ARCTIC
VOL. 46, NO. 3 (SEPTEMBER 1993) P. 264-277

Decline of Spectacled Eiders Nesting in Western Alaska

ROBERT A. STEHN,[1] CHRISTIAN P. DAU,[2] BRUCE CONANT[3] and WILLIAM I. BUTLER, Jr.[4]

(*Received 13 October 1992; accepted in revised form 12 May 1993*)

ABSTRACT. Spectacled eider (*Somateria fischeri*) populations in western Alaska are now less than 4% of the numbers estimated in the early 1970s. In 1992, an estimated 1721 nesting pairs remained on the Yukon-Kuskokwim Delta. Causes of this rapid and continuing decline of -14% per year are undocumented. Many aspects of spectacled eider biology remain unknown, including their marine foraging habitats, food items, migratory movements, and population ecology. A review of some biological characteristics and possible threats to the species suggests the importance of quantifying potential impacts from parasites and disease, subsistence harvest, predation during brood rearing, and alteration of Bering Sea food resources. Factors causing the population decline of spectacled eiders must be determined and appropriate actions taken to reverse the trend.

Key words: Alaska, declining species, *Somateria fischeri*, spectacled eider, waterfowl, Yukon-Kuskokwim Delta

RÉSUMÉ. Les populations d'eiders à lunettes (*Somateria fischeri*) de l'Alaska occidental s'élèvent maintenant à moins de 4 p. cent du total estimé au début des années 70. En 1992, on a estimé à 1721 le nombre de paires nicheuses qui restaient dans le delta du Yukon-Kuskokwim. Les causes de ce déclin rapide et continu de -14 p. cent par an ne sont pas documentées. Bien des aspects de la biologie de l'eider à lunettes restent inconnus, y compris l'habitat marin où il trouve sa nourriture, ses aliments, ses déplacements migratoires et l'écologie de la population. Un examen de certaines caractéristiques biologiques et des menaces dont l'espèce pourrait faire l'objet suggère l'importance qu'il y a à quantifier les retombées potentielles des parasites et des maladies, des récoltes destinées à assurer la subsistance, de la prédation durant l'élevage de la couvée et des changements dans les ressources alimentaires de la mer de Béring. Il faut déterminer les facteurs responsables du déclin de la population de l'eider à lunettes et prendre les mesures qui s'imposent pour renverser la tendance.

Mots clés : Alaska, espèce en déclin, *Somateria fischeri*, eider à lunettes, oiseau aquatique, delta du Yukon-Kuskokwim

Traduit pour le journal par Nésida Loyer.

INTRODUCTION

About 50 000 pairs of spectacled eider, half the estimated world population, nested on the Yukon-Kuskokwim Delta (YKD) in 1971 (Dau and Kistchinski, 1977). In 1992, we estimated 1721 pairs. The decline was not recognized until 1990 and its cause is unknown. Except during late May and June while nesting on arctic coastal tundra, spectacled eiders are rarely seen. Locations of their molting and wintering areas are unknown, although sightings along the northwest coast of Alaska, at St. Lawrence Island, and along the north, east, and south coasts of the Chukotski Peninsula (Fig. 1) suggest that fall and winter marine foraging habitat occurs among polynyas and edges of pack ice in the northwestern or central Bering Sea (Dau and Kistchinski, 1977; Kessel, 1989).

Early notes on spectacled eider breeding distribution (Gabrielson and Lincoln, 1959) contrast with the reduced range shown by increased surveys and biological studies beginning in the 1960s. Several sites mentioned in historic accounts had already lost nesting populations of eiders, including the northern YKD near St. Michaels, the southern YKD near the Kuskokwim River, and many of the small river deltas in western Alaska. Observations and surveys by J.G. King and C.J. Lensink, refuge managers from 1963 to 1975 at Clarence Rhode National Wildlife Range, and studies from 1968 to 1973 (Dau, 1974; Mickelson, 1975) provide baseline information on spectacled eider biology on the YKD (Dau and Kistchinski, 1977). Kistchinski (1973) and Kistchinski and Flint (1974) reported on 1965 and 1971 studies and observations in northern Siberia. Without any quantitative data prior to the 1960s, there was no indication of a population decline at that time. Throughout the 1960s and 1970s, the expanding use of outboard motors and snow machines, access to better firearms and ammunition, and many other changes in the Yup'ik villages on the YKD caused increasing concerns about the spring harvest of nesting waterfowl populations (King, 1963, 1965; Klein, 1966).

An historic estimate of spectacled eider nesting population size on the YKD was based on plot data collected from 1961 to 1976. Many of the plots searched were intended for studies of the nesting biology of cackling Canada geese (*Branta canadensis minima*) and for monitoring the density and nesting success of brant (*Branta bernicla nigricans*). The density estimates for spectacled eiders were 4.4 nests·km^{-2} in coastal regions, 1.0 nests·km^{-2} in central regions, and 0.2 nests·km^{-2} in inland regions (Dau and Kistchinski, 1977). These densities were expanded into 9600 km^2 of tide-influenced coastal tundra to estimate 42 240 pairs, plus 4500 km^2 of central habitat for 4500 pairs and 5000 km^2 of inland habitat for 1000 pairs, for a total of 47 740 nests (Dau and Kistchinski, 1977).

We compare the current population size of spectacled eiders on the YKD with these historic estimates of population size. Using both aerial survey observations and nests found on plots, we establish the recent trend in population size. Based on literature review, we summarize the biological characteristics of the species and discuss threats that may influence the population. We also speculate on possible causative factors of the population decline.

[1]U.S. Fish and Wildlife Service, Alaska Fish and Wildlife Research Center, 1011 E. Tudor Road, Anchorage, Alaska 99503, U.S.A.
[2]U.S. Fish and Wildlife Service, Izembek National Wildlife Refuge, P.O. Box 127, Cold Bay, Alaska 99571, U.S.A.
[3]U.S. Fish and Wildlife Service, Migratory Bird Management - Juneau, P.O. Box 021287, Juneau, Alaska 99802, U.S.A.
[4]U.S. Fish and Wildlife Service, Migratory Bird Management - Anchorage, 1011 E. Tudor Road, Anchorage, Alaska 99503, U.S.A.

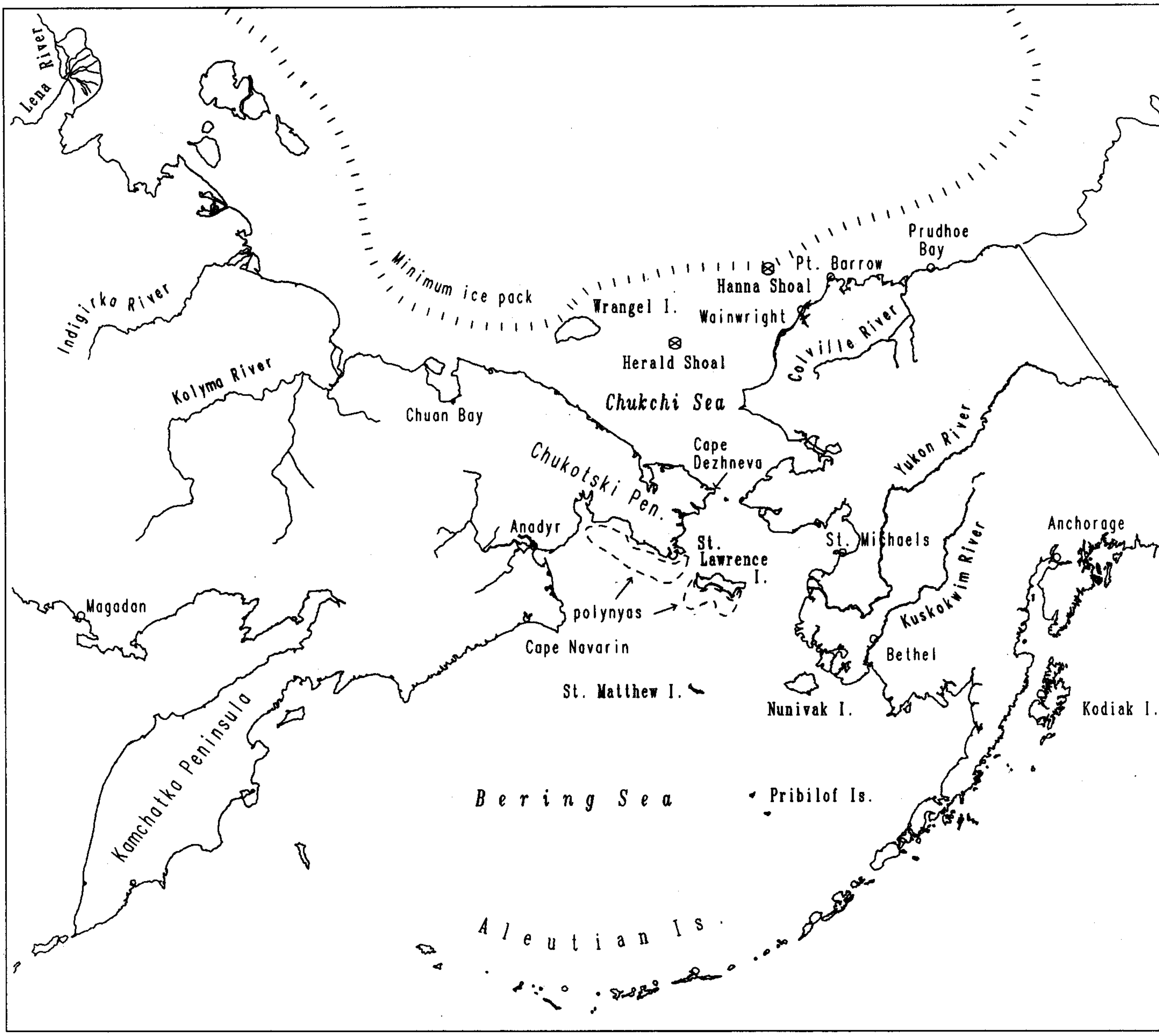

FIG. 1. Geographic locations of nesting, staging, and wintering habits of spectacled eiders as mentioned in the text.

METHODS

Aerial Surveys

We use data from three independent aerial transect surveys. The first survey best indicates the average long-term (1957-92) population trend of eiders in western Alaska. Data from the second survey (1967-70) and comparable data extracted from the third (1991-92) indicate population change for specific areas on the YKD. The third survey on the coast of the YKD best documents the recent (1988-92) population trend and is used to expand the more restricted ground-based sampling for nests.

Standardized surveys of waterfowl breeding populations have been flown in Alaska since 1957 (Conant and Dau, 1991). A pilot and an observer flying in float-equipped, single-engine aircraft at 30-45 m and 140-160 knots recorded all waterfowl species seen along strip transects. The indicated total number of eiders was calculated as twice the number of singles observed, plus all birds seen in pairs and flocks. Singles were doubled because an observation of a single eider, almost always a male, was assumed to indicate an unobserved incubating female. To estimate the mean density, the indicated total was divided by the area observed, the 400 m strip width times total transect length. Population size was estimated by multiplying mean density by total area and by a visibility correction factor of 3.58 for eiders. Visibility correction was derived from a comparison of ground plot data and aerial estimates from the coast of the YKD (Lensink, 1968). In this survey eider species were combined; however most observations were spectacled eiders. Common eiders (*Somateria mollissima v-nigra*) are localized breeders confined to nesting areas within 3 km of the coast (King and Dau, 1981) and Steller's eiders (*Polysticta stelleri*) no longer nest on the YKD (Kertell, 1991).

Additional aerial surveys were flown in 1967-70 in selected coastal areas of the Yukon Delta (Lensink, 1968, 1969; Hout and Lensink, 1968). The data recorded were total birds observed without doubling single birds, with the eider species combined, and without visibility correction. The transects sampled lowland habitats near Kokechik Bay, the Kashunuk River area between the Keoklevik and the Aphrewn rivers, north Nelson Island, and south Nelson Island.

More closely spaced aerial survey transects were flown over 12 852 km² of the coastal YKD beginning in 1985 (Butler *et al.*, 1987). The surveys provided precise annual monitoring of breeding populations of cackling Canada geese, emperor geese (*Chen canagica*), and greater white-fronted geese (*Anser albifrons frontalis*), which had experienced population declines for 20 years prior to 1985 (O'Neill, 1979; Raveling, 1984; King and Derksen, 1986). The boundaries for 16 coastal sampling strata were delineated based on similarity of features such as lake size, prevalence of ponds, homogeneous sedge meadows, and upland tundra visible on Landsat images at 1:250 000 scale. The stratified sampling design and the spacing of systematic transects were optimized for cackling geese (Butler, 1991). The timing of the survey was adjusted to match the phenology of the early incubation period. Beginning in 1988, a third observer in the aircraft's rear seat recorded eiders, other ducks, and loons. We used the observed density of twice singles plus pairs and flocks as expanded to the total area to index the total indicated breeding population without including a visibility correction factor. In 1992, both the pilot and the rear seat observer recorded eiders, as was done in the 1967-70 surveys. For comparison with 1967-70 data, we used total birds observed without doubling singles. We used only the data from the rear seat observer to determine the 1988-92 trend and the annual expansion factors (see below) for the nest data. For some observations species could not be identified; therefore we combined eider species. Because the 7-10 day survey was completed by mid-incubation, before most male eiders depart from the YKD, variation in survey timing relative to male departure was not a major influence on observed numbers. No quantitative data have been collected on the average date or distribution of male departures.

Plots Searched for Nests

Randomly located ground plots searched for nests were used to sample some of the same strata as the aerial surveys. Seven strata covering 2264 km² were sampled in 1986-91 by 55-90 plots each year and five strata of 1975 km² were sampled by 71 plots in 1992. Although the purpose was to estimate nesting population size and production by geese (Stehn *et al.*, 1992), the ground sampling procedure also provided data on nesting spectacled eiders. Random selection of a pair of longitude and latitude coordinates determined the location for each plot center. New random locations were selected each year. Plots were 0.324 km² (80 acres) in size, 804 m (0.5 mi) long, and 402 m (0.25 mi) wide and were oriented east-west. We have written computer programs to select plot center points and generate plot boundaries.

Two people searched each plot on a single visit. Duration of search varied from 2 to 6 h, depending on the complexity of the habitat and the number of nests found. To find all active and destroyed goose, brant, eider, swan, crane, loon, and gull nests, the searchers examined all possible sites dry enough for a nest, particularly lake shores and islands. Even if adult birds are not observed at nests, nearly all nests are visible and can be identified to species by down and contour feathers in the nest bowl. Nests of spectacled eiders are abundantly insulated by darker brownish-gray down, compared to the whitish-gray down of common eiders. Spectacled eiders lay smaller eggs, which measure 67.9 ± 2.9 mm (mean $\pm$ SD) by 45.3 ± 1.4 mm, n=685 (Dau, 1974), compared to 75.9 mm by 50.4 mm, n=85 (Bent, 1925) for common eiders. If adults are observed, the pale green head, white eye patch, and black breast identify male spectacled eiders, and a faint eye patch and feathering extending down the bill are diagnostic for females at close range. The approximate stage of incubation was determined by flotation of a few eggs from each clutch; the position and angle of the egg relative to the water surface correlates with stage of incubation (Westerskov, 1950; Dau, 1974).

Within each stratum, the mean nest density per plot was based on a simple random sample. The overall density of nests and population total were calculated by weighting with the area of each stratum. The number of active nests divided by total nests determined the proportion of nests remaining active, an index to nesting success. The number of eggs per active nest and the average predicted date of hatch were based on all active nests found on random plots. For these last two measures, each nest was considered an independent sample unit and averages were not weighted by stratum area.

The total number of nests for the entire coastal YKD was calculated by expanding the number of spectacled eider nests estimated in the 7 or 5 strata sampled by ground plots. The expansion factor is based on the indicated total breeding population index from aerial surveys in all 16 strata compared to the aerial index in those strata sampled by ground plots. The expanded estimate of total nests therefore includes some sampling error from the annual determination of an expansion factor, but population trend was not biased by assuming that a constant proportion of the population occurs in the ground-sampled strata compared to peripheral strata. Because the aerial population index combines eider species, the use of the expansion factor did assume that the ratio of spectacled to common eiders was the same in the strata sampled by plots and the other peripheral strata.

RESULTS

Aerial Survey Observations

On 107 16-mi segments of the standard aerial survey transects flown in western Alaska from 1964 to 1991, the sum of observations over 28 years was more than 4 eiders on 22 segments, 1-3 eiders on 25 segments, and none on the remaining 60 segments. Despite restricted distribution, infrequent sightings, and high annual variation, the number of eider observations showed a substantial decline as early as 1968 (Fig. 2). Eiders were never abundant except on the YKD (Fig. 2). Linear regression on logarithm-transformed aerial survey data from the YKD segments indicates an exponential decline in population size at a constant rate of 0.933, a 7% annual decline (Fig. 2). More rapid declines may have occurred from 1958-62 and 1966-72.

Another estimate of population decline was made by comparing 1991-92 aerial survey data with similar observations made on the YKD in 1967-70 (Hout and Lensink, 1968; Lensink, 1968, 1969). The mean density of eiders observed showed average declines by 1991-92 ranging from 54% to 91% in five geographic areas of the coast (Table 1). The total expanded number of birds observed in all five areas declined from an estimate of 4933 in 1967-70 to 631 in 1991-92, an 87% decline.

Intensive aerial surveys on the YKD coast provide an index to the breeding population of eiders. Coefficients of variation (standard errors divided by the means) were between 15% and 17% each year (Table 2). Based on linear regression on log-transformed data, the trend from 1988 to 1992 showed a 9% annual exponential rate of decline (Fig. 3) of total indicated eiders.

When possible, the rear-seat observer identified eiders to species during the coastal YKD aerial surveys. Of a total of 499 eider observations in 5 years, there were 256 spectacled eider, 61 common eider, 2 Steller's eider, no king eider (*Somateria spectabilis*), and 182 unidentified eider (Table 2). Of the 319 observations identified, 81% were spectacled

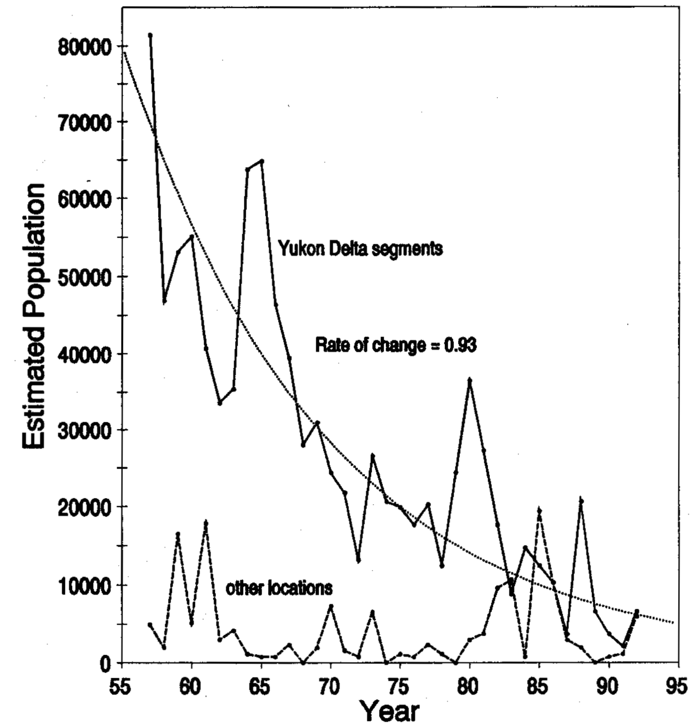

FIG. 2. Trend in eider population size on the Yukon-Kuskokwim Delta and other locations in western Alaska as indicated by waterfowl breeding pair survey data. Eider species are combined. The curved line indicates the best exponential fit (linear regression of logarithmic transformed data) of data from YKD segments with a constant annual rate of change of 0.93.

TABLE 1. Comparison of 1967-70 versus 1991-92 densities of total eiders observed on aerial survey transects sampling various coastal areas of the Yukon-Kuskokwim Delta

Date	Transect area (km^2)	Number of eiders[a]	Density/km^2	Total pop.	Avg. 1967-70	Avg. 1991-92	% change
Kokechik Bay and Kokechik River lowlands, area=395.3 km^2							
16 Jun 1969[b]	31.1	18	0.58	229			
9 Jun 1991[c]	34.3	11	0.33	132			
15 Jun 1992[d]	68.5[e]	19	0.20	79	229	106	-54
Between the Keoklevik, Kashunuk, and Aphrewn rivers, area=868.2 km^2							
13 Jun 1968[b]	58.3	218	3.74	3246			
9 Jun 1991[c]	70.2[e]	22	0.28	245			
15 Jun 1992[d]	132.7[e]	56	0.37	321	3246	283	-91
Between the Manokinak and Azun rivers, area=261.2 km^2							
14 Jun 1970[b]	45.3	48	1.06	277			
9 Jun 1991[c]	30.1	5	0.17	43			
15 Jun 1992[d]	60.1	32	0.53	139	277	91	-67
North Nelson Island lowlands, area=218.5 km^2							
11 Jun 1967[f]	31.1	6	0.19	42			
12 Jun 1968[b]	35.6	54	1.52	331			
9 Jun 1991[c]	15.4	2	0.13	28			
15 Jun 1992[d]	30.7	2	0.07	14	186	21	-89
South Nelson Island lowlands, area=510.1 km^2							
3 Jun 1967[f]	64.8	201	3.10	1582			
12 Jun 1968[b]	31.2	25	0.80	409			
9 Jun 1991[c]	23.9[e]	12	0.45	228			
15 Jun 1992[d]	47.7[e]	4	0.06	33	995	130	-87
Total					4933	631	-87

[a] Spectacled and Common eiders combined.
[b] 1968-70 observations by C.J. Lensink and J.L. Hout.
[c] 1991 observations 6-13 June by R.M. Platte.
[d] 1992 observations 10-19 June by W.I. Butler, Jr., and R.M. Platte.
[e] Total transect length in two or more substrata, each with different sampling effort; therefore density and total population were stratified estimates.
[f] 1967 observations by J.G. King and B. Hilliker.

TABLE 2. Spectacled, common, and unidentified eiders observed by the rear-seat observer on aerial survey transects on the coast of the Yukon-Kuskokwim Delta, 1988-92

	1988	1989	1990	1991	1992
Number of observations:					
Spectacled Eider	67	41	85	24	39
Unidentified eider	13	61	21	36	51
Common Eider	33	2	8	13	5
Steller's Eider	2	0	0	0	0
Singles	63	74	83	46	70
Pairs	51	30	31	27	25
Flocks	1	0	0	0	0
Total number of observations	115	104	114	73	95
Total birds observed	169	134	145	100	120
Estimated Population Index:					
Indicated total birds	2785	2260	2400	1735	1998
Standard error	412	391	372	286	335
% Coeff. of Variation	15	17	16	16	17
Lower 95% C.I.	1978	1495	1670	1174	1341
Upper 95% C.I.	3592	3026	3129	2296	2655
Proportion in 5 strata	.496	.640	.714	.535	.760
Proportion in 7 strata	.538	.773	.778	.605	.867

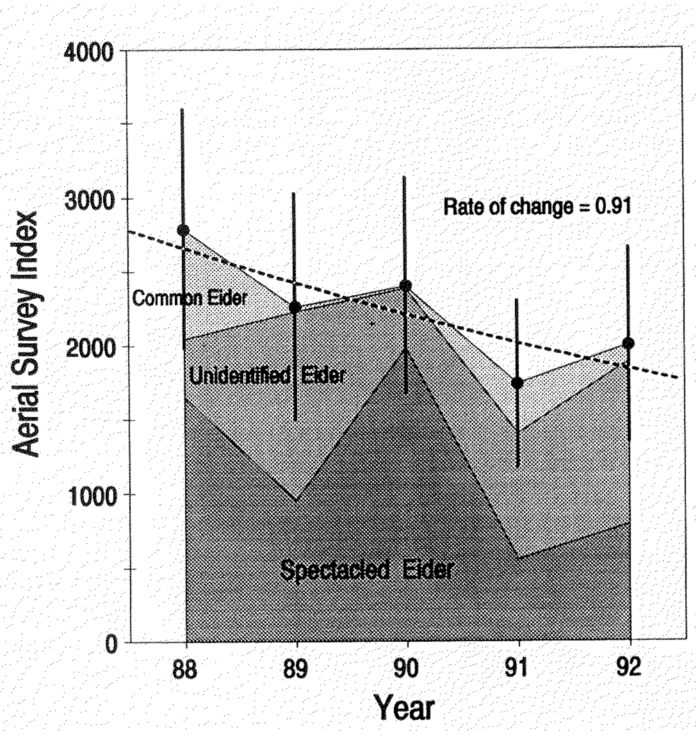

FIG. 3. Annual estimated population index and 95% confidence intervals for indicated total number of eiders observed by the rear-seat observer on coastal aerial surveys, 1988-92. The shaded areas indicate the spectacled, common, and unknown eider components of the total index. The dotted line is the best exponential regression fit to the data with an annual rate of change of 0.91.

eiders. Depending on species composition of the 36% unidentified eiders, the actual proportion of spectacled eiders could range from 51% to 88%. Based on 1991-92 stratified population indices, 75% of the identified eiders were spectacled eiders, yet 52% of the total indicated population were unidentified. The 1991-92 observations of eiders included 107 single males, 9 single females, 52 pairs, and no flocks (Table 2). These data documented that males were much more visible and likely to fly on approach of the survey aircraft than were incubating females.

Nests Found on Plots

Historic data from plots (Table 3) indicated average nest densities for spectacled eiders from 2.1 to 19.0 nests·km^{-2}. The main study areas of Onumtuk (1969-73) and Magak Flats (1971-73) had a total of 273 nests. These large study areas include habitats representative of most of the coastal zone. Although necessarily somewhat subjective due to limited sampling, the density of eiders found on these plots, as confirmed and expanded by less intensive work on many other plots, was used by Dau and Kistchinski (1977) to estimate the entire population as 47 740 nests.

With 55-90 plots sampled each year from 1986 to 1992, searches for nests have been completed on 533 plots within seven central strata (Fig. 4) and on 618 random plots in all strata. Field crews found a total of 293 spectacled eider nests on 155 plots, 144 common eider nests on 59 plots, and both species on 38 plots. Combining all the 1986-92 data, 67% of the identified eider nests were of spectacled eiders. Only 26 nests, or 6% of the total, were not identified to species. We included these in population estimates as spectacled eider nests because spectacled eiders were more frequent and more widespread than common eider. Based on the stratified estimate of population sizes for both species in seven central strata, 72% of all eider nests were spectacled eider nests.

Field crews found 40 spectacled eider nests on 22 of 98 plots (31.7 km^2) in 1991 and 27 nests on 17 of 71 plots (23.0 km^2) in 1992. The estimated population for the seven coastal strata was 1798 ± 400 (mean ± standard error) nests in 1991, and 1308 ± 270 in five strata in 1992 (Table 4). From 1986 to 1992, the number of nests estimated in five strata declined at an exponential rate of 0.86, 14% per year (Fig. 5). The rate of decline shown for nesting spectacled

TABLE 3. Historic plot data on nesting density of spectacled eiders used by Dau and Kistchinski (1977) to estimate total population size in the early 1970s

Study area	Years sampled	Area (km^2)	Total nests	Nest density/km^2 Avg.	Range
Onumtuk[1]	1969-73	10.40	213	4.2	3.1- 6.4
Magak Flats[2]	1971-73	4.48	60	4.4	2.9- 6.8
Brant plots[3]	1966-76	0.04	11	5.7	0-25.0
Random plots[4]	1968-73	0.65	27	2.1	0- 6.2
Tanuyakok[5]	1951,61-66	0.94	125	19.0	1.1-38.3

[1]A large study area along the lower Kashunuk River. Description and data were presented by Dau (1974) and Mickelson (1975).
[2]A ½-mile-wide transect study area extending from Kokechik Bay (Igiak Bay) towards an upland bluff to the south. Described by Eisenhauer and Kirkpatrick (1977) in their study of emperor geese. Data in Dau (1974).
[3]Small plots established in coastal brant nesting colonies to annually monitor brant nesting success. From a total of 21 plots, 12-20 plots were searched annually. Unpublished data described in Lensink (1968) and Lensink (1969).
[4]From a total of 40 randomly located plots, as many as 20 160-acre plots were searched each year. Unpublished data described by Lensink (1968, 1969).
[5]A large study area of 231 acres west of Hock Slough on the square bend of the lower Kashunuk River. Unpublished data J.R. King, 1963, cited by Dau (1974).

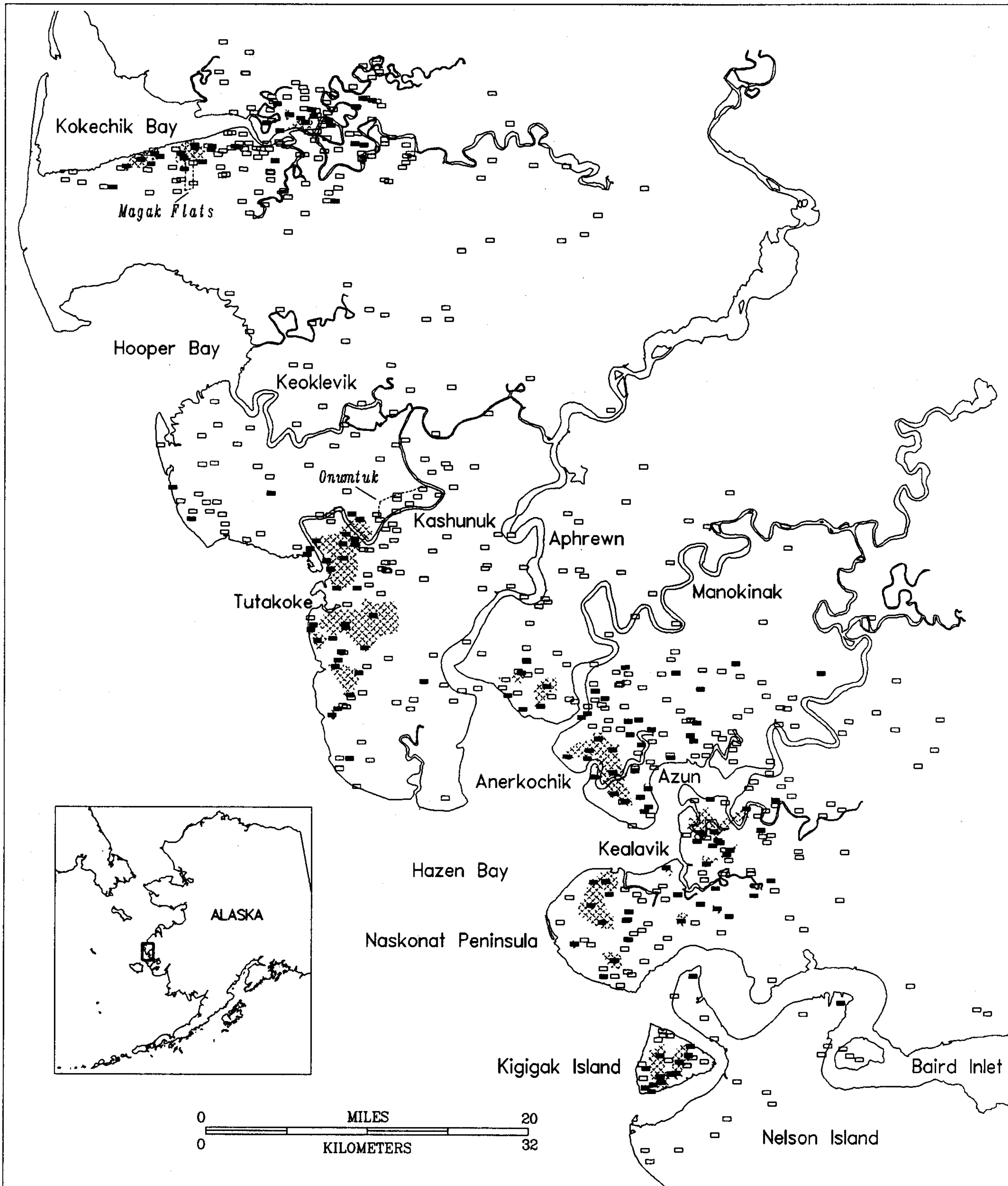

FIG. 4. Locations of random plots searched for waterfowl nests on the central Yukon-Kuskokwim Delta coast from 1986 to 1992. The total sample includes 618 random plots in 11 strata. Solid rectangles indicate plots that had one or more spectacled eider nests present; open plots indicate no spectacled eider nests were found. The light shaded areas indicate the estimated geographic range of spectacled eiders with a density of over 5 nests·km^{-2}. The dotted lines indicate boundaries of Magak Flats and Onumtuk, the two largest study areas sampled by Dau (1974).

TABLE 4. Annual nesting population size and production of young by spectacled eiders on the Yukon-Kuskokwim Delta based on the estimated number of nests and eggs in strata sampled by ground plots (7 strata in 1986-91, 5 strata in 1992)[a]

Year	Prop. of air index	Total nests	SE	Expanded	Prop. nests active	Total eggs	SE	Expanded
1986	0.673[b]	3705	864	5505	0.647	10946	3302	16264
1987	0.673[b]	3367	627	5003	0.732	12913	2711	19187
1988	0.538	3458	798	6428	0.926	15687	3740	29158
1989	0.773	2429	540	3142	0.890	10846	2373	14031
1990	0.778	2151	466	2765	0.913	10459	2426	13443
1991	0.605	1798	400	2972	0.877	8544	1929	14122
1992	0.760	1308	270	1721	0.860	6116	1394	8047

[a]Standard errors (SE) of population totals are indicated. Expanded population sizes for all 16 strata were based on the inverse of the proportion of the aerial survey population index within the sampled strata. The proportion of total nests that were active when found provided an index to nesting success.
[b]Proportion based on unweighted average of 1988-91 data from 7 strata because aerial observation of eiders in 1986-87 were not recorded.

eiders in the central YKD (Fig. 5) was greater than the average annual decline shown by aerial survey observations that include common eiders (Fig. 3).

The remaining high-density nesting areas of spectacled eiders coincided with higher density nesting areas of cackling Canada geese, emperor geese, or brant (W.I. Butler, Jr., unpubl. data). The highest eider densities on the YKD currently occurred on small portions of Kigigak Island and near Kokechik Bay. Most nests were on coastal meadows near the mouths of the Kokechik, Kashunuk, Tutakoke, Manokinak, Anerkochik, Azun, and Kealavik rivers (Fig.4).

The average clutch size of 5.10 from 1986 to 1992 (Table 5) was greater than the 4.68 mean clutch size from 1965-76 data (Dau, 1976; Lensink, pers. comm. 1992). The frequency distribution of clutch sizes was significantly different ($Chi^2=22.1$, $df=5$, $p=0.0005$) between these sets of years. For analysis the data were combined within each set of years and categorized into 1-2, 3, 4, 5, 6, 7-10 egg clutch sizes. The largest difference was the greater number of 1-3 egg clutches in the 1965-76 data, 17% of 412 clutches, compared to 9% of 263 clutches in recent years. Also, the recent data indicated 9% versus 3% frequency for large clutches with 7-10 eggs. The frequency of 4, 5, and 6 egg clutches did not differ (Table 5). Because some egg loss occurs after nest initiation, a lower rather than higher clutch size would be expected in the recent data, which were based on a single nest search during mid- to late incubation. Two explanations could account for the change in clutch size distribution. Smaller clutches may tend to fail earlier (Dau, 1974) and thus be missed entirely by sampling later in incubation. Alternatively, given that older, experienced females tend to initiate nesting earlier and have larger clutches (Dau, 1974), the age structure of nesting females may now contain relatively few young birds. This could be caused by decreased production or reduced survival rate of young to the age of first breeding in the 1980s compared to the 1960s.

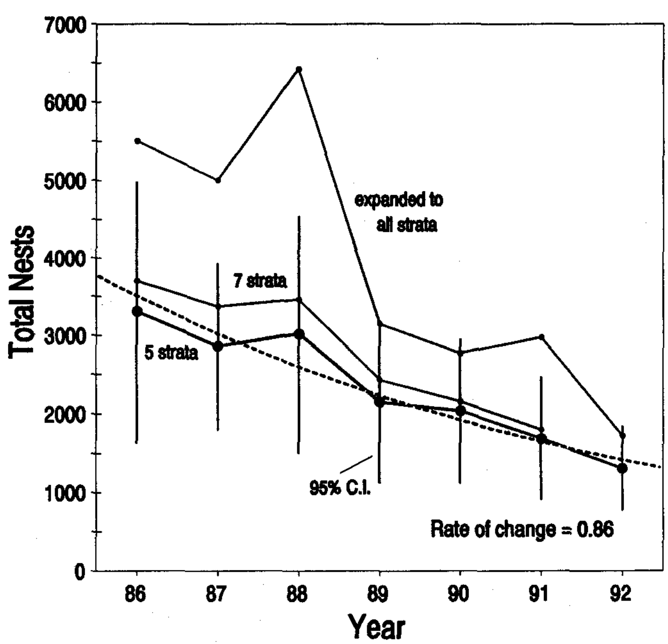

FIG. 5. Mean and 95% confidence intervals for spectacled eider nesting population size based on plots within the 5 strata sampled from 1986 to 1992, within 7 strata sampled from 1986 to 1991, and expanded to all 16 strata by aerial survey observations. The dashed line indicates the best exponential fit to the data with an annual rate of change of 0.86.

The proportion of nests remaining active at the time of search has been high in 5 of the last 7 years (Table 4). The average 1986-92 index to nesting success of 83% was higher than the 1969-73 estimate of 71% (Dau, 1974). Again, recent data were not exactly comparable because of single versus multiple nest visits; however, the production of young at hatching does not appear to be low.

Nesting population size for common eiders was estimated with less precision. The sampling strata boundaries were not useful for this species because of their clumped distribution within 3.0 km of the coast. No trend was seen in the estimated population size for common eider. Combined plot data ($n=618$) from all 7 years estimated 1353 common eider nests in all sampled strata, with a 95% confidence interval from 523 to 2183 nests. For comparison, the equivalent 7 year combined estimate for spectacled eiders was 3041 nests, with a 95% confidence interval from 2373 to 3709 nests. No Steller's or king eider nests were found, nor were pairs of these species observed on any plots.

In 1992, spectacled eider densities were 0.66 nests·km^{-2} (1308 nests on 1975 km^2) in central coastal strata and 0.06 nests·km^{-2} (590 nests on 10 634 km^2) over the remainder of the delta. The historic density estimates were 4.4 nests·km^{-2} in coastal regions, 1.0 nests·km^{-2} in central regions, and 0.2 nests·km^{-2} in inland regions (Dau and Kistchinski, 1977). We calculated the number of nests in strata not sampled by ground plots based on the aerial survey observation index as explained earlier. The 1992 expanded total

TABLE 5. Distribution and average size of active clutches, and estimated date of hatch based on egg float angles, for nests found on random plots

	Clutch size[a]													
Year	1	2	3	4	5	6	7	8	9	10	Avg.	n	Average hatch date[b]	n
1965	0	0	4	1	13	1	1	0	0	1	4.95	21		
1967	0	0	1	2	2	4	0	0	0	0	5.00	9		
1968	0	0	1	1	1	0	0	0	0	0	4.00	3		
1969	0	3	8	14	20	7	1	0	0	0	4.43	53	June 25.3	16
1970	1	7	4	13	21	20	0	1	0	0	4.66	67	June 25.6	24
1971	3	5	8	12	22	12	1	0	0	0	4.51	63	July 10.5	8
1972	3	1	4	5	20	15	3	0	0	0	4.86	51	July 2.7	25
1973	2	3	5	13	17	22	2	0	0	0	4.78	64	June 29.3	37
1974	1	0	1	4	10	1	0	0	0	0	4.47	17		
1975	0	0	0	4	11	6	0	0	0	0	5.10	21		
1976	0	3	1	8	21	9	1	0	0	0	4.81	43		
Total		32	37	77	158	97	11					412		
1986	2	0	1	9	10	3	0	0	0	0	4.36	25	July 2.2	15
1987	0	1	3	5	32	10	3	0	0	0	5.04	54	June 28.7	16
1988	0	0	4	13	18	11	1	2	0	0	4.96	49	June 26.6	17
1989	1	2	3	2	16	10	2	2	0	0	5.05	38	July 2.1	5
1990	0	2	1	7	11	11	4	2	0	0	5.26	38	June 23.0	15
1991	0	1	1	5	9	14	4	1	0	0	5.43	35	June 21.3	25
1992	1	0	0	0	9	11	2	0	1	0	5.63	24	July 2.4	17
Total		10	13	41	105	70	24					263		

[a] 1965-76, unpubl. data from C.J. Lensink (1992).
[b] 1969-73, average hatch date was estimated from date of clutch initiation from C.P. Dau (1974).

population estimate of 1721 (=1308/0.760) nests represents a 96% reduction in population since the early 1970s.

A prediction of the population size for 1970 based on the exponential regression equation fitting the last 7 years of plot data (Fig. 5) added credibility to the historic estimate. The annual rate of change from 1986 to 1992 (=0.8598) was raised to the −22nd power (=27.75) to extrapolate back 22 years and then multiplied by the 1992 estimate of 1721 nests. The result of 47 757 nests was remarkably close to Dau's estimate of 47 740 nests. Therefore, we infer that the population has declined by 96% at a constant rate of about 14% per year for 22 years. Alternatively, if we consider that the original population was overestimated and the subsequent decline was less than 96%, then we would conclude that the rate of decline has increased in the last 7 years as compared to the average rate over the previous 15 years.

DISCUSSION

We have documented a persistent rapid decline for the spectacled eider population nesting in western Alaska. A relatively recent change in survival or production must be causing the decline, but identification of the cause is not yet possible.

In contrast to most declining waterfowl populations, we found no indication that spectacled eiders have been reduced by the destruction of wetland habitat, disease, or contaminants; however, due to the lack of available data, we cannot eliminate these factors. The physical and vegetative components of nesting habitat on the central YKD coast are essentially unchanged, yet significant coastal erosion and scouring of nesting islands can occur with the infrequent 2 m storm tides (e.g., November 1978, C.P. Dau, pers. obs.). Snow accumulation, rainfall, and temperatures have been typical, the timing of spring breakup has been variable within the usual range, and storm tides have not been unusually frequent. Cackling Canada and white-fronted goose populations in the same nesting areas have been increasing rapidly since 1987 (Butler, 1991), although goose populations are still much smaller than 30 years ago. Losses of eiders to predation and subsistence hunting, while known to occur, have not been rigorously quantified. The available data indicate these losses are not large enough alone to account for reduced populations.

Observations of spectacled eiders from 1981 to 1991 near Prudhoe Bay on the northern coast of Alaska also indicate a downward trend similar to that on the YKD (Warnock and Troy, 1992). No trend data are available on the Siberian nesting populations. An hypothesis of population displacement from Alaska to Siberia by shifting nest locations of individual eiders is not supported by any reported observations on spectacled or any species of eider; the females of all eider species are highly philopatric.

To better understand possible causes for the decline, we review certain biological characteristics of spectacled eiders in relation to a series of possible threats that may impact their populations.

Distribution and Migration

Of the four extant species of eider, the spectacled eider has the smallest geographic range. Spectacled eiders nest on the coast of the YKD, at scattered locations on the west and north coasts of Alaska, and on the north coast of Siberia between the Lena River and Chaun Bay (Kistchinski, 1973; Kistchinski and Flint, 1974; Dau and Kistchinski, 1977; Johnson and Herter, 1989; Kessel, 1989). This distribution is most similar to that of Steller's eider, which also nested on the YKD prior to 1975 (Kertell, 1991). The king eider and common eider are more numerous and holarctic in distribution (Barry, 1986; Reed and Erskine, 1986; Johnson and Herter, 1989; Kessel, 1989). On the YKD, most spectacled eiders nest in tundra meadow communities within 15 km of the coast and never farther inland than 30 km. The restricted breeding range, both in geographic extent and in occupancy of a narrow coastal community, increases the chance that extreme weather conditions or any local environmental variable could limit nesting success or brood survival for a significant part of the population.

In late May or early June, spectacled eiders arrive from the northwest to the YKD coast from wintering or spring staging areas in the Bering Sea (Dau, 1974; Dau and Kistchinski, 1977). In late May, migratory flights also occur northward through Bering Strait before turning westward at Cape Dezhneva (Portenko, 1972:195). Polynyas occur just south of St. Lawrence Island and south of the Chukotski Peninsula (Stringer and Groves, 1991). These ice-free areas may be spring staging areas and they may also be important wintering areas (Fig. 1).

The YKD is frozen and covered with snow until late May or early June, with a variable amount of shorefast ice extending off the coast. Eiders stay offshore until snow melt begins and open water is available. Prior to nesting, shallow nearshore areas may provide critical food resources. Persistent ice cover, storms, or late spring breakup chronology may restrict food availability in some years and deplete energy reserves that are essential during nesting. Natives of coastal villages traditionally harvest eiders for subsistence while seal hunting near the ice edge.

Nesting on the YKD

Male and female spectacled eiders are paired from arrival until males depart during the second half of incubation. A small number of immature females arrive a few weeks later than paired adults; however, males in immature plumage are very rare on the YKD (Dau, 1974). By late June or July, males and failed or nonbreeding females congregate near the mouths of large rivers (Dau, 1974). Little foraging is observed before their departure, so apparently both sexes are still partially dependent on energy reserves accumulated at wintering or spring staging areas.

Nest sites are close to water on shorelines, peninsulas, islands, and meadows. Spectacled eider nesting is not colonial, although sometimes nests are clumped (Johnsgard, 1964; Dau, 1974). Nests are rarely placed in immediate proximity to brant, cackling geese, or gull nests on the YKD, although the tendency for close nest association with gulls is reported for Siberian spectacled eiders on the Indigirka delta (Kistchinski and Flint, 1974) and the Chaun lowlands (Kondratev and Zadorina, 1992). King eiders are observed to nest near long-tailed jaegers (*Stercorarius longicaudus*) in Greenland (Blomqvist and Elander, 1988). Colonial nesting and interspecific nest proximity is sometimes observed for common eiders on the YKD, similar to common eiders in Hudson Bay (Schmutz *et al.*, 1983).

Female eiders do not defend nests aggressively against foxes. Arctic fox (*Alopex lagopus*) depredation of avian nests and occasional predation on adult females can cause significant mortality in some years, while in other years arctic fox concentrate on microtine rodents (Quinlan and Lehnhausen, 1982; Pehrsson, 1986; Summers and Underhill, 1987; Syroechkovskiy *et al.*, 1991). Glaucous gulls (*Larus hyperboreus*) and parasitic jaegers (*Stercorarius parasiticus*) are potentially important predators of both eggs and young ducklings. Because disturbances by biologists searching for nests accentuate the impact of avian predation (MacInnes and Misra, 1972; Strang, 1980; Götmark and Åhlund, 1984; *cf.* Sedinger, 1990), careful attention to field methods and data analysis are needed to correctly interpret data on predation rates.

Eggs hatch in late June or the first few days of July after 24 days of incubation (Dau, 1974). Renesting does not occur following loss of a clutch (Dau, 1974). Females rear broods on small freshwater lakes usually within 1-3 km of the nest site (Dau, 1974). Food items for young and adult females include various aquatic insect larvae (Tipulidae, Trichoptera, Chironomidae), aquatic crustaceans (*Branchineta, Polyartemia, Lepidurus,* and *Cyzicus*), and plant material, including *Ranunculus pallasii, Hippuris tetraphylla,* and *Potamogeton filiformis* seeds and *Empetrum nigrum* berries (Dau, 1974; Kistchinski and Flint, 1974; Kondratev and Zadorina, 1992). The behavior and foods of spectacled eiders during brood rearing are quite different from common eider broods that forage in nearshore marine habitat, and unlike common eiders, spectacled eider broods do not congregate into creches. Female spectacled eiders do not become flightless during brood rearing, but molt in September after leaving the YKD. Young eiders begin to fly about 53 days after hatching, and in late August or early September females with broods move to the coast and depart (Dau, 1974). A few observations suggest that eiders depart in a northwest direction (C.P. Dau, pers. obs.). Threats during brood rearing include predation on ducklings by arctic fox, glaucous gulls, and parasitic jaegers. Severe weather conditions or limited availability or quality of foods could depress growth rates and survival of young.

For young spectacled eiders, fledging and departure from the YKD may be a critical period for survival (Dau, 1974). Departure brings the increased energetic demands of prolonged flight, an abrupt change in foraging behavior from dabbling to diving, a switch to benthic marine foods, the latent effects of infestation by helminth parasites, and possible problems with salt balance. Variations in the size of nasal salt glands occurs in adults, and smaller salt glands are present in juveniles (Dau, 1974). These physiological stresses may all combine to cause high mortality of young immediately after departure from freshwater brood rearing areas. For instance, Dau (1974) reports finding eight dead or incapacitated spectacled eiders in early September, all young birds in poor physical condition, at the west end of Kokechik Bay.

Molting and Wintering Period

Males and many females without broods leave the YKD by early July (Dau and Kistchinski, 1977). This contrasts with observations on the Indigirka delta, where, at least in a year of frequent nesting failure (1971), many females and some males remained on the breeding grounds through July (Kistchinski and Flint, 1974). Near the YKD in July, flocks of spectacled eiders linger offshore south of Nunivak Island (W.I. Butler, Jr., pers. obs.) and a few, mostly male flocks of spectacled and common eiders, stay nearshore off the central YKD (Dau, 1987). Most eiders leaving the YKD probably move directly northward to summer foraging and September molting areas. Presumed locations include nearshore or offshore areas of Norton Sound, the northern Bering Sea, the eastern Chukchi Sea north of Cape Lisbourne and Wainwright, and the western Chukchi Sea north and east of the Chukotski Peninsula (Fig. 1). Observed flocks have been small and scattered. More northern offshore portions of the Chukchi Sea, perhaps along the southern edge of pack ice near Hanna's shoal (71.9°N, 161.5°W) or Herald shoal (70.4°N, 170.9°W), may be important. Fall migration routes and wintering locations are unknown. Regular sightings occur from October to March near St. Lawrence Island (C.P. Dau, pers. obs.). Observers on a boat at the southern edge of pack ice around Nunivak and St. Matthew Island in the Bering Sea did not see spectacled eiders in March (Irving *et al.*, 1970).

Foraging habitat is presumed to be in nearshore or offshore Bering or Chukchi Sea waters that are less than 30 m in depth (Dau and Kistchinski, 1977). Foods are assumed to be shallow water marine benthic invertebrates similar to those used by common and king eiders (Cantin *et al.*, 1974; Bustnes and Erikstad, 1988). Scant data exist on spectacled eider food habits in molting, migration staging, or wintering areas. Amphipods made up 90% of the stomach contents of two female spectacled eiders taken in January 1918 at the Pribilof Islands (Preble and McAtee, 1923:53). Blue mussels (*Mytilus edulis*) and other invertebrates made up the remainder. Common and king eider winter foods in the same area were roughly 40% mollusks (mussels, limpets, snails, and many other bivalve and univalves), 30% crustaceans (amphipods, shrimp, isopods, and hermit crabs), 15% sand-dollars, sea urchins, and starfish, and 7% algae (Preble and McAtee, 1923). Two adult male spectacled eiders in excellent condition that were collected in March south of St. Lawrence Island had largely empty stomachs except for small pieces of crab shells (C.P. Dau, pers. obs.). Although not yet substantiated, the suggestion by Kessel (1989) that spectacled eiders may feed on pelagic amphipods near the ice edge rather than feeding exclusively on benthic invertebrates is potentially important, as this would allow foraging along pack ice regardless of water depth.

Threats during the winter period include severe weather, oil spills, food limitation, toxic contaminants, parasites, and possible competition with other species for food. Altered Bering Sea currents and winds could change ice conditions, water temperatures, sediment deposition, or nutrients, which would in turn affect the numbers or availability of benthic or pelagic food organisms used by eiders. We found no evidence or suggestions that any such changes or generalized threats have occurred; however, little information is available.

SPECULATION ON CAUSES OF THE DECLINE

Closer examination of various factors, although speculative, may help define future studies needed on spectacled eider population ecology. We hypothesize four main areas of concern: parasites, disease and contaminants; subsistence harvest; predation during brood rearing; and Bering Sea food resources. Any one or more may be harming spectacled eider populations.

Parasites, Disease and Contaminants

Parasites are an important mortality factor for common eiders in Sweden (Persson *et al.*, 1974). Renal and intestinal coccidiosis causes 20-45% loss of common eider ducklings of 5-18 days in age in Scotland (Mendenhall and Milne, 1985). Although some information exists on helminth parasites of the spectacled eider (Schiller, 1955; Dau, 1978), further investigations of parasites are needed. Disease epidemics have not been reported for spectacled eiders, although avian cholera has caused losses for common eiders in eastern North America (Reed and Cousineau, 1967; Korschgen *et al.*, 1978).

Endoparasites, diseases, or contaminants may each contribute to mortality in spectacled eiders, although the timing of mortality may coincide with periods of physiological stress from incubation, fledging, or molting. Although speculative, perhaps introduction of or exposure to a new parasite, disease, or contaminant began 20-30 years ago. Such a factor could be an important cause of the recent population decline. Because the species lives the entire year in far northern remote areas, diseased or weakened birds are not likely to be encountered by biologists; however, residents of St. Lawrence Island and the southern Chukotski Peninsula may have observations. Practical methods to collect such data have not been considered.

Harvest

Because spectacled eiders are inaccessible and rarely observed, the harvest by sport hunters has been insignificant. We suspect that late summer and fall eider populations forage offshore in shallow water areas of the Chukchi or northern Bering seas. In late fall, a few sport hunters and collectors took spectacled eiders near Gambell on St. Lawrence Island (C.P. Dau, pers. obs.; S. Tuttle, pers. comm. 1991) prior to 1992 when the season was closed. No other location for sport hunting is known. Rare extralimital sightings have occurred in south-central Alaska, Kodiak, the Pribilofs, and the Aleutian Islands (Dau, 1974).

Hunting of eiders and other waterfowl is a cultural tradition and an important resource valued by native people of western and northern Alaska. This is recognized both in intent and by explicit provisions within the Alaska Game Law of 1925, the Endangered Species Act of 1973, the Fish and Wildlife Improvement Act of 1978, the Alaska National Interest Lands Conservation Act of 1980, and recent judicial reviews (see discussions by Bartonek, 1986; Mitchell, 1986; Cook, 1986).

Subsistence harvest of eggs or hunting of eiders during nesting is uncommon (Wentworth, 1991; R. Stehn, pers. obs. 1984-92). Even before agreements in 1984 to reduce harvest of geese (Pamplin, 1986), subsistence harvest of spectacled eiders during nesting probably had a relatively small impact on the historically much larger eider population. Nevertheless, overharvest could have caused local reductions on the YKD and extirpation of disjunct eider populations from smaller areas of suitable habitat in western Alaska. Harvest of eiders near the edge of shorefast ice prior to nesting continues to contribute to mortality. Many villages on the YKD are voluntary participants in a subsistence waterfowl harvest survey. Spectacled eider harvest was reported in only a few coastal villages and total estimated annual take from 1985 to 1991 averaged 333 birds, with a range of 272 to 493 birds (Wentworth, 1991). Such small harvests on the YKD alone could not account for the population declines of the last 20 years unless subsistence harvest was previously much higher. The village harvest survey also indicated that other eider species were dominant in the harvest. Twice as many common eider (average of 566) and seven times as many king eider (average of 2974) as spectacled eider were taken. The harvest of Steller's eider was seldom reported. The reported subsistence harvest in 1964 of 3300 eiders (Klein, 1966) was similar to recent estimates, although the species composition of the 1964 harvest is unknown.

When disturbed in nesting areas, spectacled eider pairs or females will circle human intruders, making the birds susceptible to harvest. This is similar to the investigative behavior exhibited by nesting geese on the YKD. Beginning in 1984, when cooperative goose management agreements were negotiated on the YKD, subsistence hunting and egging after nest initiation have probably declined (Pamplin, 1986). The goose management agreement does not include eiders; however, eider harvests from goose nesting areas would decline with a reduction of hunting activity after nest initiation. On the other hand, the replacement of geese in the harvest by swans, cranes, or ducks may have increased the take of eiders. Few data are available to support this contention.

The reported subsistence harvest on the YKD of 318 spectacled eiders in 1991 (Wentworth, 1991) was about 5% of the 1991 breeding population estimated as 5944 birds (2*1798/0.605) (Table 4). Wainwright residents reported a subsistence harvest of 64 spectacled eiders in 1988 (Braund *et al.*, 1989). With 29% of the identified eider harvest reported as spectacled eiders, if this proportion is also applied to the number of unidentified eiders in the reported harvest, then the estimated spectacled eider number would include another 97 birds (Braund *et al.*, 1989). Five spectacled eiders were harvested at Barrow in 1970, 0.2% of the total July-August harvest, which was mostly of king eiders (Johnson, 1971). On St. Lawrence Island, spectacled eiders could be taken in late fall, winter, and spring, but subsistence harvest data are lacking. In Siberia, subsistence harvest also occurred (Dement'ev and Gladkov, 1952; Portenko, 1972), although no recent harvest estimate is known. These additional reported harvests may include spectacled eiders of other age classes or other breeding populations than those counted on the YKD. None of the subsistence harvest estimates mention unretrieved birds or crippling losses.

We conclude that although subsistence harvest has contributed to the decline of spectacled eiders, available evidence suggests that such harvests were not the primary cause of the decline. Nevertheless, the combined impact of subsistence hunting in various locations and seasons may now be excessive for the recovery of current spectacled eider populations. Based on common eider population dynamics (Coulson, 1984), spectacled eiders are a long-lived species with a relatively low recruitment of young to breeding age. Localized spring hunting of common eiders on nesting islands in Foxe Basin, Northwest Territories, Canada, has reduced local breeding colonies (Cooch, 1986). For common eider populations in eastern Canada (Reed and Erskine, 1986), when total annual summer and fall harvest was 15-16% of the fall population size, regional populations were relatively stable. Harvest at 11% allowed for increasing populations and harvest considerably above 16% correlated with declining populations. If spectacled eider production and survival rates are similar to those reported for common eider populations, the reported 5% harvest rate on the YKD would not account for further population decline. For the larger historic spectacled eider population, the current reported subsistence harvest would have been insignificant. Therefore, either spectacled eider production and survival rates are not similar to those of the common eider populations of eastern Canada, or the subsistence harvest was much greater than reported, or some factor other than harvest is causing the continuing population decline. Without better definitions of population size, survival, and harvest parameters throughout the range of the species, the importance of spring and fall subsistence harvest on spectacled eider populations remains unclear.

Predation

Arctic foxes, glaucous gulls, and parasitic jaegers take spectacled eider eggs and young. Trends in population sizes of these predators on the YKD are unknown. It is possible that fall and overwinter survival of predator adults, subadults, or young has increased in recent decades. Wintering gulls or jaegers may benefit from the direct or indirect influences of waste from fishing vessels, fish-processing factory ships, or onshore processing plants in the southern Bering Sea or elsewhere. Glaucous gulls winter in nearshore areas of the Bering Sea and North Pacific (Johnson and Herter, 1989). Parasitic jaegers winter offshore in the central and southern Pacific (Johnson and Herter, 1989). Arctic fox populations may benefit from village dumps and beached marine mammal carcasses. Rabies outbreaks that periodically infected fox populations on the YKD may now be less frequent because snow machines have replaced most sled dogs, which may have been a vector or reservoir for rabies in the past. Fox pelts are now less valuable and reduced fox trapping has perhaps increased fox populations. If arctic predator-scavenger populations are increasing, perhaps as a result of increased human presence in the Arctic, eiders may experience greater losses during nesting or brood rearing.

Even if population densities of predators have not changed, an increased rate of predation may have occurred. With the 90% decline from the 1960s to 1983 in cackling goose and white-fronted goose populations (Raveling, 1984), arctic foxes foraging on territories of relatively fixed size would increase their focus and impact on the remaining waterfowl nesting populations. The rate of loss per nesting attempt would increase with constant predator numbers foraging on fewer nests. The total number of eggs and young of all species lessens the impact of predation on any one species. With a decline in total nests, a disproportionate effect is likely for species such as eiders, other ducks, and shorebirds that do not defend nests successfully against foxes or gulls. Diminished numbers of avian nests are unlikely to cause a similar reduction in fox populations because, even with extensive caching of eggs by foxes, eggs are a seasonal and relatively minor part of their diet as compared to microtine rodents.

Although data from the YKD are lacking, increased predation rates on spectacled eider broods may be important. Studies indicate that predation rates by gulls can be high on common eider nests and broods. In a non-hunted, increasing island population of common eider (Coulson, 1984), only 1 in 10 eggs survived to recruit into the breeding population. In Quebec, gull predation on common eider nests resulted in a 22% nesting success rate in 1977 (van Dijk, 1986). This same study noted that increased nesting success occurred with proximity to herring gull (*Larus argentatus*) nests, but not to greater black-backed gull (*L. marinus*) nests (van Dijk, 1986). Proximity to gull nests also increased nesting success for spectacled eiders on the Indigirka Delta (Kistchinski and Flint, 1974). In Maine, common eiders experience over 60% nest predation by gulls, with the rate affected by nesting chronology, species and density of gulls, topography of the nest site, vegetative cover, and individual behavior (Choate, 1967; Bourget, 1970). Despite some protection afforded to nearby duck nests by gulls defending their own nesting territories, subsequent predation by gulls on ducklings during brood rearing can be a serious detriment to production (Dwernychuk and Boag, 1972). Gull predation rates of up to 99% on common eider ducklings less than 10 days old occurred in the Netherlands in years with inadequate foods in intertidal foraging areas (Swennen, 1989). The susceptibility to predation was mediated by the weaker condition of ducklings and slower response to female alarm calls (Swennen, 1989). In Scotland, gull predation in association with bad weather caused 80-90% mortality of common eider ducklings (Mendenhall, 1975; Mendenhall and Milne, 1985). Severe weather was also associated with subsequent predation by jaegers on 95% of the remaining spectacled eider nests (Kondratev and Zadorina, 1992).

Although the predation rate on spectacled eider nests was not high from 1988 to 1992, mortality rates of broods have not been studied on the YKD. Any increase in brood mortality rate on the YKD, perhaps caused by increased glaucous gull populations or decreased alternate prey population sizes, could be a critical factor in the population decline of spectacled eiders.

Food Resources

Spectacled eider food items likely include nearshore and offshore benthic marine invertebrates found at less than 30 m depth. Data on the distribution or abundance of suspected spectacled eider food items are not available. Feeding behavior, prey size and species preference, geographic location, water depth, and seasonal patterns of foraging are unknown. Current, sediment deposition, salinity, and nutrient upwelling may influence the production of benthic and perhaps pelagic food resources used by eiders. Availability of foods may also be dependent on temperatures, winds, and currents that affect the extent and movement of pack ice in the Chukchi and Bering seas. Seasonal and annual variations in resource abundance may be large. No data are available for all these factors.

Shifts in populations of other species may indirectly affect the benthic marine food resources used by eiders. Between 1960 and 1980, the Pacific walrus (*Odobenus rosmarus*) population apparently tripled and by the late 1970s walrus were leaner, the average size of bivalves in walrus stomach contents was smaller, unusual food items became more frequent, and the production of calves declined (Fay *et al.*, 1989). Walrus overpopulation may have an indirect impact on the food supplies used by spectacled eider. Increasing gray whale (*Eschrichtius robustus*) populations in the northern Bering and Chukchi seas feed on benthic gammarid amphipods (Rice and Wolman, 1971). Spectacled eiders probably forage in these same northern marine ecosystems during fall molting and wintering periods. Although far south of wintering eiders, the Steller's sea lion (*Eumetopias jubatus*) along the Alaska Peninsula has shown a marked population decline. Populations of other marine mammals and marine birds of the Chukchi and northern Bering seas may also be changing, and programs to adequately monitor many species have only recently begun. Steller's eider, oldsquaw (*Clangula hyemalis*), and emperor geese that winter at the southern edge of the Bering Sea along the Alaska Peninsula all had smaller populations in 1992 than in 1970 (Kertell, 1991; unpubl. data, USFWS).

The changes in mammal and bird populations of the Bering Sea may be caused by a complex of changes in fish or invertebrate populations. In the Bering Sea ecosystem, stocks of crab, pollock, herring, and bottom fish have experienced large and rapid transitions in commercial harvests over the last 30 years. No reports indicate entanglement of eiders in drift nets or any direct effects on spectacled eiders by commercial fishing (P. Gould, pers. comm. 1991; A. DeGange, pers. comm. 1991) because most fishery operations are restricted to deeper, ice-free waters well south of the presumed molting and wintering areas of eiders. Reports of bird collisions with lighted crab boats in the northern Bering Sea warrant further investigation. Secondary effects of commercial fishing could cause the expansion or decline of populations or size classes of non-harvested invertebrates or fish. Such changes could involve those invertebrate populations important to spectacled eiders, perhaps by reduction of larval stages of benthic invertebrates or a shift in available energy and nutrient flows through food chains altered by commercial harvest.

CONCLUSION

The continuing decline of spectacled eider populations on the west coast of Alaska indicates that undocumented causes of excessive mortality are still operating. Our data show that the rate of decline is not slowing. If the decline continues at the annual rate of 14%, by the year 2002 there will be fewer than 400 spectacled eider nests on the YKD, and by 2012 fewer than 90 nests. Continuation of breeding ground surveys and further data analysis are needed to better detect any change in population trend.

Population growth will require an increased survival rate for adults, subadults, first-year birds, or broods. Nesting success appears to be adequate. Causes of the low survival rates may be indicated by studies that determine brood survival; provide more complete information on harvests in all areas and seasons; investigate contaminant levels or the incidence of parasites and diseases; or determine the locations of molting and wintering habitats and assess the marine food resources used by spectacled eiders. Determination of which of these factors is most important is not yet possible.

Survey data are lacking from the northern coast and nearshore waters of northeast Siberia, where little information has been reported since 1971. The international cooperation needed for range-wide inventory and monitoring of populations far exceeds the resources available for prompt progress. The complexity of issues involving YKD goose management (Cook, 1982; Kelso, 1982; Raveling, 1984) and steps towards solutions (Pamplin, 1986; Blanchard, 1987; Wolfe *et al.*, 1990) may also be pertinent for eiders. Yup'ik and Inupiat peoples should be directly involved in the management and conservation of eiders.

ACKNOWLEDGEMENTS

We thank all the pilots, observers, and field biologists who have collected these data. The total time, distance, skill, and patience represented in these accumulated data sets are almost immeasurable. C.J. Lensink kindly provided his unpublished data. Reviews by K. Kertell, J.F. Cochrane, A. Reed, S. Blomqvist, and an anonymous reviewer have improved the manuscript. R.M. Platte prepared the map figures.

REFERENCES

BARRY, T.W. 1986. Eiders of the western Canadian Arctic. In: Reed, A., ed. Eider ducks in Canada. Canadian Wildlife Service Report Series No. 47. 74-80.

BARTONEK, J.C. 1986. Waterfowl management and subsistence harvests in Alaska and Canada: An overview. Transactions of the North American Wildlife and Natural Resource Conference 51:459-463.

BENT, A.C. 1925. Life histories of North American wildfowl. Part II. 1962 reprint. New York: Dover Publications Inc.

BLANCHARD, K. 1987. Strategies for the conservation of seabirds on Quebec's North Shore and geese on Alaska's Yukon-Kuskokwim delta: A comparison. Transactions of the North American Wildlife and Natural Resource Conference 52:399-407.

BLOMQVIST, S., and ELANDER, M. 1988. King eider (*Somateria spectabilis*) nesting in association with Long-tailed skua (*Stercorarius longicaudus*). Arctic 41:138-142.

BOURGET, A.A. 1970. Interrelationships of eiders, herring gulls, and black-backed gulls nesting in mixed colonies in Penobscot Bay, Maine. M.S. thesis, University of Maine. 115 p.

BRAUND, S.R., BURNHAM, D.C., LORING, E., MOOREHEAD, L., HOLMES, T.P., WITTEN, E., and KRUSE, J.A. 1989. North Slope subsistence study: Wainwright, 1988. Technical Report No. 136., Outer Continental Shelf Study, Minerals Management Service, 89-0078.

BUSTNES, J.O., and ERIKSTAD, K.E. 1988. The diets of sympatric wintering populations of Common eider *Somateria mollisima* and King eider *S. spectabilis* in northern Norway. Ornis Fennica 65:163-168.

BUTLER, W.I., Jr. 1991. Breeding ground surveys of geese and swans in the coastal zone of the Yukon-Kuskokwim Delta, Alaska. Unpubl. report. Available at USFWS, Migratory Bird Management Office, 1011 E. Tudor Rd., Anchorage, AK 99503.

BUTLER, W.I., Jr., STEHN, R., and LENSINK, C.J. 1987. Development of an aerial breeding pair survey for geese nesting in the coastal zone of the Yukon Delta. Unpubl. report. Available at USFWS, Migratory Bird Management Office, 1011 E. Tudor Rd., Anchorage, AK 99503.

CANTIN, M., BEDARD, J., and MILNE, H. 1974. The foods and feeding of Common eiders in the St. Lawrence estuary in summer. Canadian Journal of Zoology 52:319-334.

CHOATE, J.S. 1967. Factors influencing nesting success of eiders in Penobscot Bay, Maine. Journal of Wildlife Management 31:769-777.

CONANT, B., and DAU, C.P. 1991. Alaska-Yukon waterfowl breeding population survey. Unpubl. annual reports. Available at USFWS, Migratory Bird Management Office, 1011 E. Tudor Rd., Anchorage, AK 99503.

COOCH, F.G. 1986. The numbers of nesting northern eiders on the West Foxe Islands, NWT, in 1956 and 1976. In: Reed, A., ed. Eider ducks in Canada. Canadian Wildlife Service Report Series No. 47. 114-118.

COOK, G.F. 1982. Wildlife and fishery allocation in Alaska, 1982: Allocations for subsistence, commercial, and recreational uses. Transactions of the North American Wildlife and Natural Resource Conference 47:617-629.

______. 1986. Alaska waterfowl management and the law. Transactions of the North American Wildlife and Natural Resource Conference 51:516-526.

COULSON, J.C. 1984. The population dynamics of the eider duck *Somateria mollissima* and evidence of extensive non-breeding by adult ducks. Ibis 126:525-543.

DAU, C.P. 1974. Nesting biology of the Spectacled Eider, *Somateria fischeri* (Brandt), on the Yukon-Kuskokwim delta, Alaska. M.Sc. thesis, University of Alaska, Fairbanks. 72 p.

______. 1976. Clutch sizes of the Spectacled Eider on the Yukon-Kuskokwim Delta, Alaska. Wildfowl 27:111-113.

______. 1978. Observations on helminth parasites of the spectacled eider, *Somateria fischeri* (Brandt), in Alaska. Canadian Journal of Zoology 56:1882-1885.

______. 1987. Birds in nearshore waters of the Yukon-Kuskokwim Delta, Alaska. Murrelet 68:12-23.

DAU, C.P., and KISTCHINSKI, A.A. 1977. Seasonal movements and distribution of the Spectacled Eider. Wildfowl 28:65-75.

DEMENT'EV, G.P., and GLADKOV, N.A. 1952. Birds of the Soviet Union. Vol. 4. Translated from Russian, 1967, Israel Program for Scientific Translation. Jerusalem: S. Monson. 683 p.

DWERNYCHUK, L.W., and BOAG, D.A. 1972. Ducks nesting in association with gulls — An ecological trap? Canadian Journal of Zoology 50:559-563.

EISENHAUER, D.I., and KIRKPATRICK, C.M. 1977. Ecology of the Emperor goose in Alaska. Wildlife Monographs 57:1-62.

FAY, F.H., KELLY, B.P., and SEASE, J.L. 1989. Managing the exploitation of Pacific walruses: A tragedy of delayed response and poor communication. Marine Mammal Science 5:1-16.

GABRIELSON, I.N., and LINCOLN, F.C. 1959. The birds of Alaska. Harrisburg, PA: The Stackpole Company, and Washington, D.C.: Wildlife Management Inst. 922 p.

GÖTMARK, F., and ÅHLUND, M. 1984. Do field observers attract nest predators and influence nesting success of common eiders? Journal of Wildlife Management 48:381-387.

HOUT, J.L., and LENSINK, C.J. 1968. Survey of waterfowl populations and habitat on Nelson Island, Alaska. Unpubl. report. Available at Yukon Delta National Wildlife Refuge, Bethel, AK.

IRVING, L., McROY, C.P., and BURNS, J.J. 1970. Birds observed during a cruise in the ice-covered Bering Sea in March 1968. Condor 72:110-112.

JOHNSGARD, P.A. 1964. Observations on the biology of the Spectacled Eider. Wildfowl Trust Annual Report 15:104-107.

JOHNSON, L.L. 1971. The migration, harvest, and importance of waterfowl at Barrow, Alaska. M.S. thesis, University of Alaska, Fairbanks. 87 p.

JOHNSON, S.R., and HERTER, D.R. 1989. The birds of the Beaufort Sea. Anchorage: BP Exploration (Alaska) Inc. 372 p.

KELSO, D.D. 1982. Subsistence use of fish and game resources in Alaska: Considerations in formulating effective management policies. Transactions of the North American Wildlife and Natural Resource Conference 47:630-640.

KERTELL, K. 1991. Disappearance of the Steller's eider from the Yukon-Kuskokwim Delta, Alaska. Arctic 44:177-187.

KESSEL, B. 1989. Birds of the Seward Peninsula, Alaska. Fairbanks: University of Alaska Press. 330 p.

KING, J.G. 1963. Clarence Rhode National Wildlife Range Annual Narrative Report. Available at USFWS Library, Anchorage, AK 99503.

______ . 1965. Some aspects of the relationship of Eskimos and waterfowl. Unpubl. report. Available at Yukon Delta National Wildlife Refuge, Bethel, AK 99559. 7 p.

KING, J.G., and DAU, C.P. 1981. Waterfowl and their habitats in the eastern Bering Sea. In: Hood, D.W., and Calder, J.A., eds. The Eastern Bering Sea shelf: Oceanography and resources. Seattle: University of Washington Press. 739-753.

KING, J.G., and DERKSEN, D.V. 1986. Alaska goose populations: Past, present, and future. Transactions of the North American Wildlife and Natural Resource Conference 51:464-479.

KISTCHINSKI, A.A. 1973. Waterfowl in north-east Asia. Wildfowl 24:88-102.

KISTCHINSKI, A.A., and FLINT, V.E. 1974. On the biology of the spectacled eider. Wildfowl 25:5-15.

KLEIN, D.R. 1966. Waterfowl in the economy of the Eskimos on the Yukon-Kuskokwim Delta, Alaska. Arctic 19:319-336.

KONDRATEV, A.V., and ZADORINA, L.V. 1992. Comparative ecology of the king eider (*Somateria spectabilis*) and the spectacled eider (*S. fischeri*) on the Chaun tundra. Zoological Journal 71:99-108.

KORSCHGEN, C.E., GIBBS, H.C., and MENDALL, H.L. 1978. Avian cholera in eider ducks in Maine. Journal of Wildlife Diseases 14:254-258.

LENSINK, C.J. 1968. Clarence Rhode National Wildlife Range Annual Narrative Report. Available at USFWS Library, Anchorage, AK 99503.

______ . 1969. Clarence Rhode National Wildlife Range Annual Narrative Report. Available at USFWS Library, Anchorage, AK 99503.

MacINNES, C.D., and MISRA, R.K. 1972. Predation on Canada goose nests at McConnell River, Northwest Territories. Journal of Wildlife Management 36:414-422.

MENDENHALL, V.M. 1975. Growth and mortality factors of eider ducklings (*Somateria m. mollissima*) in north-east Scotland. Ph.D. thesis, University of Aberdeen, Aberdeen. 230 p.

MENDENHALL, V.M., and MILNE, H. 1985. Factors affecting duckling survival of eiders *Somateria mollisima* in northeast Ireland. Ibis 127:148-158.

MICKELSON, P.G. 1975. Breeding biology of Cackling Geese and associated species on the Yukon-Kuskokwim Delta, Alaska. Wildlife Monographs 45:5-33.

MITCHELL, D.C. 1986. Native subsistence hunting of migratory waterfowl in Alaska: A case study demonstrating why politics and wildlife management don't mix. Transactions of the North American Wildlife and Natural Resource Conference 51:527-534.

O'NEILL, E.J. 1979. Fourteen years of goose population trends at Klamath Basin refuges. In: Jarvis, R.L., and Bartonek, J.C., eds. Management and biology of Pacific Flyway geese. Corvallis, OR: Oregon State University Book Stores, Inc. 316-321.

PAMPLIN, W.L., Jr. 1986. Cooperative efforts to halt population declines of geese nesting on Alaska's Yukon-Kuskokwim delta. Transactions of the North American Wildlife and Natural Resource Conference 51:487-506.

PEHRSSON, O. 1986. Duckling production of the Oldsquaw in relation to spring weather and small rodent fluctuations. Canadian Journal of Zoology 64:1835-1841.

PERSSON, L.K., BORG, K., and FÄLT, H. 1974. On the occurrence of endoparasites in eider ducks in Sweden. Viltrevy 9:1-24.

PORTENKO, L.A. 1972. Birds of the Chukchi Peninsula and Wrangel Island. Vol. 1. Leningrad: Nauka Publishers. In Russian. English translation, 1981. New Delhi: Amerind Publishing Co. 446 p.

PREBLE, E.A., and McATEE, W.L. 1923. A biological survey of the Pribilof Islands, Alaska. Part I. Birds and mammals. North American Fauna 46:1-255.

QUINLAN, S.E., and LEHNHAUSEN, W.A. 1982. Arctic fox, *Alopex lagopus*, predation on nesting common eiders, *Somateria mollissima*, at Icy Cape, Alaska. Canadian Field-Naturalist 94:462-466.

RAVELING, D.G. 1984. Geese and hunters of Alaska's Yukon Delta: Management problems and political dilemmas. Transactions of the North American Wildlife and Natural Resource Conference 49:555-575.

REED, A., and COUSINEAU, J.-G. 1967. Epidemics involving Common eiders at Ile Blanche, Quebec. Le Naturaliste canadien 94:327-334.

REED, A., and ERSKINE, A.J. 1986. Populations of the Common eider in eastern North America: Their size and status. In: Reed, A., ed. Eider ducks in Canada. Canadian Wildlife Service Report Series No. 47: 156-162.

RICE, D.W., and WOLMAN, A.A. 1971. Life history and ecology of the gray whale (*Eschrichtius robustus*). American Society of Mammalogists, Special Publication No. 3. 142 p.

SCHILLER, E.L. 1955. Studies on the helminth fauna of Alaska. XXIII. Some cestode parasites of eider ducks. Journal of Parasitology 41:79-88.

SCHMUTZ, J.K., ROBERTSON, R.J., and COOKE, F. 1983. Colonial nesting of the Hudson Bay eider duck. Canadian Journal of Zoology 61:2424-2433.

SEDINGER, J.S. 1990. Effects of visiting black brant nests on egg and nest survival. Journal of Wildlife Management 54:437-443.

STEHN, R.A., WEGE, M., and WALTERS, G. 1992. Population size and production of geese nesting on the Yukon-Kuskokwim Delta. Unpubl. report. Available at USFWS, Migratory Bird Management Office, 1011 E. Tudor Rd., Anchorage, AK 99503.

STRANG, C.A. 1980. Incidence of avian predators near people searching for waterfowl nests. Journal of Wildlife Management 44:220-222.

STRINGER, W.J., and GROVES, J.E. 1991. Location and areal extent of polynyas in the Bering and Chukchi seas. Arctic 44:164-171.

SUMMERS, R.W., and UNDERHILL, L.G. 1987. Factors related to breeding production of Brent Geese *Branta b. bernicla* and waders (Charadrii) on the Taimyr Peninsula. Bird Study 34:161-171.

SYROECHKOVSKIY, Ye.V., LITVIN, K.Y., and EBBINGE, B.S. 1991. Breeding success of geese and swans on Vaygach Island, USSR, 1986-1988: Interplay of weather and arctic fox predation. Ardea 79:373-382.

SWENNEN, C. 1989. Gull predation upon eider *Somateria mollissima* ducklings: Destruction or elimination of the unfit? Ardea 77:21-45.

VAN DIJK, B. 1986. The breeding biology of eiders at Ile aux Pommes, Quebec. In: Reed, A., ed. Eider ducks in Canada. Canadian Wildlife Service Report Series No. 47:119-126.

WARNOCK, N.D., and TROY, D.M. 1992. Distribution and abundance of Spectacled Eiders at Prudhoe Bay, Alaska, 1991. Unpubl. report. Available at BP Exploration (Alaska) Inc., Environmental and Regulatory Affairs Dept., P.O. Box 196612, Anchorage, AK 99519.

WENTWORTH, C. 1991. Subsistence waterfowl harvest survey, Yukon-Kuskokwim Delta. Unpubl. report. Available at USFWS Migratory Bird Management Office, 1011 E. Tudor Rd., Anchorage, AK 99503.

WESTERSKOV, K. 1950. Methods for determining the age of game bird eggs. Journal of Wildlife Management 14:56-67.

WOLFE, R.J., PAIGE, A.W., and SCOTT, C.L. 1990. The subsistence harvest of migratory birds in Alaska. Alaska Department of Fish and Game Technical Paper 197:1-178.