THE UNIVERSITY OF ALBERTA

# BIOLOGY OF KING EIDER (<u>SOMATERIA SPECTABILIS</u>) IN A FRESH WATER BREEDING AREA ON BATHURST ISLAND, N.W.T.

by

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A THESIS

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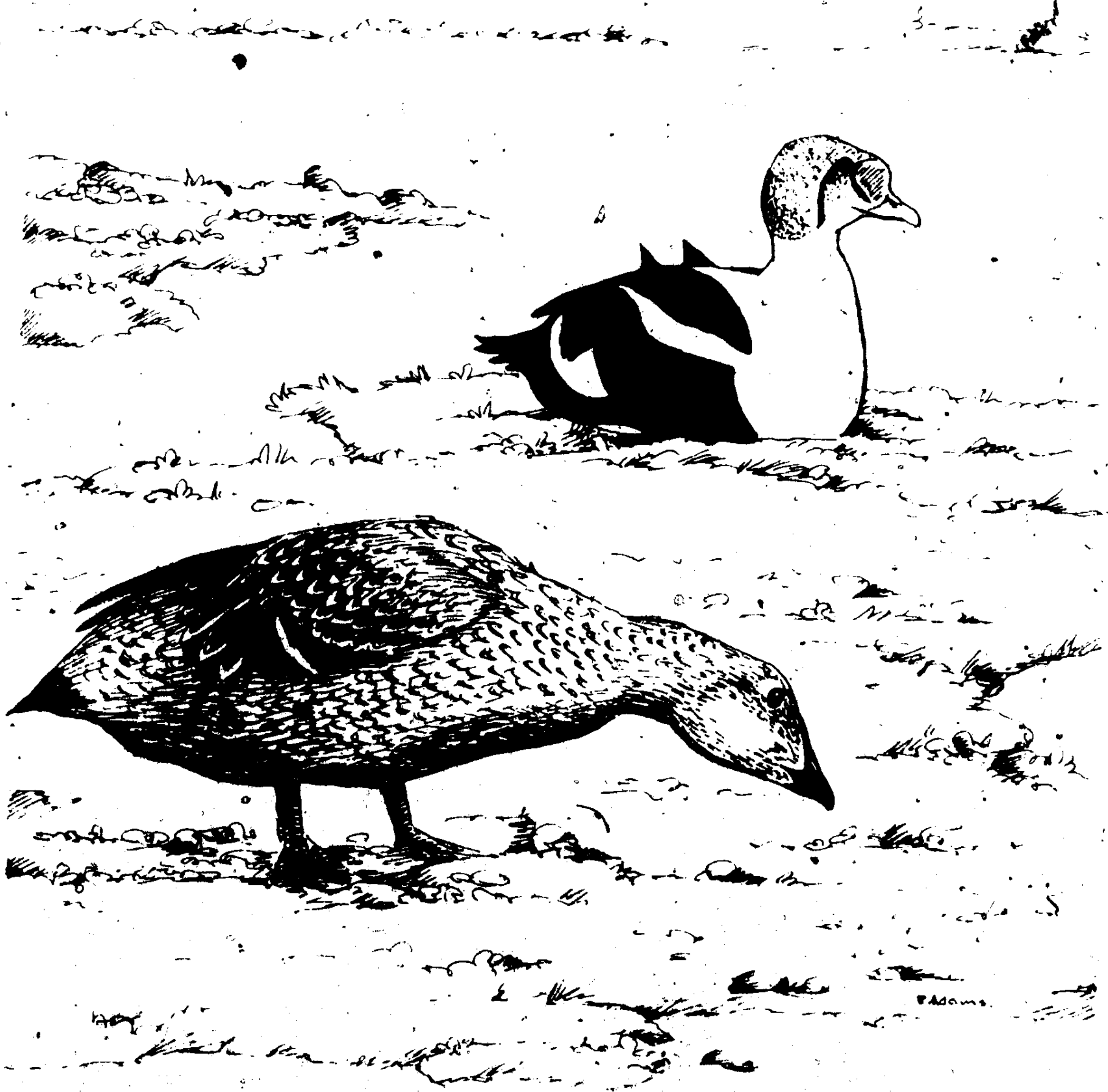

## ABSTRACT

King eider (<u>Somateria spectabilis</u>) were studied on Bathurst Island, Northwest Territories, in 1971 and 1972. Special emphasis was placed on the reproductive cycle.

Most birds were paired on arrival in mid June; thereafter activities related to maintenance of the pair bond increased. Copulation was observed on the study area. Nest initiation occurred in late June and early July. The duration of the laying period, longer in 1972, seemed related to severe weather conditions encountered in that year.

King eider nests were found in three major habitats but a marked preference for saxifrage barren ridges was recorded. Birds selected a microhabitat that included more vegetation than surrounding areas and they also added vegetation to line the nest. Down was progressively added after laying the third egg. The female did little or no feeding during incubation and showed a high degree of nest attentiveness.

High numbers of predators were recorded during this study; arctic foxes and long-tailed jaegers were the

main predators taking king eider eggs. My presence around the nests may have resulted in increased rates of predation. Incubating females in this area were not seen to defecate when flushed from the nest. The lack of this repulsive material may have led to increased predation by arctic foxes.

Creches were not observed in fresh water areas although more than one female was occasionally seen accompanying broods.

Feeding behavior and analyses of gizzard contents contents revealed that king eider fed on plant and animal matter when in fresh water.

# RESUME

L'écologie de l'eider remarquable (<u>Somateria spectabilis</u>) a été étudiée du 9 juin au 16 août 1971 et du 17 mai au 12 août 1972, à la station de recherche du Musée National du Canada, sur l'île Bathurst, T.N.-O. Des données pour 1968, 1969 et 1970 ont été obtenues du personnel de la station.

En 1971 et 1972, l'arrivée des eiders dans la région à l'étude a été précédée d'un front chaud venant du sud. Les dates d'arrivée s'échelonnent du 11 au 16 juin pour 1968 à 1972.

Le comportement nuptial et le comportement agonistique de l'eider remarquable sont décrits par rapport à la reproduction. Les couples étaient formés à leur arrivée dans la région à l'étude. Les activités du mâle diffèrent légèrement de celles décrites par Johnsgard (1964); les activités de la femelle ont reçues une attention particulière. La copulation a été observée 17 fois sur le terrain de reproduction. La femelle choisit l'emplacement du nid, en présence du mâle. Le rôle de ce dernier semble associé à la protection de la femelle contre les prédateurs. La femelle pond habituellement le premier oeuf dès qu'elle a fait son choix. Elle ajoute des

végétaux au nid pendant la ponte des deux premiers oeufs pour couvrir ceux-ci lors de son absence. Elle ajoute aussi du duvet progressivement jusqu'à ce que la couvée soit complète, mais surtout pendant les trois premiers jours d'incubation. Le mâle reste dans les environs du nid jusqu'à ce que le troisième oeuf soit pondu. Une dissolution passive du couple s'accomplit.

Les mâles se regroupent sur les étangs d'eau douce, et quittent la région peu après. Pendant l'incubation la femelle est très attentive au nid; elle se nourrit peu ou pas, et passe plus de 95% de son temps à incuber. Les femelles non-reproductrices et celles qui ont échoué dans leur tentative restent en groupes en eau douce pour environ 3 semaines après que les mâles soient partis.

La couvée moyenne varie entre 5.25 oeufs en 1968 et 4.00 en 1972. Entre 1968 et 1972, 1969 fut la meilleure année avec 21.5% des nids dont un ou plusieurs oeufs ont éclos. Pendant ces 5 années, 0.5 conneton par nid (n=63) a été produit. Plus de 95% des nids observés ont été détruits avant l'éclosion des oeufs; des renards arctiques sont responsables de la prédation dans 79% des cas. Il semble y avoir une relation entre la perte des nids, la population de lemmings, et la forte densité de prédateurs dans la région à l'étude.

Entre 1968 et 1972, 69% des nids observés étaient situés sur des terrasses et des pentes graveleuses. Le couvert végétal (moins de 30%) était constitué surtout de *Saxifraga oppositifolia*. Les nids trouvés dans cet habitat étaient situés dans des dépressions formées à la périphérie des polygones. Ces dépressions créent un microclimat où la température est de 7°C à 9°C plus élevée que celle de l'air ambiant.

L'alimentation en eau douce est semblable à celle des Anatinae. L'analyse du contenu des gésiers révèle que l'eider remarquable se nourrit en eau douce de matière végétale et de matière animale.

Des individus non-reproducteurs ont été observés en 1971 et en 1972. En 1971, la date moyenne de l'initiation des couvées était le 28 juin, et en 1972, le 8 juillet. Le délai était associé surtout à des températures basses, à la présence de glace sur les étangs et les lacs et de neige dans les régions de nidification.

## ACKNOWLEDGEMENT

The initial summer of the study was supported by the National Museum of Canada. The second and final season was performed under a Boreal Institute for Northern Studies, the University of Alberta, research grant. The Department of Zoology, University of Alberta, also provided equipment required for the study.

I wish to express my gratitude to the following people: Mr. S.D. MacDonald for suggesting Bathurst Island as a study area and for his invitation to the National Museum of Canada High Arctic Field Station on Bathurst Island; his help and encouragement were appreciated. Dr. V. Lewin, Chairman of my advisory committee, Dr. D.A. Boag, Dr. D.A. Gill, Dr. W.G. Evans and Mr. S.D. MacDonald, members of my advisory committee for their constructive comments during the study and on an early draft of this thesis. I am also grateful to Dr. R.S. Palmer for his assistance in the initial summer and for his help in providing unpublished manuscripts and valuable Russian translations.

Dr. R.R. Ireland kindly identified when possible remains of bryophytes found in the gizzard or feces of king eider. Drs. G.R. Daborn and H.F. Clifford identified fresh water invertebrates collected in the study area. Mr. P.S. Taylor let me have access to his notes on king eider on Bathurst Island for 1968 and 1970. Miss M. Dumais verified identification of vascular plants collected in the study area. Mr. W.J. Adams skillfully made drawings from photographs taken in the field by the author. My wife, Thérèse Beaudet Lamothe, was of great assistance throughout the study. For their companionship and assistance in various aspects of my research, I am grateful to Drs. D.H. Heyland, D.R. Gray, M. Shish, P. Barret and D. Rewee, and Messrs P.S. Taylor, D.A. Gill and H. Mayfield.

The National Museum of Canada, Imperial Oil Ltd., and the Boreal Institute for Northern Studies provided transportation to and from Resolute, N.W.T. Logistic support while at the National Museum Field Station on Bathurst Island and transportation while in the Arctic was provided by Polar Continental Shelf Project of the Department of Energy, Mines and Resources. The Quebec Department of Education provided scolarships during my two years at the University of Alberta.

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# INTRODUCTION

King eider (Somateria spectabilis) is a monotypic species whose breeding activities in North America are confined mostly to the Arctic. It seldom nests south of 65°N and is by far the most numerous of the four species of duck known by the vernacular name eider (Myres, 1958).

Barry (1960) estimated the king eider population for Victoria Island to be in the order of 800,000 birds and that of Banks Island to be nearly 100,000. Taking into consideration the extent of the king eider range, the total population is in the order of 2 to 4 million birds.

Surprisingly, the ecology of the species is poorly known. The reasons for the lack of knowledge may lie in the remoteness of the breeding ranges, the non-colonial aspect of its breeding and the difficulties associated with travelling and living in the Arctic.

Observational data obtained in 1969 while at the National Museum of Canada High Arctic Field Station stimulated my interest in the ecology of the species. MacDonald and Parmelee (pers. com.) recorded 102 male king eider in the valley prior to nesting in 1968. With such densities it was deemed feasible to examine the biology of king eider while present on its summer fresh water habitat.

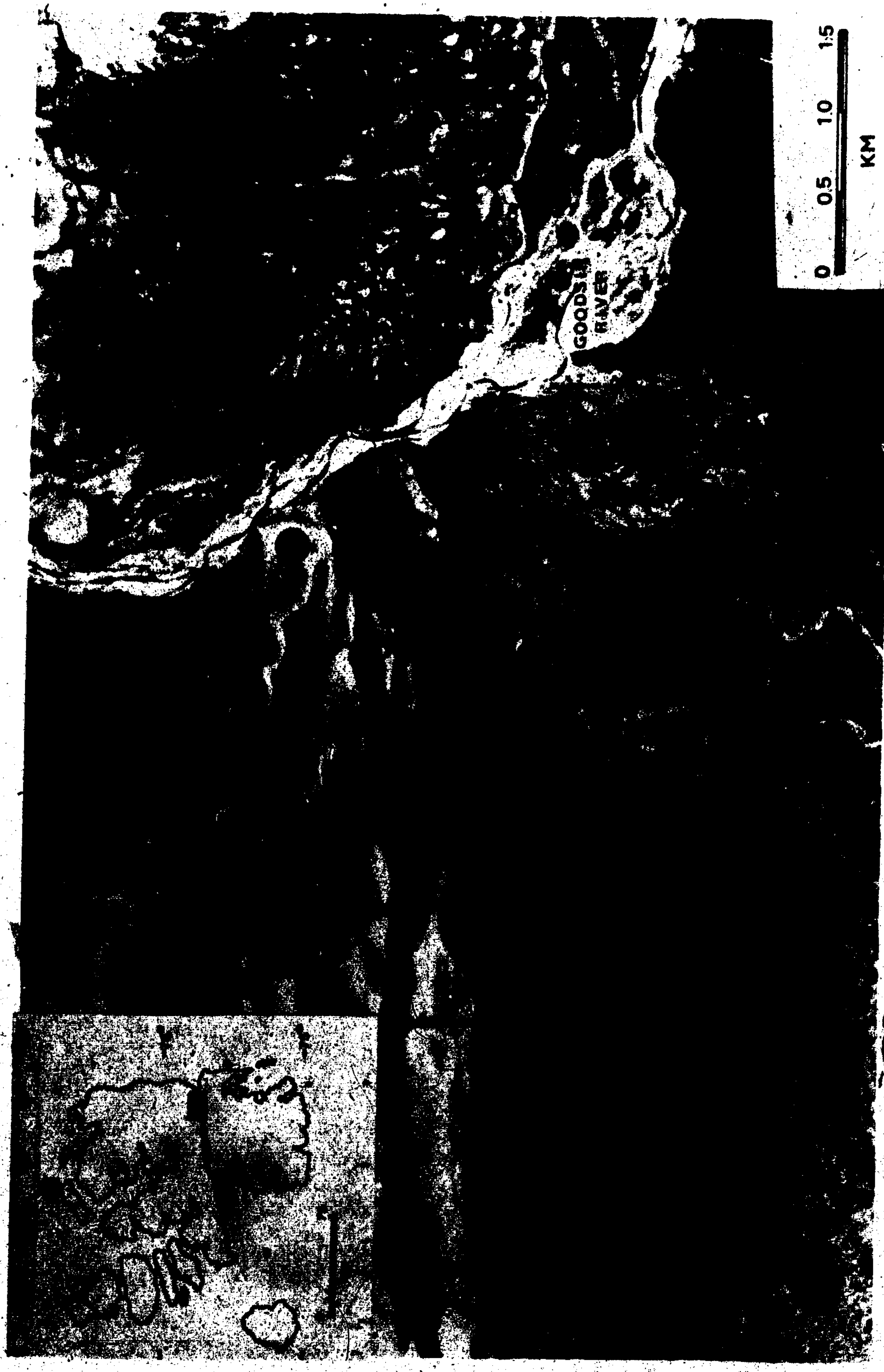
Specifically, I studied courtship activities on the breeding grounds, feeding behavior, nest site selection, incubation, predation pressure on incubating females and habitat utilization. The effects of meteorological conditions on the production of king eiders, as well as the presence of numerous avian and mammalian predators were also investigated.

Geography

The study area (Figure 1) is included in a circle of radius five kilometers from the intercept 75° 43' N and 98° 25' W, the position of the National Museum High Arctic Field Station on Bathurst Island, N.W.T. The area lies in a depression which, according to Taylor (1956), must have been until quite recently an east-west strait across the island connecting Bracebridge and Goodsir Inlets. The depression itself is actually a low and broad valley roughly 115 $km^2$, the marshy bottom of which is marked by innumerable small lakes and ponds. It also contains two large lakes in the west part of the valley. The largest has been recently named by Station personnel "Hunting Camp Lake" and is roughly 5 $km^2$. The second is "Ooblomie Lake", roughly 3.5 $km^2$. The marshy area that includes the small lakes and ponds is about 25 $km^2$.

Taylor (1956) considered the valley a fault zone that occurred as a depression probably filled with sediments. The series of rolling hills to the north and south are mainly sandstone becoming more "dentritic" and "intricated" (Bird, 1967) toward the east. Other geological formations on both sides of the valley are

Figure 1. Air photo of the valley between Bracebridge and Goodsir Inlets, Bathurst Island, N.W.T., showing the study area in the vicinity of the National Museum Field Station, which is indicated by a dot.


RIVER
0 0.5 1.0 1.5
KM

composed of folded sedimentary rocks, limestone, dolomite and shale (Blake, 1964).

The drainage of the area is rather complex. The adjacent hills and upland ridge, which usually has a shingle surface, are well drained and their effluent goes directly into the valley or else through small tributaries to the main river which eventually empties into Goodsir Inlet and which has been named Goodsir River by Station personnel. Its southern tributaries drain the lakes and ponds of the valley for ten miles to the west. Its northern tributaries drain the system of barren ridges for twenty miles to the north and north-west.

## Climate

Bathurst Island is located in the middle of the Canadian Arctic Archipelago. No location on the island is more than 15 miles away from the Arctic Ocean. The maritime influence of the different channels surrounding Bathurst Island stands out as a major control of the summer climate. Average snow fall is less than 30 inches (Rae, 1951) and most of it occurs in October and May. Snow and frost can occur at any time during the summer. Little melting occurs prior to the second week in June. However, once the melting process has started, snow disappears rapidly and by the end of June, the island is snow free, except in hilly terrain where it lies in gullies.

In June, July and August, low lying stratus clouds and coastal fog are common climatic features. Partially ice covered waterways influence the climate by adding sufficient moisture while holding air temperatures to within a few degrees of the melting point (Rae, 1951). Mean temperatures gradually decrease in August, and by the middle of the month, below freezing temperatures occur frequently. Table 1 gives the monthly mean weather recorded in a Stefanson screen for 1971 and 1972 on Bathurst Island, compared with 23 year average for Resolute, N.W.T. (Atmospheric Environment Service, 1971).

Table 1. Monthly mean weather recorded for 1971 and 1972 on Bathurst Island, compared with 23 year average for Resolute, N.W.T.

| | Mean °F | Max. °F | Min. °F | Snowfall Days | Snowfall Inches | Rainfall Days | Rainfall Inches | Days with frost |
|---|---|---|---|---|---|---|---|---|
| Resolute N.W.T. weather average (1947 to 1970) (Atmospheric Environment Service, 1971) | | | | | | | | |
| May | 12.8 | 18.7 | 6.9 | (9) | 3.5 | | trace | 31 |
| June | 31.5 | 35.4 | 27.4 | (5) | 2.6 | (2) | 0.23 | 24 |
| July | 39.7 | 44.5 | 34.9 | (2) | 1.2 | (8) | 0.92 | 9 |
| August | 36.9 | 41.2 | 32.5 | (3) | 1.9 | (8) | 1.01 | 16 |
| Bathurst Island National Museum Field Station weather for summer 1971 | | | | | | | | |
| May | 10.6 | 15.9 | 5.3 | (19) | | | | 31 |
| June | 35.1 | 39.9 | 30.3 | (5) | | (5) | | 19 |
| July | 43.7 | 50.2 | 37.1 | (0) | | (13) | | 0 |
| August | 34.1 | 37.8 | 30.3 | (12) | | (4) | | 24 |
| Bathurst Island National Museum Field Station weather for summer 1972 | | | | | | | | |
| May | 7.6 | 14.5 | 0.7 | (16) | | (0) | | 31 |
| June | 27.6 | 32.1 | 23.1 | (11) | | (3) | | 30 |
| July | 38.4 | 43.4 | 33.5 | (5) | | (10) | | 11 |
| August* | 31.8 | 33.5 | 30.2 | | | | | |

* Based on first 23 days

## LITERATURE REVIEW

Except for the few descriptions of behavior from field observations by Höhn (1957), Myres (1964) and Drury (1961), most of the published behavior studies are from captive ducks kept at the Wildfowl Trust in England (Johnsgard, 1964) and from film strips taken at the same institution and analysed by Sherman (1965). The various plumages are well described by Portenko (1952). A complete description of the taxonomy and ecology of the king eider is to appear in Handbook of North American Birds, Vol. II (R.S. Palmer, in prep.). The amplitude of the fall migration is documented by Wynne-Edwards (1952) and Thompson and Person (1963).

Faunal studies, including observations on the ecology of king eider while on the breeding grounds, have been conducted on West Central Ellesmere Island (Parmelee and MacDonald, 1960), Prince Patrick Island (MacDonald, 1954), Ellef Ringnes Island (MacDonald, 1961), Melville and Southampton Islands (Bray, 1943), Banks Island (Manning et al., 1956), Bylot Island (Tuck and Lemieux, 1959; Drury, 1961), Baffin Island (Soper, 1940, 1946; Watson, 1957), Foxe Basin (Ellis and Evans, 1960), Southampton Island (Sutton, 1932), Chesterfield Inlet (Savile, 1951), the Perry River region (Gavin, 1947; Hanson et al., 1956), Bathurst Inlet (McEwen, 1957), the Adelaide Peninsula (MacPherson and Manning, 1959), the Central Canadian Arctic (Fraser, 1957), Victoria Island (Parmelee et al., 1967), Hershel Island and the arctic coast of Alaska (Dixon, 1943). The works of Manniche (1910) and Dalgety (1936) for Greenland and Ogilvie and Taylor (1967) for West-Spitsbergen are also of interest.

Taxonomy

Much confusion still exists concerning the taxonomy of the eiders. Delacour and Mayr (1945) and Johnsgard (1960), the latter on the basis of behavior and cranial osteology, refer to king eider as a member of the tribe Mergini. The A.O.U. (1957) classifies the eiders in the subfamily Aythyinae.

A fresh water origin and subsequent invasion to the marine habitat (Humphrey, 1958), breeding in fresh water, feeding behavior and mixed diet while in fresh water, and similarity of the female plumage to that of the Anatini are characteristics which lead me to agree with

Delacour (1954) and Humphrey (1958) in placing them in a separate tribe, Somaterini, near the tribe Anatini.

Distribution

Considering the published accounts, it seems that the distribution as given in the A.O.U. check-list (1957) and Godfrey (1967) is too extensive and should be revised. A review of faunal studies performed in the Canadian Arctic showed that the range is discontinuous in a few locations. A new distribution map for Canada (Figure 2) was drawn.

Manning (1952) found king eider nesting at Cape Henrietta Maria in Ontario but the species has not been found on the Manitoba coast (Jehl and Smith, 1970). Todd (1963) did not find king eider breeding on the east coast of Hudson Bay but Godfrey (1967) refers to the species breeding at Stupart Bay and Kigaluk River in Quebec. MacPherson and McLaren (1959) found king eider only to be spring and fall transients at Cape Dorset and on the southern coast of Baffin Island. Northerly king eider have not been found nesting on Ellef Ringnes Island (Savile, 1961). The species probably nests only in small numbers north of the 78th parallel as sightings are not

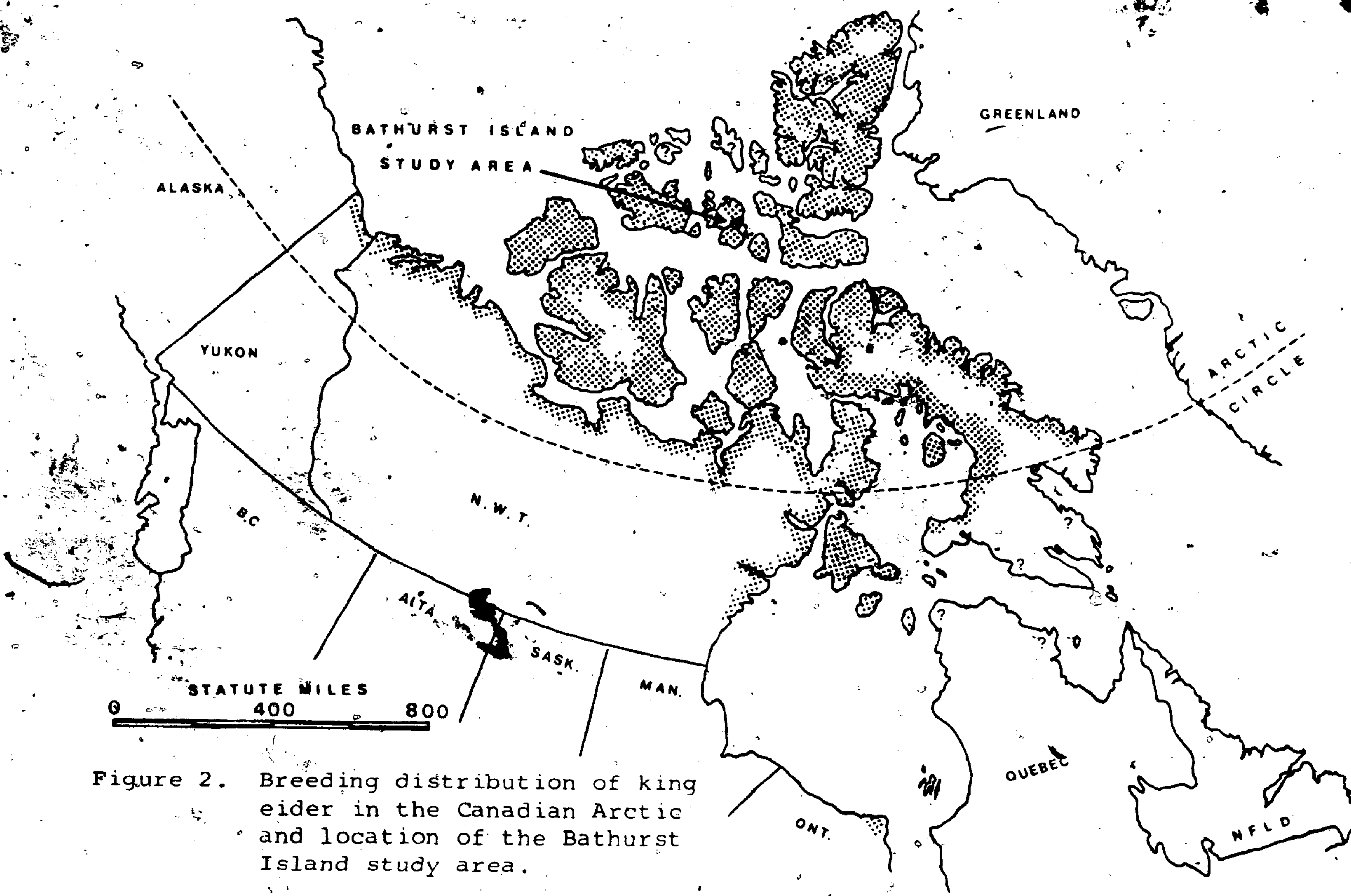



Figure 2. Breeding distribution of king eider in the Canadian Arctic and location of the Bathurst Island study area.

numerous. On the basis of observations by Barry (1960) and Parmelee et al. (1967), I believe that the most numerous breeders are concentrated in the western part of the Central Arctic.

# MATERIALS AND METHODS

The study was conducted from June 9 to August 16, 1971, and from May 17 to August 12, 1972. Upon arrival at the study area in May or June, snowmobiles were used to reach areas where open water was available to shorebirds and waterfowl. During and after the melt period, the study area was visited on foot; motorcycles were seldom used because of the resultant damage to the tundra.

Observations of courtship and feeding behavior, and nesting habits were conducted from a distance using a 30X spotting scope or 7x35 binoculars. Weather permitting, censuses were done daily at approximately 2300 hours from Camp Ridge. King eider were normally grouped on large ponds and lakes, and conditions were ideal for scanning most of the study area.

Courtship behavior, nest site selection and nesting habits were recorded on 16 mm film using a Beaulieu R. 16 ciné camera equipped with a 12 to 120 mm zoom lens; additionally black and white and color stills were taken with a 35 mm Nikon camera equipped with a 450 mm lens.

In order to acquire information on maintenance of the pair bond and feeding behavior, I spent 68 hours in the vicinity of ponds and lakes of the study area.

Approximately 21 hours were spent on ridges observing nest site selection and 52 hours were spent in a blind to obtain data on laying and early stages of incubation at one nest. Further time was spent at activities outlined below.

Upon nest initiation, a 4 $km^2$ quadrat with markers every ½ km, already in use by H. Mayfield to obtain data on nesting densities, included 4 different types of habitat found in the region. The quadrat was walked every second day when time and weather permitted, usually in transect lines approximately 100 meters apart, to find all nests within its boundaries and establish which habitats were used by king eider. The same quadrat was sometimes walked at random during the melt. The rest of the region included in the study area was walked several times taking into consideration suitable habitats for nesting king eider. King eider nests were plotted on an air photo and the habitat recorded in order to establish habitat preference for the nest site. Outlines of the major habitats were drawn on the same air photo.

Upon nest initiation in 1972, two blinds were constructed approximately 50 meters from 2 different nests to observe behavior of the female during the laying and incubation period. At one nest, a multichannel portable thermistor thermograph was used with 6 probes placed at various locations around and in the nest. This enabled me to obtain data on various conditions encountered in the vicinity of the nest and to obtain continuous temperature recording in the nest.

Vegetation analysis of 1 $m^2$ surrounding 19 nests was performed using the standard meter square method (Oosting, 1956) to see if vegetation cover showed similarity between nests found in the same habitat. With the incorporation of the Daubenmire rectangle 1/10 $m^2$ plant cover was estimated to the nearest 5%. Plants collected were identified in the field using Porsild (1964) and subsequently verified by botanists present at the Station and at the Herbarium at the University of Alberta.

In 1971, 4 females were banded using the standard metal bands provided by the Canadian Wildlife Service and plastic color bands. Two of the previous females were also collar banded in order to see their movements in the study area and to observe their possible return to the area in 1972. Subsequently both females collar banded left the study area and were never observed again. In 1972, one tame female under observation was banded using only a standard metal band.

In addition, 6 arctic foxes (Alopex lagopus) were live trapped in early June 1972. They were ear marked with plastic phosphorescent tape, sexe was determined and they were released in order to determine hunting territories and to observe if predation on king eider nests was performed by one individual more than another.

A total of 15 king eider were shot from the Bracebridge-Goodsir valley in order to determine their breeding status. Upon collecting, 30 cc of 70% alcohol was forced down the oesophagus of each bird using a calibrated wash bottle. This prevented post mortem digestion of gizzard contents that were subsequently analysed in the laboratory to ascertain, by an index method, food material obtained in fresh water. Droppings of king eider were also collected during both breeding seasons to establish food types and state of digestion.

On July 10, 1971, a Twin-Otter plane and on August 9 of the same year, a Hughes 500 helicopter were used for waterfowl censuses in the Bracebridge-Goodsir valley.

RESULTS AND DISCUSSION

## Habitat

In the Arctic, differences in use of habitat by species of birds may occur seasonally and also as a result of fluctuating environmental factors from one year to the next (Kessel and Cade, 1958). Habitat was classified into different types (Figure 3) in order to determine whether king eiders selected one type more than another for nesting. The description of the different habitats was based on Polunin's (1948) and Kessel and Cade's (1958) descriptions and applied to the High Arctic environment. The study area contained 7 habitat types:

1. Sedge-grass marshes.

These marshes occurred in the lower part of the valley, particularly around ponds and lakes and included for the purposes of this study, the "hillock" tundra type. They were characterized by high moisture content upon which the vegetation was dependant. During the spring melt this habitat type was usually covered by a few cm of water. Members of the Gramineae, Cyperaceae and bryophytes were the most common plants; secondary species such as *Saxifraga hirculus* and species of Ranunculaceae were numerous. Vegetation

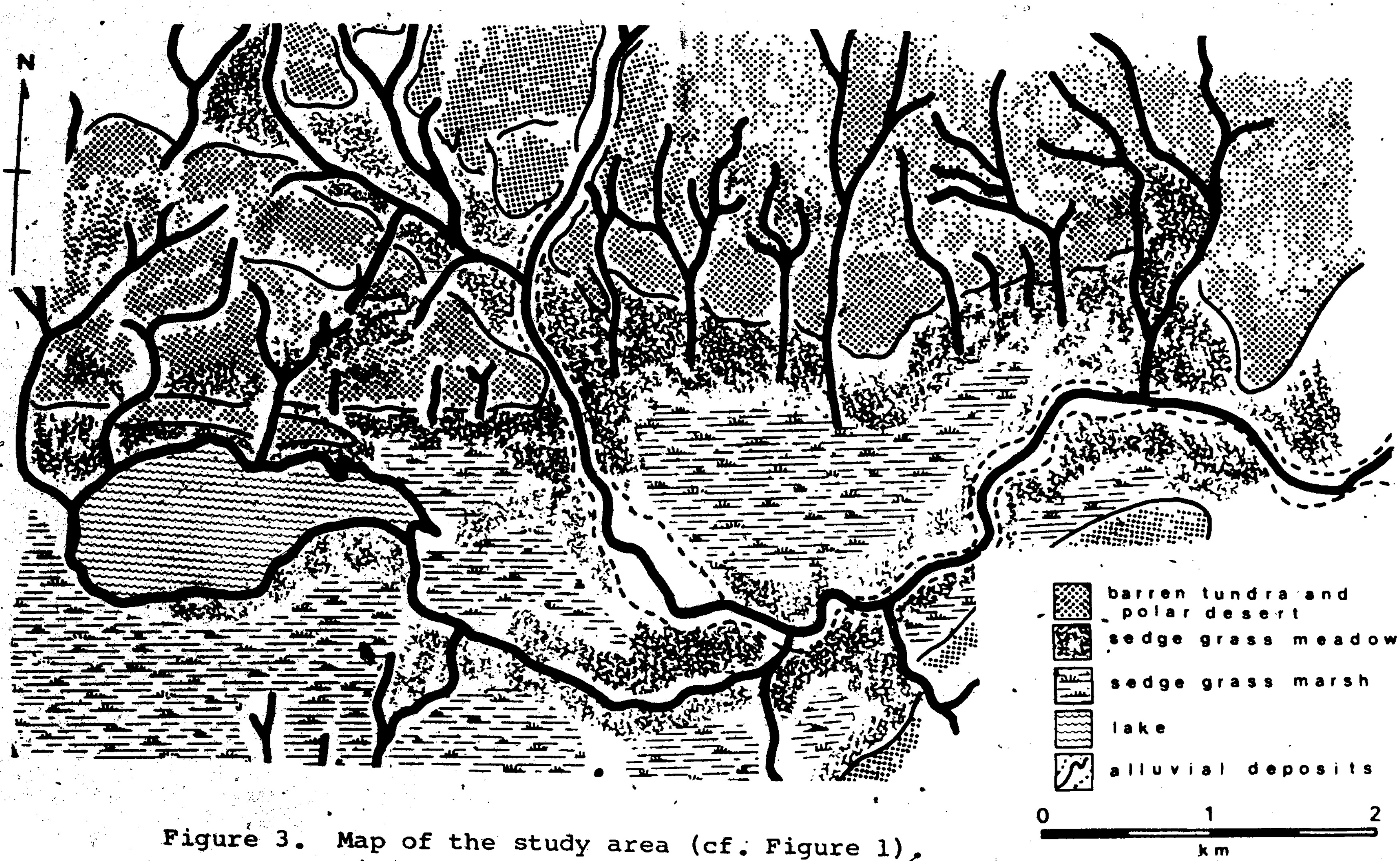



Figure 3. Map of the study area (cf. Figure 1) Different habitat types are shown.

cover ranged from 90% to 100% and the substrate was usually covered by bryophytes. Low center polygons were commonly found in this habitat type. Sedge-grass marshes covered 24% of the study area and were utilized by king eider in spring.

2. Sedge-grass meadows.

These meadows were found peripherally to the sedge-grass marshes, on terraces, or sometimes in small valleys in the surrounding hills and were characterized by damp to dry substrate. Tussock tundra was also present and was characterized by well drained soil. Salix arcticus and Graminea were the primary species with relatively few secondary species. Vegetation cover was usually 70% to 100% with relatively less bryophytes covering the substrate than in the sedge-grass marshes. Sedge-grass meadows covered 17% of the study area and were utilized to a limited extent by king eider for nesting.

3. Late-snow area.

This was usually a transition zone between sedge-grass meadow and barren tundra. On the study area, it was usually found at the bottom of the system of low barren ridges extending westward towards Bracebridge. In this area, drifting snow accumulated during the winter and persisted well into July. This area was characterized by a damp layer of bryophytes. Vascular plants associated with this zone were numerous, but considered secondary species due to the thick layer of bryophytes. The late-snow area covered approximately 2% of the study area and, depending on the amount of snow, was utilized to a limited extent by king eider for nesting.

4. Barren tundra.

Barren tundra, called dry tundra by Kessel and Cade (1958) was mainly a highland habitat, but was occasionally found in lowlands associated with hummock tundra and high center polygons. On the raised beaches, barren ridges and rolling hills of the study area, where barren tundra was most common, it was characterized by the presence of sorted-net polygons where *Saxifraga oppositifolia* was the primary species with few high Arctic associates such as *Salix arctica*, *Papaver radicatum*, *Saxifraga caespitosa*. Plant cover usually ranged between 15% and 30%; bryophytes were usually found in the depressions formed by sorted-net polygons. Lichens were usually abundant and diversified, with *Thalmolia vermicularis* being the most common. The barren tundra habitat covered 36% of the study area and was most important in terms of nest sites for king eider.

5. Polar desert.

Although polar deserts were widespread in the higher regions of Bathurst Island, they comprised only 9% of the study area. They were characterized by their rocky substrate with less than 5% plant cover with lichens being relatively common. They were never used by king eider.

6. Alluvial deposits.

Alluvial deposits were mostly found along the Goodsir River and were characterized by gravel bars, sand bars and mud flats. Alluvial deposits covered approximately 3% of the study area.

7. Lake.

Hunting Camp Lake was eutrophic and covered about 9% of the study area. Its depth ranged between one and four feet. The bottom was covered by a three to four inch layer of mud underlain by permafrost. The eastern end of the lake was free of ice earlier than the western end and was always occupied by king eider once open water was present. Submergent plants such as Arctophila fulva and bryophytes were commonly found. Aquatic invertebrates were abundant for the High Arctic environment (Shish, pers. com.).

Spring migration and arrival at the breeding grounds

Birds were observed in the vicinity of Bathurst Island at the end of April, 1971. Jonkel (pers. com.) observed male king eider in an open lead in the vicinity of Bailie Hamilton Island, fifty miles east of Goodsir Inlet.

Spring arrival dates for king eider in the Bracebridge-Goodsir valley for the period 1968-1972 ranged from June 11 to June 1[illegible]. In 1971, 20 to 40 knot winds blowing from the [illegible] were recorded during the first observati[illegible]g eider in the valley, on June 11. With the prolon[illegible]f these strong winds until June 14, melting was [illegible]erated and large pools of water were available fo[illegible] bulk of the population which arrived on June 18 (Fi[illegible]4). In 1972, south-west winds preceded the arrival of t[illegible] first pairs on June 13. The population increased slowly until the next period of recorded south-west winds on June 22 when the king eider population reached its maximum of 108 birds.

Migrational movements of birds have been associated with general climatic conditions (Drost, 1956). According to R[illegible] (1966) birds are capable of using barometric pr[illegible] for long flights during these seasonal

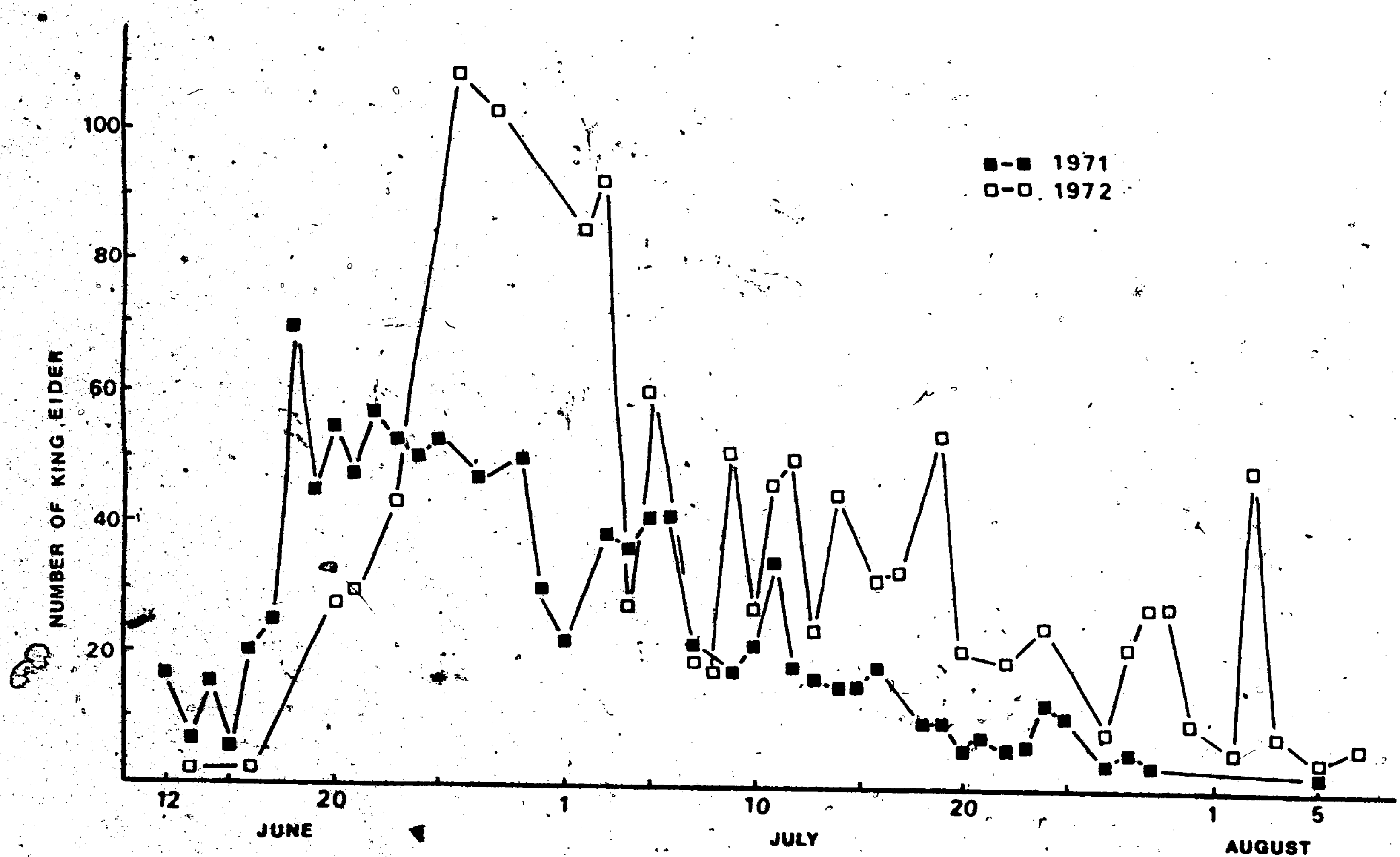
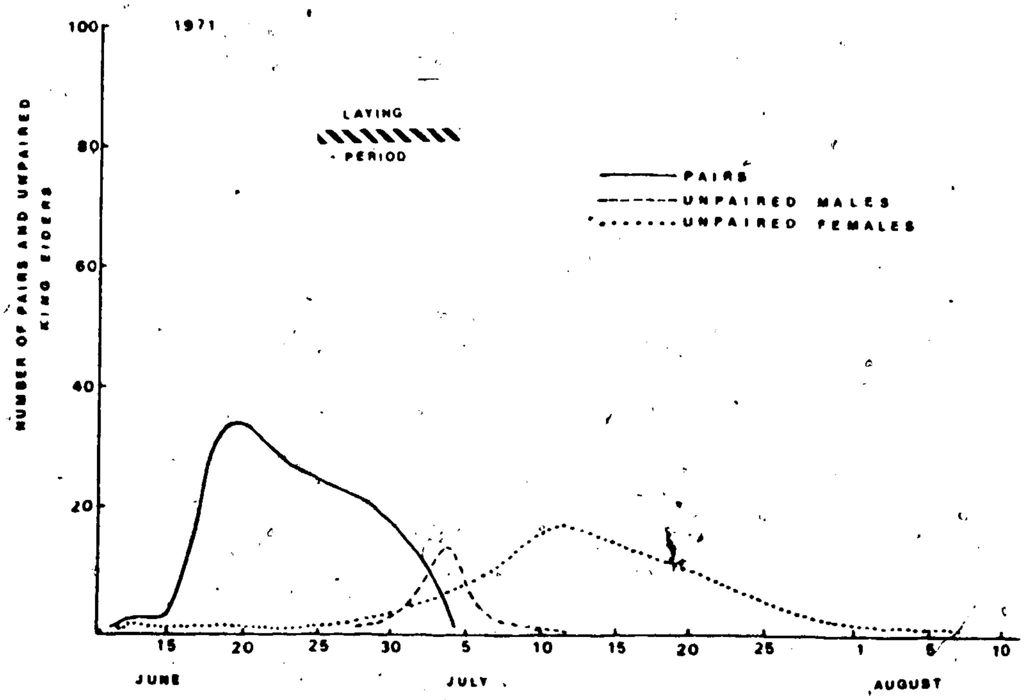



Figure 4. Numbers of king eider observed in the valley portion of the Bathurst Island study area during the 1971 and 1972 breeding seasons.

variations. Bagg et al. (1950) after observing bird movements in relation to meteorological patterns, concluded that during spring migration pronounced movements take place into or through a given region during the interval between the passage of a warm front through that region and the subsequent arrival of a cold front.

Numbers of king eider observed in the study area in 1971 and 1972 are shown on Figure 4 and the composition of the population in Figure 5.

Several factors such as available water, food and social interactions are also important at the time of arrival and probably influenced movements through the study area. In 1971, 50% of the summer water surface was free of ice on June 18, as shown on Figure 6A. Movements throughout the valley were numerous and flocks of from 2 to 16 birds were spatially distributed in the valley, occupying preferred ponds. Courtship activity and feeding were intensive. In 1972, few ponds totalling less than 10% of the summer water surface were available to king eider (Figure 6B). Movements in the valley were restricted to the eastern part where open water was present and in one instance 108 birds occupied a pond less than ½ $km^2$. Displays associated with maintenance of the pair were



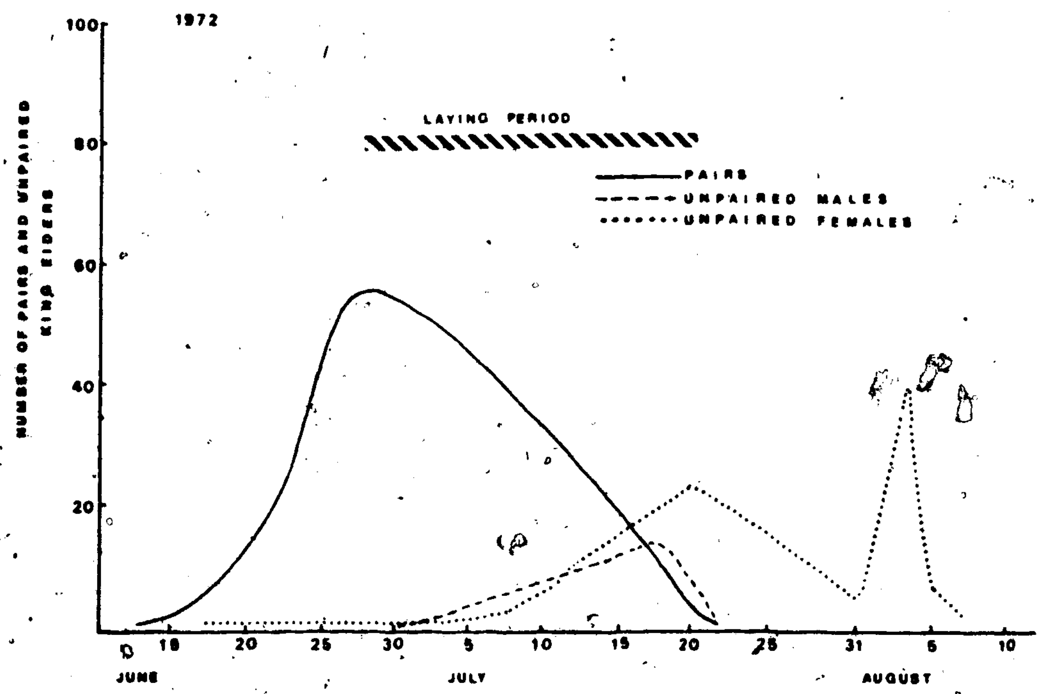




Figure 5. Population composition and laying periods as observed in 1971 and 1972 on Bathurst Island.

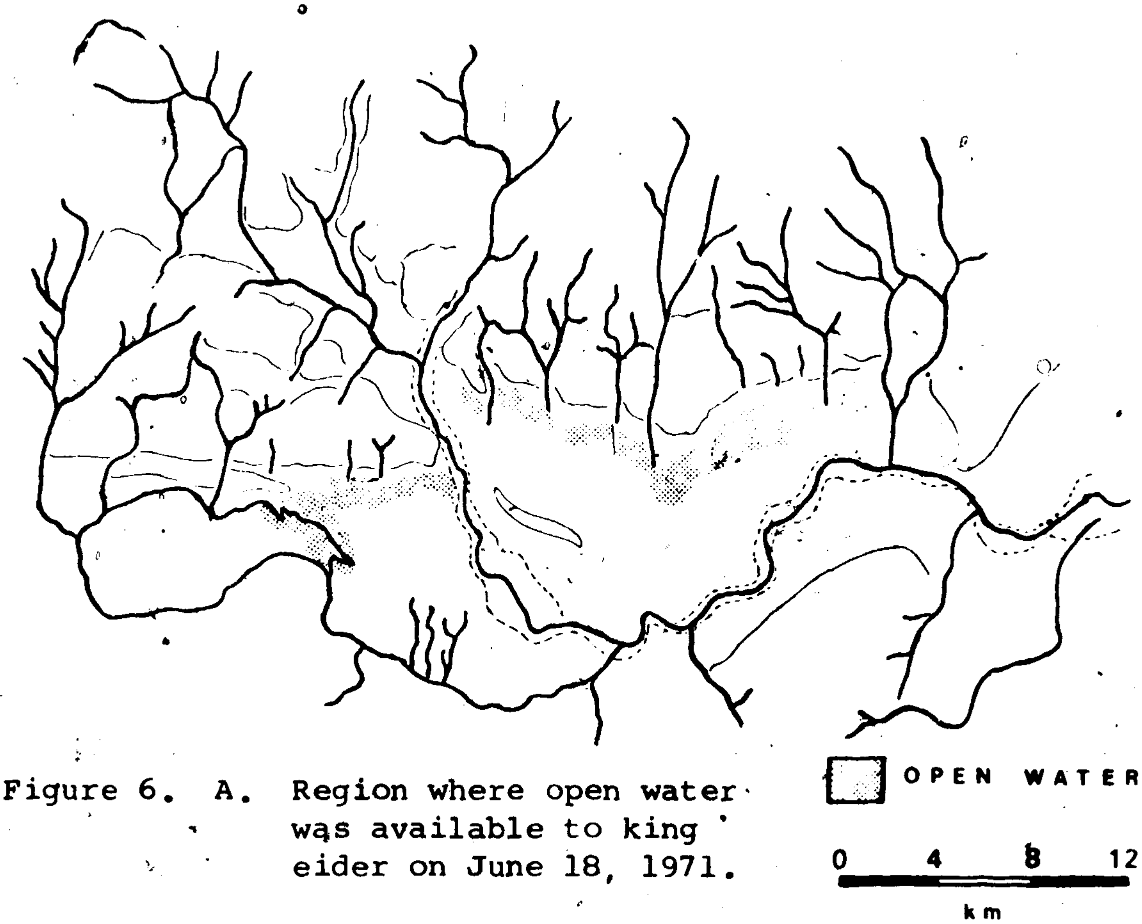



Figure 6. A. Region where open water was available to king eider on June 18, 1971.

Figure 6. B. Region where open water was available to king eider on June 22, 1972.

Figure 6. C. Region where open water was available to king eider on July 4, 1971.

Figure 6. D. Region where open water was available to king eider on July 4, 1972.

less numerous than for the same period in 1971, and feeding was much reduced. Observations showed that loafing was preferred to other activities. As melting progressed, more open water was available to king eider (Figure 6C and 6D).

## Pairing

The timing of pair formation in king eider is poorly known. It is performed both on the wintering grounds and during northward movements (Palmer, unpubl.). Most king eider were paired upon arrival on the breeding grounds. Five flocks containing unpaired individuals were recorded prior to the peak arrival on the study area. In 1972, two unpaired females remained in the study area throughout courtship and initiation of laying. Afterward, if present, they could not be separated from the groups of females found in the valley. They were usually seen with the larger flocks and little agonistic behavior was shown toward them by other females. These two females might have been immature birds, but age characters as described by Portenko (1952) are almost impossible to observe in the field. Nevertheless, unpaired females were uncommon prior to the initiation of laying.

General behavior

The behavior of male king eider has been partially described by Brooks (1915), Hanson et al. (1956), Höhn (1957), Myres (1959), Drury (1961) and Johnsgard (1964). Johnsgard's descriptions of courtship activities are the most complete. The form and duration of seven courtship displays in males have been investigated by Sherman (1965). He concluded that most male displays are stereotyped in both form and duration. The terminology used follows that of Johnsgard (1964, 1965).

The behavior of the species is described with respect to the major events of the reproductive cycle. Behavior patterns related to pair formation were not observed on the study area as most king eider were paired upon arrival on the breeding ground. The bond existing between pairs seemed rather weak at that time and many social interactions took place especially between males. The intensity seemed also dependant upon the density of the population, as more interactions were observed in late June 1972 when 108 king eiders were restricted to one pond. All interactions observed resulted in maintenance of the pair bond. With opening of the ponds king eider tended to be widely distributed in groups of

2 to 16 birds and couples. Most interactions were observed during loafing as pairs were closely grouped at this time.

Once the pairs were widely distributed, it was found that king eider at Bathurst Island supported Johnsgard's (1965) hypothesis in which he suggested that synchronization of male displays was almost exclusively the result of stimuli provided by the female. However on 9 occasions males were observed to display by "pushing" on water in front of the female. The females reacted 7 times by "chin lifting" and the 2 other times they continued feeding.

Copulation was observed 15 times during 33 hours of observation in 1971 and only twice in 1972 during 14 hours of observation. No predetermined sequence of courtship displays was observed in males prior to copulation but in females "chin lifting" always preceded the prone posture (Figure 7A). The time it took the male to respond to the prone posture varied from 10 seconds to approximatively 90 seconds. On two occasions the female temporarily left the prone posture to perform up and down movements of the head (Figure 7B). Copulation (Figure 7C) was always observed to occur after the female had taken the


Figure 7. Mating posture in king eider.

A. Prone posture in female.
B. Solicitation by female.
C. The male grabs the nape of the female prior to the termination of copulation.

prone posture.

The behavior observed during nest site selection, nest initiation and incubation is described in a later section of this thesis.

With initiation of incubation, there was apparently a weakening of the pair bond. On July 4, 1971, while observing males congregating before leaving the breeding grounds, intense courtship displays were observed among the males and polygamous behavior occurred. A single male swam away from the group to join 4 nearby females. Within a five minute interval, the male was seen copulating with two different females. Similar behavior has been observed in common eider (Somateria mollissima) (Palmer, unpubl.).

With departure of the males, non-breeding and non-successful females were observed on the study area up to three weeks. Then they gradually departed from the fresh water area. Their activity consisted mainly of feeding and loafing. Little agonistic behavior was recorded among these groups.

Cour.ship displays

A total of twelve male and one female courtship displays have been described by Johnsgard (1964). All of these displays were observed on the study area and their occurrence is given in Appendix I. Of the twelve male displays performed "wing flapping" and "bathing" differed markedly in form.

According to Sherman (1965), "wing flapping" was commonly observed after landing, resting and bathing and often before "upward stretch". Johnsgard (1964) and Sherman (1965) found that during "wing flapping" the head in male was raised from 45$^o$ to well over 90$^o$ from the horizontal axis. I observed in the field and later analysed from 16 mm film strips that the position of the head in males was not always at an angle but was often horizontal to the water (Figure 8B). On the basis of the head position and activities preceding "wing flapping", it was then classified either as a courtship display or as a comfort movement. Courtship "wing flapping" in male consisted in lifting the head vertically so that the black "V" mark present on the throat of the male was exposed (Johnsgard, 1964) to other males or females present. Comfort "wing flapping" in males consisted of keeping the


Figure 8. Variations in "wing flapping" by king eider.

A. "Wing flapping" as a courtship display in male.
B. "Wing flapping" as a comfort movement in male.
C. "Wing flapping" commonly observed in female.

head in the horizontal position and was observed after landing, bathing and prior to "upward stretch".

"Wing flapping" was also observed in females. The head position was observed to be close to the horizontal axis (Figure 8C). In females it is believed by Johnsgard (1964) to be entirely a comfort movement.

"Bathing" varied in form and duration. When associated with body and plumage care, "bathing" involved little splashing and lasted from 10 to 35 seconds. "Bathing" associated with copulatory behavior was vigorous and much splashing was involved. It lasted from 20 to approximately 90 seconds, although one female was observed to continue bathing for about 5 minutes after copulation. After "bathing", displays such as head rolling, wing flapping, upward stretch and preening were commonly observed.

The study previously mentioned emphasised courtship displays of the male but little information on females is available. My observations of courtship activities revealed that "pushing" on water was rare in females and was observed only on two occasions. The movement of the females was less complete than that described for males by Johnsgard (1964). The females also lack[illegible]the[illegible]e" sound emitted by the male.

[illegible]ch[illegible]s absent from the female courtship display re[illegible]oi[illegible]

"[illegible]ling" also occurred in females but was observed les[illegible]n (Appendix I). This movement was less exagerated th[illegible]n the male and seemed to provoke agonistic behavior in it[illegible]te.

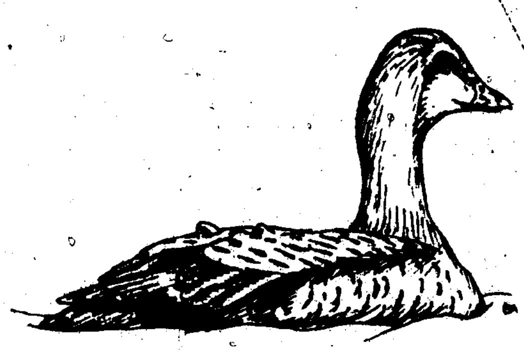
"Pre[illegible]g behind the wing" was less common in the female than in th[illegible] male (Appendix I) and was considered of secondary impo[illegible]nce among the displays of the female.

<u>Agonistic behav[illegible]</u>

Agonistic behavior was observed only when king eider were paired. On water agonistic behavior was observed frequently when birds were in large groups. Agonistic behavior was most intense from two days to a week after arrival when large groups were restricted to 2 or 3 melted ponds. On land agonistic behavior was observed when king eider were loafing on islands or shores of melted ponds. It consisted of "chin lifting" in females, "head tossing" and chase in males.

"Chin lifting" (Figure 9A) was the most frequent display observed in the female and was similar to "head

A



B

Figure 9. Agonistic displays in female king eider.

A. "Chin lifting".
B. "Alert posture".

tossing" in the male. Primarily "chin lifting" was a threat display and was often accompanied by a "grunting" sound. It was observed in the presence of males and females.

A similar display (Figure 9A) also described by Johnsgard (1964) as "chin lifting" is considered by him to be a courtship display and was observed during courtship activities. It was difficult to determine the significance of the display when it did not result in threat or chase. "Chin lifting" as a threat was always performed toward another female or another male other than its mate.

The "alert posture" (Figure 9B) was also noticed during periods of agonistic behavior. It consisted of elongation of the neck and raising of the head and was observed in both sexes and usually preceded taking off or threat behavior.

Water surface chases (Figure 10) were infrequent and were observed 8 times between males. No surface chases were observed between or toward females. "Head tossing" preceded surface chases and no body contact was ever recorded. They were always the result of "chin lifting" by the female. Its mate was always observed to initiate the chase. The distance covered was approximately 4 to 7 meters.

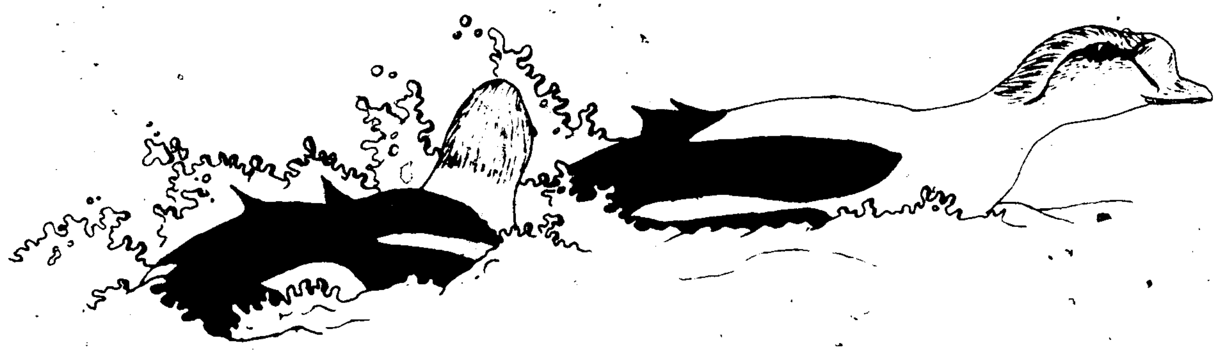


Figure 10. Agonistic displays in male king eider. Chasing and "neck stretching".

Diving in fresh water by adult king eider was infrequent and was only observed on 2 occasions in 1972. On both occasions the female was isolated from her mate by a group of eiders and responded by diving. In both cases, diving of 2 males followed. Such diving was repeated 5 and 7 times and on each occasion lasted approximately 3 to 8 seconds. I believed that the nature of these dives was agonistic and consisted of underwater chases.

On land chases were more frequent and occurred during loafing periods. They were preceded by "chin lifting" or "head tossing" toward pairs walking around selecting resting sites. The chase was initiated by an adjacent male after the pair had settled down and was centered toward the other male. From the position of the observer it was impossible to establish space requirements during these activities.

The presence of long modified scapulars termed "sails" by Palmer (unpubl.), on the back on both male and female king eider, is of interest with regard to the behavior of the species. These scapulars are also present in the common eider but are retractable (Palmer, unpubl.). He observed these only during agonistic behavior and high intensity displays in male common eider. In male king eider these scapulars are always present and visible when the bird is in the nuptial plumage. In females they are only visible at times and apparently are retractable. They are visible only during intense courtship activities or agonistic behavior. In both sexes scapular erection seems to vary according to intensity of display (Figure 11A and 11B) or in response to a stress situation (Figure 11C). In females these "sails" vanish during quieter spells (Figure 11D).

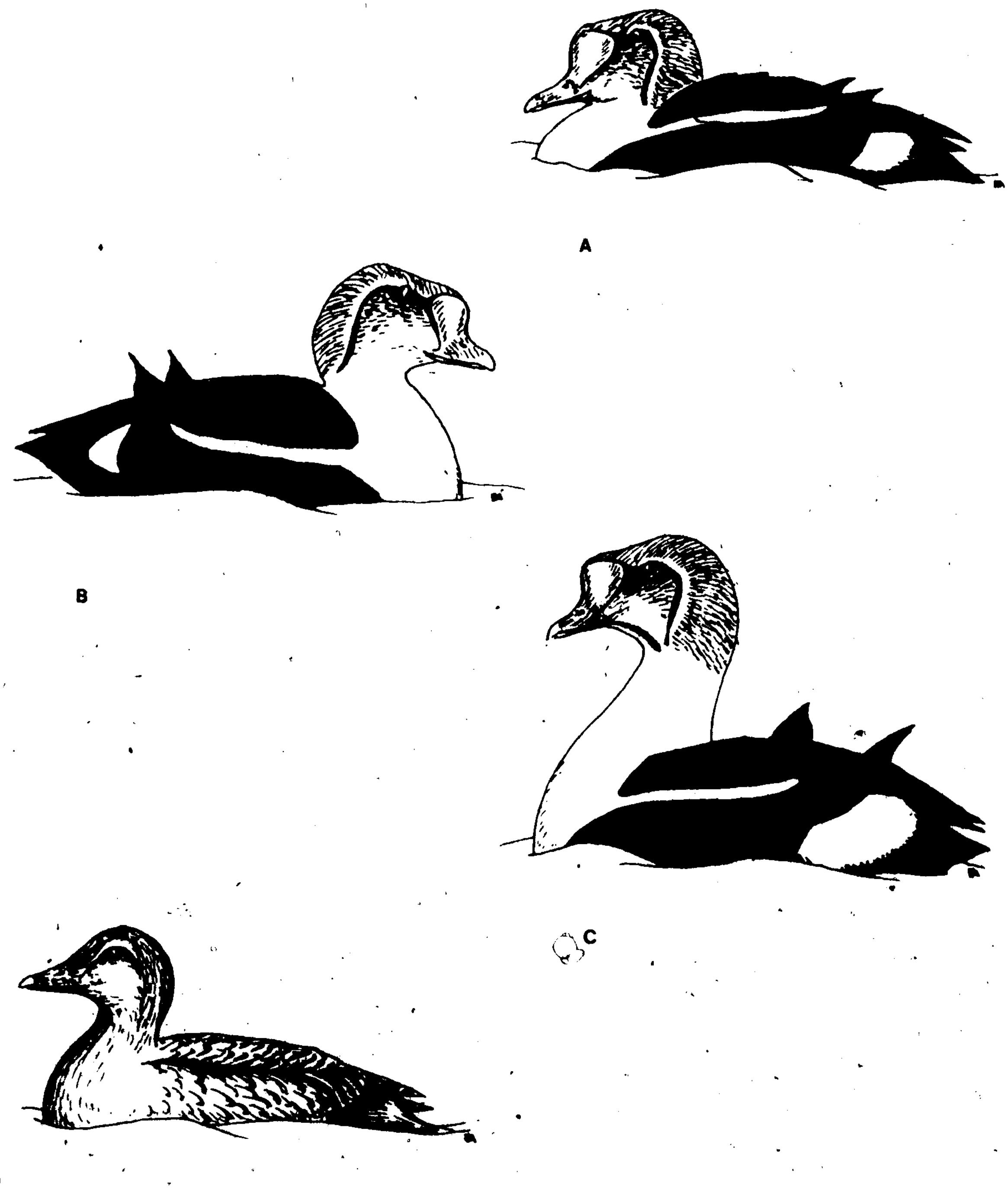



Figure 11. Degree of erection observed in modified scapulars of king eider.

A. Quiet spell in male.
B. Low intensity in male.
C. High intensity in male.
D. Quiet spell in female.

## Nest site selection

Nest site selection is poorly known in king eider although it seems to show similarities to other members of the genus *Somateria* (Cooch, 1965; Dau, 1972). Observations on Bathurst Island showed that, in ten cases out of eleven, male king eider accompanied the female during nest site selection; in only seven was a definite nest cup selected and in six cases the female actually laid her first egg during this process.

There seemed to be a correlation between observation of first copulation and initiation of first low flights over the barrens as both were observed on June 25 in 1971 and on June 27 in 1972. In both years initiation of nest site selection took place two days after observation of the first copulation.

Nest site selection was usually performed by single pairs but one observation revealed that two pairs were involved. This was rather unusual because of the aggressiveness that existed between males during the breeding season. Both males were sitting approximately 5 meters apart facing each other, while both females were walking in opposite directions probing the ground in small depressions and sitting in some of them. No crouched positions were performed by the females. After 25 minutes, an arctic fox appeared in the area, the males showed the alert posture and walked towards the females and after regrouping as pairs, they took flight.

The displays that lead to nest site selection were performed by the female. The male was also active but his behavior was ritualized and his presence seemed to be associated with other functions, than nest site selection. Four main displays were involved in nest site selection. Except for the incubating posture, which was performed only by the female, and for "reaching on land", which was performed only by the male, the other two were common to both sexes and consisted of bill probing and sitting. Displays performed by females were in a stereotyped succession if the area seemed to be proper for the establishment of a nest and were usually initiated by bill probing.

Both males and females performed bill probing. This display was most often performed in vegetation. In the barrens, where most of the observations were made, it was always performed in a polygonal net unless other objects attracted the attention of the female. The movement consisted of a 90° forward arc movement of the neck, until the bill touched the ground. When the arc was completed, the female might probe the ground several times in different areas or advance while in this position and continue probing prior to assuming the erect position. During vegetation probing, the female was seen to remove some of it and toss it aside. The movement might resemble reaching on land, but it was less exagerated and no vocalization accompanied it. The function of the display seems to be related to determining vegetation depth and probably substrate humidity. It is interesting to note that the skeletal part of the distal end of the bill of most of the Anatidae, including female king eider, contains a multitude of foramina, which may be associated with sensory receptors.

The male also performed bill probing and its function is not well understood however it might be a highly ritualized pattern associated with strengthening the pair bond. It is also believed that both male and female might obtain grit during such a practice.

After selecting a possible nest site, the female sat in the area previously probed. Such behavior was different from sitting or resting performed by males and females at other times. It was usually associated with wiggling of the body in the depression. The hen sometimes turned around and sat facing a different direction. She stood, probed under her breast and sat again. If the location was suitable, she assumed incubating posture.

The incubating posture took several forms but in normal incubating posture the wings were held out from the body and rested on the substrate. The female tried such a position several times, facing different directions. In all observations of nest site selection, the female also performed the crouched incubating posture (Figure 14A) with the neck tucked in and the head low, near the ground. This position was believed to be associated with high priority sites, as in 6 sites where an egg was deposited afterwards the female performed this crouched position.

Sitting posture in males was associated with resting. In all cases when a female took the incubating posture, the male was sitting with his head raised. In some cases, when the female took the crouched posture the male performed reaching on land and vocalized. The male usually sat in a location higher than the female or on snow patches when present.

In 7 cases where nest site selection was observed the birds showed no fear of man. In only two cases did the male leave the female presumably because of human interference. In one case, the female was in the laying process. In the second, she continued on her own and after several hours laid an egg. The male did not return for the second egg. In another case, the male was absent during nest site selection.

The distance covered during nest site selection varied and seemed to be related to the time involved. The maximum distance covered was approximately ½ km. Most observations of nest site selection started when the process was already underway, but 3 observed from the beginning lasted from 1½ to 4 hours.

There may be several advantages to the males presence during nest site selection and laying. Protection and defence of the female against predators seemed to be the most important. Two observations revealed the protective role of the male when the female was under attack. The male was observed to be highly aggressive toward a long-tailed jaeger (Stercorarius longicaudus) and in both occasions was heard "grunting". Maintenance of the pair bond is likely to be another factor related to the presence of the pair during nest site selection. Because of the disruptive plumage of the male, its presence may be considered a predator diversion mechanism enabling the female and the nest to remain unnoticed during the early stage of laying.

Only one observation was made of an encounter between a pair in the process of selecting a nest site and another incubating female. Both the male and the female were making the selection, when the female walked within a few meters of another incubating female. The pair quickly walked several hundred meters away from the incubating female. No observations of behavior nor sound emission from the incubating female could be recorded because the nest was located out of sight.

It was observed that during nest site selection, king eider were attracted to shiny pieces of metal or other foreign objects, which they tossed around. They sometimes ingest these as one king eider was found with its gizzard perforated by a 1¼ inch nail.

Nest Initiation

Once the nest site had been selected, the female started digging a scrape in the vegetation. The process consisted of shifting her weight forward. While resting on her breast, she started digging with her feet, pushing the loosened vegetation backward in successive slow movements. After several movements with both feet, she raised, probed the scrape with her bill, rotated to face another direction, sat and repeated the same process. At various times throughout the process, she took the incubating position. Once the scrape seemed suitable she rose half way resting forward on her breast (Figure 12) then laid her first egg and wiggled her tail. In six observations where the final scrape was built by a female, one egg was laid during the process. Taylor (pers. com.) observed a female build a scrape, then leave the area and subsequently return to the scrape several hours later and lay her first egg.

After laying the first egg, the female usually rested for 5 to 50 minutes. The time spent resting varied with individual birds; subsequently the female started picking vegetation (Figure 12B) and tossed it around the nest. She then rose and started covering the scrape and

Figure 12. Laying and nest building in king eider.

A. Laying posture.

B Female picking vegetation to be added to the nest.

C. Female obtaining down feathers from the breast region to be added to the nest

egg with vegetation. She left thereafter and returned 22 to 27 hours later for the next laying session (Figure 13A). On several occasions, the female did not leave the area immediately, but walked around in a zig-zag fashion, sitting in several depressions formed by sorted-net polygons for periods of time ranging from 15 minutes to well over one hour, prior to departing. Such behavior might be associated with learning the nest surroundings, for recognition upon return for the next laying session or else as a predator diversion mechanism. The same procedure was observed when females returned to the nest for laying. Females were observed to sit in 3 to 11 depressions formed by sorted-net polygons prior to sitting in their nest.

The male kept between 10 to 50 meters from the nest. He remained for the duration of the nest site selection and during the laying of the first egg. The visit of the male was subsequently shorter for the second and third egg.

Time spent on the nest by the female increased with the number of eggs added to the clutch (Figure 13B). This is understandable if we consider the behavior of the female at the nest during laying periods. After laying the second egg, she continued working at the nest scrape by

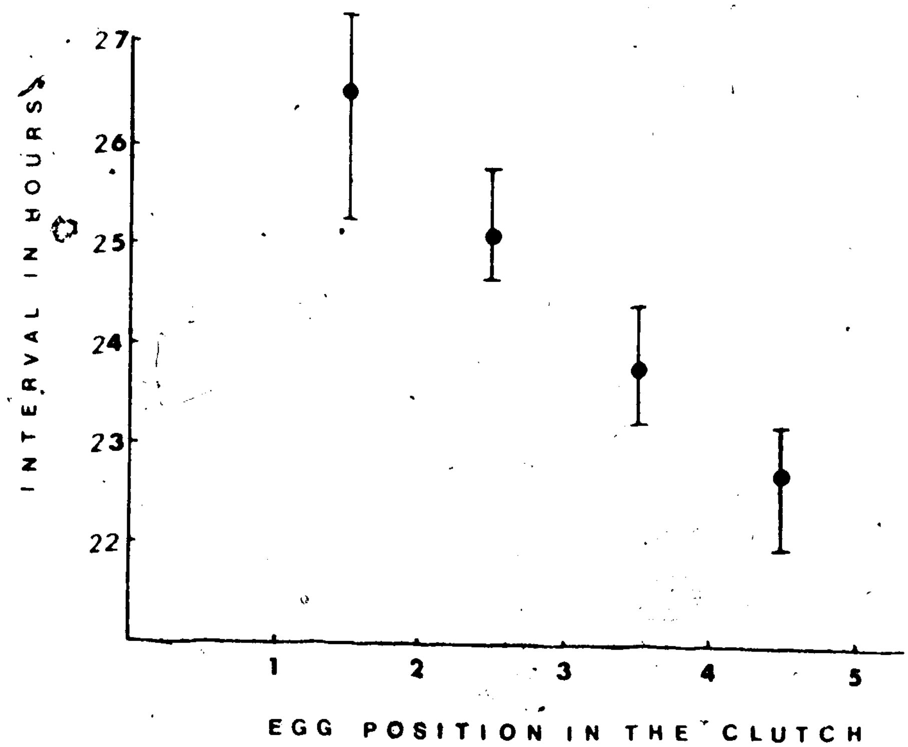



Figure 13. A. Range and mean time recorded between laying of each egg (n=12) in relation to its position in the clutch.

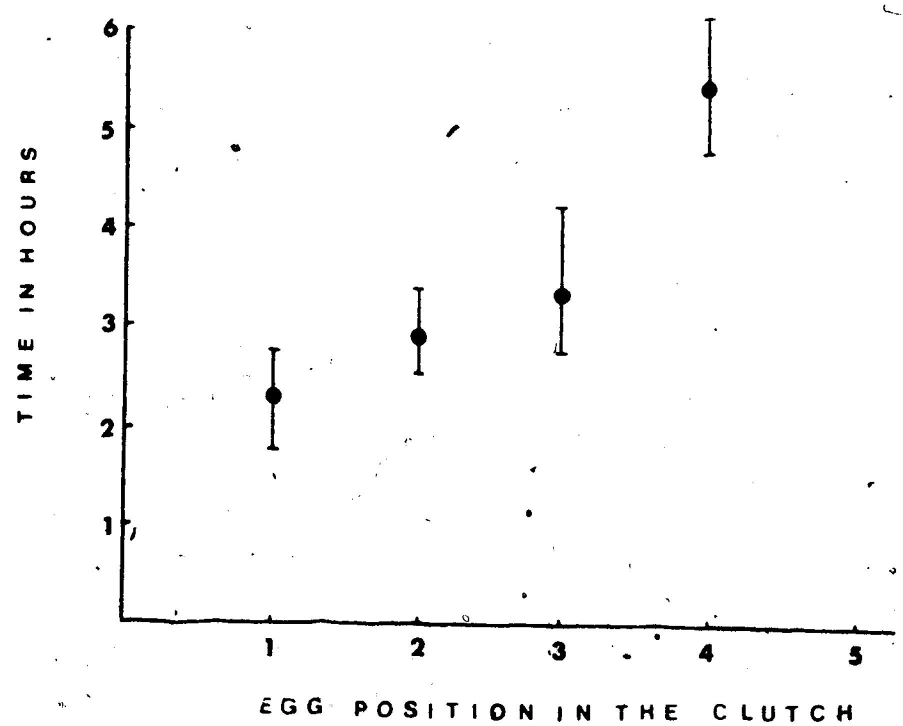



Figure 13. B. Range and mean time spent by the female on the nest during laying in relation to the egg (n=12) position in the clutch.

adding a vegetation layer under and around the eggs. Vegetation was gathered within a one meter radius of the nest. The female obtained bits of plant material at various places without disturbing the general appearance of the surrounding vegetation. All plant material was added to the nest prior to addition of down feathers. When leaving the nest after the laying session, she covered the eggs with vegetation; the nest was then almost identical to the surrounding area.

Down was added in small quantities after the third or forth egg, but the greatest amount was added after completion of the clutch when incubation had started.

Incubation

Incubation in king eider started within 2 to 3 hours prior to laying of the last egg. Fifty-two hours of visual observations and analysis of 136 hours of continuous nest temperature data revealed that the female probably did not leave during the first 7 days of incubation as no sudden fluctuation in nest temperature was recorded. At that point she was flushed by an arctic fox and the nest was partially saved by me. She returned within 20 minutes. The temperature in the nest had dropped 12.5°C during that short period. The female continued to incubate for 3 days, until an egg partially cracked by the fox broke in the nest. After spending 90 minutes carrying away and eating soiled down and pieces of eggshell she abandoned the nest. Within 30 minutes the temperature in the nest was 6°C.

Observations from 9 nests revealed that in early stages of incubation the female was active in obtaining down from several regions of her body (Figure 12C). It was obtained by passing the bill in the down feathers, not by plucking them (Palmer, pers. com.). Down was then placed carefully around the nest cup.

Female king eiders assumed several incubating postures, which were determined by the presence or absence of intruders in a circle of approximately 250 meter radius from the nest.

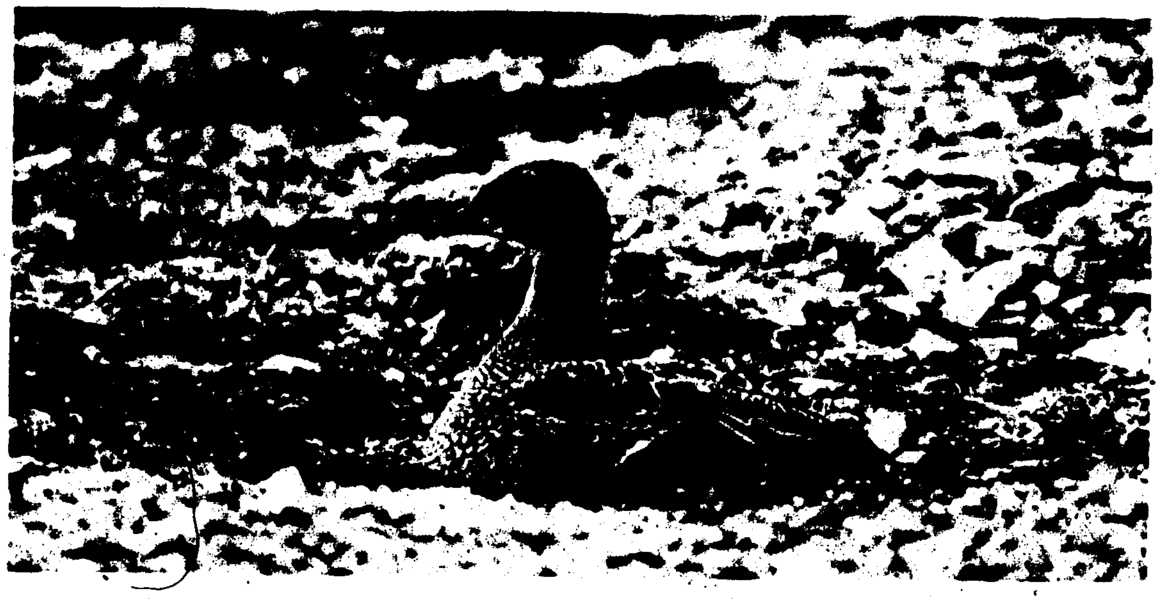
The crouched posture (Figure 14A) was always assumed when intruders were within the circle previously mentioned. The female sank partially into the nest cup with her head flattened to the ground. This posture enhanced concealment. The crouched posture was preceded and followed by the alert posture (Figure 14B). This posture was observed when the female saw or heard intruders and consisted of stretching the neck vertically

Figure 14. Incubating postures of female king eider on the nest.

A. Crouched and head flat to the ground assumed in the presence of intruders.

B. Alert posture.

C. Normal incubating posture.



with rotation of the head as to scan the area.

The normal incubating posture (Figure 14C) was assumed in period of no disturbance. The neck was drawn backward and the head seemed to rest on the back. While assuming this posture the female was often seen resting with her eyes closed and on 6 occasions she had her head turned back with the bill inserted in the scapulars. Such posture was not observed for more than 10 minutes at the time.

Orientation of the female on the nest (Figure 15) showed that most often the female avoided being broadside to the sun and managed to keep her body facing or backing toward it. The differences in orientation between the periods 0600-1200 hours and 1200-1800 hours, and 1200-1800 hours and 1800-2400 hours were significant (P<0.025). Such behavior is believed of some anti-predator value as it reduced light reflection from feathers and no shadow thus rendering the female less conspicuous.

Continuous temperature analysis showed that the temperature in the nest during incubation (Figure 16) [illegible]s fairly constant but varied over long period between 21.[illegible] and 27.0°C during the first six days of incubation.

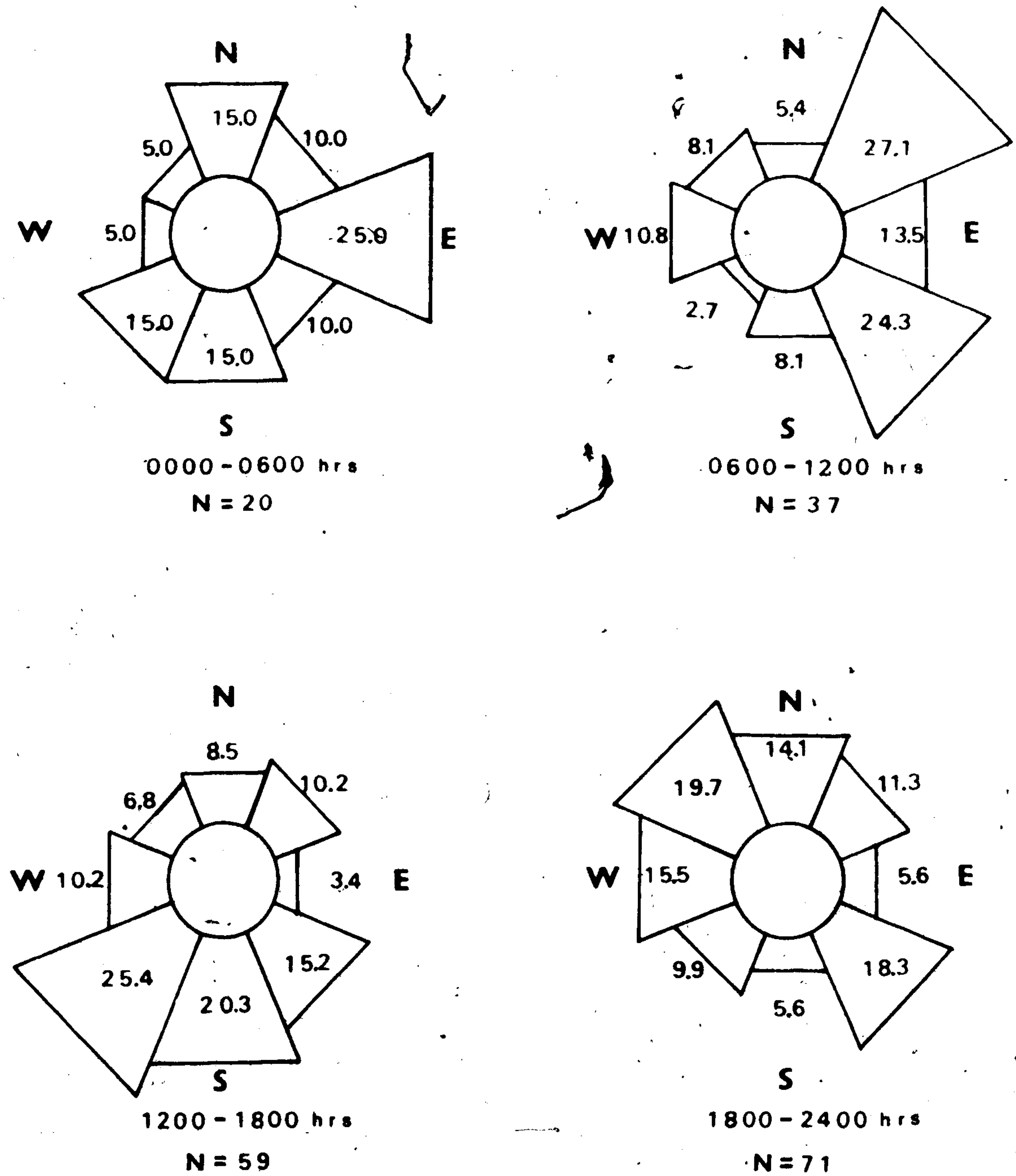



Figure 15. Female orientation while on the nest. Numbers indicate percentages of observations.

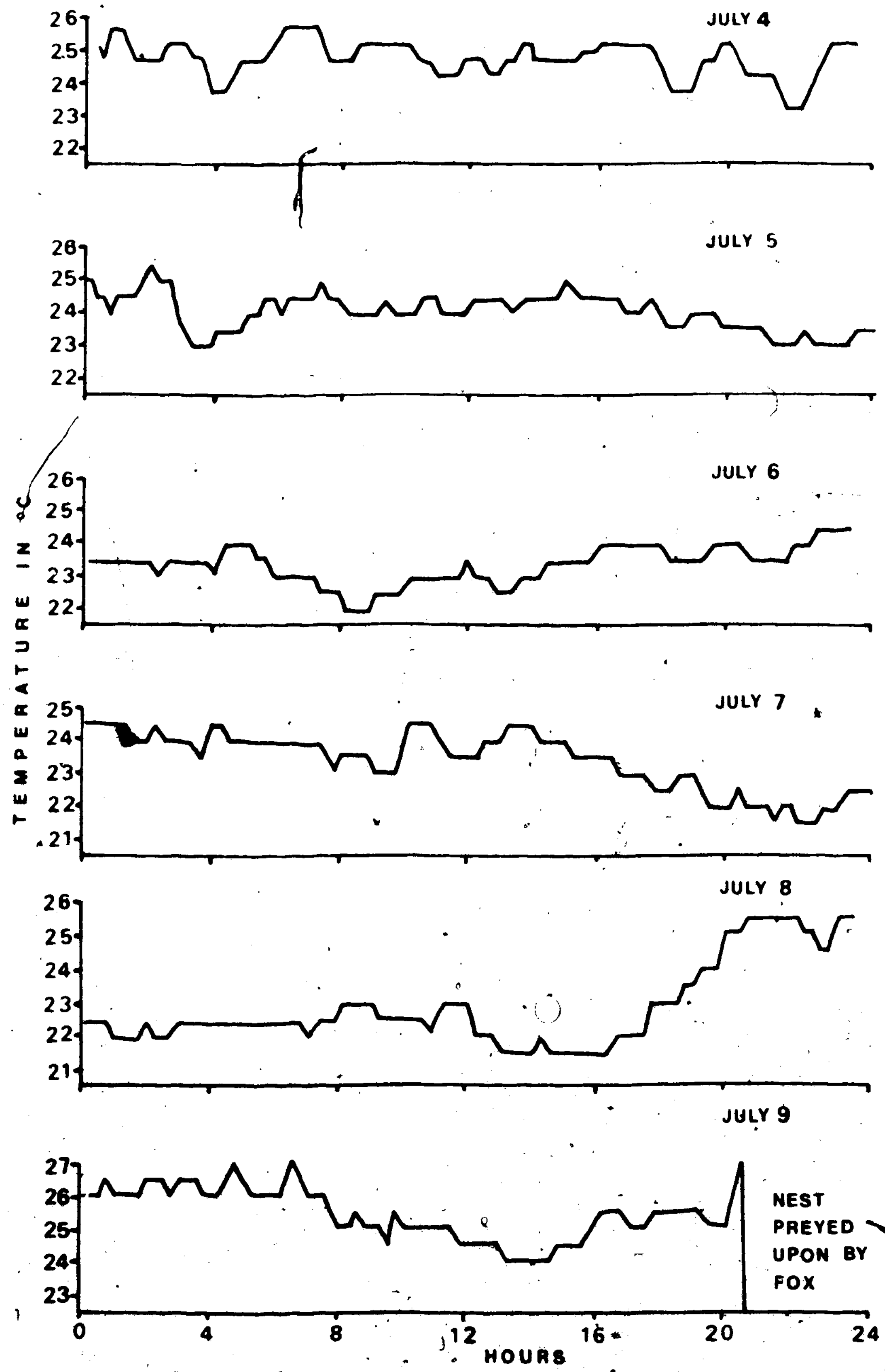



Figure 16. Continuous nest temperature during the first six days of incubation.

Clutch size

Clutch size in ducks may have evolved in relation to the amount of food available to the laying female modified by the relative size of the eggs (Lack, 1968). In ducks a seasonal decline in mean clutch size is a general phenomenon but annual variations have rarely been recorded (Hilden, 1964). Bengtson (1971) showed for a long term study that adaptive variation in clutch size likely occurred in ducks and is related to food supply. He suggests that the mean date of the first egg be used as an overall measurement of the response to external factors such as break up of ice, snow cover, temperature, precipitation, etc. Mean date of laying of the first egg observed on Bathurst Island for 1972 was 11 days later (July 8) than 1971 (June 28). Such variations follow Lack's (1967) theory that conditions of food shortage will postpone laying in waterfowl.

Clutch size data acquired from 1968 to 1972 on Bathurst Island varied from year to year (Table 2). Despite the fact that year-to-year variation was not statistically significant, it is interesting nevertheless to note that the lowest calculated clutch size occurred in 1972, a year of severe environmental conditions when

| Location | Author | Year | Range | No. of clutches | Mean |
|---|---|---|---|---|---|
| Bathurst Island | P.S. Taylor (Pers. com.) | 1968 | 4-6 | 4 | 5.25 |
| Bathurst Island | (This study) | 1969 | 3-6 | 7 | 4.6 |
| Bathurst Island | P.S. Taylor (Pers. com.) | 1970 | 3-5 | 3 | 4.3 |
| Bathurst Island | (This study) | 1971 | 3-6 | 14 | 4.4 |
| Bathurst Island | (This study) | 1972 | 3-5 | 8 | 4.0 |
| Perry River | Hanson et al. (1956) | 1949 | | 14 | 4.9 |
| Adelaide Peninsula | MacPherson and Manning (1959) | 1957 | 2-6 | 6 | 4.4 |
| Prince of Wales | Manning (1961) | 1958 | 1-8 | 26 | 4.1 |
| Victoria and Jenny Lind Islands | Parmelee et al. (1967) | 1965-66 | 3-6 | 27 | 5.0 |

Table 2. Clutch size in king eider observed on Bathurst Island from 1968 to 1972 compared to data from other Canadian Arctic regions.

available food seemed less abundant than 1971. Collection of aquatic invertebrates performed at the end of July and early August of both years (Appendix III) revealed that the size of individuals collected in 1972 was one quarter the size of those collected in 1971. Assuming there is a growth correlation with those invertebrates present in June and early July, a decrease in food abundance in 1972 is suggested.

It seems that Bengtson's (1971) suggestion is applicable to this study and that king eider were directly affected by food shortage and thus incapable of producing the normal number of eggs leading to an adaptive response of relatively more food available to the smaller broods which would appear later in the season. Thus it seems that clutch size in king eider nesting on Bathurst Island was dependant upon several environmental conditions that inhibited laying and it seemed that such factors discussed by Lack (1967) and Bengtson (1971) played a role in clutch size reduction.

Egg characteristics

The eggs of king eider resembled those of the common eider but were smaller, more elongated and rather more pointed. The shape was elliptical ovate or elongated ovate (Bent, 1925) and color ranged through various shades of "olive buff" (Bent, 1925).

Eggs measured in the field in 1971 and 1972 were similar to those of Bent (1925) and Parmelee et al. (1967). Measurements are in mm.

| | | |
|---|---|---|
| Bathurst Island | $\bar{X}$: 66.8 x 45.1 | (n=14) |
| Bent (1925) | $\bar{X}$: 67.6 x 44.7 | (n=152) |
| Parmelee et al. (1967) | $\bar{X}$: 64.4 x 43.2 | (n=6) |

The weights of freshly laid eggs varied from 64 to 75 gms with a mean of 71.6 gms (n=14).

Renesting

No definite evidence of renesting in king eider was found in 1971. Most nests for which complete data were available were initiated between late June and early July (Appendix II ). In addition male flocks started forming during laying and were absent shortly after incubation was underway. In 1972, because of severe weather conditions such evidence was not as well defined. Nest initiation was spread over a 3 week period (Appendix II ) and males were observed on the study area well into July. Cooch's (1965) criteria for determining renesting in the northern eider (*S. m. borealis*) were clutch size reduced to half of that achieved in the first half of the nesting period, and the presence of little down with numerous contour feathers. If such criteria are applied to king eider, the last three nests found in 1971 and the last four nests found in 1972 have to be considered late nests.

Hatching

Hatching was observed just once in king eider. The incubation period could not be measured in this case as the nest was found after clutch completion. Parmelee et al. (1967) gives the only field incubation data and states that it varied between 22 and 24 days on Victoria and Jenny Lind Islands. The whole hatching process, from piping to hatching, was completed within 24 hours. After the last duckling hatched, the brood remained in the nest for about 16 hours but activity of the ducklings around the nest increased after 12 hours. Brooding by the female was observed to be almost continuous for the first 7 hours after hatching. Departure from the nest was not recorded as it took place between 0400 and 0800 hours. No further sighting of this brood was recorded.

Hatching success

In 1968, none of the nests was successful, compared to 21.5% for 1969, none in 1970, 5.6% in 1971 and none for 1972. In 1970, 2 broods not accounted for were observed on the study area (Taylor, pers. com.). Not taking these broods into consideration, hatching success in 61 nests was 0.36 ducklings per nest observed over the five year period. If the two broods are included as part of two nests, hatching success is raised to 0.50 ducklings per nest. Hatching success per egg laid could not be computed because of inclusion of nests found preyed on prior to observation.

The observation of a creche while on a survey on August 27, 1969, revealed that 1969 was no doubt the best year for eiders on Bathurst Island in terms of hatching success. Snow geese (Chen hyperborea) showed a close association with snowy owl nests and it was found that two king eider nests that were successful were also in the vicinity of snowy owl nests. Perhaps the most important reason is related to the presence of 19 snowy owl nests in the region in 1969. Snowy owls (Nyctea scandiaca) establish territories in early spring and keep other predators away, especially arctic foxes.

Observations of broods

A total of only 4 broods were observed in fresh water on the Bathurst Island study area over a five-year period. Behavior of ducklings when in tundra pools is of interest in terms of survival. One observation showed scattering of the brood at the presence of the observer while the female repeatedly made a loud growling sound.

In another instance the young approximately one week old performed aggressive threats consisting of neck stretching and repeated wing flapping (Taylor, pers, com.). On a subsequent observation ducklings swam rapidly toward grassy cover at the presence of the observer. Young ducklings were also capable of diving. A group of 3 was observed performing dives 3 to 4 seconds in duration while the female remained attentive. It was believed that feeding might have been involved during the process.

Only one brood was observed 4 times over a period of 6 days on Hunting Camp Lake. Subsequently the brood was not seen in the region. No creches were observed on fresh water on Bathurst Island although two separate broods were seen accompanied by two females. No broods more than 10 days old were observed in fresh water. Parmelee et al. (1967) observed extensive movements and shuffling of broods in fresh water on Victoria Island, when broods were gradually moving to the marine habitat. While on a short survey over Bathurst Island on August 27, 1969, a large group of 45 eider was seen on Bracebridge Inlet. These appeared to be young of the year with molting females, and all birds were incapable of flying. The young birds at that time were estimated to be 35 to 40 days old and seemed almost fully grown. At the passage of the low flying aircraft no birds responded by diving but attempted flight by flapping along the surface of the sea.

Habitat utilization

King eider utilized various habitats for nesting purposes. As shown on Table 3, king eider nests were scattered over the study area, but saxifrage barren ridges were selected more often than other habitats. Within the classification given by Polunin (1948) king eider selected sorted-net polygons that showed depressions in excess of 10 cm, and in which vegetation (saxifrage and bryophytes) was abundant. Utilization of saxifrage barren ridges versus other habitats varied from 40% in 1968 to 91% in 1972. A total of 69% of the nests found during the past five years at the National Museum Field Station on Bathurst Island were associated with saxifrage barren ridges (Figure 17). There seemed to be no correlation with direction of slope and nest sites, as 56% were found on south-facing slopes and the other 44% on north-facing slopes.

There was however variation in composition of the ridges in the study area. The ridge system extending

| Year | Nest location | No. of nests | Distance from nearest water (km) Range | Average |
|---|---|---|---|---|
| 1969 | Sedge-grass marsh | 1 | 0.01 | |
| | Sedge-grass meadow | 3 | 0.2-0.5 | 0.35 |
| | Barren tundra | | | |
| | (Ridge crest) | 2 | 0.4-0.6 | 0.50 |
| | (North-facing slope) | 3 | 0.3-0.6 | 0.45 |
| | (South-facing slope) | 2 | 0.4-0.5 | 0.45 |
| | Alluvial deposits | 1 | 0.2 | |
| 1970 | Sedge-grass meadow | 3 | 0.2-0.7 | 0.50 |
| | Barren tundra | | | |
| | (Ridge crest) | 5 | 0.4-0.9 | 0.60 |
| | (North-facing slope) | 5 | 0.3-1.1 | 0.80 |
| | (South-facing slope) | 3 | 0.5-1.3 | 0.80 |
| | Alluvial deposits | 1 | 0.05 | |
| | Island (Barren) | 1 | 0.01 | |
| 1972 | Sedge-grass meadow | 2 | 0.2-0.8 | 0.50 |
| | Barren tundra | | | |
| | (Ridge crest) | 3 | 0.4-1.3 | 0.80 |
| | (North-facing slope) | 2 | 0.3-0.8 | 0.55 |
| | (South-facing slope) | 4 | 0.5-2.1 | 1.10 |

Table 3. Habitat utilization by king eider: location of the nests and distance from nearest water.

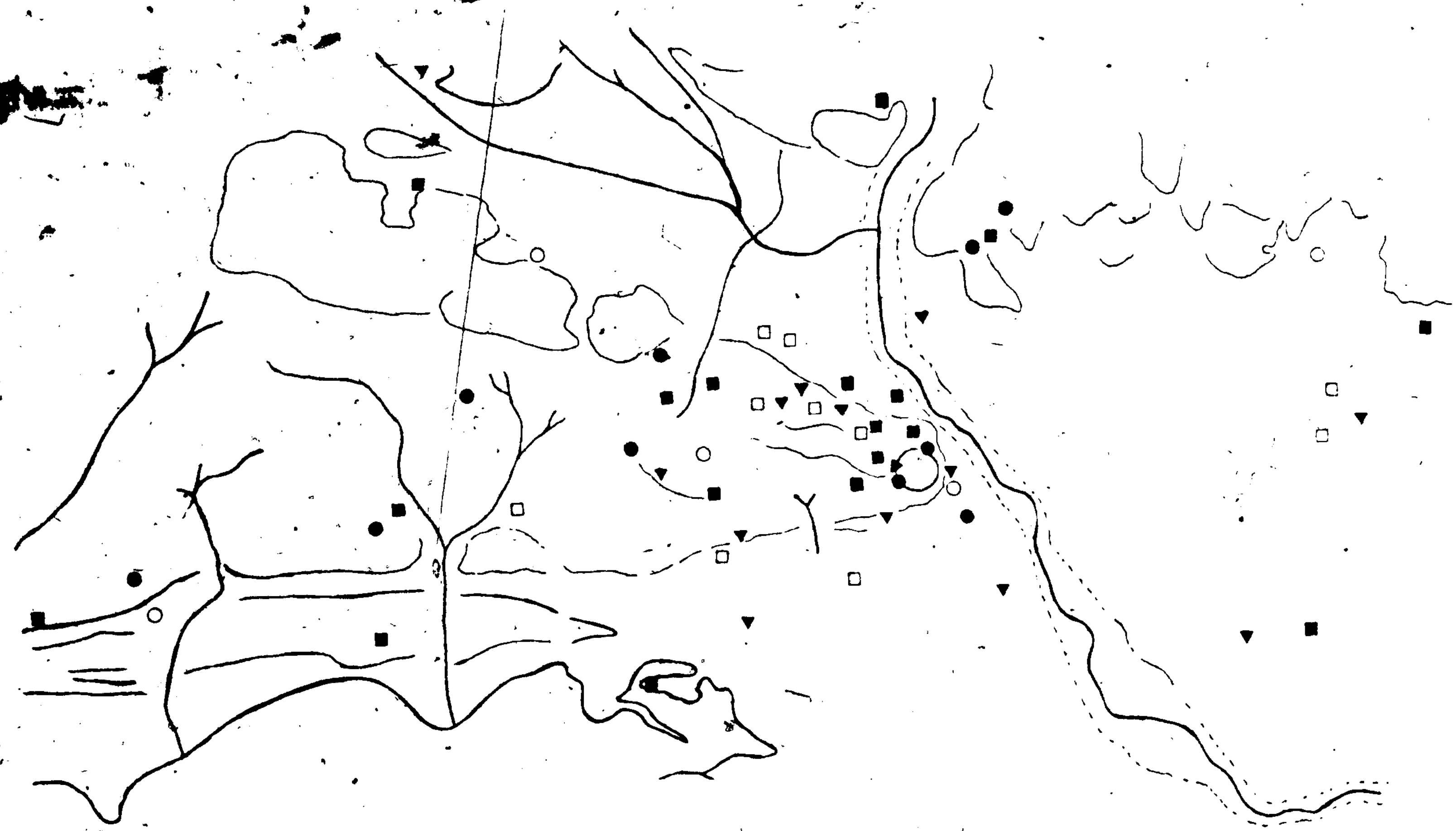



Figure 17. Map of the study area showing the location of king eider nests found from 1968 to 1972. Open symbols courtesy of P.S. Taylor.

west of camp had much paler substrate toward the west end of the study area, and variation in the sorted-net polygons was also noticed. Generally, the sorted-net polygons showed smaller depressions and less plant cover toward the west end of the study area and toward the interior. Such a difference could account for the highest nest density found in the camp region, although there is no doubt that the efficiency was greater in finding nests in a 1.5 km radius of camp due to increased human activity. Saxifrage barren ridges were the predominant habitat within this circle.

Of the total 61 nests found from 1968 to 1972 and besides the 69% found on Saxifrage barren ridges, 12% were in the meadows where nests were easily found as the female plumage blended less with the surroundings than the plumage of females nesting on Saxifrage barren ridges; 7% of the nests were found in the marshy area on elevations formed by low center polygons and only once was a nest observed to have water in the scrape; 8% of the nests were in late snow area and 4% on alluvial deposits.

The Goodsir River flowing through the study area might also have influenced the distribution of king eider nests. Parmelee et al. (1967) observed king eider broods to utilize streams in their movements throughout the area and on their way to the sea.

Nest plant association within 1 $m^2$ of the nest was determined for 19 nests found in 3 different habitats of the study area (Table 4). For 12 nests found on Saxifrage barren ridges, the average vegetation cover was 57.7%, compared to the average cover of less than 30% (Parmelee, 1970) for the same ridge system in 1968. In the meadows, plant cover ranged from 97% to 100%; all nests were lined with a thick layer of bryophytes. In late snow area, cover ranged from 89% to 96%; bryophytes accounted for more than 50% of the cover.

Bryophytes provided more than 10% cover (within 1 $m^2$) to all nests found in the study area; _Saxifraga oppositifolia_ was present in all nests investigated on the barren ridges and 80% to 100% of the cups were lined with vegetation in all nests investigated.

## Microhabitat utilization

Temperature analysis of one nest located in a 11 cm depression formed by sorted-net polygons on a Saxifrage barren ridge revealed that prior to addition of down feathers to the nest cup, temperature was up to 4°C higher

Table 4. Nest-plant association analysis in 3 habitats found in the study area.

(1) Number of nests around which the plant species was recorded

(2) Average % cover provided by the plant species when present

n= 12 Barrens
n= 4 Meadows
n= 3 Late snow

| | BARRENS | | MEADOWS | | LATE SNOW | |
|---|---|---|---|---|---|---|
| | Freq. (1) | % (2) | Freq. (1) | % (2) | Freq. (1) | % (2) |
| LICHENS | 12 | 2.6 | 4 | 0.2 | 3 | 3.4 |
| BRYOPHYTES | 12 | 13.6 | 4 | 40.7 | 3 | 5[illegible] |
| VASCULAR PLANTS | | | | | | |
| <u>Arctogrostis</u> sp. | | | 4 | 28.5 | 1 | 1.1 |
| <u>Dupontia</u> sp. | | | 3 | 11.5 | | |
| <u>Hierochloe</u> sp. | | | 2 | 2.2 | | |
| <u>Poa</u> sp. | 5 | 1.2 | | | 3 | 4.7 |
| Gramineae(Other) | 7 | 1.8 | 1 | 0.7 | 2 | 3.3 |
| <u>Eriophorum</u> sp. | | | 2 | 5.7 | | |
| <u>Juncus</u> and <u>Luzula</u> sp. | 4 | 0.6 | 2 | 0.8 | 3 | 0.5 |
| <u>Salix arctica</u> | 4 | 11.7 | 2 | 14.7 | 2 | 2.3 |
| <u>Oxyria digyna</u> | 3 | 0.7 | | | 1 | 3.3 |
| <u>Arenaria</u> sp. | 5 | 0.6 | | | | |
| <u>Cerastium</u> sp. | 4 | 0.4 | | | | |
| <u>Melandrium</u> sp. | 2 | 0.3 | | | | |
| <u>Stellaria</u> sp. | 10 | 2.3 | 1 | 2.7 | 2 | 3.5 |
| <u>Ranunculus</u> sp. | | | 2 | 1.7 | | |
| <u>Papaver radicatum</u> | 12 | 1.7 | 1 | 0.4 | 3 | 1.4 |
| <u>Cardamine bellidifolia</u> | | | | | 1 | 0.1 |
| <u>Draba</u> sp. | 10 | 0.9 | 2 | 0.3 | 3 | 0.9 |
| <u>Eutrema Edwardsii</u> | | | 2 | 0.1 | | |
| <u>Saxifraga caespitosa</u> | 9 | 1.8 | 1 | 0.1 | 2 | 1.[illegible] |
| <u>S. cernua</u> | 5 | 0.6 | 1 | 0.3 | 3 | 0.3 |
| <u>S. flagellaris</u> | 3 | 0.6 | | | 2 | 1.3 |
| <u>S. hirculus</u> | | | [illegible] | 2.1 | | |
| <u>S. nivalis</u> and <u>tenuis</u> | [illegible] | 1.1 | 1 | [illegible].7 | 3 | 0.4 |
| <u>S. oppositifolia</u> | 12 | 14.[illegible] | | | 3 | 9.[illegible] |

than the same depression 30 cm away from the nest and up to 8°C warmer than air temperature. The temperature in the moss substrate recorded from probe 3 (Figure 19D) showed that the microclimate varied from day to day and was probably influenced by factors such as wind velocity (Figure 19A), air temperature (Figure 19B), cloud cover (Figure 19C) and rain.

Brown (1965) showed that bryophytes, when dry, have such a high insulating value that the depth of the active layer underneath varies within a narrow range. They prevent warm temperature from penetrating the ground under the moss and trap warm air at the surface.

Temperature analysis under the down layer (probe 2) during incubation revealed that temperature in the vegetation was fairly stable (Figure 18B) indicating it acted as an insulator. Temperature in the nest filled with down feathers during incubation was higher by 10°C to 12°C than temperature under the down (Figure 18B). The difference between the two indicates that some insulation is also provided by the down.

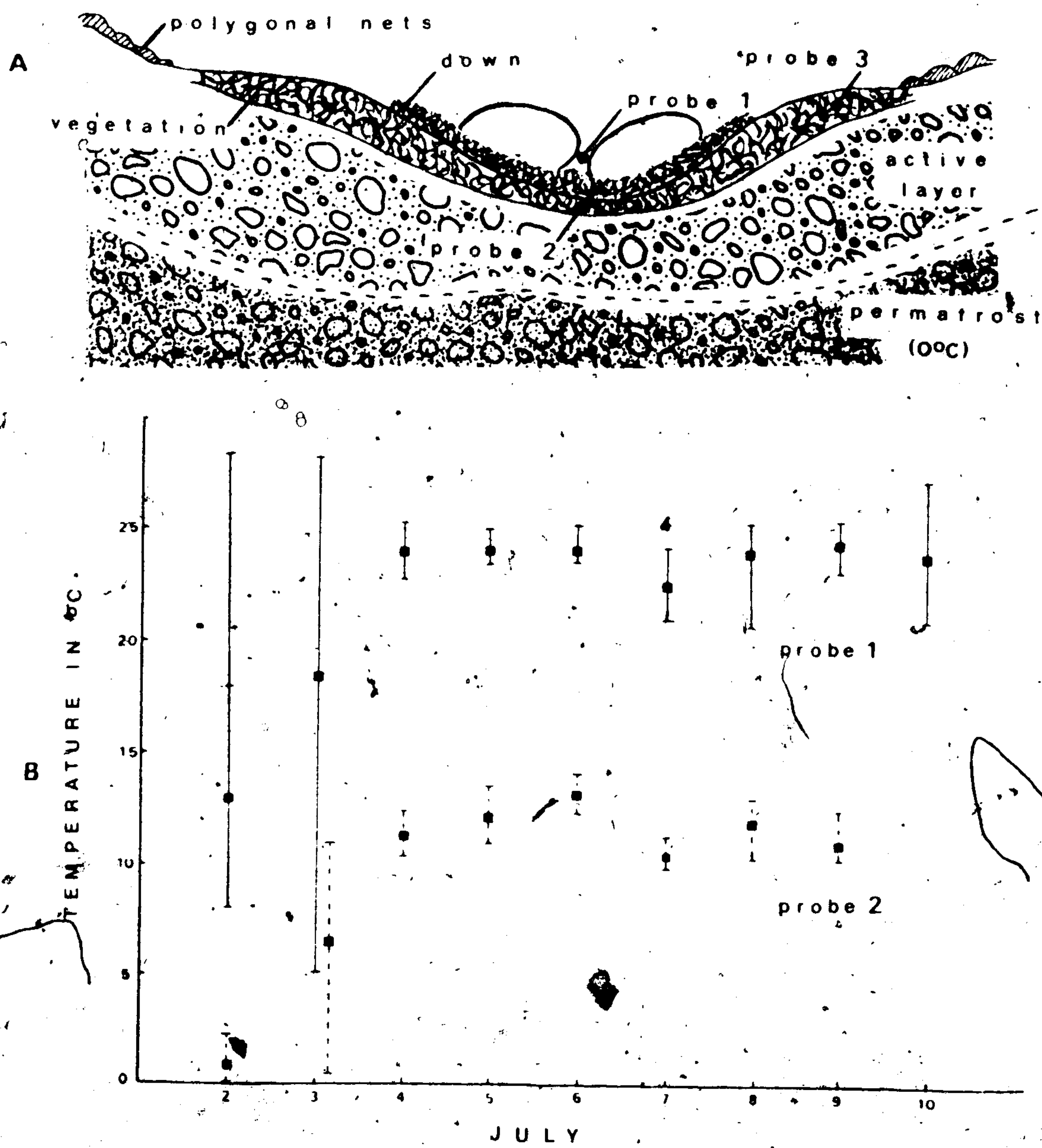



Figure 18. A. Cross section of the nest and location of temperature probes.

B. Daily ranges of temperatures recorded in the nest (probe 1) and in the vegetation under the nest (probe 2).

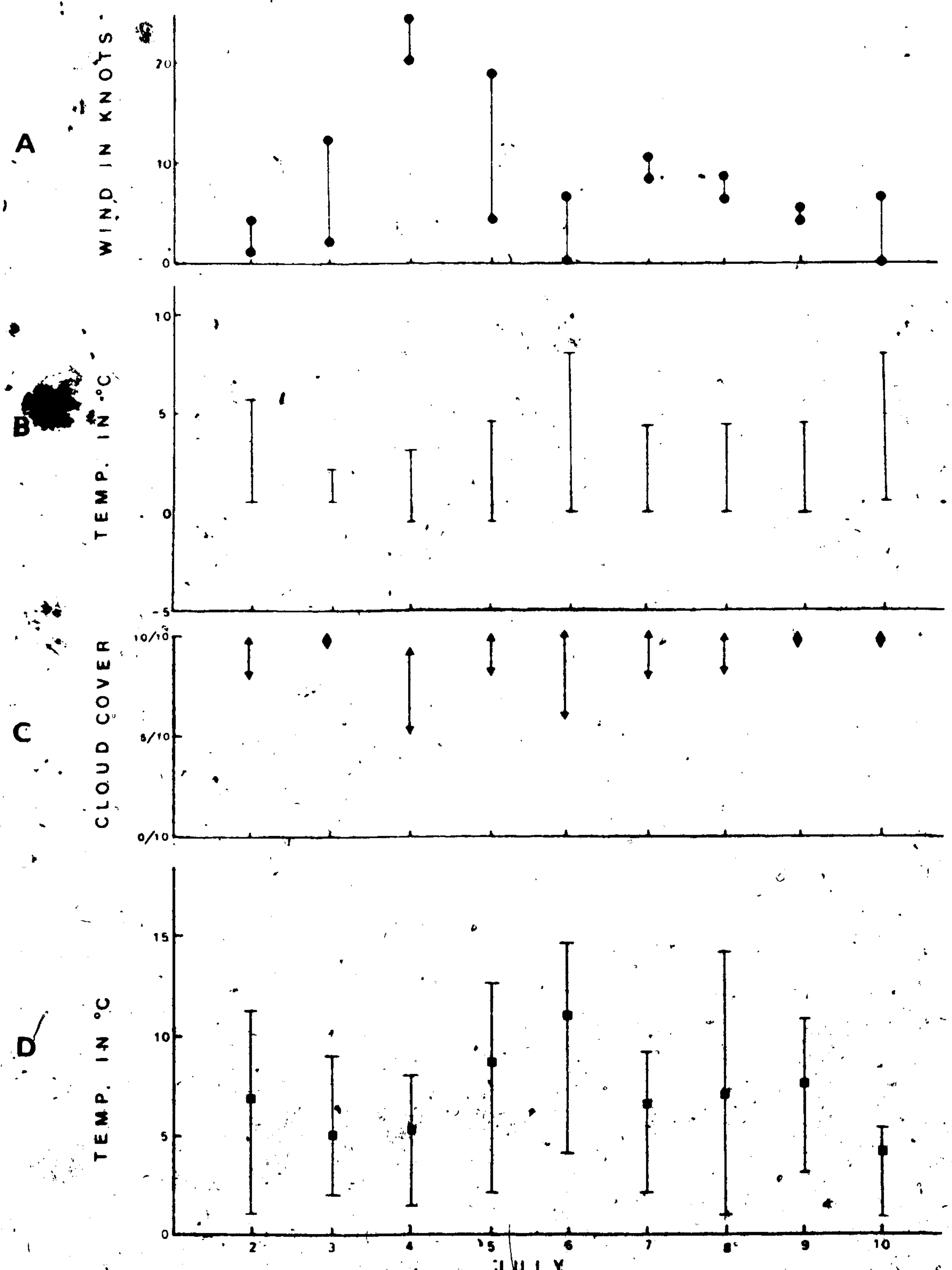



Figure 9. Daily range of a) wind speed; b) air temperature; c) cloud cover; d) temperature in moss substrate around the nest; during laying and first 8 days of incubation.

Feeding behavior

King eider utilized several methods of feeding when in fresh water similar to those found in Anatinae. Food was obtained at the bottom, in vegetation or else by filtering water. The utilization of these different methods was dependant on water depth and type of food.

Up-ending: This pattern consisted of tipping up the body posterior with the tail emergent while the duck paddled to keep its vertical position. With the neck elongated it could feed at the bottom of a depth of 35 to 45 centimeters (Figure 21A). An indication of the degree of intensity performed by the two sexes prior to egg laying is shown in Figure 20. Up-ending was observed to last 3 to 14 seconds with a mean of 4.7 seconds (n=77) in the females and 2 to 9 seconds with a mean of 4.1 seconds (n=43) for males. Vegetable matter as well as fresh water invertebrates were believed to be taken during up-ending. There also seemed to be a correlation between chironomid larvae leaving their muddy substrate once the pond had started to melt (Danks, 1971) and the practice of up-ending. The 120 up-endings were observed in June and early July of 1971 in the period of larval and pupal activities described by Danks (1971).

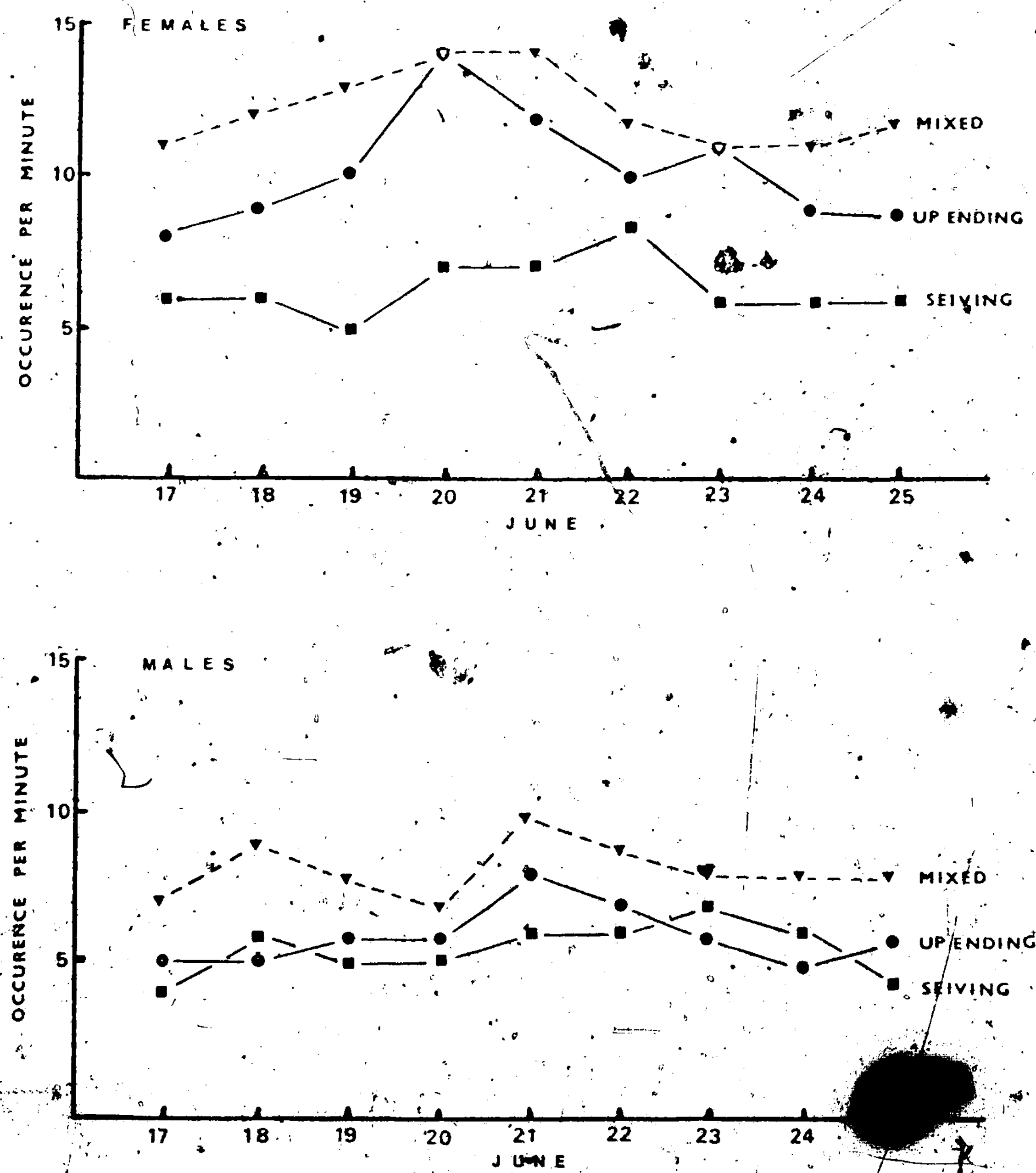
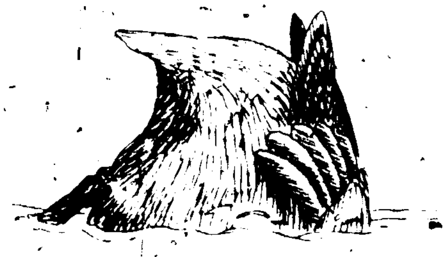
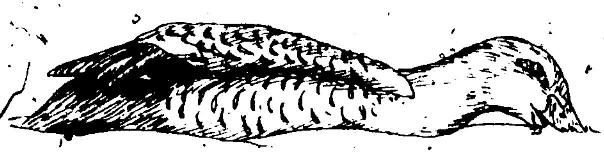



Figure 20. Frequency of behavior patterns in king eider associated with feeding, in 1971.



A

B



C

Figure 21. Feeding types commonly observed in king eider while in fresh water.

A. Up-ending (tipping).
B. Intermediate between up-ending and seiving.
C. Seiving.

Five birds collected after feeding periods in July 1972 had numerous chironomid larvae in their gizzards. In 1972 up-endings were observed well into July and probably related to the late melt encountered and subsequent delay in chironomid activity.

Intermediate between up-ending and seiving. The head was completely submerged while the body was still horizontal. This practice seemed to provide the same type of food as up-ending but was performed in shallow water 15 to 20 cm in depth. Time of immersion of the head was equal to up-ending and its duration varied from 3 to 10 seconds (n=65) with a mean of 4.9 seconds for both males and females.

Seiving: The head was partially submerged while the duck was either stationary or was advancing and the head was moved from side to side. This type of feeding had been observed mostly at the periphery of ponds and lakes.

Standing in shallow water: This type consisted of standing in shallow water a few centimeters in depth and probing the substrate or vegetation. This type had been observed only 4 times and was performed only by females.

Stomach content analysis

The gizzard contents of 14 king eider secured during the study were analysed. In 1971 three males and three females and in 1972 two males and six females were examined (Appendix IV). Except for two females in breeding condition secured in 1972 the analysis showed that this species was dependant on a mixed diet of vegetable and animal matter however some were found to contain almost exclusively vegetable material. The results are similar to those of Manniche (1910) for Greenland and Hanson et al. (1956) for birds breeding in the Perry River region. They differ from Cottam (1939) who analysed the contents of 85 gizzards and showed mainly marine material. Gizzards of 35 eiders collected in May and June contained an average of 7.5% vegetable matter. Cottam (1939) suggested that "...it is possible that if more stomachs had been taken at or near the nesting sites, or the tundra pools the percent would have been somewhat higher". In an Alaskan study Dau (1972) showed that there was a major dependance on vegetable matter while on the fresh water nesting grounds by both adult and young spectacled eider (Lampronetta fischeri). On Bathurst Island king eider fed on a mixed diet; an index of abundance of the diet is indicated in Table 5 for 14 birds. Even if birds secured were injected with 70% alcohol to preserve gizzard contents from post mortem digestion, it was found that soft bodied invertebrates commonly found in the study area in 1971 and 1972 (Appendix III) were almost absent in the food of king eider, although chironomid species in all their stages were present. Moyle (1961), commenting on the digestive rate of waterfowl, said that soft bodied invertebrates would be identifiable in the gizzard for a much shorter time than plant material. Dirschl (1969) found that gizzard contents inflate the importance of plant material in the diet of lesser scaup (*Aythya affinis*). Swanson and Bartonek (1970) found experimentally that bias associated with gizzard content analysis increases in direct proportion to the time elapsed between feeding and sample collection.

In several studies on the breeding biology of common eider it was determined that it engages in little or no feeding during the incubation period (Cooch, 1965; Gorman and Milne, 1971). However common eider do leave the nest to drink and bathe (Gudmundson, 1932; R.S. Palmer, unpubl.). Freuchen and Salmonsen (1958) think that

| | Abundance Index |
|---|---|
| **Plant material** | |
| *Bryophytes* | |
| *Drepanocladus* sp. | 4 |
| *Bryum* sp. | 4 |
| *Meesia* sp. | 3 |
| *Pohlia* sp. | 2 |
| *Calliegron* sp. | 2 |
| *Brachythecium* sp. | 2 |
| *Vascular plants* | |
| *Arctophila fulva* | 3 |
| *Carex stans* | 2 |
| Unidentified graminea | 2 |
| **Animal material** | |
| Chironomidae | |
| Larvae | 4 |
| Pupae | 3 |
| Adults | 1 |
| Hymenoptera | 1 |
| Calliphoridae | 1 |
| Anastroca | 1 |
| Notostraca | 2 |

Abundance index: 1 rare; 2 uncommon; 3 common; 4 abundant.

Table 5. Plant and animal material identified from gizzard contents of 5 male and 9 female king eider.

behavior of king eider resembles that of common eider in this respect. Analysis of incubation behavior carried out prior to predation in the nest under surveillance showed that king eider in fact followed a more severe trend. As was mentioned previously a female remained continuously on her nest over a 7 day period prior to being flushed by an arctic fox.

Drinking while on the nest was performed by removing drops of rain which accumulated on the feathers during storms.

Feces analysis

Swanson and Bartonek (1970) showed experimentally that some food items are easier to digest than others and that in some cases up to 24% of plant food given to blue-winged teal (Anas discors) was recovered and could be identified while in the lower intestinal tract or in the feces. Experimentally, Randwell and Downing (1959) were capable of quantitatively determining food using feces of brent geese (Branta bernicla). Feces of king eider were collected on the tundra and some material appeared only partially digested. Undigested larvae and adult chironomids as well as plant material were present in some.

Gorman and Milne (1971) revealed that because the female common eider does not feed during incubation she has to depend upon fat deposits and muscle protein for her energy requirement. Their explanation is that "...increased corticosteroid output by the incubating eider is clear, since it will enhance the breakdown of muscle protein, releasing glucogenic amino-acids to be used in the utilization of fat reserves...The actions of glucocorticoids...direct activities towards increasing carbohydrate by increasing glucogenic processes and at the same time inhibiting glycolytic ones." They also observed an interrenal tissue activity increase which leads to the above process in common eider during courtship activities. The presence of some droppings containing high percentages of undigested food may be explained by the fact that birds under an increasing or decreasing glucogenic process did not totally use the food swallowed.

Food in droppings collected in 1972 was more completely digested than those collected in 1971 (Table 6). The weather conditions encountered in 1972 and the postponed breeding activities may have affected internal tissue activity thus preventing the process previously described.

| Date collected | Sex | Volume of feces (cc) | Index | Animal % | Plant % |
|---|---|---|---|---|---|
| July 10/71 | ♀ | 23 | 3 | 48 | 52 |
| July 11/71 | ♀ | 26 | 4 | 56 | 44 |
| July 16/71 | ♀ | 20 | 2 | 14 | 86 |
| July 18/71 | ♀ | 27 | 3 | 8 | 92 |
| June 17/72 | ? | 17 | 4 | 1 | 99 |
| June 17/72 | ? | 22 | 4 | 1 | 99 |
| June 22/72 | ? | 19 | 2 | 1 | 99 |
| June 25/72 | ? | 26 | 3 | 0 | 100 |
| July 23/72 | ? | 23 | 3 | 80 | 20 |
| July 26/72 | ♀ | 22 | 3 | 30 | 70 |
| July 28/72 | ♀ | 25 | 2 | ? | ? |

Table 6. Undigested food from feces of king eider with degree of digestion indicated.

1: Food digestion maximum; little determination possible.

2: Food digestion good; determination possible with care.

3: Food digestion poor; fairly accurate determination.

4: Food digestion minimum; accurate determination, comparable to gizzard content analysis.

Predators and predation pressure

The importance of predation upon arctic ground nesting birds cannot be minimized. The density of predators found in the study area is summarized in Table 7. Eider nests lost due to predation throughout the study were important in terms of productivity. More than 95% of the nests with known history were preyed upon prior to hatching and 18% were preyed upon prior to the start of incubation. The fate of 29 nests is summarized in Appendix II.

In areas where arctic foxes are not trapped by Eskimos the resulting predation pressure on birds seems detrimental especially where arctic foxes are numerous. Usher's (1971) study on Banks Island revealed that for the 1966-67 trapping season, 9,491 arctic foxes were caught in a maximum trapping area of 10,770 square miles, of which 6,290 square miles were intensively used by Eskimos, north and east of Sachs Harbour. Parmelee et al. (1967) reported that arctic foxes are trapped in large numbers along the southeast coast of Victoria Island and he observed very few foxes in 1960 although a "bumper crop" was harvested the following winter. King eider showed good breeding success along the southeast coast of Victoria

| | Breeding pairs/100km² | | Single animals/10km² | |
|---|---|---|---|---|
| | 1971 | 1972 | 1971 | 1972 |
| Long-tailed jaeger (*Stercorarius longicaudus*) | 63 * | 20 | 1-17 * | 1-38 |
| Parasitic jaeger (*S. parasiticus*) | 3 * | 3 | 1-2 * | 1-2 |
| Pomarine jaeger (*S. pomarinus*) | 27 * | 0 | 0-8 * | 0-5 |
| Glaucous gull (*Larus hyperboreus*) | 5 | 4 | | |
| Thayer's gull (*L. thayeri*) | 1 | 1 | | |
| Arctic fox (*Alopex lagopus*) | | | 2 | 2 |
| Arctic wolf (*Canis lupus arctos*) | | | 10 ** | 3 ** |
| Snowy owl (*Nyctea scandiaca*) | 1 | 2 | 3-20 * | 1-14 |

* Data from P.S. Taylor, M.Sc. thesis in preparation at the University of Alberta, Edmonton.

** Area undetermined (probably exceeding 100km²).

Table 7. Estimated density of predators recorded on Bathurst Island in 1971 and 1972.

Island that summer (Parmelee et al., 1967).

Ryder (1967) found that arctic fox damage to the Arlone Lake colony of Ross's geese (Chen rossii) resulted in the complete evacuation of one of the major nesting islands. Barry (1967) observed heavy destruction of blue geese (C. caerulescens) and brant (Branta bernicla) nests in a colony at Anderson River delta. McInnes and Misra (1972) reported that in 1962 arctic foxes removed more than 95% of Canada geese (B. canadensis) eggs found in a 20 $km^2$ area west of the Boas River on Southampton Island. They also found that in 1967 a single arctic fox within five days destroyed over 200 blue geese nests in a 3 $km^2$ area of the McConnell River, N.W.T.

Fox population density in the study area (Table 7) affected the annual productivity of king eider as well as long-tailed jaeger (Taylor, pers. com.) and red phalarope (Phalaropus fulicarius) (Mayfield, pers. com.). Although arctic fox populations are known to undergo fluctuations (MacPherson, 1969), the number estimated for a 50 $km^2$ section of the Goodsir-Bracebridge valley and adjacent northern ridges was 12 individuals (not including litters) for both years of the study. Most foxes were believed to be on territory although wanderers were also present. In 1972 one active den with undetermined numbers of pups was found late in June by D.F. Parmelee (pers, com.). Three other fox dens were inhabited for the duration of the study. The presence of more dens is probable but due to the relief of ridges they were difficult to locate.

In 1972, six more foxes were lived trapped, sexed and ear marked. Data obtained from a pair which had their territory in the study area showed that they were usually active from 1800 to 0900 hours with peak activity between 2200 and 0600 hours. They usually hunted alone but were also seen to operate in pairs. Records of their locations are indicated on Figure 22.

Two observations of nest robbing by arctic foxes were made during 1972. Both predations were believed to have resulted following nest location by scent. The first nest was robbed prior to completion of the clutch and occurred during the absence of the female. In this instance the nest cup was properly covered by vegetation. In the second case the fox was approaching down-wind of an incubating female. The animal approached at a slow trot, stopped suddenly 25 meters from the nest and looked toward the incubating female then rushed at the nest while the

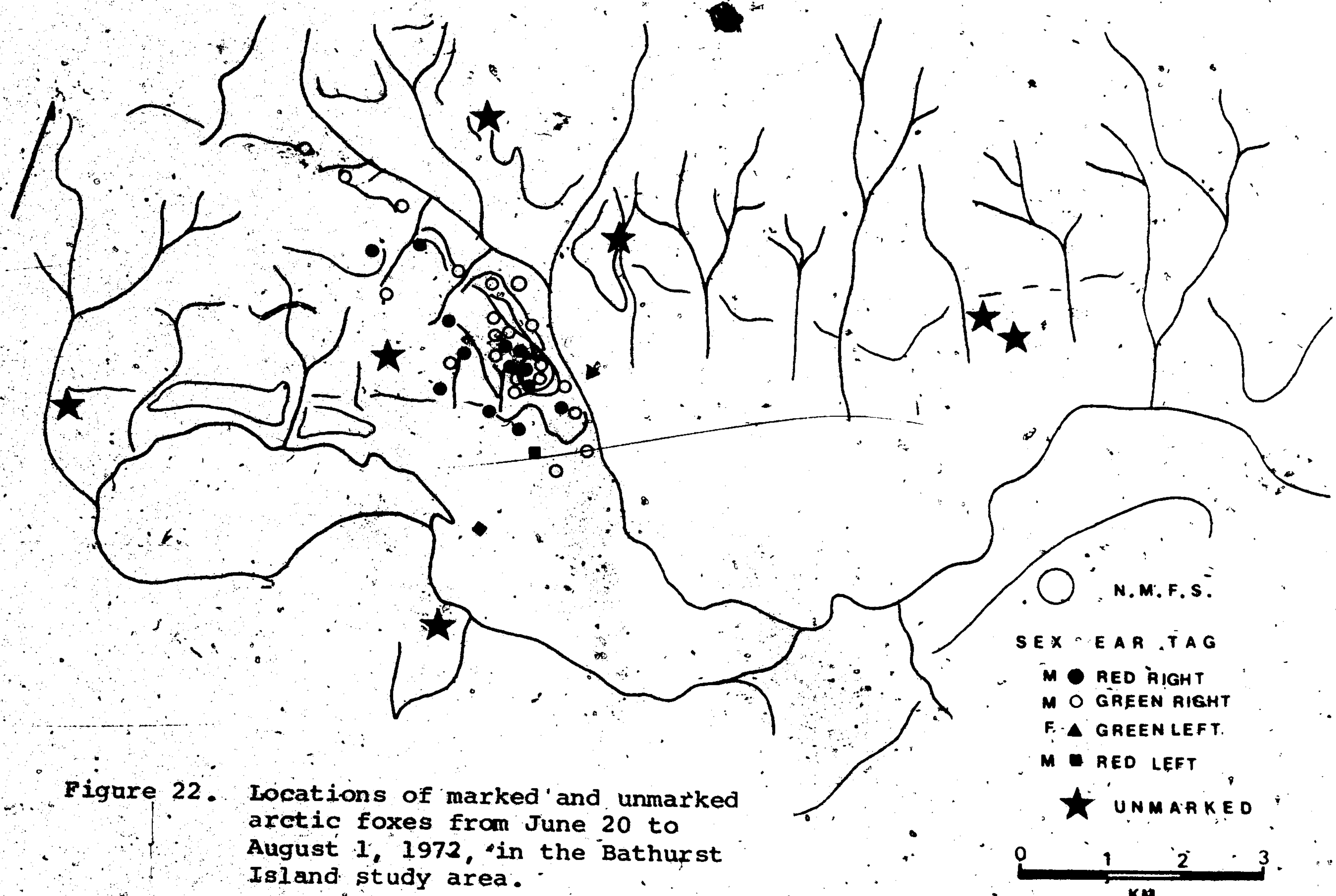



Figure 22. Locations of marked and unmarked arctic foxes from June 20 to August 1, 1972, in the Bathurst Island study area.

female flushed. It managed to rob two eggs and break another prior to immediate human intervention. In both cases the eggs were not eaten immediately but carefully carried by mouth and were cached in vegetation. In 1971 a fox was seen robbing the last egg from a nest and was also seen to cache the egg. The same fox was believed to have robbed 4 adjacent nests within a one hour period.

McInnes and Misra (1972) observed that arctic foxes are particularly attracted by human activity and learn to follow biologists in the field. Some known nests were left undisturbed to see if fox predation would be reduced but these nests were subsequently preyed upon and often at the same rate. Several nests had already been preyed upon when they were found. The presence of fox feces in the nest clearly indicates the predator. Jaegers and glaucous gulls (Larus hyperboreus) always leave empty shells in and around a nest from which they have destroyed the eggs.

The presence and density of foxes seem to be controlled by the density of lemmings in the area (MacPherson, 1969). The abundance of these microtines also seems to control the number of avian predators (Pitelka et al., 1955).

Long-tailed jaegers were the most numerous avian predators on the study area (Table 7). Its predation was mostly restricted to the period when eggs were left unattended; however some predation (less than 5%) has been observed when incubation was in progress.

A parasitic jaeger (Stercorarius parasiticus) and a pomarine jarger (S. pomarinus) were known to have preyed upon one nest each (less than 5%) and both instances occurred in the laying period. A glaucous gull was believed to have preyed upon one nest when the female was incubating. Thayer's gull (L. thayeri) was believed capable of predation but none was observed.

Snowy owls were the only predators observed to have killed adult king eiders. Remains of 4 female king eider were found in snowy owl nests in 1969. No evidence was found which indicated that they were breeding or non-breeding eiders. Predation on king eider ducklings was observed by P.S. Taylor and D.A. Gill (pers. com.) in 1970 when an arctic fox brought a freshly killed duckling to an active den under observation.

Defecation upon flushing

Parmelee et al. (1967) observed female king eider to regularly defecate as they flushed from the nest at Victoria Island. Very little predation occurred on king eider during their study. On Bathurst Island female king eider sat tightly and were reluctant to flush. Defecation on leaving the nest was uncommon and was recorded twice in 40 observations. Both nests were not preyed on by arctic fox although they were located in an area of high fox activity. Nine nests preyed on by arctic foxes were examined shortly after for soiled down or for the extremely foul odor described by Parmelee et al. (1967) but no evidence was found. There seemed to be a relationship between degree of defecation upon flushing and predation by arctic fox. Swennen (1968) found experimentally that feces found at eider nests if added to food of ferrets in a quantity exceeding 0.2 cc resulted in refusal of the meal by the animal. When feces from non-breeding eider were used the food was not rejected.

Nest parasitism

Nest parasitism is common throughout the family Anatidae (Willer, 1959). In the tribe Somaterini the practice is not well documented. Nest parasitism is known to occur in the spectacled eider where the species is both parasitic and parasitized (Dau, 1972). In king eider, little is known of this phenomenon. Dump nesting has been observed for semi-colonial nesting birds in the Perry River area (Hanson et al., 1956). If nest parasitism occurs in the High Arctic, it would be in regions where king and common eider overlap, or else in the southern part of the king eider breeding range, where these birds might be sympatric with other species capable of performing such a practice. However, on the Bathurst Island study area, one king eider nest on the periphery of a sedge-grass marsh contained one eider egg and one pigmented egg of relatively the same size but of a different shape than the eider egg. The female eider subsequently added a second egg, prior to predation of the nest. The egg was later identified as that of a pomarine jaeger. Such practice was considered as accidental parasitism, and is rare under low nesting density.

In order to document if king eider would reject eggs of other species, an experiment was performed in 1972 using a small snow goose egg weighing 90 gm, found on the feeding grounds. The snow goose egg was added to a king eider nest which had been preyed on by an arctic fox after the first egg was laid. When the female returned to lay her second egg normal behavior was observed, although time spent on the nest was relatively short in comparison to other observations.

## Non-breeding in king eider

Birds normally nesting in arctic regions are known to become non-breeders under various conditions (Marshall, 1952). Manniche (1910), Lack (1933), Bertram et al. (1934), Bird and Bird (1940) and Seligman and Wilcox (1940) have reported non-breeding among all arctic birds except passerines and have speculated on its probable causes.

During both years of this study non-breeding king eider females were found on the study area. In 1971 two king eider females collected in the vicinity of the study area were non-breeders. The absence of enlarged ovarian follicles and plumage characteristics as described by Portenko (1952) suggested that the birds were subadults.

A male collected in the same area was also a subadult in its second year plumage. In 1972 four king eiders collected were in breeding conditions and one other had atretic follicles. The presence of flabby follicles in two specimens in breeding conditions suggests that the follicles had started to resorb. In addition, a subadult male in its first basic plumage was observed for one week in the study area, and a subadult female collected showed that immature birds were present on the study area.

Reproductive failure in female king eider was believed to be particularly prevalent in 1972 and was associated with severe environmental conditions. The 1972 season also showed marked effects on the reproduction of greater snow geese in the area and throughout the High Arctic (Heyland, pers. com.). Lack (1933) suggested that delayed availability of sites and failure of gonads to remain in breeding condition may sometimes combine to make reproduction impossible. This has been shown for brant when encountering severe conditions (Barry, 1962). Bertram et al. (1934) suggested that snowfall and late ice break up may affect availability of nest sites or food supply. Such factors may account for the high percent of non-breeders in the study area in 1972. Bird and Bird

(1940) suggested that severe weather may cause a delay in arrival at the breeding grounds with accompanying gonad regression. Such phenomena might occur in king eider but females secured on the 10th and 19th of July were still in breeding condition as each had an egg in the oviduct. Marshall (1952) suggests that environmental factors such as "fear" (in region of high predator populations), lack of traditional food, or temporary absence of nest sites can inhibit breeding. Marshall (1952) concluded that "... adult non-breeders of both sexes were capable of reproducing but that the environment of Jan Mayen (Island) failed to present to the female exteroceptors the pattern of external stimuli to which the species traditionally responds".

The analysis of weather data collected on Bathurst Island (Figure 23) and compared with 23 years of Resolute weather data suggests that 1972 was a severe year in the Arctic Islands. Snowfall was greater and the melt season was about 10 days later than usual which resulted in reduction of open ponds in the later part of June (Figure 6) if compared with conditions encountered in 1971. Fresh water invertebrates were known to be affected. Chironomid larvae, an important eider food, which usually

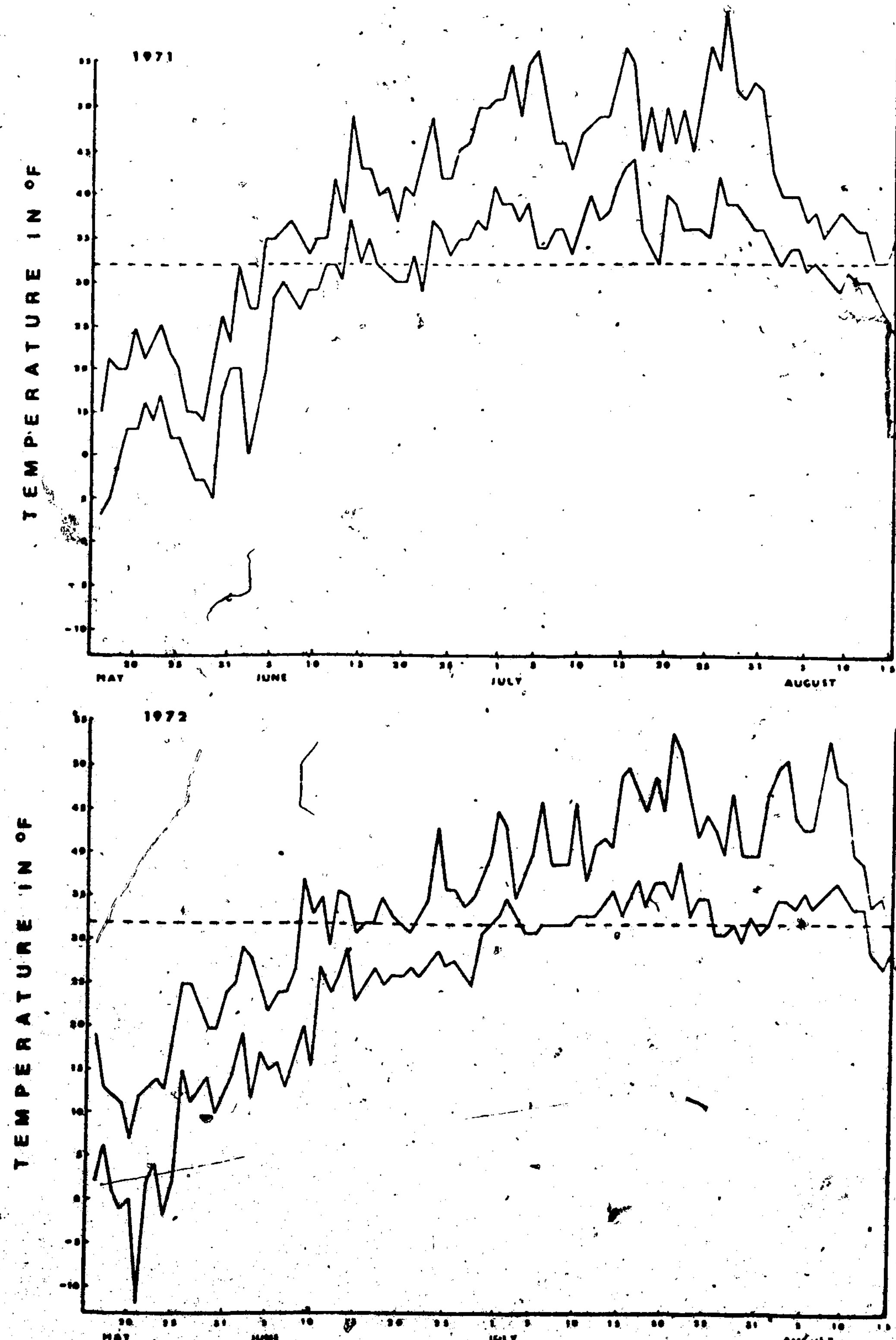



Figure 23. Daily maximum and minimum temperature at the National Museum Field Station on Bathurst Island, from mid May to mid August 1971 and 1972 on file at the National Museum of Natural History and Atmospheric Environment Division, Ottawa.

become active after thawing (Danks, 1971), in 1972 probably became active late in June or in early July because of late thawing of pools. The emergence of chironomid adults was also recorded to be more than 15 days later than in 1971. As shown previously, fresh water invertebrates of the order Anostraca were less numerous and their growth was also affected by the late season and severe conditions. Those collected in 1972 were remarkably smaller if compared to those collected at the same date in 1971. Lepidurus arcticus were numerous and easily collected in 1971 but were not abundant in the study area in 1972.

Considering the severe environmental factors and intense agonistic behavior due to crowded conditions in small available pools it seems evident that non-breeding during 1972 resulted from low temperatures, retention of ice on ponds and snow cover in nesting areas. Resulting food shortage may also have been associated with non-breeding.

Management of the species

At times of accelerated Northern exploration and exploitation of non-renewable resources it is especially important to acquire knowledge of these unique and fragile breeding grounds and their avifauna.

The total king eider population is estimated between two and four million. Apparently more than half of the breeding population occurs in the Canadian Arctic, the rest breeds mostly in Greenland and a few in Paleo-arctic regions and Alaska (Palmer, unpubl.).

The king eider serves as a food source for natives throughout the Canadian Arctic (Klein, 1966), in some coastal regions of Alaska (Myres, 1959; Barry, 1968), in Greenland (Schell, 1963) where the molting birds are taken in parts, and are also taken in limited numbers in Arctic Russia (Dementev and Gladkov, 1952). The annual kill of eider using the Beaufort Sea migration route is 1% or less (approximately 10,000 birds) (Thompson and Person, 1962). Barry (1968) adds that "...at the present time the native kill is greatly reduced in most settlements but the king eider can become very important any time that other foods are scarce or not readily obtainable". Because of the remoteness of the breeding grounds the hunting take is probably less than 1% of the population. Hunting is performed both during the spring and fall migration. In spring the fat knob present on the male is regarded a delicacy by the Eskimos and the people of the Labrador coast use this structure as a source of gun oil because of its frost-free properties. It seems that males are selected by hunters and apparently suffer a heavier mortality. The spring hunt performed throughout its range is poorly documented.

There seem to be large fluctuations in populations of king eider. Extensive spring die offs have been recorded by Myres (1958) and Höhn (1957) and seem to be more common in years of severe weather conditions during migration. Barry (1960) estimated that 100,000 birds were present on Banks Island in June 1960 but upon returning to the island at the end of July he found only six live king eiders. On finding 125 dead female and young along 2½ miles of lake shoreline he estimated that close to 50,000 female and young had died on Banks Island that year. The cause of death was unknown and he only found six females on Banks Island in 1961 and they were still rare in 1962. Estimating that average total losses are in the order of 7.5% to 15% annually it seems that this species can maintain a stable population with an annual productivity in the order of 15% which is considered low for waterfowl.

With regard to species of Anatidae in which breeding first occurs at two years of age, Lack (1968) claims that a reasonable mortality estimate would lie between 20% and 40%. In king eider some adults may breed at the age of two, but most are believed to start breeding at the age of three (Palmer, unpubl.). Lack (1968) adds that "...in all species so far studied in which breeding starts at the age of three or more, the age of the first breeding varies individually. Some of these variations are probably hereditary but others are correlated with local conditions".

Down from common eider has economic value and its collection is still a commercial venture in Iceland colonies (Pettingill, 1959) and also in Greenland where eider farms have been created. These farms are well managed and include predator control measures and reproduction is not adversely affected. Down from king eider is much darker than common eider down and shows good insulating properties. Because king eider is a non-colonial species, it is uneconomical to consider its nests as a source of commercial eider down.

Faunal studies in Arctic Canada show that king eider broods form only a small percentage of the total counted. Parmelee et al. (1967) however observed king eider broods to be common at sea around Cambridge Bay. There might be a correlation between harvest of arctic foxes by Eskimos and high productivity in king eider. Areas where Eskimos hunt arctic foxes heavily in the early spring should be compared to areas where they are seldom harvested by natives. The influx of people in the North might affect the Eskimo hunters and increase the accumulation of organic wastes around newly formed settlements. As a result, fox populations, whose breeding and litter size are controlled by lemmings or other microtines (MacPherson, 1969), may become less dependant upon their natural food and show an increase in numbers to the detriment of local bird populations.

With industrial growth, lately encountered in the Canadian Arctic, a shift toward increased losses due to oil pollution, hunting pressure and predation might be detrimental to king eider populations. Stronger legislation for pollution control directed to oil exploration in the North needs to be incorporated in existing legislation. Hunting regulations should be based on annual surveys in August when the young are in creches in regions of high breeding density.

## SUMMARY

This study on the ecology of king eider was conducted from June 9 to August 16, 1971, and from May 17 to August 12, 1972, at the National Museum High Arctic Field Station on Bathurst Island, N.W.T. Additional data for 1968, 1969 and 1970 was obtained by the station personnel.

I. In both 1971 and 1972 the arrival of king eider on the breeding grounds was preceded by a warm front from the south. Spring arrival dates for the period 1968 to 1972 ranged from June 11 to June 16.

II. The general behavior of king eider is described with respect to the breeding cycle. Pair formation was completed prior to arrival on the breeding grounds. Courtship displays varied slightly from those described by Johnsgard (1964). Difference in the form and sequence of "wing flapping" enabled me to differentiate the display from the comfort movement. Copulation took place on the breeding grounds. Nest site selection was performed by the female although the male was present. The presence of the male seemed to be associated mainly with protection of the female against predators. Laying of the first egg was usually performed during nest site selection.

III. Addition of plant material to the nest scrape was done during laying of the first two eggs and subsequently down feathers were progressively added until completion of the clutch and during the first three days of incubation. Males were observed in the vicinity of the nest until laying of the third egg. A passive dissolution of the pair bond occurred. The males grouped on fresh water ponds and left the area shortly thereafter. During incubation the female showed a high degree of nest attentiveness and during this time she engaged in little or no feeding and spent more than 95% of the time incubating. Non-breeding and non successful females remained in the fresh water habitat in groups, for a period of approximately three weeks after the departure of the males.

IV. Clutch size varied from year to year and ranged from 5.25 in 1968 to 4.00 in 1972. Hatching success was low if compared to other Anatidae. During the five years of this study, 1969 was the best year with 21.5% nest success. A total of 0.5 ducklings per nest (n=63) were produced from 1968 to 1972. The time from pipping to when ducklings leave the nest was less than 24 hours. Creches were not observed in fresh water, where ducklings probably remained for less than two weeks. They subsequently moved to salt water inlets.

V. Utilization of barren ridges for nesting varied from 40% in 1968 to 91% in 1972; 69% of the nests found from 1968 to 1972 were associated with saxifrage barren ridges. There seemed to be no correlation between nest site and slope orientation. Nests found on saxifrage ridges were in depressions formed by sorted-net polygons. Microclimate 7°C to 9°C warmer was found in these depressions.

VI. Feeding behavior in fresh water was similar to that performed by Anatinae. Gizzard content analysis showed that king eider rely on a mixed diet of vegetable and animal material while in fresh water.

VII. More than 95% of nests of known history were preyed upon primarily by arctic foxes and long-tailed jaegers prior to hatching. This seemed to be related to the high density of predators on the study area, however close association with snowy owl nests appeared to be beneficial.

VIII. Non-breeding among some king eider was recorded in 1971 and 1972. In 1971, the mean date of clutch initiation was June 28 and in 1972 the comparable date was July 8. The delay was associated mainly with low temperatures, retention of ice on ponds and lakes and snow cover in nesting areas.

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| Displays | 1971 Male on water | 1971 Male on land | 1971 Female on water | 1971 Female on land | 1972 Male on water | 1972 Male on land | 1972 Female on water | 1972 Female on land |
|---|---|---|---|---|---|---|---|---|
| **Courtship** | | | | | | | | |
| "Pushing" | 194 | 30 | 0 | 0 | 53 | 41 | 2 | 0 |
| "Reaching" | 11 | 35 | 0 | 0 | 4 | 59 | 0 | 0 |
| "Head rolling" | 38 | 5 | 5 | 0 | 16 | 7 | 2 | 0 |
| "Preening behind the wing" | 29 | 0 | 3 | 0 | 12 | 0 | 2 | 0 |
| "Upward stretch" | 40 | 2 | 23 | 0 | 27 | 4 | 11 | 3 |
| "Wing flapping" | 22 | 2 | 17 | 0 | 15 | 4 | 6 | 1 |
| "Bathing" | 6 | -- | 20 | -- | 2 | -- | 5 | -- |
| "Prone posture" | -- | -- | 15 | 0 | -- | -- | 2 | 0 |
| **Agonistic** | | | | | | | | |
| "Chin lifting" | -- | -- | 43 | 25 | -- | -- | 57 | 39 |
| "Head tossing" | 13 | 5 | -- | -- | 34 | 27 | -- | -- |
| Chase | 2 | 7 | 0 | 0 | 6 | 19 | 0 | 0 |

**Appendix I.** Occurrence of male and female king eider behavior patterns observed in the valley portion of the study area, during the 1971 (33 hours of observation) and 1972 (14 hours of observation) breeding seasons.

| Habitat | Laying initiated | No. of eggs | Fate | Cause | Date |
|---|---|---|---|---|---|
| Marsh | June 27/71 | 5 | Pred. | Fox | July 3 |
| Moss | June 27/71 | 1 | Pred. | Fox | June 28 |
| Ridge | June 28/71 | 1 | Aband. | Human | June 29 |
| Ridge | June 27/71 | 4 | Pred. | Fox | July 3 |
| Marsh | June 28/71 | 1 | Pred. | L.t.jaeger | June 29 |
| Ridge | June 27/71 | 5 | Pred. | Fox | July 3 |
| Moss | June 29/71 | 3 | Pred. | Fox | July 3 |
| Ridge | June 30/71 | 3 | Pred. | Fox | July 4 |
| Ridge | July 1/71 | 4 | Pred. | L.t.jaeger | July 6 |
| Marsh | ? | 3 | Pred. | Fox | July 10 |
| Ridge | ? | 5 | Pred. | L.t.jaeger | July 8 |
| Ridge | ? | 4 | Pred. | Fox | July 7 |
| Moss | ? | 6 | Pred. | Fox | July 15 |
| Ridge | ? | 5 | Aband. | Human | July 6 |
| Island | ? | 3 | 3 duckl. | ----- | July 28 |
| Moss | ? | 4 | ? | ? | ? |
| Ridge | ? | 5 | Pred. | L.t.jaeger | July 18 |
| Moss | ? | 5 | ? | ? | ? |
| Ridge | June 29/72 | 5 | Pred. | Fox | July 9 |
| Ridge | July 2/72 | 4 | Pred. | Fox | July 18 |
| Moss | July 2/72 | 3 | Pred. | Fox | July 16 |
| Ridge | July 8/72 | 2 | Aband. | ? | July 10 |
| Meadow | July 9/72 | 4 | pred. | Gulls | July 16 |
| Ridge | July 99/72 | 4 | pred. | Fox | July 16 |
| Ridge | July 11/72 | 5 | Pred. | Fox | July 18 |
| Ridge | ? | * | Pred. | Fox | July 18 |
| Ridge | ? | 3 | Pred. | Fox | July 21 |
| Ridge | ? | * | Pred. | Fox | Aug. 2 |
| Ridge | ? | 4 | Pred. | Fox | Aug. 6 |

* Nest found preyed on prior to human interference.

Appendix II. King eider nest chronology and fate, Bathurst Island, 1971 and 1972.

| Invertebrates | Date |
| --- | --- |
| O. Rhabdocoela | |
| Sp. not identified | Aug.1/71 |
| | Aug.6/71 |
| Turbellaria | July 30/72 |
| O. Anostroca | |
| Branchinecta paludosa (Muller) | July 24/71 |
| | Aug.6/71 |
| | Aug.7/71 |
| | July 30/72 |
| Artemiopsis stefanssoni (Johansen) | Aug.6/71 |
| | July 30/72 |
| O. Notostraca | |
| Lepidurus arcticus (Pallas) | July 24/71 |
| | Aug.6/71 |
| | July 30/72 |
| O. Diplostraca | |
| S.O. Cladocera | |
| Daphnia pulex | Aug.1/71 |
| | Aug.6/71 |
| D. middesdoyrana | July 30/72 |
| O. Diptera | |
| Chironomidae sp. larvae | Aug.1/71 |
| | Aug.6/71 |
| | July 30/72 |
| pupae | July 30/72 |
| O. Cyclopoida | |
| Cyclops sp. | July 30/72 |

Appendix III. Fresh water invertebrates collected in three different ponds on Bathurst Island during the king eider hatching period.

| Date | Sex | Weight (gm) | Status | Gonad (cm) | Gizz. (cc) | % Gr. | % An. | % Pl. |
|---|---|---|---|---|---|---|---|---|
| June 26/71 | ♂ | 1660 | Breeding adult | 3.3x2.2 | 18.5 | 57 | 1 | 42 |
| June 26/71 | ♂ | 1440 | Breeding adult | 3.3x2.0 | 5.5 | 78 | 1 | 21 |
| July 1/71 | ♂ | 1480 | Breeder? 2nd year | 3.4x2.7 | 11.5 | 64 | 0 | 36 |
| July 9/71 | ♀ | 1340 | Brood patch | ? | 10.5 | 49 | 20 | 31 |
| July 17/71 | ♀ | 1280 | No brood patch | Large oviduct | 6.5 | 73 | 4 | 23 |
| July 17/71 | ♀ | 1560 | No brood patch | Large oviduct | 4.5 | 61 | 3 | 26 |
| July 10/72 | ♂ | 1495 | Breeding adult | 3.0x1.9 | 4.5 | 45 | 1 | 54 |
| July 14/72 | ♂ | 1570 | Breeding adult | 2.7x1.6 | 6.5 | 60 | 14 | 26 |
| July 10/72 | ♀ | 1940 | No brood patch | Egg in oviduct | 43.0 | 5 | 85 | 10 |
| July 14/72 | ♀ | 1835 | No brood patch | Egg in oviduct | 12.0 | 35 | 49 | 16 |
| July 19/72 | ♀ | 1900 | No brood patch | Egg in oviduct | 37.0 | 15 | 84 | 1 |
| July 20/72 | ♀ | 1740 | Brood patch | Egg in oviduct | 11.0 | 40 | 36 | 24 |
| July 20/72 | ♀ | 1460 | Brood patch | Oviduct medium | 7.0 | 55 | 2 | 43 |
| July 20/72 | ♀ | 1325 | No brood patch | Oviduct regressed | 6.0 | 30 | 1 | 69 |

Appendix IV. Data obtained from king eider collected at Bathurst Island in 1971 and 1972.

Gizz.: Gizzard content
Gr.: Grit
An.: Animal material
Pl.: Plant material
%: By volume