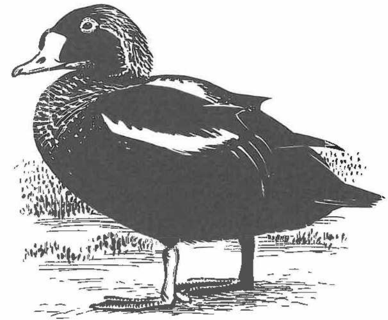

The behaviour of moulting King Eiders *Somateria spectabilis*

OLE FRIMER

Activity budgets and distribution patterns of King Eiders were studied at Disko Island, West Greenland during the moulting season of July to September, and compared with the activity budgets of non-moulting King Eiders. King Eiders were generally active in the daylight hours, and spent most of the night and a period at mid-day resting. The feeding intensity peaked early and late in the day, with no marked tidal influence on the feeding pattern. The amount of time devoted to diurnal feeding increased during the moulting period, and was negatively correlated with daylength. There was no evidence of increased feeding intensity by moulting birds compared to non-moulting birds. Moulting King Eiders devoted more time to comfort movements than non-moulting birds. Ice conditions and daylength are suggested to be ultimate factors affecting the timing of moult.

Keywords: Greenland, Moulting, Feeding, Activity Budget, King Eider

The principal moulting area for King Eiders *Somateria spectabilis* of the eastern Canadian Arctic is situated in central West Greenland, particularly in the Disko Bay region, where some 100,000 birds congregate in the autumn (Salomonsen 1968). In 1991 and 1992, the timing of the arrival of King Eiders and their moult was studied at western Disko Island, and it was shown that post-breeding males and females migrate to this area to undergo prebasic moult along with a number of immature birds which may have spent the summer south of their potential breeding range (Frimer 1994). The post-breeding males arrive mainly in early August and undergo wing-moult between mid-August and late September, while the females arrive during the second half of August and undergo wing-moult from late August and well into October (Frimer 1994).

The behaviour of King Eiders outside the breeding area is not well known (see Cramp & Simmons 1977). Apart from the physiological stress involved during the moulting process (including a period of flightlessness), the eiders are subject to environmental changes, the most conspicuous being the rapidly declining daylength and decreasing temperature.

The aims of this paper are to describe the behaviour of King Eiders moulting at Disko Island, central West Greenland, and relate their behaviour to the time of day, the tide, daylength, state of moult, and the behaviour of non-moulting King Eiders, and to look for behavioural indications of habitat requirements and selective factors affecting the timing of moult.

Study Area and Methods

Moulting King Eiders were studied at Kangersooq (Nordfjord) and Akugdliit (Mellemfjord), western Disko Island (70°N, 55°W) (**Figure 1**) in August 1991 and through late July to mid-September 1992. During these periods daily temperatures ranged between -2° and 8°C. Fiord-winds from the west and northwest appeared almost daily from late morning to late afternoon. Precipitation was fairly low for most of July and during September. In August of both years, the weather conditions were generally more unstable, with periods of strong winds, precipitation and fog, and heavy dew often occurred at night. The tidal amplitudes are up to 2.2 m.

Observations were made from elevated points, using binoculars (10x) and telescopes (20-60x). Observation distances ranged from 100 to 2000 m. The shortest distances did not appear to affect the behaviour of the birds.

Activities were recorded by instantaneous scan sampling (Altmann 1974) of individuals in randomly selected flocks, every 60 seconds for minimum 30 minutes or until the birds were out of sight. I attempted to obtain at least 30 minutes of scans within each hour of the diurnal cycle. Prior to scans, the number of individuals in the sample flock was counted carefully to

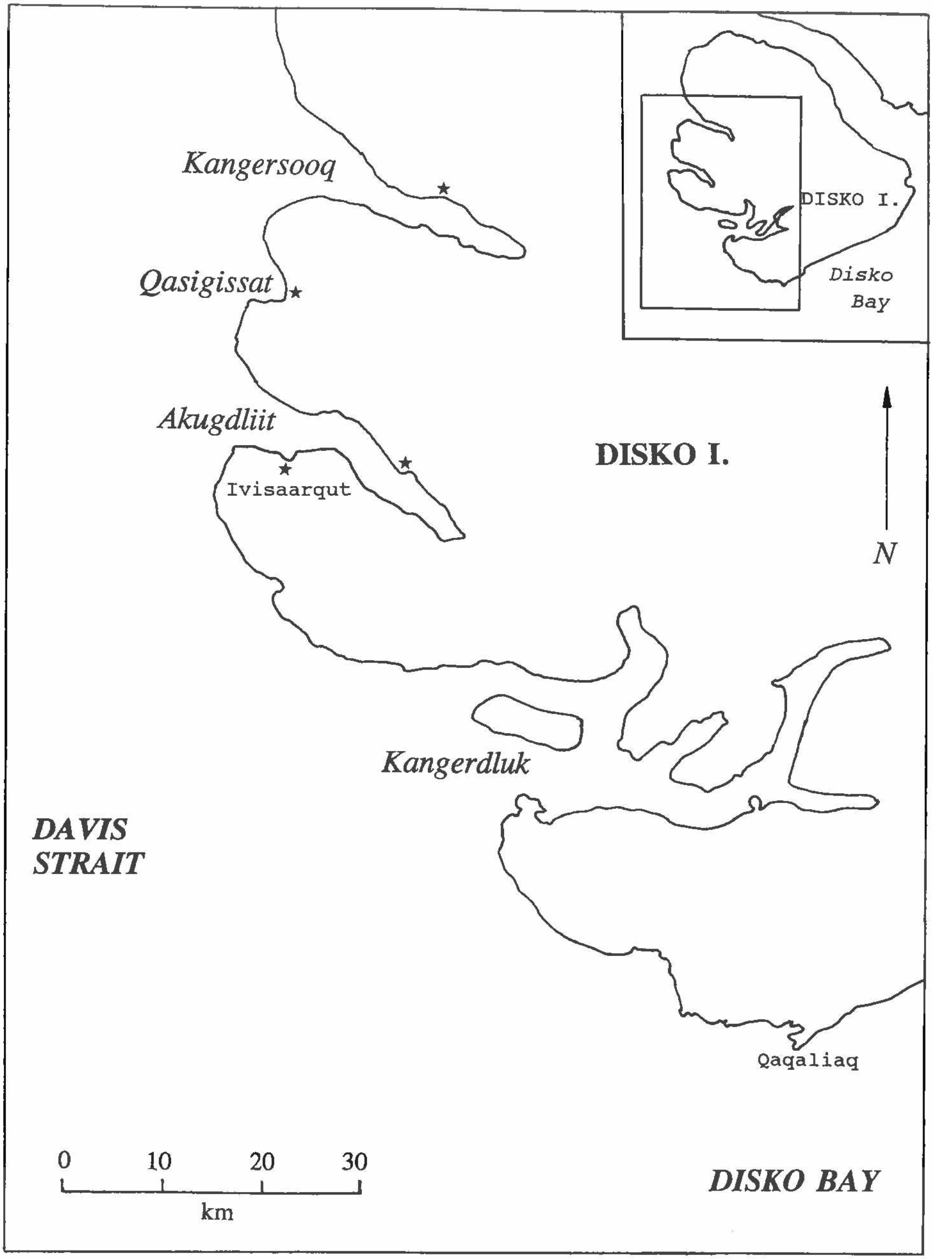

Figure 1. Map of the study area in central West Greenland, showing places mentioned in the text. * = camp site.

allow later estimates of how many birds were underwater. Following the flock, the proportion of individuals engaged in every activity was recorded, according to the following categories: feeding (diving, surface feeding, feeding on shore), inter-dive loaf (pausing between consecutive dives), comfort (preening, bathing, wing-flapping, stretching), swimming, resting (head on back) and other activities (flying, aggression). The number of birds submerged at any time was calculated by subtracting the number of birds on the surface from the flock total. Pausing between dives at intervals of less than three minutes was defined as inter-dive loaf (this time interval was the maximum pause time, timed to nearest minute, recorded between consecutive dives). Altogether, eight diurnal cycles were covered, regularly distributed over the moulting period - six with both sexes combined, one with males (12 September) and one with females (15 September). On some occasions, data from two successive days were combined, because of interruptions by severe weather or passing boats. In August 1992, the number of King Eiders present within the bay Ivisaarqut (**Figure 1**) was counted every hour as I attempted to cover four diurnal cycles distributed regularly over the tidal cycle.

Also recorded were the level of tide (using a surveyor's pole with marked 10 cm intervals placed at sufficient depth) and the temperature, usually every hour of the sampling periods. To help determine diving depths, the bottom profile of Ivisaarqut and inner Akugdliit (**Figure 1**) was mapped from our research vessel, using echo-sounder (Skipper 802) and radar (Furuno), and depths of 5 and 15 m were marked with buoys.

Scans of non-moulting King Eiders were made on 22 April 1992 at Qaqaliaq, southernmost Disko Island (69°N, 54°W) (**Figure 1**), when temperatures ranged from -10° to

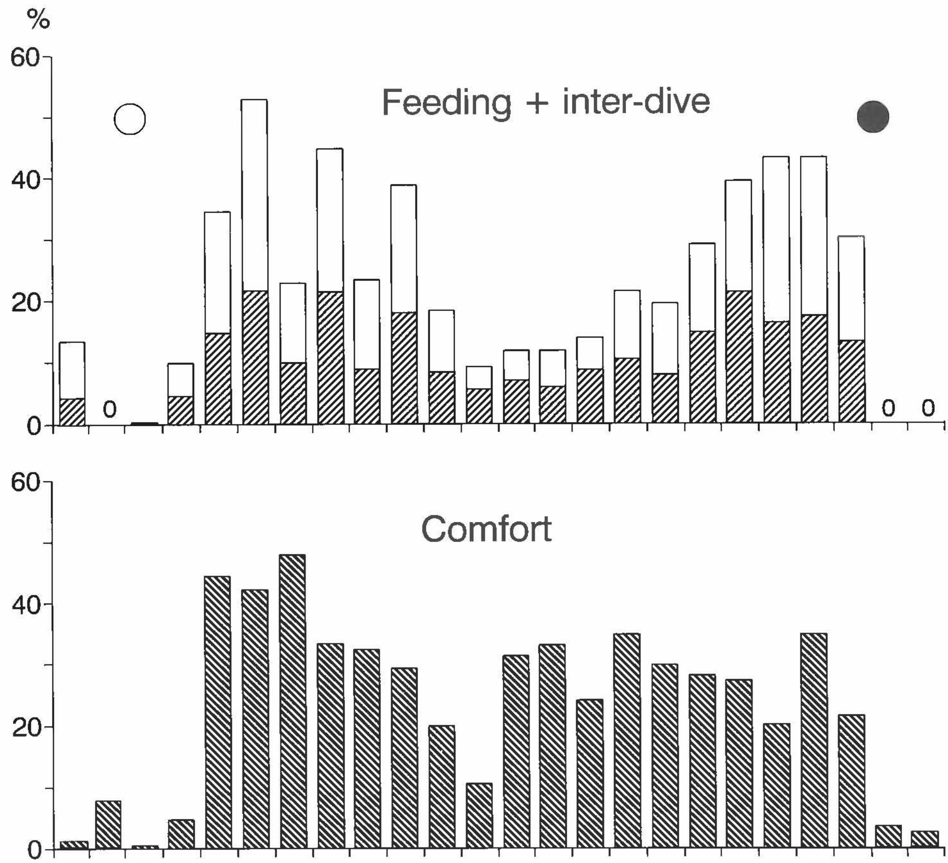

Figure 2. Proportion (%) of time spent in the most common behaviour classes in relation to time of day by moulting King Eiders. Data are means of four observation periods during 31 July-14 August (the number of behavioural records was 6,658-20,511 in each of the four periods). Open part of bars = inter-dive; 0 = no records; circles = sunrise (open) and sunset (closed). Test of variation over the diurnal cycle in the mean (or median) proportion of each behaviour class of the four time periods 04-11, 11-14, 14-22 and 22-04: Foraging (diving + inter-dive), total 24-hour period, $F_{3,79} = 11.91$, $P<0.001$; between time periods, T-K: 22-04 < 04-11 > 11-14 ns 14-22 > 22-04. Comfort, total 24-hour period, H = 34.35, $P<0.001$; between time periods, N-B: 22-04 < 04-11 ns 11-14 ns 14-22 > 22.04. Swimming, total 24-hour period, $F_{3,79} = 0.57$, $P>0.6$. Resting, total 24-hour period, H = 24.86, $P<0.001$; between time periods, N-B: 22-04 > 04-11 < 11-14 ns 14-22 < 22-04.

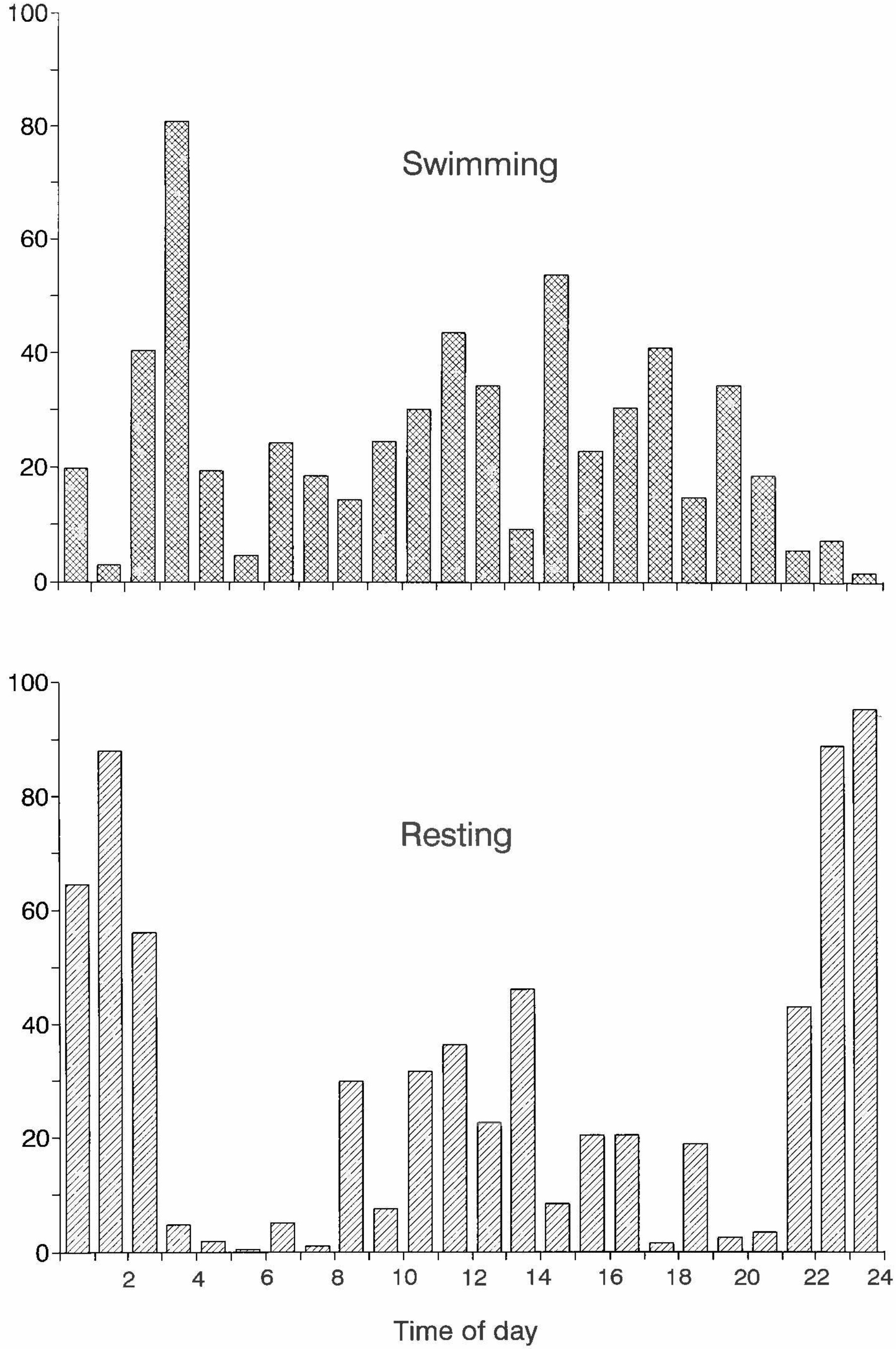

Figure 2 ***continued*****. See caption opposite.**

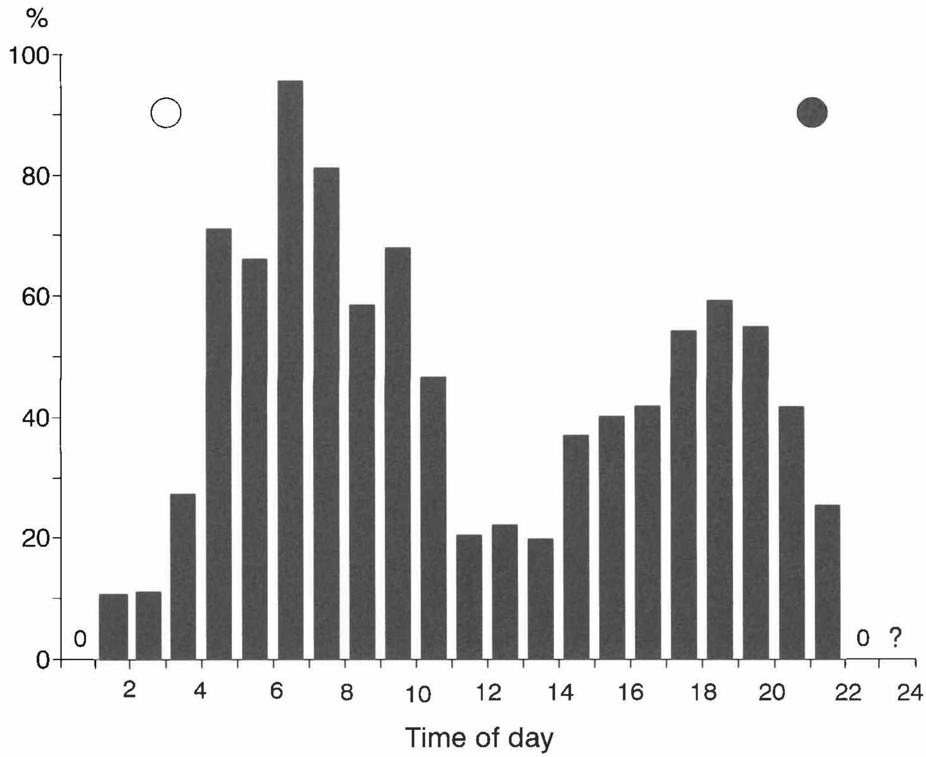

Figure 3. Hourly variation in mean number of King Eiders (% of daily maximum numbers) in the bay Ivisaarqut. Data from four observation days regularly distributed over the period 11-20 August 1992. The daily maximum numbers present were 108-216 on each of the four days. 0 = no King Eiders present; ? = not sampled; circles = sunrise (open) and sunset (closed). Test of variation over the diurnal cycle in the mean number present in the four time periods 04-11, 11-14, 14-22 and 22-04: Total 24-hour period, $F_{3,77} = 30.68$, $P<0.001$; between time periods, T-K: 22-04 < 04-11 > 11-14 < 14-22 > 22-04.

-1°C. Scans of pre-moulting King Eiders were made on 5 July 1992 at Qasigissat, western Disko Island (70°N, 55°W) (**Figure 1**), when temperatures ranged from 1≠ to 9°C.

Data analysis

The computer statistical package Execustat (Loll 1993) was used for the statistical analysis. Differences between means were analyzed using t-test and one-way ANOVA, and temporal trends using simple linear regression, following Fry (1993). Before the tests were performed, the data were arcsine transformed to obtain normally distributed samples (Sokal & Rohlf 1981). The non-parametric Kruskal-Wallis test was used in case the transformed data did not meet the assumptions of ANOVA. Pairwise comparisons of means in ANOVA were performed using Tukey-Kramer HSD procedure (see Sokal & Rohlf 1981), in the following termed "T-K", and medians in Kruskal-Wallis test using approximate confidence intervals (notched boxplots) (McGill *et al.* 1978, Fry 1993), in the following termed "N-B". The estimated proportion of time allocated to each activity class within one hour of a sampling period constituted a unit of observation. The level of significance accepted was $P<0.05$.

Results

Activity budgets and distribution patterns of moulting King Eiders

Early in the moulting season, observations were made throughout the 24-hour cycle. From mid-August, the light intensity became too low at night to carry out scans, and observations were restricted to the period from dawn to dusk. In the following, the daily activity patterns are represented by observations made between 31 July and 14 August of both years.

Feeding

At sea, King Eiders feed primarily on benthos, with molluscs, crustaceans and echinoderms comprising an important part of the diet (Palmer 1976, Cramp & Simmons 1977, Bustnes & Erikstad 1988). At Disko, King Eiders employed several methods of feeding. Diving to the bottom was by far the most common feeding activity observed (>99%). The birds often fed in densely packed rafts of up to about 70 individuals with highly synchronized diving, but feeding singly or in loose flocks with unsynchronized diving was not uncommon. The maximum diving depth recorded was about 30 m. Diving times varied from 9 to 100 seconds (correlated with diving depth, Frimer, unpubl.), at intervals of 1 to 205 seconds, usually in bouts of 10 to 30 minutes followed by periods of preening and resting.

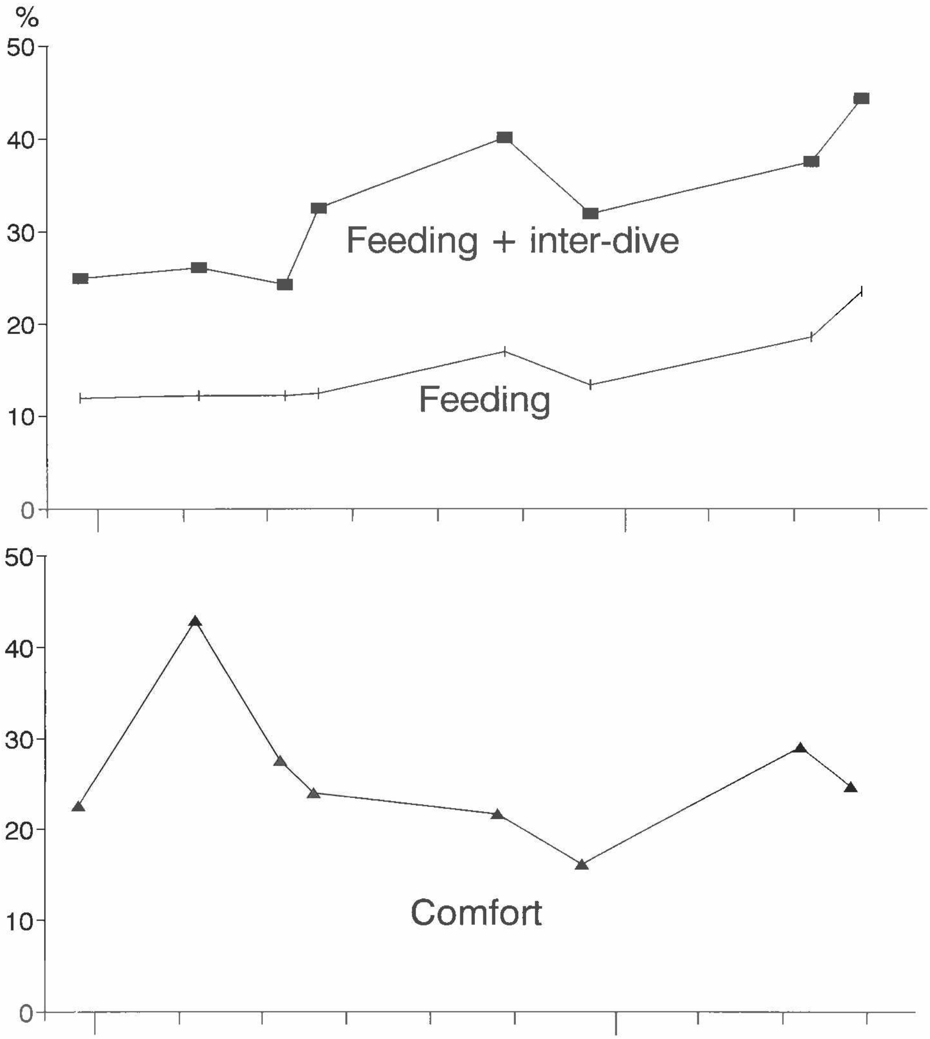

Figure 4. Variation in the most common behaviour classes of King Eiders during the moulting period, expressed as percent of the daylight hours. Data are means of the per hour proportions (the number of behavioural records was 6567-20511 in each of the six sampling periods in July-August 1991 and 1992; 2140 for males on 12 September 1992 and 4899 for females on 15 September 1992). Test of each behaviour class of males versus females in mid-September (feeding and inter-dive were pooled): df = 26, P<0.01 for swimming and P>0.1 for others (for rest of Figure 4 see next page).

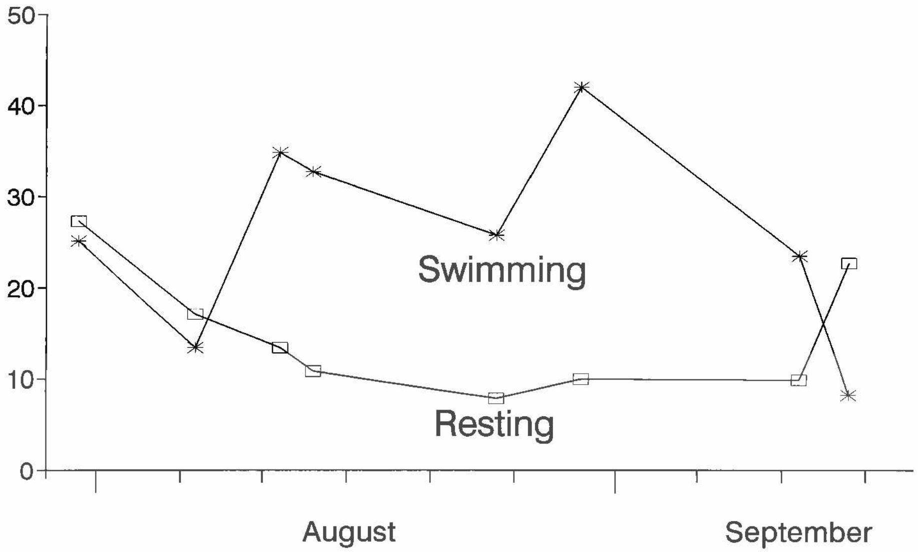

Figure 4 *continued*. See caption on previous page.

The birds occasionally made *horizontal* dives (a few m. below the surface) in deep water. In shallow waters, the eiders may make several rapidly repeated dives, with only part of the head and back above water during surfacing of about one second's duration. Dabbling (head-dip and up-end) was observed on both deep and shallow waters, and King Eiders occasionally went ashore to feed. A more detailed description of the diving behaviour will be given elsewhere.

The feeding pattern was diurnal, with peak intensity early and late in the day (**Figure 2**), although the ANOVA just failed to show significant difference between the mid-day and afternoon feeding intensity (HSD=15.2, the difference between means=14.6). The combined proportions of time devoted to feeding and inter-dive loaf between sunrise and sunset did not vary markedly with the tide (divided into four approximately 3-hour stages of the tidal cycle: high, falling, low and rising tide) $F_{3,68}=1.23, P>0.1$. This is further supported by the distribution patterns observed during four day-long watches at the deep feeding site Ivisaarqut (maximum depth 33 m), demonstrating a higher presence early and late in the day (**Figure 3**). Although the tide may hardly be expected to influence the cost of diving in this case, the feeding rhythm was essentially the same in the other feeding sites investigated. Feeding around midnight was only observed on one occasion (7 August 1991, at twilight). In this case, the birds had been disturbed by a boat in the afternoon before scans were made, which may have forced them to compensate by feeding at night.

The amount of time devoted to daytime (sunrise to sunset) feeding and inter-dive loaf increased markedly during the moulting period (**Figure 4**), and was correlated negatively with daylength (**Figure 5**).

Comfort movements

The amount of time allocated to comfort movements was regularly distributed throughout the day (**Figure 2**). In early August, the proportion of time devoted to comfort movements was relatively high (**Figure 4**) and differed significantly from

Table 1. Diurnal activity budgets (%) for non- and pre-moulting King Eiders in 1992.

Date	Feeding	Inter-dive	Comfort	Swimming	Resting	Other	*n*
22 April (non-moulting)	13.9	22.6	13.0	39.0	10.0	1.5	15,385
5 July (pre-moulting)	17.6	17.2	18.3	10.5	36.2	0.2	12,180

n = total number of behavioural records

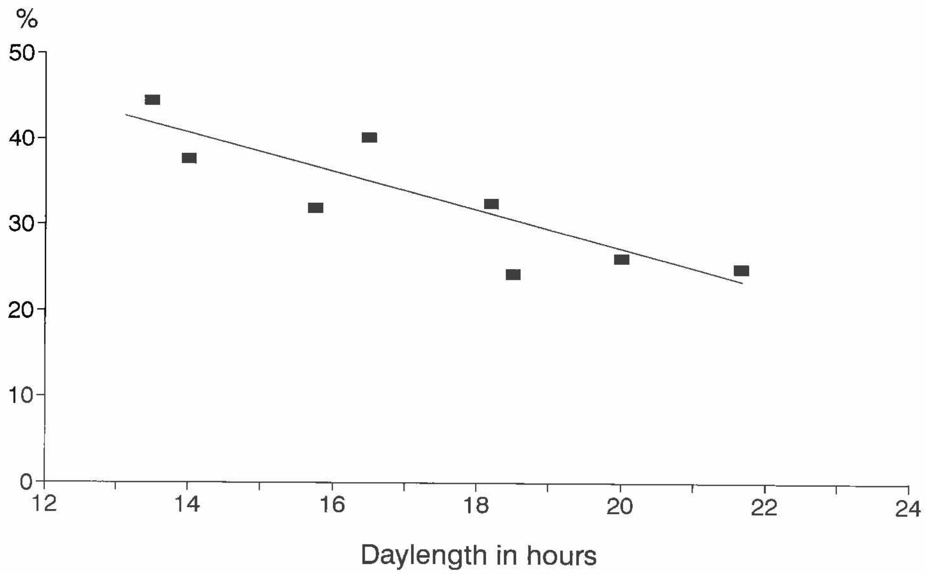

Figure 5. Proportion (%) of daylight hours that King Eiders devoted to feeding and inter-dive combined, in relation to daylength. Y = 71.5 - 2.2X (t_6= - 3.98, *P*<0.01).

the proportions estimated during some of the other observation days of the moulting period (total observation period: $F_{7,119}$=3.21, *P*<0.01; among sampling periods T-K: 7 August > 31 July, 25 August and 30 August).

Swimming

The swimming pattern appears to reflects the amount of daily movement (**Figure 2**). The swimming intensity is high at sunrise when the birds move, rather simultaneously, to the feeding areas (see also **Figure 3**), and around mid-day in association with a period of resting offshore, but this was not statistically signicant. The birds leave the feeding areas in small groups around sunset, and gather offshore to spend the night. The time devoted to swimming varied greatly between sampling periods (**Figure 4**). In mid-September, males spent significantly more time swimming than females.

Resting and other activities

A daily resting routine, inversely proportional to the feeding pattern, was evident (**Figure 2**), the birds spending most of the night and a period around mid-day resting offshore on the deepest waters of the fiords.

Other activities (flying, aggression) together accounted for less than 1% of all diurnal activities during most sampling periods.

Activity budgets of non- and pre-moulting King Eiders

In late April 1992, shortly after the sea-ice began to break up in Disko Bay, a flock of 36 King Eiders (eight males and 28 females, nearly all adults), stayed for about a week within a limited area of open water at the rocky coast of Qaqaliaq, southernmost Disko Island (**Figure 1**). Scans carried out on 22 April showed that the activities of these non-moulting birds differed markedly from those of moulting birds in mid-August (at the same daylength) in the time allocated to comfort movements (22 April versus 12 and 14 August: t_{34}=2.86, *P*<0.01 and t_{32}=2.55, P<0.05, respectively), non-moulting birds devoting about half as much time to comfort movements as moulting birds (**Table 1** and **Figure 4**).

Both immature and adult non-breeding King Eiders occur in fairly high numbers around Disko during the summer period (Frimer & Nielsen 1990). In early July 1992, up to 160 King Eiders (*c* 70% males) were present at Qasigissat (**Figure 1**). Most birds were in worn alternate plumage, but a minor proportion showed signs of incipient body moult on the head. Scans carried out on 5 July (at continuous daylight) showed that the amount of time devoted to comfort movements was intermediate between non-moulting birds and birds in advanced body and wing moult (**Table 1** and **Figure 4**). Considering the correlation of the feeding intensity with daylength, the feeding intensity was high in early July compared to all other activity budgets measured during this study.

Reactions to disturbance

King Eiders are generally shy birds, particularly during the period of moult. At a distant sound of an engine, even from an aeroplane passing several kilometres overhead, the birds ceased feeding and began to gather and swim offshore, adopting an alert upright-neck posture. Boats passing close by the feeding areas caused the birds to take flight or escape by diving and swimming. A few birds would return to the feeding area within 1-2 hours after the disturbance, but the great majority did not return until 6-8 hours after the incident. King Eiders interrupted their feeding when a flock of seals came into the feeding area, but they were not seen taking flight or otherwise trying to escape. King Eiders did not appear to pay any attention to other bird species, and they often mixed with, e.g., Common Eiders *Somateria mollissima* and Black Guillemots *Cepphus grylle*.

Discussion

Early in the moulting season, when scans were made throughout the 24-hour cycle, King Eiders fed in the daylight hours, with peak intensity early and late in the day, and spent most of the night resting. That King Eiders generally are diurnal feeders is also supported by the fact that the diurnal feeding intensity increased through the moulting period, as days became shorter.

A similar feeding pattern has been described for the closely related Common Eider (Pethon 1967, Player 1971), although the feeding pattern of Common Eider may be influenced by the tide in areas with a high tidal range or where food items are more available at certain stages of the tide (Player 1971, Cantin *et al.* 1974, Campbell 1978, Minot 1980). Considering the moderate tidal amplitudes in the present area and the general association of the King Eider with fairly deep water, the absence of a tidal effect on the feeding activity is not surprising.

The proportion of time spent feeding was high in early July compared to all other sampling periods (**Table 1** and **Figure 4**), suggesting that the birds were about to built up energy reserves for feather growth prior to prebasic moult. It should, however, be emphasized that the observations of pre-moulting King Eiders covered only one diurnal cycle, which may not be representative for this moulting state.

During the moulting period, the feeding intensity was similar to that of non-moulting birds in April (**Figure 4** and **Table 1**). Assuming that the activities recorded in April are representative for non-moulting birds, the food supplies in the autumn were apparently sufficient to support large numbers of moulting King Eiders, without needs for increased feeding intensity.

On average, moulting King Eiders allocated 26% of the daylight hours to comfort movements. Comfort movements were, however, relatively intense in early August (43%) during the peak arrival of the post-breeding males (Salomonsen 1968, Frimer 1994). At arrival, most males are in well advanced body-moult (Frimer 1994). The males apparently need to spend much time preening after the long flight from the breeding grounds, unlike females who arrive in worn alternate plumage and undergo body and wing-moult more simultaneously (Frimer 1994). The time allocated to comfort movements was apparently related to the state of moult, moulting King Eiders devoting twice as much time to comfort movements as non-moulting birds (**Figure 4** and **Table 1**). Comfort movements may also be related to feeding methods. King Eiders studied at a shallow pond on the breeding grounds in Northeast Greenland devoted 4.3-4.5% of the 24-hour cycle to preening, irrespective of feeding intensity (Meltofte *et al.* 1981), which is less than half the time recorded for non-moulting birds at Disko. As surface feeding in shallow ponds is the most common feeding behaviour on the breeding grounds (Lamothe 1973, Elander & Blomqvist 1986), the difference indicates that preening, to some degree, accompanies diving.

Table 2. Estimated proportions (% of 24 hours) of time allocated to feeding and inter-dive by moulting King Eiders during July-September.

	Feeding	Inter-dive	Total
31 July	10.8	11.7	22.5
7 August	10.7	12.7	23.4
12 August	10.2	10.5	20.7
14 August	9.4	15.2	24.6
25 August	11.6	16.0	27.6
30 August	11.4	15.2	26.6
12 September (♂♂)	10.8	11.1	21.9
15 September (♀♀)	13.2	11.8	25.0
Mean	11.0	13.0	24.0

The swimming intensity varied greatly between sampling periods. However, King Eiders may move by swimming, and preen or rest simultaneously; in such cases the behaviour was classified as comfort movements and resting, respectively. Thus, the recorded swimming intensity is, to some extent, influenced by the intensity of comfort movements and resting, and should be viewed in the light of the methodological ranking of the behaviour classes. The low swimming frequency recorded at Qasigissat in early July (**Table 1**), however, was due to the fact that the birds rested mainly on ice-floes within the feeding area and therefore did not need to spend much time swimming.

King Eiders rarely engaged in activities other than those discussed. However, data on time spent flying may be underestimated, because flying King Eiders, except at take-off or landing, were not sampled. It was my impression, however, that moulting King Eiders (including those capable of flying) mostly swim (rather than fly) between feeding and resting areas.

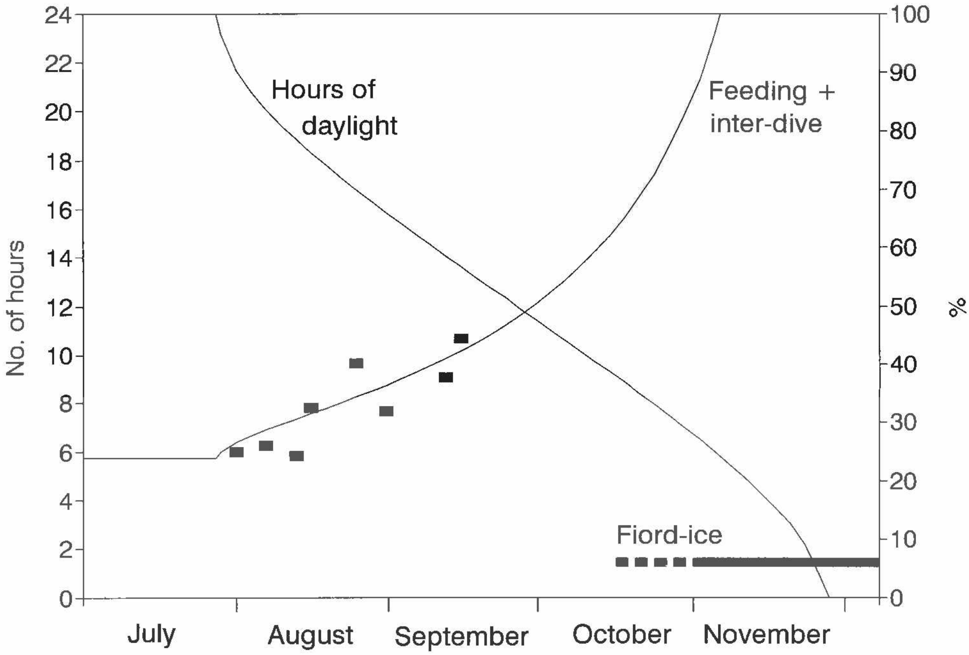

Figure 6. Correlation of the combined proportions of time devoted to daytime feeding and inter-dive (%) with daylength (hours) by moulting King Eiders at Disko, July through November. The diagram was calculated assuming that moulting King Eiders allocate 24% of the 24-hour cycle to feeding and inter-dive combined, and that all feeding takes place in the daylight hours. Also shown are the proportions obtained from scans (solid squares) and the fiord-ice conditions.

In mid-September, when the proportions of males and females in wing moult were almost equal (Frimer 1994), females swam less than males. An explanation for this difference may be that the males were in a more advanced state of body moult than females (Frimer 1994), and females therefore needed to save more energy for feather growth. The difference should, however, be treated with some caution, as scans of males and females were carried out on different days.

The importance of central West Greenland as a moulting area for these populations of King Eiders has been explained partly by Salomonsen (1968), who stated that, because of the short ice-free period in the high arctic regions, King Eiders must leave the high arctic breeding grounds before they become flightless and move to the nearest low arctic areas where the risk of being caught in new-ice in the flightless state is low, and where autumn days are longer. For populations breeding in the Canadian Arctic west to about 110°W one of the nearest low arctic areas is central West Greenland (Salomonsen 1967, 1968, 1979). The present investigation adds the following two considerations to the explanation: 1) there was no evidence in this study that King Eiders had any difficulty in obtaining enough food, and the amount of time spent feeding did not appear to differ from that of non-moulting birds, suggesting that food was plentiful, and 2) flightlessness makes birds vulnerable, therefore a habitat which provides safety from predators is critical during the moulting period. Arctic areas generally have a relatively low carrying capacity for predators throughout the year. In the ice-free period, the western parts of Disko are only visited occasionally by humans, who probably are the main predators of King Eiders in the autumn (Salomonsen 1967). Other potential predators are the Arctic Fox *Alopex lagopus*, the Gyrfalcon *Falco rusticolus* and the Peregrine Falcon *Falco peregrinus*, all present in the area. However, no attacks on King Eiders from these three species were observed, suggesting that predation was low.

Which selective factors affect the evolution of the timing of moult, apart from those determining the onset of breeding? As mentioned above, there are indications in this study that King Eiders generally do not feed at night, i.e., between dusk and dawn. Thus, 24-hour feeding-and inter-dive budgets for all eight sampling periods within the moulting season were estimated, assuming that no feeding took place in the night hours when the light intensity was too low to carry out scans. As shown in **Table 2**, these estimates varied only slightly during the moulting period; the birds devoted on average 24% of the 24-hour cycle to feeding and inter-dive loafing combined. Using this mean, and assuming that all feeding takes place between sunrise and sunset, the proportion of the daylight hours necessary for feeding and inter-dive loafing was calculated for the period July-November (**Figure 6**, shown together with the proportions obtained from scans). According to **Figure 6**, King Eiders should complete flight-feather growth before the end of October for two reasons: 1) the days become too short for the birds to cover their need for food in the daylight hours, and 2) the new-ice begins to form in the fiords. Birds whose wing-moult has been delayed are forced out of the fiords to less favourable feeding areas and, furthermore, would have to cover part of their need for food by feeding at night, possibly with reduced efficiency, or they are being overtaken by the new-ice. This was the situation in late October 1992, when several King Eiders were found drowned under thin ice in Kangerdluk (**Figure 1**) (K. W. Kleist, pers. comm.).

Most male King Eiders have regained flight capability by the end of September, while the period of wing-moult in females extends well into October (Frimer 1994). Considering the extreme shyness of moulting King Eiders, an undisturbed habitat is critical, particularly during the latter part of the moulting season, when days are short and the birds need to spend most of the day in feeding.

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