < 0.04) (Fig. 1-5). Variation was significant among years for unmarked females ($F_{4, 263}$ = 7.02, P <0.001), but not for marked females ($F_{4, 102}$ = 2.07, P = 0.09). We found no interaction between marked status and year ($F_{4, 379}$ = 0.77, P = 0.55). Clutch size also declined through the nesting season ($F_{1, 377}$ = 50.82, P < 0.001), but the relationship was significant only for unmarked females. Clutch size of unmarked females was negatively related to nest initiation date ($F_{1, 335}$ = 52.19, P < 0.001). Repeatability of clutch size was 0.17.

Mean length, width, and volume of unmarked females's eggs (n = 251 eggs) were 68.1 ± 0.13 mm (62.6 - 74.1 mm), 45.1 ± 0.07 mm (41.4 - 48.5 mm), and 141.1 ± 0.55 cc (118.2 - 165.6 cc). Mean length, width, and volume of marked females's eggs (n = 211 eggs) were 68.1 ± 0.13 mm (63.3 - 75.8 mm), 45.6 ± 0.07 mm (42.8 - 49.2 mm), and 141.5 ± 0.60 cc (122.1 - 171.0 cc). Egg volume was similar among years ($F_{3, 250}$ = 1.16, P = 0.32) and marked status ($F_{1, 250}$ = 0.788, P = 0.38). Egg volume tended to vary among clutch sizes ($F_{5, 250}$ =2.20, P = 0.06), with larger eggs occurring in larger clutches.

We estimated that an average of 114.7 ± 14.0 spectacled eider nests were initiated on the island each year. More than any other stratum, nests in the high density stratum were commonly associated with mixed species aggregations, including black brant, glaucous and mew gull colonies, and cackling Canada geese. A higher proportion of marked females (38.3%) nested in the high nest density stratum than unmarked females (25.4 %), though not significantly (χ^2 = 12.0, P = 0.21). Proportions of marked and unmarked females were similar in medium (14.4% and 13.1%, respectively) and low (3.3% and 5.6%, respectively) strata. Most nests were located on pond shorelines followed by sloughbanks and islands (Fig. 1-6). Distance to water from nests ranged from 0.1 m to 34.0 m ($\bar{X}$ = 2.1±0.2 m).

Mayfield nest success estimates ranged from 54% to 85% and were overall higher than on the Kashunuk River study area (χ^2 = 6.78, df = 1, P = 0.01; Table 1-2; Grand and Flint 1997). Similar to Grand and Flint (1997), daily survival rate (DSR) of nests varied among years (χ^2_5 = 11.45, P < 0.04). DSR of nests in 1992 was significantly different from all other years except 1996. Nest success varied with exposure days in all years and initiation date in 1992, 1994, 1995, and 1997. Nest success tended to increase with clutch size and decrease with nest initiation date (χ^2 = 9.98, df = 4, P = 0.06 and χ^2

= 0.68, $df = 5$, $P = 0.08$, respectively). Nest success did not vary among density strata, though high density areas tended to have higher nest success than low density areas. Nest success of both marked and unmarked females varied among years ($\chi^2 = 32.43$, $df = 5$, $P < 0.001$ and $\chi^2 = 10.83$, $df = 4$, P = 0.03, respectively) and was significantly higher for marked females ($\chi^2 = 27.63$, $df = 1$, $P = 0.000$).

Years of low nest success (1993, 1995) coincided with years when the island's arctic fox population exceeded one animal. Depredation by arctic fox (48.4% of failed nests) and glaucous gulls (3.2% of failed nests) were the main causes of nest failure. Between 1992-1997, 14-29% of nests sustained partial depredation of 1 to 5 eggs ($\bar{X} = 1.5 \pm 0.1$).

The mean number of eggs hatched per nest varied significantly among clutch sizes ($F_{4, 372} = 19.30$, $P < .001$), but not among years ($F_{4, 263} = 1.0$, $P = 0.41$). As expected for a species where dump nests do not occur, the number of eggs hatching per nest increased with increasing clutch size. In most years, depredation was the most common cause of hatch failure for individual eggs (Table 1-3). The average proportion of eggs that were not viable or contained dead embryos was 5.3%. At least one inviable egg was found in 10.2% of the nests and between 1 and 3 nests per year contained completely inviable clutches.

DISCUSSION

Timing of Arrival and Nesting

Most females arrived on the island as ponds started to open and melt water flooded vegetated areas. As documented by other studies on the Y-K Delta for cackling Canada geese (Mickelson 1975), emperor geese (Petersen 1992), and spectacled eiders (Dau 1976, Grand and Flint 1997), chronology of arrival and nesting by spectacled eiders in this study varied among years and was delayed in response to later spring break up. Afton (1984) found annual variation in nest initiation for lesser scaup (*Aythya affinis*) was partially related to variation in arrival dates, but earlier arrivals did not initiate nests significantly earlier than later arrivals. We found, however, that some females start nesting before peak arrival and peak nest initiation may occur as early as the day after peak arrival. Unfortunately, we could not relate nest initiation date to arrival date for individual females because reading coded color markers was very difficult during arrival.

Peak arrival and nest initiation was usually 1-3 days earlier than at Kashunuk River, however peak arrival was more subjective than nest initiation. Most females tend to stage just off the coast a few days until ponds start to open (Dau 1977). Approximately 80% of females nested within a 10 day period and 90% within a two week period, similar to Grand and Flint (1997) and Pearce et al. (1998). Such synchronous nesting is probably an adaptation to the limited breeding season (Rowher 1992) and contrasts with the pattern for ducks nesting at temperate latitudes where nests are initiated earlier and the initiation period is longer than in northern latitudes (Toft et al.

1982, Johnson et al. 1992). Earlier arrival and nesting at Kigigak Island may occur because of its more southern and coastal location and higher elevation, resulting in nest sites becoming available earlier than at Kashunuk River.

For waterfowl in general, older, more experienced females pair earlier, and philopatry imparts knowledge of their breeding area which may result in more efficient feeding and finding nesting habitat (Anderson et al. 1992). These factors may allow these females to select nest sites earlier and be in better body condition to meet energy demands of egg formation, incubation, and brood rearing (Krapu and Doty 1979).

Because only nesting females were trapped and marked, all observations of marked females were of birds that had nested successfully on Kigigak Island at least once previously. In contrast, in the later years of this study, many unmarked females were nesting for the first time. During the last 2 years of this study 46% of nesting females on the study area were unmarked. Because female spectacled eiders survive at an annual rate of 78.3% (Grand et al. 1997), in a stable population, 22% of females would be first-time breeders in a given year and about 48.8% of unmarked females would likely be first-time breeders. At Kigigak Island, marked females, who were assumed to be generally older than unmarked breeders, nested significantly earlier and on dates that were repeatable. The result is consistent with other duck studies showing that relative laying dates for older ($\geq$ 4 years) females stabilize at an earlier date than those for the first few nesting attempts (Spurr and Milne 1976, Krapu and Doty 1979, Afton 1984, Baillie and Milne 1982).

Variation in Clutch Size

Clutch sizes were comparable to those reported by Grand and Flint (1997), but slightly higher than those of Dau (1976) and Bowman et al. (1999), due to undetected partial depredation as concluded by Grand and Flint 1997. Unlike Grand and Flint (1997), we documented a decline in clutch size during the study. Studies of species comparable in size to spectacled eiders suggest they rely on stored nutrients to meet 12-32% of their requirements during egg production (Korschgen 1977, Ankney and Afton 1988, Afton and Ankney 1991). Little is known about when spectacled eiders accumulate nutrient reserves for egg production or whether annually fluctuating environmental conditions in breeding, wintering, and migration areas affect reproductive performance (Crissey 1969, Bengston 1971, Heitmeyer and Fredrickson 1981, Davies and Cooke 1983, Krapu et al. 1983). It is likely that all spectacled eiders from the Y-K Delta share the same wintering location south of St. Lawrence Island in the Bering Sea (Petersen et al. 1995). A possible explanation for the contrasting trends in clutch size fo two breeding areas on the Y-K Delta may be variation in food availability on or near breeding areas.

Trend in clutch size during this study also could have resulted from changing age structure of spectacled eiders on Kigigak Island. Clutch sizes declined significantly in the unmarked population. We observed that clutch sizes of marked females were larger than those of unmarked females. This pattern is consistent with a change in age structure of the unmarked population during the study. At the beginning of this study, unmarked females were composed of females representing the entire age structure at the local population. Later in the study, however, unmarked females were predominately first-time breeders and for reasons stated previously were assumed younger on average than marked females (Baillie and Milne 1982, Afton 1984, Dow and Fredga 1984). Other waterfowl studies (Krapu and Doty 1979, Krapu et al. 1983, Rockwell et al. 1983, Afton 1984, Duncan 1987), including those of common eiders (Baillie and Milne 1982) have observed that more experienced females nest earlier and lay larger clutches. A commonly accepted hypothesis for this result is young birds have less experience, which reduces their reproductive performance (Rowher 1992). In connection with the nutrient constraint hypothesis, young birds' clutch sizes may be low because they are inefficient at acquiring nutrients for egg production (Krapu and Doty 1979, Rowher 1992).

Similar to other studies, we documented a seasonal decline in clutch size (Gorman 1970, Milne 1974, Dau 1976, Grand and Flint 1997, Pearce et al. 1998). The decline occurred for both marked and unmarked females; but it was statistically significant only for unmarked birds, perhaps reflecting their younger age, lack of breeding experience, and poorer body condition (Milne 1963, Krapu and Doty 1979, Dow and Fredga 1984, Esler and Grand 1994).

Nest Success

Areas may attract high densities of nesters because they are associated with lower rates of depredation (Duebbert et al. 1983, Lokemoen et al. 1984). These areas typically attract more experienced older females with younger less experienced breeders delegated to less preferred areas because they cannot compete for sites in high density areas (Duebbert et al. 1983). We expected to see a difference in reproductive performance among density strata, however, we did not detect variation in clutch size or nest initiation date among the three spectacled eider nesting density strata on Kigigak Island. Our inability to detect such variation may have resulted from our small sample of low density birds.

Nest success of marked females was higher than unmarked females on Kigigak Island. Afton (1984) reported that young lesser scaup (*Aythya affinis*) females had lower nest success than older females. Older spectacled eider females on Kigigak may have more experience in locating and competing for better nest sites and food resources (Krapu and Doty 1979, Baillie and Milne 1982). Nest success of spectacled eiders was also higher on Kigigak Island than Kashunuk River, Indigirka Delta, Russia and North Slope, Alaska (Dau 1976, Grand and Flint 1997, Pearce et al. 1998, D. Troy pers. comm.). Limited predator assemblage along with numerous nests of other species probably minimized partial and reduced complete nest loss at Kigigak Island relative to other locations (Krebs 1974, Burger 1984). Consistent with this hypothesis, nest success increased dramatically at Kashunuk River, following mew gull removal (Grand and Flint 1997). The small sample size for nests in low density stratum may have prevented density dependent trends in nest initiation date, clutch size, and nest success from achieving statistical significance.

Proportion of nests containing at least one inviable egg on Kigigak Island was

14% lower than Kashunuk River (Grand and Flint 1997). Environmental contamination, particularly from lead shot, has been identified as a cause of embryonic mortality or egg inviability (Elder 1954, Heinz et al. 1989). Results of other studies have indicated the presence of lead shot in nesting habitat, gizzards, and esophagi of spectacled eiders on both study areas (Franson et al. 1995, Flint et al. 1997). Lead exposure rates, however, were lower on Kigigak Island compared to Kashunuk River and this difference may explain the lower frequency of unhatched eggs on Kigigak Island (Grand et al. 1998).

The Y-K Delta spectacled eider breeding population is approximately 95% below the 1970's level (Stehn et al. 1993). Nevertheless, several aspects of spectacled eider nesting biology indicate a healthy and increasing population on Kigigak Island compared to Kashunuk River: (1) number of nests initiated on a core set of plots located in preferred habitat increased nearly 50% between 1995-1997, (2) nest success remained consistently high throughout the study, and (3) recent data indicate high duckling survival (Flint and Moran, unpubl. data 1999). The only exception is a declining trend in clutch size during the study, which could reflect a changing age structure or density dependent feedbacks on reproduction.

Spectacled eiders at both Kigigak Island and Kashunuk River were similar to other sea duck species in their reproductive biology (Kehoe et al. 1994, Elliot 1997, Krementz et al. 1997, Grand et al. 1998). Nevertheless, a metapopulation structure seems appropriate for the Y-K Delta, because distinct breeding areas appear to have different survival, productivity, and consequently population trajectories. Evidence that age can

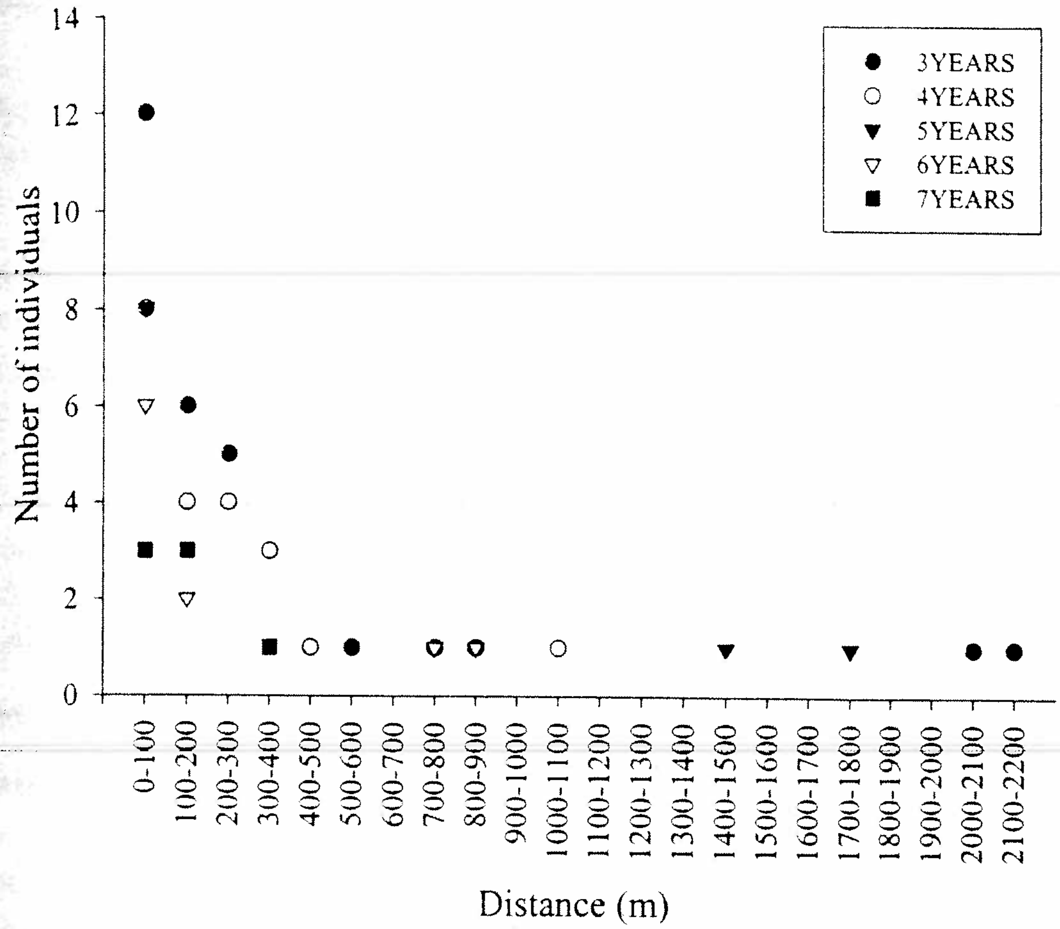

Figure 2-9. Distance moved (m) between consecutive year nest sites by age class for spectacled eiders on Kigigak Island, Yukon-Kuskokwim Delta, Alaska, 1994-1997.

Table 2-4. Adult female spectacled eider resightings on Kigigak Island, Yukon-Kuskokwim, Alaska, 1992-1997.

		Return				
Banding Year	# Banded	1993	1994	1995	1996	1997
1992	26[a]	15(10)[b]	12(10)	10(7)	11(11)	7(7)
1993	37	--	18(17)	22(21)	16(16)	21(18)
1994	27	--	--	16(12)	14(14)	13(11)
1995	37	--	--	--	23(22)	14(14)
1996	34	--	--	--	--	19(18)
1997	49	--	--	--	--	--
Total	210	15(10)	30(27)	48(40)	65(64)	74(68)

[a] Forty-two ducklings were also banded in 1992, but were not sexed. One returned as a nesting female from 1994-1997. A second female nested in 1995 and a third female nested in 1996 and 1997. They are not included in this table.
[b] Numbers in parentheses indicate females observed on nests.

Table 2-5. Adult female spectacled eider resightings on Kashunuk River, Yukon-Kuskokwim Delta, Alaska, 1992-1997.

Banding Year	# Banded	Return				
		1993	1994	1995	1996	1997
1992	10	1	3	3	2	3
1993	26	--	5	8	7	4
1994	20	--	--	7	7	6
1995	46	--	--	--	4	4
1996	35	--	--	--	--	2
1997	22	--	--	--	--	--
Total	159	1	8	18	20	19

Table 2-6. Mean Distance moved (m) between nest sites in consecutive years by spectacled eider females on Kigigak Island and Kashunuk River, Yukon-Kuskokwim Delta, Alaska, 1992 - 1997.

	Kigigak Island			Kashunuk River			Pooled		
	n	$\bar{x} \pm$ SE (range)	median	n	$\bar{x} \pm$ SE (range)	median	n	$\bar{x} \pm$ SE (range)	median
Successful Nests	75	273.7 ± 54.3 (0 - 2151.7)	121.1	35	504.1 ± 93.9 (52.4 - 2187.5)	322.6	110	352.0 ± 49.0 (0 - 2187.5)	175.1
Unsuccessful Nests	14	243.3 ± 65.0 (43.9 - 827.6)	140.6	18	623.2 ± 131.3 (47.0 - 2333.5)	375.4	32	457.6 ± 85.1 (43.9 -2333.5)	306.5
Retained Full Clutch	61	262.1 ± 59.7 (0 - 2151.7)	106.1	25	497.1 ± 121.7 (52.4 - 2187.5)	278.52	86	330.4 ± 56.1 (0 - 2187.6)	132.1
Partially Predated	14	308.6 ± 72.6 (41.1 - 859.1)	238.1	10	499.5 ± 122.77 (106.4 -1555.5)	399.8	24	392.6.1 ± 68.8 (41.1 - 1555.5)	314.2

[a] data used in analyses, includes 1 randomly selected observation/individual female.

Table 2-7. Sources of variation, degrees of freedom (*df*), mean squares (*ms*), *F*-Statistics from ANOVA for effects of nest fate, partial depredation, year *t*, density (Kigigak Island), age (Kigigak Island) and distances moved by spectacled eiders on Yukon-Kuskokwim Delta, Alaska, 1992-1997.

	Kigigak Island				Kashunuk River				Pooled			
Source	*df*	*MS*	*F*	*P*	*df*	*MS*	*F*	*P*	*df*	*MS*	*F*	*P*
Nest Fate	1	1.31	0.44	0.51	1	1.82	2.24	0.14	1	15.58	6.54	0.01
Partial Depredation	1	6.39	1.97	0.17	1	0.78	0.96	0.33	1	6.40	2.28	0.13
Density	2	5.54	1.85	0.16								
Age	1	0.27	0.09	0.77								
Clutch Size	5	5.58	2.0	0.09	4	0.259	0.27	0.89	5	2.21	0.80	0.55
Study Area									1		24.09	0.67
Year *t*	4	2.20	2.70	0.06	4	2.51	0.84	0.45	4	3.46	1.39	0.24

Table 2-8. ANOVA table used for distance movement repeatability estimates for female spectacled eiders on Kigigak Island and Kashunuk River, Yukon-Kuskokwim Delta, Alaska, 1992-1997.

	Kigigak Island				Kashunuk River				Total			
Source	*df*	*MS*	*F*	*P*	*df*	*MS*	*F*	*P*	*df*	*MS*	*F*	*P*
Within groups	41	138755	1.48	0.06	23	1050180	3.37	0.001	65	567063	3.42	0.001
Among groups	63	94083.7			31	311995			94	165948		
Total	104				54				159			

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