ARCTIC
VOL. 52, NO. 2 (JUNE 1999) P. 188–203

Distribution, Abundance and Reaction to Aerial Surveys of Post-breeding King Eiders (*Somateria spectabilis*) in Western Greenland

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(*Received 17 June 1997; accepted in revised form 1 November 1998*)

ABSTRACT. Moulting and post-breeding king eiders in western Greenland were surveyed in late August and early September of 1993, 1994, and 1995. We counted all eiders observed during fixed-winged aircraft flights along coastlines and offshore transects. The coastline in the survey area is roughly 13 400 km long, and our flightlines totaled approximately 16 500 km. The areas optimal for the birds were covered fully several times; in less suitable areas, only a fraction of the coastline was covered. Using the largest count for coastlines covered more than once, we counted a total of 22 980 king eiders. Large numbers of king eiders were observed at a number of remote localities on the west coast of Disko Island and in southern Upernavik. At localities considered to have frequent human disturbance, few birds were observed. Highest densities were found along coasts with sandy or muddy areas at the shorelines. Overall we estimate that 30 000 to 40 000 king eiders reside in the coastal zone of western Greenland in late August. Even allowing for a high turnover rate, as different individuals may occupy the moulting areas during the extended period from July to October, this figure can account for only half of a 1950s estimate that 200 000 males and immatures were moulting in western Greenland.

Key words: king eider, *Somateria spectabilis*, moulting areas, abundance, aerial surveys, disturbance, western Greenland

RÉSUMÉ. Fin août et début septembre en 1993, 1994 et 1995, on a dénombré les eiders à tête grise durant la mue et après la reproduction dans l'ouest du Groenland. On a compté tous les eiders aperçus durant des vols effectués par des aéronefs à voilure fixe le long de transects longeant la côte et au large. La côte de la zone étudiée fait en gros 13 400 km de long et nos vols ont couvert une distance d'environ 16 500 km. Les meilleures zones pour les oiseaux ont été complètement couvertes plusieurs fois; dans les zones leur convenant moins bien, on n'a couvert qu'une partie de la côte. En se basant sur les plus grands nombres dans le cas des lignes côtières couvertes plus d'une fois, on a compté un total de 22 980 eiders à tête grise. On a observé de grands nombres d'eiders à tête grise dans plusieurs localités reculées, sur la côte occidentale de l'île Disko et dans l'Upernavik méridional. On a observé peu d'oiseaux dans les localités considérées comme subissant des perturbations anthropiques fréquentes. Les densités les plus fortes se trouvaient sur les côtes possédant des zones sableuses ou boueuses le long du rivage. On estime que, dans l'ensemble, de 30 000 à 40 000 eiders à tête grise résident dans la zone côtière du Groenland occidental à la fin du mois d'août. Même en tenant compte du haut taux de renouvellement, car différents individus peuvent occuper les mêmes zones de mue durant la période prolongée de juillet à octobre, ce chiffre ne représente que la moitié de celui des années 1950, alors qu'on estimait à 200 000 le nombre d'oiseaux mâles et immatures qui muaient dans le Groenland occidental.

Mots clés: eider à tête grise, *Somateria spectabilis,* zones de mues, abondance, relevés aériens, perturbation, Groenland occidental

Traduit pour la revue *Arctic* par Nésida Loyer.

INTRODUCTION

King eiders (*Somateria spectabilis*) migrate from dispersed breeding sites in eastern and central Arctic Canada (eastern Canadian population), and possibly northwestern Greenland, to undergo prebasic (post-breeding) moult along the central west coast of Greenland (Fig. 1). According to Salomonsen (1968), several hundred thousand male and immature king eiders congregate in this area, with peak numbers in early August. Maximum densities were found in the area of Disko Island and Disko Bay (Fig. 2). Salomonsen (1968) presumed that the moult migration to western Greenland included only males and immatures, while adult females moulted in Canada. In contrast, Frimer (1994a, b) noted a second wave of migrants in late August and early September that consisted of female king eiders arriving at Disko Island for moulting. The result is peak numbers of moulting king eiders at Disko Island in early to mid-September (Frimer, 1994a, b). It is not known whether the pattern of female moult migration has changed, whether there is variation between years, or whether females were previously overlooked because they arrive when most of the male king eiders are in eclipse (basic) plumage (Frimer, 1994b). Some female king eiders are reported to moult their wing feathers near the southeastern breeding areas in the Canadian Arctic. Up to 10 400 moulting king eiders

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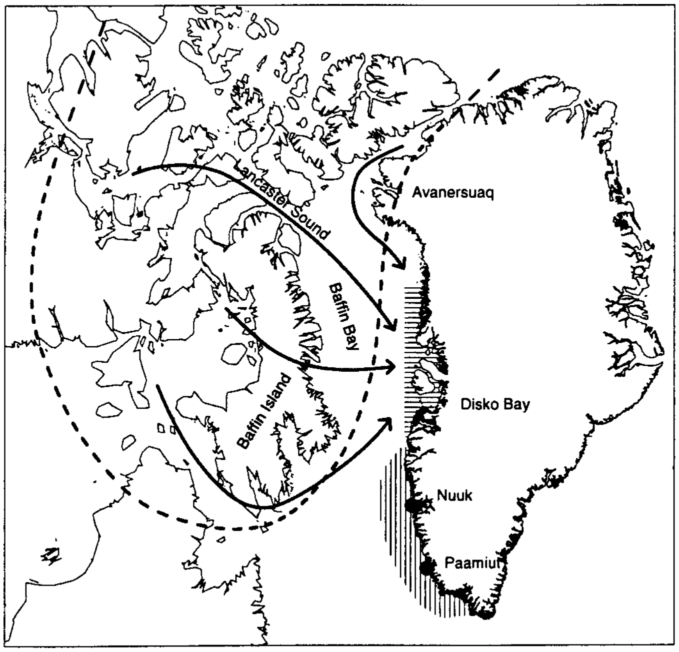

FIG. 1. Moult migration of king eiders (arrows) breeding within the broken line. The main moulting area is horizontally hatched, and the wintering area in Greenland is vertically hatched (redrawn from Salomonsen, 1990).

have been observed in eastern Lancaster Sound and western Baffin Bay (Tuck and Lemieux, 1959; McLaren and McLaren, 1982).

Little is known about the current size or trend of the population of king eiders moulting in western Greenland. In a survey of king eiders moulting at Disko Island, Frimer (1993, 1995b) estimated that 15 000–20 000 individuals were present in September 1990–92. Aqajarua/ Mudderbugten, the only moulting site at Disko Island from which historic estimates have been reported (Salomonsen, 1967), was almost abandoned in 1990–92 (Frimer, 1993).

The primary wintering areas for the eastern Canadian king eiders are southwestern Greenland and the Atlantic coast from Newfoundland south to Maine (Abraham and Finney, 1986). Ringing data indicate that male king eiders that moult in western Greenland then winter in southwestern Greenland (Salomonsen, 1967). On the basis of a boat survey, Durinck and Falk (1996) estimated that 280 000 king eiders were present in a small area (6000 km^2) outside Nuuk Fjord in February–March 1989. Observations during marine mammal surveys suggest the total number of wintering king eiders in the southwestern Greenland area to be at least 270 000 birds (Mosbech and Johnson, in press).

Concentrations of moulting waterfowl in coastal zones are vulnerable to oil slicks. This study was conducted as part of an environmental baseline program that will provide data for the planning and mitigation of oil exploration activities in western Greenland. The present paper reports the results of the first extensive survey of post-breeding king eiders in western and northwestern Greenland. From data collected during a three-year aerial survey study, we identified significant moulting sites and estimated the numbers of moulting king eiders. The avoidance behaviour shown by king eiders in response to airplanes (Frimer, 1994c; own observations) prompted a study of the optimal survey altitude, to find a trade-off between avoidance at low altitudes and reduced observation efficiency at high altitudes.

METHODS AND EQUIPMENT

Survey Design

The aerial surveys were designed to identify locations and numbers of moulting and post-breeding waterfowl along the western coast of Greenland, between Paamiut (62˚ N) and Avanersuaq (79˚ N) (Fig. 1). However, since fewer than 100 king eiders were seen south of 68˚ N, only surveys done between 68˚ N and 79˚ N are included in the present study (Fig. 2). A total of 25 survey days were flown in the area between 68˚ N and 79˚ N, within a time period of 12 days (23 August to 4 September) in 1993, 1994, and 1995. Approximately 16 500 km of flightlines sampled roughly 13 400 km of coastline. The Disko Island and Disko Bay area (68˚–71˚ N) was covered in all three years, and the area north of Disko Bay to Avanersuaq (79˚ N) was covered in 1994 and 1995. The survey routes were planned on the basis of previous observations (Salomonsen, 1950, 1967, 1968, 1979; Frimer, 1993), information on ringing localities (files at the Zoological Museum, University of Copenhagen), and local knowledge (Petersen, in press). Most effort was allocated to the outer coastal zone, where the risk of oil spills is highest; however, fjord areas likely to support major waterfowl concentrations were also surveyed.

We counted all birds observed along coastlines, covering a width of 1500–3000 m, depending on sea state. A fixed distance off shore could not be maintained because of the irregularity of the coastline. Line transect sampling (Buckland et al., 1993) was conducted in offshore areas of Disko Bay and in a few other offshore areas (total effort approximately 1300 km).

The reliability of our estimates depends on three major assumptions: first, that all post-breeding king eiders reside within 2000 m of the coast or in known shallow areas (<50 m depth); second, that all coastlines and shallows with significant numbers of king eiders were covered; and third, that all king eiders present were detected and correctly counted. The survey was designed with respect to these assumptions. The assumption that king eiders in wing moult stay near the coast or in shallow areas was tested by flying a number of offshore transects. Likewise, the assumption that all king eiders present were detected and correctly counted was tested by repeated aerial counts at various altitudes, complemented by concurrent ground counts and direct observations of the behavioural reactions of the birds to the approaching survey airplane.

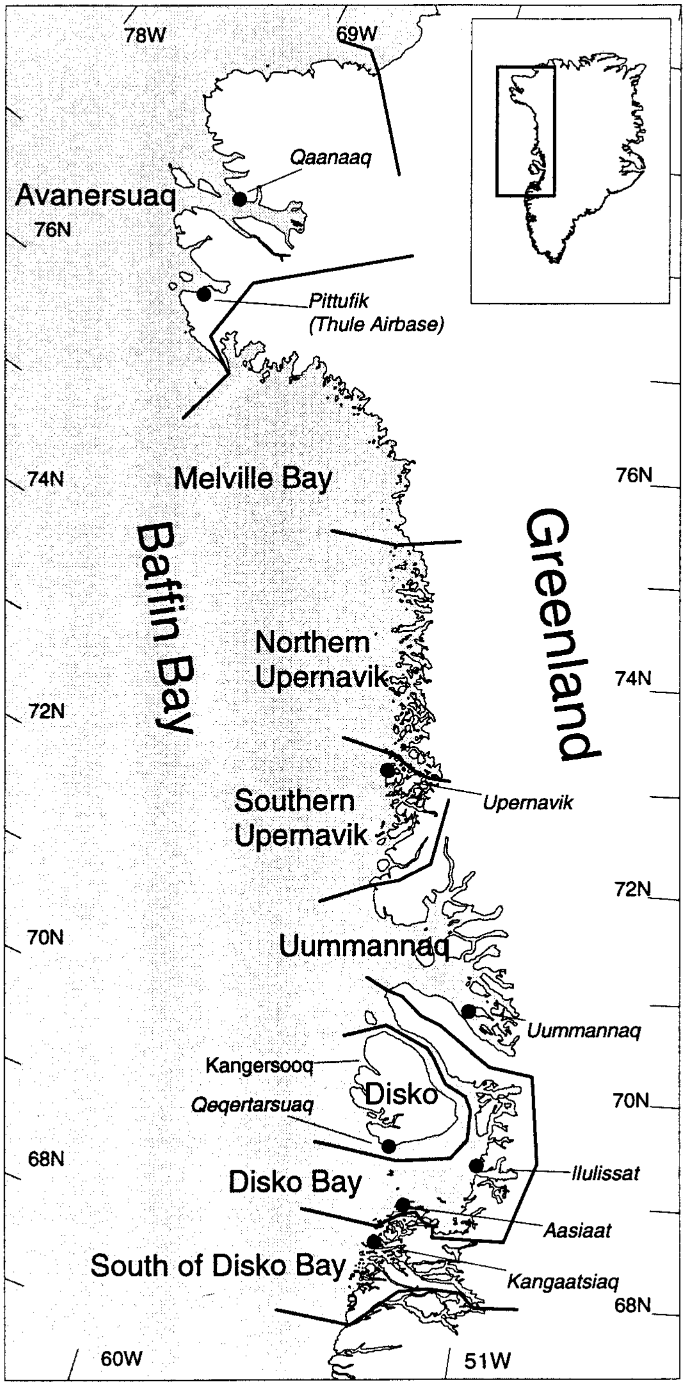

FIG. 2. Map of western Greenland north of 68° N, showing survey regions, towns (black dots), and the study site of Kangersooq.

Survey Procedures and Data Analysis

All surveys were conducted from a high-winged, twin engine Partenavia P68 observer aircraft equipped with a Plexiglas nose and bubble windows. Flying altitude was generally 80–125 m (250–400 feet) above sea level, with a ground speed of 150–170 km/h (85–95 knots). The noise emitted by the airplane peaks at 200 Hz, with a source level of 128 dB(A) (1/3-octave band in dB re 20 mPa @ 1 m) (L. Thiele, pers. comm. 1994). Geographical positions (Global Positioning System), together with radar altimeter measurements, were collected automatically by a portable computer. Observations were recorded on tape by means of a headset microphone, and an automatic time signal linked observations and position.

In 1993 and 1994, the survey crew consisted of three observers: a navigator/observer/photographer in the co-pilot seat and one observer in each rear seat. The navigator/observer photographed the flocks during the counting. In 1995, we reduced weight by using a two-observer survey crew to increase flight endurance. Longer flights were necessary, as there were no airports between 69° and 76° N. Observers had prior experience with flock size estimation and were trained with computer simulation (Wildlife Counting Simulation, 1986). Their observations were tested against photographic documentation (Mosbech and Glahder, 1990). Binoculars (7 × 42 and 6 × 20) were commonly used. During offshore transects, perpendicular distance of birds from the transect centre line was obtained by measuring the vertical angle with inclinometers.

All birds observed were recorded and identified to species when possible. However, since common and king eider are similar, some observations of females and eclipse plumage birds were recorded as unidentified eider (*Somateria* spp.). Flying or diving activity in a flock was recorded. In areas where surveys were repeated during the same year, the highest number recorded was used. Surveys were conducted only at low sea states (0–2 Beaufort scale).

The survey area was divided into 45 geographical sub-areas, which were grouped into eight regions. Using a GIS software package (Mapinfo Professional Ver. 4.1., 1996), we summarized the observed birds within sub-areas and calculated the coverage of coastlines from the flightline distance per length of coast within sub-areas (base-scale of digitized map 1:2 500 000, National Survey and Cadastre, 1994). A two-way ANOVA, followed by Tukey pairwise mean comparisons on log-transformed data (SAS, 1990), was used to analyze differences in mean densities (king eiders per km coastline covered) between years and between sub-areas.

The abundance of king eiders in West Greenland around 1 September was estimated from the largest number counted in each sub-area. Where different surveys covered significantly different parts of the same sub-area, the counts were combined by overlaying the geo-coded observations in a GIS.

Coastal Habitat Classification

The majority of the bedrock on the west coast of Greenland consists of Precambrian gneiss. Rocks, often with pocket beaches, dominate the coastlines. The shores in western Greenland are generally relatively steep. Beaches and foreshores consist of coarse clastic deposits, often dominated by boulders and gravel. However, extensive shore platforms with sandy and muddy sediments do occur

TABLE 1. King eiders in Kangersooq, Disko Island, counted from airplane at various altitudes. When sea state in the fjord varied during a survey, the range is given, and the area with the highest sea state is mentioned.

Date	Altitude (feet)	Time of day	Dive %[1]	King eider	Common eider	Eider spp.	Total	Sea state Beaufort
01 Sept.	1800	10:09	0	35	0		35	1
03 Sept.	600	11:56	29	3491	485	305	4281	0–1 inner fjord
01 Sept.	400	12:29	35	4042	338	0	4380	0–2 outer fjord
02 Sept.	400	09:17	8	**7008**[2]	6	0	**7014**	1
02 Sept.	250	12:10	15	**4527**	483	426	**5436**	0–1
03 Sept.	250	13:05	22	**4296**	641	280	**5217**	0–1 inner fjord
Mean of favourable counts (in bold)				5277			5889	

[1] Dive % = percent of the flocks counted from the airplane with diving activity.

[2] Bold indicates favourable counts, i.e., those taken from optimal altitude (250 and 400 feet) and with optimal sea state.

outside deltas and along more protected coasts, such as those near Aquajarua and around Naterneq/Lersletten (M. Rasch, pers. comm. 1997). Unfortunately, different bottom types have generally not been mapped in Greenland. Nautical charts (National Survey and Cadastre) with reconnaissance sounding tracks from inshore routes provide some bathymetrical information. These charts were used primarily to identify shallow areas. Classification of the coastal areas was based on direct observations from the airplane. Therefore these observations apply only to the uppermost few metres of water depth and indicate merely whether barren rock, coarse clastic deposits, or fine-grained sediments were found near the shoreline. On the basis of dominant coastal type, each geographical sub-area was classified in one of two categories: rocky coasts, with little or no fine-grained sediment at the shoreline, and sandy coasts, with extensive sandy or muddy areas (fine-grained sediments) at the shorelines.

The influence of coastal category on king eider distribution was tested by treating zero density data and non-zero density data separately. For non-zero density data, differences in mean density between coast types were tested by a t-test on log-transformed data (Zar, 1996). The proportion of zero density observations (sub-areas with no king eiders) was calculated for both coastal types, and the difference was tested using resampling (1000 times; Simon, 1997).

Behavioural Response Study

King eider behaviour was studied during undisturbed conditions and during overflights of the observer aircraft at four different altitudes in Kangersooq/Nordfjord (Fig. 2 and Fig. 5, sub-area 27; Table 1). The same flight path was replicated six times within three days. The latter observations were made to check survey efficiency: i.e., the effect of king eiders' avoidance behaviour (diving) versus the spotting efficiency of the airborne observers.

Two observers, from a coastal observation point 20 m above sea level and 100–500 m from the birds, recorded behaviour before, during, and after overflights, using scan-sampling (sensu Altmann, 1974). The following seven behaviour categories were used: diving (submerged), swimming, comfort behaviour (preening, sleeping), antagonistic behaviour, half-diving (head visible, body submerged), alert, and flying (or trying to take off). Before and after each overflight, behaviour was scanned during several 10 minute periods. Scanning periods were initiated at 20 minute intervals. Ten scans (1 per minute) were conducted during each scanning period. During each of the six overflights, each of the two coastal observers selected a flock of king eiders and dictated all changes in the birds' behaviour to a continuously running tape recorder. During the overflights, sound pressure levels were measured with a sound level meter (Brüel and Kjær Type 2205) at the observation point. The observers noted wind speed and direction, recorded sound pressure levels, and time-coded observations from the coast and from the airplane with synchronized watches.

The Kangersooq study site (in the Disko W sub-area) was divided into four sub-units, where ground counts were performed once or twice during aerial survey days to estimate visibility bias (Pollock and Kendall, 1987).

RESULTS

King Eider Response to Approaching Survey Airplane

Apart from distance, flock size, glare, and sea state, the airborne observers noted that efficiency of detecting king eiders was dependent on king eider response to the approaching survey airplane. On several occasions, flocks of king eiders dispersed by diving in different directions when the airplane was still a kilometre away. This behaviour was observed particularly in areas near human settlements and also when the survey airplane was flying at high altitudes (2000 feet). In remote areas (Kangersooq/Nordfjord (Fig. 5) and Umiarfik (Fig. 6)), avoidance diving was reduced, but to obtain reliable data, we still had to count birds several hundred metres ahead of the airplane.

During the behavioural study in Kangersooq, king eiders foraged mainly in the morning and rested at mid-day. Undisturbed feeding birds were submerged about 50% of

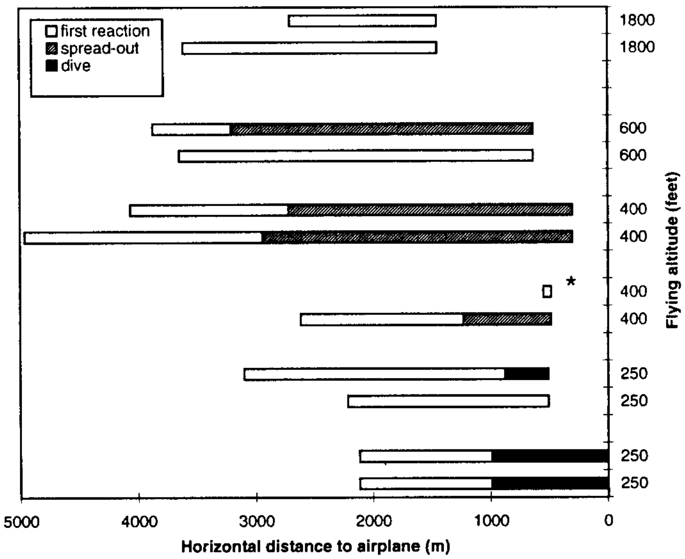

FIG. 3. King eider response to six airplane approaches at four different altitudes during surveys in Kangersooq. Each pair of bars represents two flocks continuously observed by two coastal observers during the same overflight. The left end of each bar represents the first reaction (alert or swimming) to the airplane; the space to the right of each bar represents the minimum distance at which the airplane passed the eiders. The pairs of bars are arranged in the same order as the corresponding counting results in Table 1. The asterisk (*) indicates a morning survey.

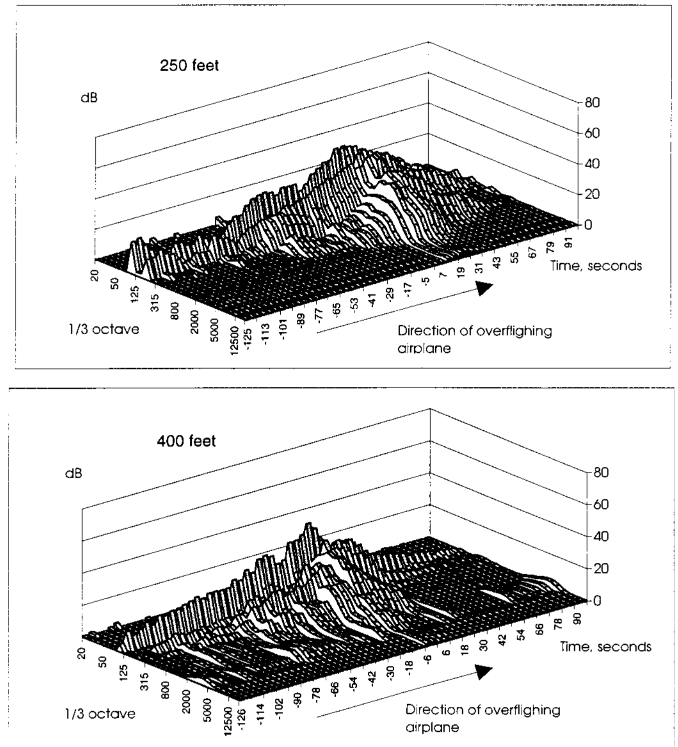

FIG. 4. Sound pressure levels recorded at the observation site before (negative time), during, and after airplane passage at 250 feet and 400 feet. Sound pressure levels have been corrected for ambient noise; ambient noise level spectra (in dB) have been subtracted.

the time before 9 a.m. (local time), but this percentage decreased to about 20% between 10 a.m. and 1 p.m., when most of the surveys were performed. Alert behaviour and antagonistic behaviour were rarely recorded among undisturbed birds (0.12% and 0.51%, respectively).

In Kangersooq, less than 1% of the king eiders observed from the airplane took flight. The avoidance diving response recorded from the airplane (Table 1) was measured roughly, because it was secondary to counting of birds. However, in the five surveys conducted at 250–600 feet altitude, the proportion of flocks displaying avoidance diving response differed significantly (chi-square test for test of proportion: chi-square = 41.8, df = 4, $p < 0.001$). During the single morning survey, a larger number of birds was counted and king eiders showed less avoidance diving than during the mid-day surveys (Table 1).

Seen from the coastal observation point, the first sign of king eiders' disturbance reaction to the approaching airplane was either alert behaviour or swimming away from the coast. Flocks began responding to the approaching airplane at distances between 500 and 5000 m (Fig. 3). For mid-day overflights (excluding the morning overflight at 400 feet), the reaction distance for the first reaction was found to be significantly greater at 400 feet than at 250 feet (t-test: t = 4.69, df = 4, $p = 0.009$, n = 6). For approaches at 400–1800 feet, however, the distance for the first reaction was found to be negatively correlated with flying altitude (Spearman correlation coefficient: $r_s = -0.956$, $p = 0.003$, n = 6).

The intermediate reaction of avoidance swimming and spreading out started up to 3 km from the approaching airplane. This reaction was not observed in all flocks or in approaches at an altitude of 250 feet. The strongest reaction of avoidance diving was observed approximately 1 km from the approaching airplane, at an altitude of 250 feet, but not at approaches at higher altitudes (Fig. 3). Avoidance diving typically started with all birds diving simultaneously. This preliminary dive was followed by a period during which more than 50% of the birds were submerged until after the plane had passed.

As expected, sound pressure levels showed a steeper increase in noise when approaching at lower altitudes (Fig. 4). The maximum noise recorded was 65 dB(A) at an altitude of 250 feet and a lateral distance of 400 m. At the observation site, the noise level peaked at 12 and 20 seconds after the airplane passed at an altitude of 250 feet (n = 2), and 8 seconds (n = 4) before the airplane passed at an altitude of 400 feet or more. The later peak in airplane noise at 250 feet flying altitude corresponds to the late but strong reaction that king eiders showed to airplane approaches in this altitude (Figs. 3 and 4).

Repeated Counts

The eiders in Kangersooq were counted in six aerial surveys, at four different altitudes (Table 1). Detection at 1800 feet was very poor. For the other altitudes tested, altitude and survey time (categorized as "morning" from 9:00 to 10:00 a.m., or as "noon" from 11:00 a.m. to 2:00 p.m.) were not found to have a significant effect on the total number of eiders or of king eiders alone

TABLE 2. Counts of eiders in inner Kangersooq (3 inner sub-units), Disko Island, from the coast and from the airplane. The total ground count is based on counts performed in sub-units 1–3 in September 1994. The airplane total count is based on counts of the same sub-units on the same day as the ground counts.

Survey method	King eider	Common eider	Eider spp.	Total
Ground	4656	200	15	4871
Airplane	4152	322	37	4511

(Kruskal-Wallis test: H = 2, p = 0.37, n = 5 and Mann Whitney U-test: U = 4, p = 0.16, n = 5). The survey at 600 feet resulted in the next lowest count. The two counts at 400 feet gave quite different results, possibly because in the morning there was less avoidance diving, and at mid-day a higher sea state (Beaufort 2) in the westernmost part of the fjord lowered detection efficiency (Table 1). Excluding counts at 1800 feet and 600 feet, and the count at 400 feet where observation conditions were suboptimal, the remaining three counts averaged 5277 king eiders (range = 4296 to 7008). The same counts for all eiders (king eider + common eider + eider sp.) averaged 5889 birds (range = 5217 to 7014).

Ground counts showed that eiders moved between sub-units in the fjord both during days and between days, thus hampering comparisons of ground counts and aerial counts. For ground counts and aerial counts of sub-units in the inner fjord conducted the same day (Table 2), the total aerial count of king eiders underestimates the total ground count by 11%.

Mean flock size recorded during the ground observations was 27 (range 1–71). Sex was determined in 35 flocks: of 956 birds, 61% were females and 39% were males. On the basis of wing flap recordings, 17% of the females and 73% of the males (n = 495) were in wing moult (newly shed to half-grown flight feathers). However, since wing-flapping in non-moulting king eiders is about 1.75 times higher than in moulting king eiders (Frimer, 1994b), the proportion of moulting birds is likely to be an underestimate. Photos of king eider flocks taken from the airplane did not aid in flock size estimation because of the avoidance behaviour.

Inshore/offshore Distribution

In the aerial survey along coastlines, nearly all king eiders were observed within 1 km of the coast, even though the survey covered a 1500–3000 m coastal path. Offshore transects more than 2 km from the coast confirmed this observation. Outside the large, shallow Aqajarua, only five flocks of king eiders (mean flock size = 125) were observed on approximately 700 km of transect line, and all the birds were flying. While in Aqajarua (Fig. 5, sub-area 28), eight flocks (mean flock size 55) were observed on 180 km of transect line distributed from 2 to 10 km from the coast, and half of the flocks observed were not flying.

TABLE 3. Total counts of common eider, king eider and unidentified eider (eider spp.) in the 1993–95 surveys. Allocation of eider spp. observations to king eiders is based on the proportion of common eiders and king eiders in each survey sub-area.

Year	1993	1994	1995
Common eider	8606	44966	41212
King eider	5893	16216	9147
Eider spp	207	1834	2325
Eider spp allocated to king eiders	80	1059	240
King eider total	5973	17275	9387

West of Tukingassoq (72°10′N), in the Southern Upernavik region (Fig. 6, sub-area 17), a concentration of common eiders was observed extending several kilometres off the coast; however, no king eiders were observed on approximately 60 km of transect line.

Regional Distribution and Fenology

Total counts of king eider, common eider, and unidentified eider (eider spp.) for the three survey years 1993, 1994, and 1995 are reported in Table 3. Observations of unidentified eiders account for 3% of the total counts, and have been referred to common eider counts and king eider counts in proportion to observations of common eider and king eider in each geographical sub-area (Table 3). King eider counts and survey coverage in each sub-area are given in Table 4.

Most of the king eiders were observed at Disko Island (62%), and in southern Upernavik (16%). They were found at several localities, with considerable variation in numbers from year to year (Table 4, Fig. 5). At Disko Island, where there are three years of survey with a nearly 100% coverage, data have been used to analyse for difference in mean densities (king eiders per km) between years and between sub-areas (two-way ANOVA on log-transformed data). Data showed no significant difference between years (F = 0.57, p = 0.59, n = 14), but a significant difference was found between sub-areas (F = 4.67, p = 0.04, n = 14). King eider density on western Disko (sub-area 27) was significantly higher than on northeastern and southern Disko (sub-areas 26 and 30; Tukey pairwise mean comparisons: Mean Square Error = 0.66, $p < 0.05$, n = 14).

Very few king eiders were observed during the surveys in the northern regions, Avanersuaq and Melville Bay. However, supplementary observations of large flocks of males in the northern regions in mid-July (Table 7) indicate a possible earlier moult in this area.

The influence of coastal type on king eider density was tested for geographical sub-areas within the main distribution range from the Northern Upernavik region to the Disko Bay region. Grønne Ejland (sub-area 40) was omitted from the test because only flying birds several kilometres from the coast were observed. Analysis of the non-zero density showed that mean density was dependent on the

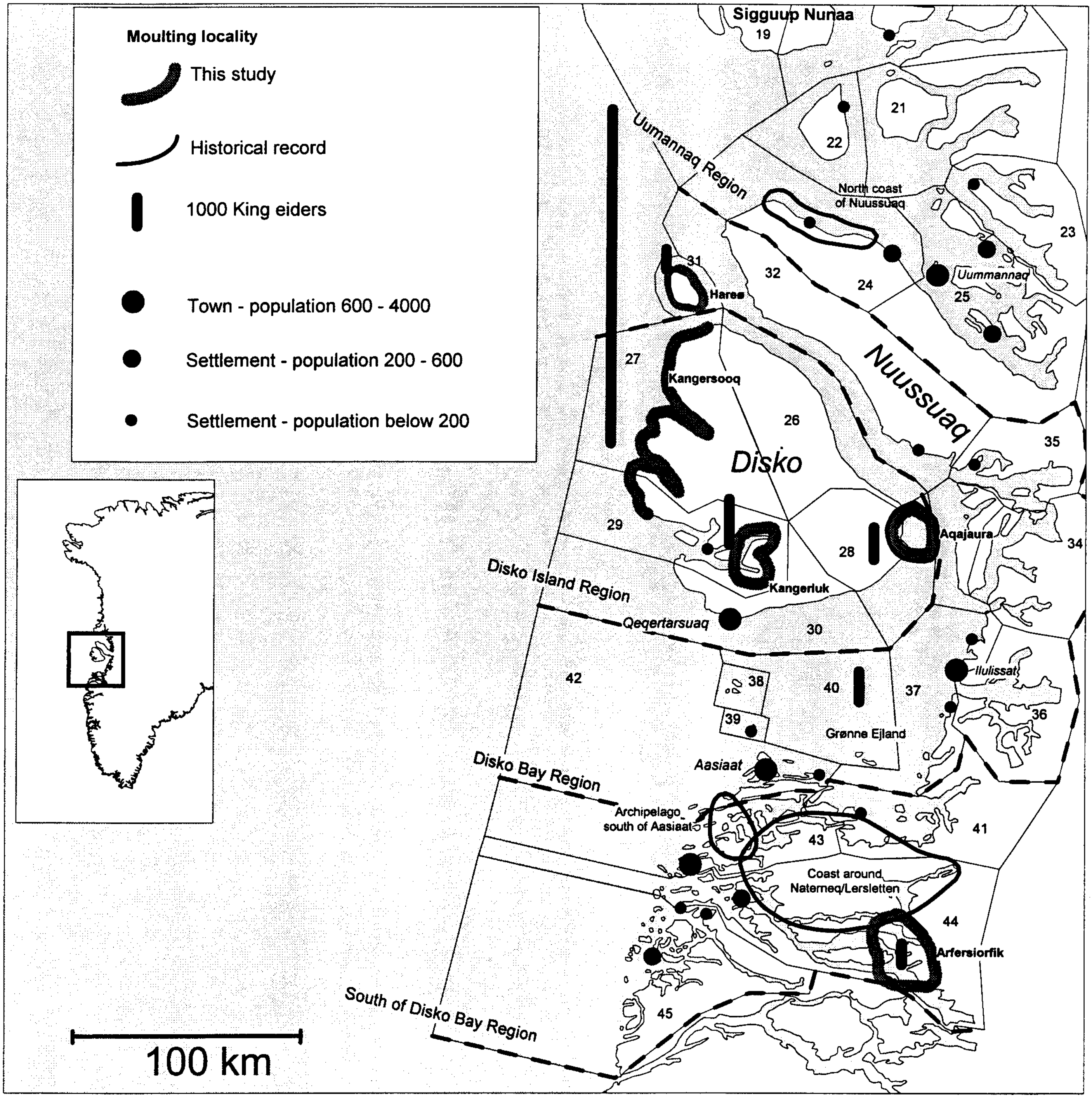

FIG. 5. Main king eider moulting sites and geographical survey sub-areas in the South of Disko Bay, Disko Bay, Disko Island, and Uummannaq survey regions (68˚N to 71˚N). The black vertical bars represent the combined counts (1993 – 95) of king eiders in each geographical sub-area, for counts >500 (Table 4). The length of the bar is proportional to the number of king eiders (see legend). The bold grey lines show the main moulting sites identified during aerial surveys in 1993–95. The thin black lines show historical localities (listed in Table 8).

coast type (t-test on log-transformed data: t = 2.23, $p = 0.04$, n = 17), and the highest mean density was found for coasts with fine-grained sediments. This result was supported by a lower proportion of zero density observations (sub-areas with no king eiders) for sub-areas with fine-grained sediment than for sub-areas with rocky coast, although these data did not differ significantly ($p = 0.09$, resampling 1000 times).

In the Avanersuaq region, surveys covered most of the coastline; however, only 69 king eiders were observed during surveys in 1994, and only 120 in 1995. At Hakluyt Ø, no king eiders were observed during the late August surveys in 1994 and 1995 (Fig. 7, sub-area 3); however, up to 380 king eiders were observed there in early August 1996, including at least 40 birds in wing moult (K. Falk, A. Frick, and K. Kampp, pers. comm.1996; Table 7). On the

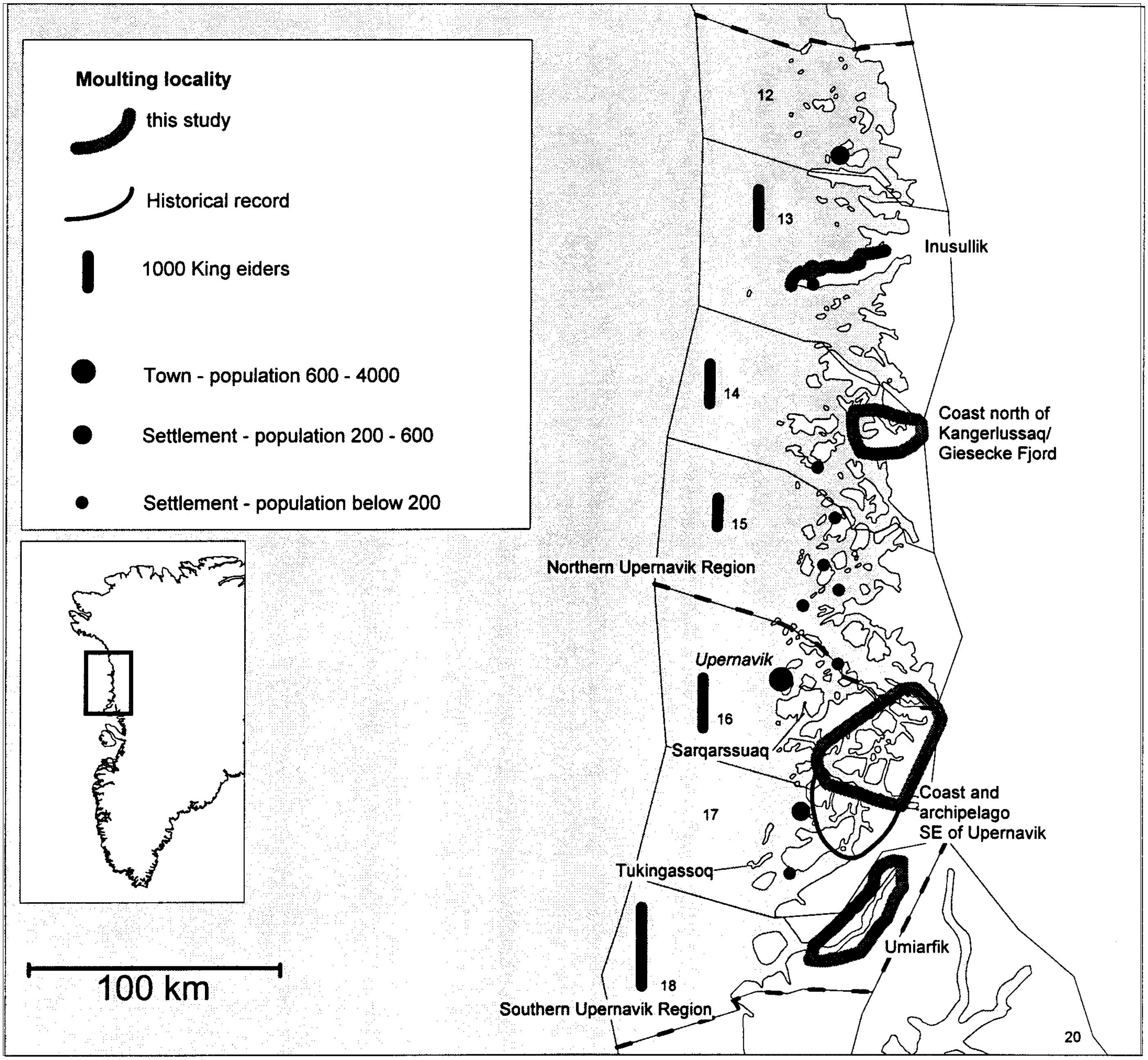

FIG. 6. Main king eider moulting sites and survey sub-areas in the survey regions of Southern Upernavik and Northern Upernavik (71° to 75° N). Black vertical bars represent the combined counts (1993–95) of king eiders in each sub-area (for counts > 500) (Table 4). The length of the bar is proportional to the number of king eiders (see legend). The bold grey lines show the main moulting sites identified during aerial surveys in 1993–95. The thin black lines show historical localities (Table 8).

north coast of Inglefield Bredning (sub-area 4), on 1 July 1975, Thing (1976) had observed two flocks of king eiders, in total about 200 birds, mostly adult males not yet in wing moult.

Very few king eiders were observed in the Melville Bay region. Dominated by glacier fronts, the area is hardly suitable for moulting king eiders. However, large parts of the mainland coast could not be surveyed because of strong local winds near the glacier fronts. Drift ice—and in some years, fast ice—occurs in Melville Bay throughout summer and autumn. Strong winds and freezing temperatures may pack and consolidate the ice in the coastal zone, making foraging areas inaccessible. However, less ice than average was present in 1994 and 1995 (Valeur et al., 1996).

The Northern Upernavik region includes extensive archipelagos, and the combined surveys in 1994 and 1995 covered only about half of their coastlines. The birds were observed in small flocks, primarily on the mainland coast and the inner archipelagos. The largest concentration was found on the south coast of Innusulik Bay (Fig. 6, sub-area 13), where 556 king eiders were observed, and on the complex mainland coast north of Kangerlussuaq/Giesecke Isfjord (Fig. 6, sub-area 14; 73°45′ N), where 487 king eiders were observed.

TABLE 4. Number of king eiders observed (count) and estimated coverage of coastline (coverage) in regions and geographical sub-areas during aerial surveys in 1993 (24–30 August), 1994 (23 August–3 September), and 1995 (24 August–4 September).

Region / Sub-area	Coast length	1993		1994		1995		Combined count 1993–95[1]		Relative density	Coast type[2]	Historical observations[3]
	km	coverage %	count	coverage %	count	coverage %	count	coverage %	count	birds/km		
Avanersuaq												
1 Inglefield Land N	288	nc[4]		nc		10	0		0	0.00		
2 Inglefield Land S	140	nc		nc		90	0		0	0.00		
3 Inglefield Bredn. V	396	nc		60	7	80	120		120	0.38		
4 Inglefield Bredn. E	581	nc		50	0	60	0		0	0.00		
5 Wolstenholme Fj. N	139	nc		100	32	100	0		32	0.23		
6 Carey Øer	31	nc		100	0	100	0		0	0.00		
7 Wolstenholme Fj. S	163	nc		60	25	70	0		25	0.22		
8 Conical Rock	156	nc		100	5	90	0		5	0.03		
	1894			50	**69**	66	**120**		**182**			
Melville Bay												
9 Savissivik	428	nc		10	0	60	0		0	0.00		
10 Melville Bugt	526	nc		20	0	30	0		0	0.00		
11 Kap Seddon	362	nc		20	100	60	0		100	0.46		
	1316			17	**100**	48	**0**		**100**			
Northern Upernavik												
12 Djævlens Tommelf.	356	nc		30	200	30	15	60	215	1.01	r	
13 Ryders Isfjord	545	nc		25	20	30	636	55	656	2.19	r	
14 Kap Shackleton	593	nc		35	538	20	102	55	640	1.96	r	
15 Tasiussaq	719	nc		10	16	35	332	45	348	1.08	r	
	2213			24	**774**	29	**1085**	**53**	**1859**			
Southern Upernavik												
16 Upernavik	769	nc		20	790	30	724	40	1514	4.92	r	t
17 Prøven	357	nc		50	292	20	0		292	1.64	r	t
18 Svartenhuk N	212	nc		75	2394	70	1370		2394	15.06	s	
	1338			37	**3476**	34	**2094**	**48**	**4200**			
Uummannaq												
19 Svartenhuk S	103	nc		20	0	20	0		0	0.00	s	
20 Karrats fjord	557	nc		100	13	100	0		13	0.02	r	
21 Kangerlussuaq	333	nc		nc		35	0		0	0.00	r	
22 Ubekendte Ejland	82	nc		80	0	nc			0	0.00	r	
23 Ukkusissat	264	nc		nc		35	0		0	0.00	r	
24 Nuussuaq N	95	15		20	0	40	0		0	0.00	s	h
25 Uummannaq	538	nc		nc		15	0		0	0.00	r	
	1972			15	**13**	27	**0**		**13**			
Disko Island												
26 Disko NE	114	25	0	100	174	100	236		236	2.07	s	
27 Disko W	169	100	1374	100	10663	100	3460		10663	63.09	s	
28 Disko E	49	100	1108	100	714	100	159		1108	22.61	s	t
29 Disko SW	218	100	1483	100	1058	100	667		1483	6.80	s	
30 Disko S	97	100	65	100	234	100	319		319	3.29	s	
	647	87	**4030**	100	**12843**	100	**4841**		**13809**			
Disko Bay												
31 Hareø	43	100	289	100	0	100	640		640	14.88	s	
32 Nuussuaq	168	nc		100	0	35	0		0	0.00	s	
33 Arveprinsen Ejland	105	nc		25	0	nc			0	0.00	r	
34 Attaa Sund	286	40	0	20	0	nc			0	0.00	r	
35 Torsukattak	208	nc		10	0	nc			0	0.00	r	
36 Jakobshavn Isfjord	333	20	0	nc		10	0		0	0.00	r	
37 Christianshåb	145	80	0	80	0	40	0		0	0.00	r	
38 Kronprinsens Ejland	24	100	11	nc		nc			11	0.46	r	
39 Hunde Ejland	9	100	0	nc		nc			0	0.00	r	
40 Grønne Ejland	22	100	1010	100	0	100	0		1010	45.91	r	
41 Sydostbugt	302	30	38	nc		50	0		38	0.25	s	t
42 Aasiaat	204	20	350	3	0	35	0		350	4.90	r	
	1849	28	**1698**	25	**0**	24	**640**		**2049**			
South of Disko Bay												
43 Kangaatsiaq	518	30	0			5	0		0	0.00	r	h
44 Afersiorfik	970	2	85			35	607		607	1.79	s	t
45 Attu	666	22	161						161	1.10	r	
	2154		**246**				**607**		**768**			
TOTAL	**13383**		**5974**		**17275**		**9387**		**22980**			

[1] When the same areas were surveyed more than once, the highest counts are used in the combined count. When different parts of a sub-area were surveyed in different years, the combined coverage and count are given.

[2] Coasts are categorized as fine-grained sediment (s) or rocky (r) types. See text for further explanation.

[3] Historical observations are categorized as thousands recorded (t) or hundreds recorded (h). Details are given in Table 8.

[4] nc = not covered.

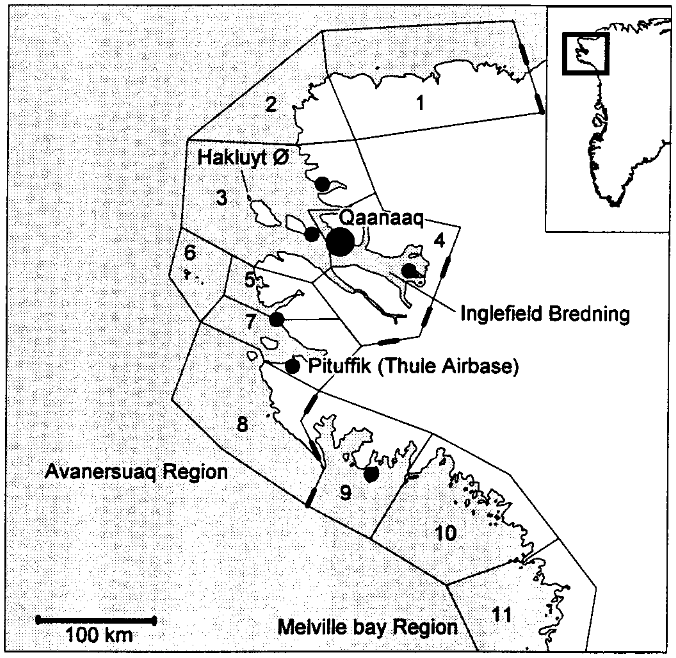

FIG. 7. Survey sub-areas and place names mentioned in the text in the Melville Bay and Avanersuaq survey regions (75° N to 79°N).

The Southern Upernavik region has important moulting sites in the southern part, and nearly all of the southern coastline was covered. Most king eiders (2280 birds) were observed in Umiarfik (Fig. 6, sub-area 18), a remote, shallow fjord 60 km long that previously had not been recognized as a king eider moulting site.

A number of small bays and fjords southeast of Upernavik town (Fig. 6, sub-areas 15 and 16) had been used for catching and ringing flightless king eiders between 1948 and 1972 (Salomonsen, 1979). Most of these sites were surveyed in 1994, and all were surveyed in 1995; 1077 king eiders were observed in 1994, and 655 in 1995.

Only 13 king eiders were observed during the surveys in the Uummannaq Fjord region, despite considerable effort in 1994 and 1995 (Table 4).

The coastline of the Disko Island region was almost fully covered each year during surveys in 1993, 1994, and 1995. The largest numbers of king eiders observed during the surveys were found in this area. The major moulting sites were located in fjords in the Disko West sub-area; i.e. Kangersooq/Nordfjord, Qasigissat, Akulliit/Mellemfjord, (Fig. 5, sub-area 27); and at Eqaluit/Nordre Laksebugt and Kangerluk/Diskofjord in the Disko Southwest sub-area (Fig. 5, sub-area 29).

Most of the coastline in the Disko Bay region was covered at least once during the surveys of 1993–95. King eiders were only found in moderate numbers in a few sub-areas (Table 4).

The outer coastline from Disko Bay to Paamiut (62°N) was surveyed in 1993: of the 309 king eiders observed, 246 were north of 68°N. The large fjord—Arfersiorfik, just south of Disko Bay—was surveyed in 1995. A total of 606 king eiders were observed, mainly in the inner remote parts south of Lersletten/Naternaq (Fig. 5, sub-area 44).

Abundance

Without correcting for coastlines not covered by the surveys, the raw count was 22 980 king eiders. This number was derived by adding the maximum counts from each sub-area and combining counts where surveys covered different parts of a sub-area.

The Northern Upernavik region is a rather uniform archipelago, where about 50% of the coastline was covered, with approximately equal effort to the outer zone and the inner zone close to the mainland. It was assumed that the king eider density observed in each sub-area was representative and therefore could be extrapolated to the total coastline length in that sub-area (Table 4). This extrapolation added 1629 king eiders to the combined counts (Table 5), bringing the total number of king eiders to 24 609.

Extrapolations using the fraction of the coastline covered in each sub-area require that coastlines be sampled systematically or randomly, which was not the case. However, such extrapolations give a total estimate of 30 396, which is only about 25% greater than the original estimate, probably because a large fraction of the coastline sample came from important moulting areas.

DISCUSSION

Survey Efficiency

Since king eiders exhibit avoidance behaviour when an airplane is approaching, observers risk underestimating bird numbers during aerial surveys. Birds submerged during passage are not recorded, and those spreading out during avoidance swimming (and diving) are less likely to be detected.

During the experiment in Kangersooq, the optimal flight level with the highest eider counts was found to be 250–400 feet (Table 1). King eiders reacted differently to planes approaching at altitudes of 250 feet and 400 feet: approaches at 250 feet triggered stronger avoidance behaviour; however, birds did not respond until the plane was closer to them. In response to mid-day approaches at 600 feet and 1800, avoidance behaviour was also delayed, but weaker than at 250 feet (Fig. 3). However, observer detection efficiency was apparently lower at 600 feet, and was very low at 1800 feet.

It is worth noting that avoidance reaction was less and more eiders were counted in the morning, when king eiders forage, than at mid-day, when most king eiders rest (Table 1). About 50% of the king eiders are submerged during undisturbed foraging. However, they were apparently taken by surprise and ceased diving during the airplane approach (Table 1). The response seems similar to

TABLE 5. Estimate of king eider abundance in the eight regions. Estimate 1 is based on the combined counts in all sub-areas (Table 4). For the Northern Upernavik region only, the density found in surveyed areas was extrapolated to the coastlines not covered, adding 1629 birds to the estimate. Estimate 2 assumes a detection efficiency of 75% except in Kangersooq at Disko Island, where the highest count was used.

Region	Coast length (km)	Combined count 1993–95	Estimate 1	Estimate 2
Avanersuaq	1894	182	182	243
Melville Bay	1316	100	100	133
Northern Upernavik	2213	1859	3488	4651
Southern Upernavik	1338	4200	4200	5600
Uummannaq	1972	13	13	17
Disko Island	647	13809	13809	16075
Disko Bay	1849	2049	2049	2732
South of Disko Bay	2154	768	768	1024
TOTAL	13383	22980	24609	30475

Schiøler's (1926) description of how Inuit hunters in kayaks approached king eiders only during foraging, to take advantage of reduced alertness and/or exhaustion. Forage dives are less than one minute in duration (Frimer, 1994a), so all submerged king eiders will surface within 2.5 km of the approaching airplane (speed 2.5 km/min.) and apparently cease diving. It is therefore preferable to conduct surveys in the morning.

The repeated counts in Kangersooq showed that under favourable observation conditions, aerial counts correspond with ground counts and can be fairly reproducible. However, since eiders move between sub-units in Kangersooq, ground counts cannot be considered a complete and accurate control count. It is believed that the highest aerial count obtained (7008) was closest to the true number, since the risk of getting a count higher than the true number is small. The mean of the favourable counts was 75% of the highest count (Table 1). Thus, 75% was taken to be a crude estimate of the average detection efficiency experienced in Kangersooq. In areas with more disturbance, avoidance behaviour was more pronounced and a higher proportion of king eiders remain undetected. On the basis of experience from aerial surveys where a detection function was established (Heide-Jørgensen et al., 1992) and observer efficiency measured in double observer-experiments (Aastrup and Mosbech, 1993), it is estimated that between 60% and 80% of the king eiders in the coastal zone are detected, depending mainly on intensity of avoidance response and sea state.

Frimer (1994c), who observed moulting king eiders at Disko, noted alert behaviour and swimming in response to an airplane passing several kilometres above the water and escape swimming and diving in response to a passing boat. Avoidance behaviour of moulting ducks and its implications for aerial surveys were described by Joensen (1973, 1974) in a study of moulting sea ducks in Danish waters. These surveys also relied on optimal observation conditions; sometimes moulting ducks had to be counted from several kilometres away, before avoidance diving started. Prestrud (1991) summarized the summer distribution and population size of king eiders in Svalbard, partly on the basis of aerial surveys from a helicopter. No mention was made of any special survey problems in relation to moulting birds. King eiders did dive in his study, but not at distances where detection became a problem. When a flock was detected, the helicopter hovered near the flock and waited until the birds surfaced and were counted (Vidar Baggen, pers. comm. 1997). The apparently reduced avoidance response, compared to that observed in the present study, may have been due to a hunting ban on Svalbard since 1978 (Norderhaug, 1989).

The difference in avoidance behaviour observed in West Greenland between king eiders in remote areas and those in areas closer to towns and settlements is probably a function of hunting. The hunting season for king eiders opens on 15 August, and although herding of flightless birds is prohibited, hunting in the moulting areas is generally not restricted. The range of hunters, often limited by the amount of fuel they can carry along in outboard motorboats, is usually less than 50 km.

Offshore transects confirm the assumption that during wing moult, king eiders stay within 2 km of the coast, or close to shallow areas where they can forage at the bottom. However, some king eiders that are able to fly may be found further offshore. Results from ship-based offshore transects in Disko Bay and Uummannaq in August and September support the conclusion that there are few king eiders more than 2 km from the coast (Durinck and Falk, 1996; own observation).

It is concluded that the survey efficiency is sufficient to give a reliable picture of the distribution of moulting king eiders at the end of August and to allow a rough estimate of abundance.

Distribution and Habitat Demands

The surveys identified king eider concentrations in late August. Major concentrations were found at Disko Island and Southern Upernavik, where a new major moulting site was discovered at Umiarfik. The most crucial requirements for a moulting area are considered to be sufficient food at an adequate water depth, safety from predation, and, in the Arctic, that there is no risk of flightless birds being overtaken by new ice (Salomonsen, 1968). It is also considered an advantage that the moult be completed before the end of October, at a time when the birds still can satisfy their energy demands through daylight foraging (Frimer, 1994c).

The king eider may show large seasonal variation in diet, often feeding in deep waters, possibly up to 55 m in depth (Cramp and Simons, 1977). At Disko Island, Frimer (1995a, b) found that king eiders foraged mainly at depths of 15–25 m, spending about 78% of the foraging time over soft bottom and about 22% over hard bottom. This pattern was also reflected in stomach contents, which consisted

TABLE 6. King eiders observed in the Disko Island region. Coastal coverage was 100% except for Disko NE, where coastal coverage was 25% in 1993.

Sub-area	Code	Coast length (km)	1993	1994	1995	Combined 1993–95	Estimated abundance[1]	1990–92 July-September (1)	1976 July (2)	1975 July (2)	1949 and 1954 August (3)
Disko NE	26	114	0	174	236	236	315	(500–1000 assumed)			
Disko E[2]	28	49	1108	714	159	1108	1477	4000–4800			
Disko S	30	97	65	234	319	319	425	100–200			
Disko SW	29	218	1483	1058	667	1483	1977	2700–3400			
Disko W	27	169	1374	10663	3460	10663	11881	8000–10500			
Total Disko Island		647	4030	12843	4841	13 809	16075	15300–19900			
Aqajarua (Disko E)			1023	469	104			max. 400	2500	2800	approx. 30 000

[1] Estimated numbers from (1) Frimer, 1993; (2) Boertmann, 1979; and (3) Salomonsen, 1967 (and unpublished field notes, Zoological Museum of Copenhagen) are given for comparison.
[2] Aqajarua/Mudderbugten is a locality in the Disko E sub-area.

mainly of 20–40 mm small soft bottom bivalves, such as *Mya truncata, Serripes groenlandicus*, and *Cardium ciliatum* (Frimer, 1994a, 1997). Frimer further concluded in those studies that food was not a limiting factor for the king eiders at Disko. Little is known of the food sources available in other areas, but the major moulting sites identified by the surveys presented here all appear to have unconsolidated, fine-grained sediments near the shoreline, even though rocky coastlines dominate in West Greenland. Thus, sediment-living fauna seem to be an important habitat requirement. However, in Sarqarssuaq (Fig. 6, sub-area 16), moulting king eiders were observed in an area dominated by rocky coast in the first half of July. During this period, king eiders may feed on capelin (*Mallotus villosus*) eggs, as observed along the coast of northern Norway (Gjøsæter and Sætre, 1984). The area southeast of Upernavik (Fig. 6, sub-area 16) is considered to be a major spawning area for capelin (Petersen, in press).

Man is probably the most important predator of the moulting king eiders. The reported bag record for 1993 was 86 988 birds (both king and common eiders), with 5% identified as king eiders (Greenland Home Rule, 1995). However, since common eiders and king eiders are not reliably separated in the bag reports, the total king eider harvest is probably much larger. In addition to mortality, hunting causes disturbance (Madsen, 1995). The most important moulting sites found in this survey are located where hunting and disturbance are considered to be low, i.e., far from towns, settlements, and boat routes. Aqajarua/Mudderbugten (Disko East; see Fig. 5) was formerly the most important moulting site. Today it is almost abandoned as a moulting site (Table 6), and is exploited mainly by birds capable of flying. Aqajarua is easily reached from Ilulissat, the largest town in the region, and is considerably trafficked by small boats. In addition, a scallop trawler has been operating in the area for several years.

Other major moulting sites mentioned in the older literature are listed in Table 8. Practically no king eiders were observed at what were considered to be the most disturbed of these sites: the north coast of Nuussuaq (Fig. 5, sub-area 24), the archipelago south of Aasiaat (Fig. 5, sub-area 43), and the north and west coasts of Naterneq (Fig. 5, sub-areas 41, 43, and 44). Numbers were apparently reduced at the more remote sites, i.e., the fjords east of Upernavik (Fig. 6, sub-area 16) and east and south of Naterneq (Fig. 5, sub-area 44). However, before the hunting season in July 1993, Gilchrist (pers. comm. 1996) observed 3000–4000 moulting king eiders at Sarqarssuaq, only 25 km from Upernavik town (Table 7, Fig. 6).

It is well known that disturbance from human activities can affect the distribution of waterfowl (Madsen, 1995), as seems to be the case here. However, because we do not know if the birds find equally suitable space, it is difficult to assess the ultimate impact of a changed distribution at the population level.

The risk of ice formation may explain the lack of moulting king eiders observed in the inner fjords of Uummannaq and on other shores close to the ice cap further north. For the area north of Disko Bay, new (temporary) ice can be formed in the inner fjords during clear, calm nights in late August. New ice formation probably occurs regularly from the last half of September, most frequently in the northern part of the area (Kjeld Q. Hansen, Danish Meteorological Institute, pers. comm. 1997). This assumption is consistent with local knowledge stating that in the inner parts of fjords with glaciers, temporary ice may form even in summer (Petersen, in press). Two observations of moulting eiders found drowned under new ice have been reported: on 8 September 1987, 12 common eiders in Kangerlluarssuk in the Uummannaq region (NERI, 1983–88); in late October 1992, several king eiders in Kangerluk, western Disko Island (Frimer, 1994c). These examples indicate that the formation of new ice is a hazard to moulting eiders even though this new ice quickly disappears with wind and wave action.

Abundance

Assuming that there are approximately 7000 king eiders in Nordfjord, and that 75% of the birds are detected in

TABLE 7. Unpublished supplementary observations of king eiders in western Greenland in summer and autumn. Observations are arranged from north to south. Observations from Disko Island are included in Table 6.

Region/Locality	Sub-area	Date	Numbers	% Male (adult)	Wing Moult[1]	Reference[2]
Avanersuaq						
Hakluyt Ø (77˚30′N)	3	July-August 1996	380	–	+	3
Northern Upernavik						
Inusullik Bay (74˚15′N)	13	12–13 July 1994	328	61	+	1
Archipelago 73–74˚N	14–15	13–14 July 1994	185	81	+	1
Southern Upernavik						
Northwestern archipelago	16	9–10 July 1994	579	6	n	1
Sarqarssuaq (72˚40′N)	16	first half of July 1993	3–4000	100	++	4
Archipelago (72˚15′N)	17	7–8 July 1994	63	6	n	1
Uummannaq						
Karrat (71˚40′N)	20	early September 1983	15	93	++	2
South coast of Sigguup Nuna (71˚25′N)	19	8 July 1994	350	2	n	1
Ukkusissat (71˚15′N)	23	early September 1983–88	13	92	++	2
North coast of Nuussuaq (70˚50′N)	24	1 July 1994	57	4	n	1
Disko Bay						
South coast of Nuussuaq (70˚30′N)	32	1 July 1994	116	1	n	1

[1] Wing moult: ++ most, + some, n none, – unknown.

[2] Reference: 1 = own observations during a ship-based seabird colony survey at the outer coast between 70˚ and 74˚ N. 2 = NERI unpublished field reports, 1983–88. 3 = Falk, Frick, and Kampp, pers. comm. 1996. 4 = Gilchrist, pers. comm. 1996.

the rest of the survey area, the total number of birds is estimated at 31 000, with 16 000 at Disko Island. The estimate for Disko Island is in accordance with Frimer's (1993) estimate of 15 300–19 900 king eiders (Table 6), based on boat and land-based surveys in 1990–92.

Assuming that the detection efficiency for the whole area is within a range of 60–80%, the total number of moulting king eiders is estimated at 30 000–40 000. Compared to estimates of "some hundred thousand" (Salomonsen, 1968), and "a minimum of 200 000" (Salomonsen, 1967) moulting males and immatures in the area, the surveys presented here indicate a considerable decline, even if the estimates of Salomonsen are considered rough. However, compared to estimates of 270 000 king eiders wintering in Southwest Greenland in 1981–82 (Mosbech and Johnson, in press) and 280 000 king eiders wintering in a small area in Southwest Greenland in 1989 (Durinck and Falk, 1996), it appears unlikely that the decrease in the number of moulting birds observed reflects only a general population decline. Other plausible explanations of the revealed discrepancy are either that a significant part of the wintering population no longer moults in West Greenland, or that many king eiders moult earlier than 1 September and leave the area, at least the coastal zone, after wing moult. The surveys presented here represent a snapshot of the numbers present close to the time for the peak in numbers at Disko, previously recorded in the beginning of September (Frimer, 1993). Supplementary information from July and the beginning of August strongly suggests that significant numbers moult earlier than the time at which surveys were conducted in the northern areas. Furthermore, the survey estimate of 30 000–40 000 does not account for turnover of the birds present at the moulting sites. Birds in wing moult are observed from July to October (Salomonsen, 1968; Frimer, 1994b). The wing moult takes approximately three weeks (Salomonsen, 1990), and it is possible that many king eiders stay in the moulting areas for only about one month. The high proportion (73%) of male king eiders in wing moult in Kangersooq in early September indicates that, if significant numbers have finished wing moult earlier in the area, some early moulters have left the area by September.

We have made a simple static model (calculation) to test the hypotheses that early wing moult and a high turnover can explain a difference between a late winter population of 300 000 and a 1 September moulting population of 30 000–40 000. The model describes the moult phenology of 200 000 king eiders in the coastal zone from July to October, corresponding to a late winter population of 300 000 (Fig. 8). The model is based on the following five assumptions: (1) nonbreeders, adult males, and 50% of the adult females moult in West Greenland; (2) the wing moults of nonbreeders, adult males, and adult females peak in mid-July, late August, and mid-September, respectively; (3) birds are present in the coastal zone for only one month; (4) the proportion of nonbreeders (including immatures) is one-third of the late winter population; and (5) the population sex ratio is 1:1. The referred timing of wing moult peaks is based on Frimer's (1994b) observations from Disko. However, the wing moult peaks of immatures and adult males were moved two weeks forward to account for the apparently earlier moult in the northern part of the area. Earlier wing moult in breeding males is considered unlikely, because wing moult starts

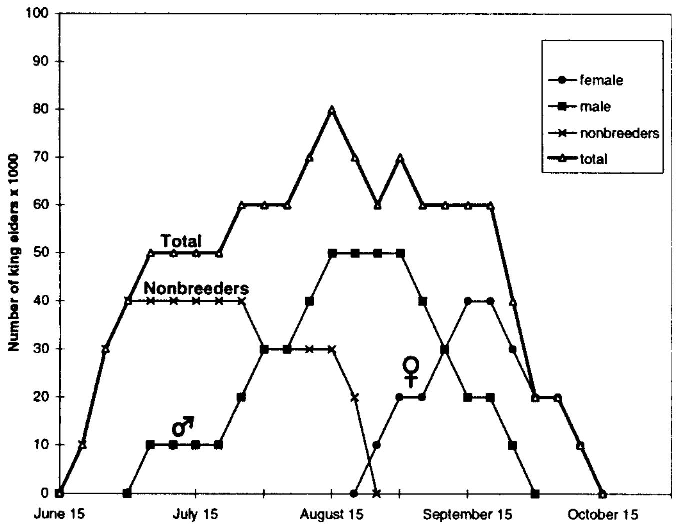

FIG. 8. Simple model describing phenology and turnover of moulting king eiders in West Greenland. See text for explanation.

after moult of body feathers to "eclipse" plumage (basic plumage). Given the five assumptions mentioned above, the model predicts (Fig. 8) that if 200000 king eiders moult in the coastal zone from July to October (corresponding to a late winter population of 300000), then approximately 50000 birds should be present in the coastal zone in July, 70000 during most of August, and 60000 in early September. The predicted 60000 in early September is nearly double the number of king eiders estimated in this study. It is therefore concluded that either approximately half of the population performs wing moult elsewhere, or the population has declined. Ground surveys of breeding king eiders in the Rasmussen Lowlands, NWT, eastern Canadian Arctic, which reveal an 86% decrease in king eider abundance from 1976 to 1994–95 (Gratto-Trevor et al., 1998), support a general population decline. However, the percentage of king eiders from this area that moult and winter in Greenland is unknown.

Store Hellefiskebanke (68°N) could be a moulting area or staging area after moult. It consists of large areas with less than 50 m depths up to 50 km from the coast, and large numbers of king eiders are known to winter in the area (Mosbech and Johnson, in press). However, these shallow areas have not been adequately surveyed during August and September. The area is hardly suited for wing moult, as the birds are unable to compensate for surface drift by flying.

Although some king eiders moult in eastern Arctic Canada, there have been no recent surveys. Tuck and Lemieux (1959) estimated 10400 moulting king eiders along 24 km of the north coast of Bylot Island at the entrance to Lancaster Sound, including a flock of 2400 mostly male birds, on 15 July 1957. In contrast, in 1976 and 1978 only a few moulting eiders (2300 common eiders and king eiders together) were observed during aerial surveys in eastern Lancaster Sound and western Baffin Bay (approximately 70°30′ to 76° N) by McLaren and McLaren (1982). Possibly, some of the king eiders wintering in Greenland might have changed moulting area and now perform wing moult in remote areas in eastern Arctic Canada.

Conservation Aspects

Although there is no reliable measure of the intensity of disturbance at the western Greenland moulting sites, the most severe reductions in numbers of moulting king eiders were found in the areas which were considered to have a high degree of disturbance. This impression is supported by local knowledge from the Naterneq area (Fig. 5), which describes how the increased boat traffic since the 1950s has diminished suitable undisturbed moulting areas (Petersen, in press).

Except for mineral resource exploration activities (Mineral Resources Administration for Greenland, 1996), there is no regulation of the traffic in the moulting areas. Although herding of flightless birds is prohibited, the present opening of the hunting season (15 August) can cause severe stress on many of the birds still flightless in the moulting areas. We cannot conclude on the disturbance effects at the population level, however, there is a risk of significant effects. Some of the moulting areas are designated as important wetlands according to the Ramsar Convention (as per Article 2 in the Convention, on Wetlands of International Importance especially as Waterfowl Habitat) by the Greenland Home Rule government (Jepsen et al., 1996); however, no special protective measures have yet been implemented (Tom Christensen, Greenland Home Rule, The Ministry of Environmental and Natural Resources, pers. comm. 1999). The regulation of all traffic—including hunting—at the most significant moulting sites during the main moulting period (mid-July through September) would be the most effective conservation action.

Western Disko (Disko W and Disko SW sub-areas) was found to be a main moulting area, where about half of the moulting birds were observed. The king eider population will be very sensitive to oil spills in this area, since the moulting birds are concentrated at or near the outer coast. With the exception of Innusulik Bay, the other moulting sites are in deep fjords or sheltered by outer archipelagos, which offer some protection from an offshore oil spill.

ACKNOWLEDGEMENTS

We are grateful to Ole Frimer and Ib K. Petersen for support, fruitful discussions, and comments on an early version of the manuscript. We thank Grant Gilchrist, Canadian Wildlife Service, and Knud Falk, Ornis Consult, Alex Sand Frich, Peter Nielsen, and H.C. Petersen, Greenland Home Rule, who allowed us to use unpublished data. Kaj Kampp, Zoological Museum of Copenhagen, provided access to ringing data and Finn Salomonsen's field notes. Lars Thiele of Ødegaard and Danneskiold-Samsøe Aps. did the technical noise data analysis. F. Riget provided statistical advice.

TABLE 8. Historical observations of king eiders in western Greenland in summer and autumn. Observations are arranged from north to south. Observations from Disko Island are included in Table 6.

Region / Locality	Sub-area	Date	Numbers and sample method[1]	Sex[2]	Wing Moult[3]	Reference[4]
Southern Upernavik						
Archipelago east of Upernavik (72°20′ N)	16	1948–72, mainly second half of August	6421 (total ringed)	M	++	1
Uummannaq						
North coast of Nuussuaq	24	June-October, 1905–20	"large flocks", o + s	–	+	2
Disko Bay (except Disko Island)						
Sydostbugten (north coast of Naterneq (68°30′ N))	41	"until 1950s when speedboats became common"	"thousands"§	–	++	4
South of Disko Bay						
Archipelago south of Aasiat (68°30′ N)	43	16–17 August 1925	"many hundreds", o + s + i	M + I	++	3
Arfersiorfik (east and south coast of Naterneq, 68°30′ N)	44	"until 1950s when speedboats became common"	"thousands"§	–	++	4

[1] Sample: o = observed, s = shot, i = interview with local hunters, § = both common and king eiders.
[2] Sex: M = male, F = female, I = immature.
[3] Wing moult: ++ most, + some.
[4] Reference: 1 = Salomonsen, 1979. 2 = Bertelsen, 1923. 3 = Schiøler, 1926. 4 = Petersen, in press.

M. Rasch provided advice on coastal geomorphology. Also we thank Thomas Kjær, Jose Nymand, Marianne K. Petersen, and Ib K. Petersen for their assistance during various parts of the fieldwork and our pilot, Leif Petersen, for skillful navigation of the aircraft. Finally we acknowledge the reviews of anonymous referees whose comments and suggestions markedly improved the paper.

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