

The diet of common eiders wintering in Nuuk, Southwest Greenland

Flemming R. Merkel · Sarah E. Jamieson ·
Knud Falk · Anders Mosbech

Received: 1 August 2005 / Revised: 8 June 2006 / Accepted: 8 June 2006 / Published online: 11 August 2006
© Springer-Verlag 2006

Abstract Southwest Greenland provides wintering grounds for 70% (~460,000) of the northern common eider (*Somateria mollissima borealis*) population. From 241 gullet samples (esophagus and proventriculus content) collected over three winters (1999–2002) near Nuuk, we identified 39 species consumed by the eiders. In contrast to studies elsewhere, fresh mass of the diet was dominated by soft-bottom species: the bivalve *Mya eideri* (32.8%) and the polychaete *Pectinaria* spp. (24.2%). The hard-bottom blue mussel (*Mytilus edulis*), usually the dominant prey of common eiders, was only the fourth most important diet species (7.5%). Overall, bivalves accounted for 56% of the diet. Twenty-seven prey species were minor foods with aggregate fresh mass of only 5.5%. Diets of males and females were similar, whereas juveniles consumed greater mass of crustaceans and less of bivalves. Diet diversity was higher in mid-winter than late winter, and higher in coastal habitats than in fjords. Within one important wintering area the results indicate that optimal size of blue mussels may be depleted over winter.

Introduction

The northern common eider (*Somateria mollissima borealis*) is one among six or seven recognized subspecies of common eiders in North America, Europe and Asia (Goudie et al. 2000). Northern common eiders breed in the eastern Canadian Arctic and western Greenland (Abraham and Finney 1986; Boertmann et al. 1996; Merkel 2004a). All birds from western Greenland and most Canadian breeders, about 70% (463,000) of the subspecies, migrate to over winter in open water in Southwest Greenland (Lyngs 2003; Boertmann et al. 2004). As autumn migration starts in September and spring migration peaks in May, the eiders spend most of the year in this area (Lyngs 2003). Consequently, it is important to identify key prey of the eiders at this important site.

Despite the status of Southwest Greenland as an international significant wintering area for common eiders (Boertmann et al. 2004), little is known about the winter ecology of the eiders, including their diet. In other areas, common eiders generally feed in shallow water over rocky substrates and kelp beds, with high preference for benthic invertebrates, such as the blue mussel (*Mytilus edulis*) (review in Goudie et al. 2000). In central West Greenland, the foraging behaviour of sympatric moulting populations of king eiders (*S. spectabilis*) and common eiders suggested limited overlap in foods (16%) between the two species (Frimer 1995).

This study is part of a research programme on northern common eiders wintering in Southwest Greenland, including links between breeding and wintering grounds, physical condition and habitat use during

F. R. Merkel (✉) · K. Falk
Greenland Institute of Natural Resources,
PO Box 570, 3900 Nuuk, Greenland
e-mail: flme@natur.gl

S. E. Jamieson
Centre of Wildlife Ecology, Simon Fraser University,
8888 University Drive, V5A 1S6 Burnaby, BC, Canada

A. Mosbech
Department of Arctic Environment, National
Environmental Research Institute, Frederiksborgvej 399,
4000 Roskilde, Denmark

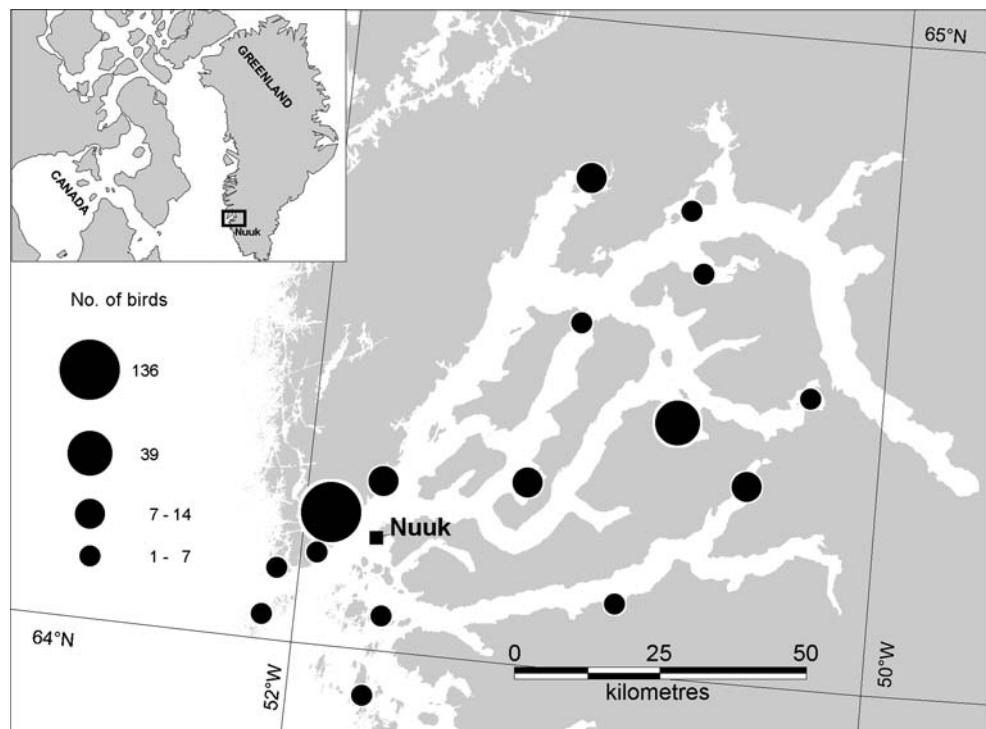
winter, and human exploitation (Jamieson et al. 2005; Merkel 2006; Mosbech et al. in press). In this paper, we describe (1) their winter diet in Southwest Greenland, (2) quantify the degree of dietary overlap between two general types of habitats in Southwest Greenland, coastal habitats and fjord habitats, (3) assess dietary overlap in relation to age and sex of the birds, and (4) analyse whether diet changed over the winter. We discuss the results in relation to additional knowledge about the habitat use of common eiders in Southwest Greenland and other studies of eider feeding habits.

Methods

Study area

The study area included the coastal waters and fjords surrounding Nuuk, the capital city of Greenland (Fig. 1; Merkel 2004b). The study area is a key wintering site for common eiders, with about 25,000 birds in the coastal area and 32,000 in the adjoining fjord system (Merkel et al. 2002). The coastal area is an extensive archipelago that includes relatively large areas of shallow water, whereas the fjords to the east are lined with steep cliffs and have few shallow water areas. In this paper, we refer to samples collected west of Nuuk as coastal samples, as opposed to fjord samples collected east of Nuuk.

Fig. 1 Study area and sampling sites (1999–2002). The large circle ($n = 136$) represents the Nepisat Sund sampling site



Collections and statistical methods

We collected samples during three winters: 1999–2000, 2000–2001 and 2001–2002. Birds were delivered by local fishermen, who caught them as by-catch in gill-nets. All birds were frozen on the day of collection. During subsequent dissections we removed and refroze the esophageal-proventricular (gullet) contents of 241 animals. We identified prey items to species whenever possible using standard identification literature (Sars 1895; McPherson 1971; Laubitz 1972; Just 1980; Lubinsky 1980; Squires 1990; Foster 1991; Petersen 1999). Individual crustaceans were not counted since they were often in poor condition and only few whole specimens were present.

For the 3 years combined, we compared 57 samples from the coast with 57 samples from the fjord. We tried to obtain 10 birds from each of seven coastal sites and nine fjord sites (Fig. 1). We included immature birds (2–3 years old) if <10 adults were available. When more than 10 birds were available we randomly picked 10. From diet samples obtained in the winter 2001–2002 from 10 fixed sampling locations in the Nepisat Sund area (net dimensions: 15×30 m; water depths: 10–15 m), we analysed the influence of sex, age and season: we compared 43 males to 43 females; 38 juvenile birds to 38 immatures and 43 adults, and 34 samples from December–January to 37 samples from March–April. We also made an age-class comparison for the

fjord birds, however, based on a shorter period (April only) and fewer birds: 11 juveniles, 10 immatures and 10 adults. The number of samples and their distribution over time and age-classes did not allow a robust year-to-year comparison.

Based on the fresh mass of the different food items, weighed to the nearest 0.1 g., we used Schoener's Index (SI) to calculate the overlap in diet between periods, habitats, age-classes and sexes (Schoener 1970):

$$SI = 1 - \left(\frac{1}{2} \sum_{i=1}^s |P_{ij} - P_{ik}| \right),$$

where s is the number of prey species (or categories) and P_{ij} and P_{ik} are the relative proportions (fresh mass) of a given prey species in the diet of age-class j and k , between sexes j and k , in periods j and k , or within habitats j and k . As a measurement of diet diversity, we calculated the Shannon–Weaver Diversity Index (H' , Zar 1999):

$$H' = \frac{n \log n - \sum_{i=1}^k f_i \log f_i}{n},$$

where k is the number of categories, f_i is the number of observations in category i , and n is the sample size. To test for difference in diversity between two groups we used a t -test calculated as (Hutcheson 1970; Zar 1999):

$$t = \frac{H'_1 - H'_2}{\sqrt{s_{H'_1}^2 + s_{H'_2}^2}},$$

where the variance s^2 of each H' is approximated as:

$$s_{H'}^2 = \frac{\sum f_i \log^2 f_i - (\sum f_i \log f_i)^2 / n}{n^2},$$

where f_i and n are defined as above.

We compared prey size selection between different periods and groups of birds for the three bivalve species most frequently found in the gullet samples from the Nepisat Sund in 2001/2002: *Mya eideri* ($n = 791$), *Mytilus edulis* ($n = 697$) and *Hiatella byssifera* ($n = 462$). For these, we measured the shell length to the nearest 5 mm length group. When calculating the mean length of bivalves we assigned each bivalve the mid-point value from the given size group. To test for differences in the mean length of bivalves, we used a two-sample t -test. We used a significance level of 0.05 for all statistical tests. Values are reported as means \pm SE.

Results

The 241 common eider gullet samples analysed contained 39 diet species and 10,113 food items, excluding non-countable species such as the crustaceans (Table 1). Four species made up 72.4% aggregate per cent fresh mass of the diet: *Mya eideri* (32.8%), *Pectinaria* spp. (24.2%), *Hiatella byssifera* (7.9%) and *Mytilus edulis* (7.5%). As per cent occurrence, these species were eaten by 68, 71, 45 and 20%, respectively of the birds. Bivalves accounted for 56% fresh mass of the diet. Many diet species were insignificant by fresh mass: 27 species each accounted for <1% of the diet and they added to only 5.5% (Table 1). On average, the 241 common eiders gullets contained 3.9 ± 0.1 diet species, ranging from 1 to 15 species.

The highest overlap of species consumed (Table 2) was found between immature and adult birds (Fjord: 85%; Coast: 72%), and between males and females (75%, Nepisat Sund only). Juveniles versus immatures, and juveniles versus adults, all had smaller diet overlap, ranging from 46 to 55%. In three of four cases the diet of adult birds was significantly more homogeneous than for younger birds (Table 2). The juvenile diet included significantly more crustaceans and significantly less bivalves compared to older birds (Table 3). There was a considerable difference in the diet between coastal habitats and fjord habitats; diversity indices differed significantly, although the diet overlap was not very low (59%, Table 2). The fjord diet was significantly stronger dominated by bivalve species, with *Mya eideri* constituting more than half the diet (53.6% fresh mass), significantly less dominated by polychaetes and crustaceans were not present in the fjord diet (Fig. 2).

In coastal habitats, gullet contents from Nepisat Sund (Fig. 1) changed from mid-winter to late winter. Thirty-one species were present in the diet in December/January, while only 16 were present in March/April. The diversity index for the late winter diet was significantly smaller than for mid-winter, and the diet overlap was only 43.1% (Table 2). Crustaceans, echinoderms, and gastropods were absent in the late winter diet (12 of 20 species). The dominant diet species changed also from mid-winter to late winter with a significant increase in *Mya eideri*, from 19% fresh mass in mid-winter to 48% in late winter (Fig. 3). In contrast, blue mussels decreased significantly from 22% in mid-winter to only 2% during late winter. This large drop coincided with a significant increase in shell size of blue mussels, from a mean size of 11.6 ± 0.2 mm in mid-winter to 14.9 ± 0.6 mm in late winter ($t = -5.06$, $df = 694$, $P < 0.001$, Fig. 4). The mean shell length did

Table 1 Esophageal content (fresh mass) of 241 common eiders collected during winter and spring (December–April) in Nuuk, Southwest Greenland, 2000–2002

Taxon	Total number of items	Total fresh mass	Aggregate fresh mass (%)	Occurrence (%)
Cnidaria				
<i>Actiniaria</i> sp.		0.8	<0.1	0.4
Annélida				
<i>Pectinaria</i> spp.	2,074	515.0	24.2	71.4
Mollusca				
Polyplacophora				
<i>Tonicella marmoreal</i>	35	33.1	0.5	3.3
Gastropoda				
<i>Tectura testudinalis</i>	40	8.5	0.3	9.5
<i>Margarites groenlandicus</i>	2	0.1	<0.1	0.8
<i>Margarites helicinus</i>	548	8.0	0.7	13.3
<i>Margarites olivaceus</i>	3	0.3	<0.1	0.8
<i>Puncturella noachina</i>	4	0.5	0.1	1.7
<i>Boreotrophon truncatus</i>	2	0.6	<0.1	0.4
<i>Buccinum</i> spp.	13	9.8	0.4	3.7
<i>Oenopota</i> spp.	31	1.9	<0.1	6.2
<i>Lacuna vincta</i>	8	1.4	<0.1	2.5
<i>Littorina obtusata</i>	31	6.0	0.1	2.1
<i>Littorina saxatilis</i>	3	0.2	<0.1	1.2
<i>Cylichna</i> sp.	3	0.2	<0.1	1.2
Total of Gastropoda	688	37.3	1.7	30.3
Bivalvia				
<i>Crenella faba</i>	63	6.8	0.6	6.6
<i>Musculus discors</i>	86	70.9	2.1	6.2
<i>Musculus niger</i>	12	4.8	0.2	2.5
<i>Mytilus edulis</i>	979	326.6	7.5	20.3
<i>Macoma calcarea/balthica</i>	243	33.7	2.2	31.1
<i>Serripes groenlandicus</i>	32	42.5	0.9	8.7
<i>Hiatella byssifera</i>	629	205.6	7.9	45.2
<i>Mya eideri</i>	1,510	1,022.7	32.8	68.0
<i>Unid. Siphons</i>	25	17.3	1.5	4.6
Total of Bivalvia	3,579	1,730.8	55.8	87.6
Total of Mollusca	4,302	1,801.2	58.1	92.1
Crustacea				
<i>Balanus</i> sp.	–	7.8	0.2	4.6
<i>Calliopius laeviusculus</i>	–	53.0	3.7	9.5
<i>Gammarellus homari</i>	–	0.1	<0.1	0.4
<i>Gammarus oceanicus</i>	–	2.7	0.4	2.1
<i>Unid. amphipods</i>	–	7.6	0.4	0.8
<i>Hyas araneus</i>	–	118.6	3.2	6.6
Total of Crustacea	–	189.8	7.8	18.7
Echinodermata				
<i>Asterias rubens</i>	–	2.5	0.1	0.4
<i>Leptasterias polaris</i>	3	5.2	0.1	1.2
<i>Ophiura sarsi</i>	7	3.1	0.1	2.9
<i>Strongylocentrotus droebachiensis</i>	22	45.9	1.8	6.2
<i>Pentamera calcigera</i>		58.7	3.0	9.1
<i>Psolus fabricii</i>	11	53.7	1.0	2.9
Total of Echinodermata		169.0	6.2	19.9
Pisces				
<i>Ammodytes</i> sp.	10	54.2	0.4	0.4
<i>Cyclopterus lumpus</i> (eggs)	3,626	35.9	0.4	0.4
<i>Unid. fish eggs</i>	58	0.3	<0.1	0.4
Total of Pisces	3,694	90.4	0.8	1.2
Algae	–	41.3	1.2	10.8
Pebbles	–	29.4	1.7	22.4

not differ between mid-winter (12.2 ± 0.4 mm) and late winter (12.4 ± 0.3 mm) ($t = -0.41$, $df = 316$, $P = 0.68$) for *Mya eideri* and for the third most

important bivalve species, *Hiatella byssifera* (11.4 ± 0.3 and 12.1 ± 0.5 mm, respectively, $t = -1.32$, $df = 355$, $P = 0.19$).

Table 2 Diet overlap and diet diversity indices for prey species consumed by different groups of common eiders wintering in Southwest Greenland

Groups compared	Diet overlap (SI) (%)	Shannon–Weaver Index (H')	<i>t</i> -value (df)
Coast versus fjord	59	1.059 vs. 0.964	2.229 (341)*
Mid-winter versus spring	43	1.281 vs. 0.945	6.732 (281)***
Males versus females	75	1.202 vs. 1.225	0.470 (340)
Coast: juvenile versus immature	54	1.248 vs. 1.225	0.505 (314)
Coast: juvenile versus adult	55	1.248 vs. 1.067	3.937 (326)***
Coast: immature versus adult	72	1.225 vs. 1.067	3.252 (340)***
Fjord: juvenile versus immature	53	0.908 vs. 0.736	1.974 (49)
Fjord: juvenile versus adult	46	0.908 vs. 0.759	2.154 (66)*
Fjord: immature versus adult	85	0.736 vs. 0.759	0.264 (44)

The number of asterisks show the level of significance from 0.05* to 0.001***

Table 3 The winter diet (December 2001–April 2002) of common eiders in Nepisat Sund, Southwest Greenland, according to age-class and diet group

Diet group	Juveniles n=38	Immatures n= 38	Adults n=43
Anthozoa	0.00	< 0.01	0.00
Polychaeta	0.31 ± 0.06	0.26 ± 0.05	0.27 ± 0.05
Polyplacophora	< 0.01	0.0	< 0.01
Gastropoda*	0.04 ± 0.02	0.04 ± 0.02	0.01 ± 0.00
Bivalvia***	0.23 ± 0.05	0.54 ± 0.06	0.63 ± 0.05
Crustacea***	0.34 ± 0.07	0.06 ± 0.03	0.06 ± 0.03
Echinodermata	0.05 ± 0.03	0.07 ± 0.04	0.01 ± 0.01

Values represent the fresh mass expressed as the mean (aggregate) proportion ± SE of the esophageal content within the age group. Asterisks show the level of significance from 0.05* to 0.001*** according to one-way ANOVAs. Groups that are not underlined with the same dotted line differ significantly (Tukey's pairwise comparisons)

Discussion

Diet composition

In a wide range of Arctic as well as temperate locations, blue mussels are the dominant prey of common eiders (e.g. Bagge et al. 1973; Goudie and Ankney 1986; Bustnes and Erikstad 1988; Nehls and Ketzenberg 2002), similar to our Nepisat Sund mid-winter data (Fig. 3). However, on average, blue mussels were only the fourth most common prey species in the Nuuk study area. In terms of both per cent occurrence and aggregate per cent fresh mass, *Mya eideri* was more than three times as important (Table 1). Only one other study observed a similar dominance of *Mya* clams in the diet: 67% of king eiders moulting in the Disko Bay in central West Greenland consumed *Mya*

(Frimer 1997). The second most common prey species in our study, the polychaete *Pectinaria* spp., was also the second most common prey for the king eiders in Disko Bay (Frimer 1997). The consumption of soft-bottom community taxa like *Mya* and *Pectinaria* contrasts to most other studies, where common eiders fed mainly over rocky substrates and kelp beds (e.g. Bustnes and Erikstad 1988; Guillemette et al. 1993).

Our study confirms local knowledge, and the study of Frimer (1997), that eiders in west Greenland occasionally eat fish (Table 1). Both in Nuuk and in the Disko Bay area the fish preyed upon was *Ammodytes* spp., which probably was taken while buried in the sediment (Frimer 1997). In northern Norway, Bustnes and Erikstad (1988) found that the eggs of lumpfish were important spring diet for the common eider. Our sampling period did not include the peak spawning period for the lumpfish in Southwest Greenland (May, Salomonsen 1990) and probably explains why we found only one eider containing large quantities of lumpfish eggs (Table 1).

Sex, age, season and sampling

Our results support previous findings that the diet of male and female eiders is much the same (Pethon 1967; Bustnes and Erikstad 1988; Frimer 1997) but also, that food preferences changed with age: young birds selected more readily digestible crustacean and annelid prey species (Pethon 1967; Bustnes et al. 2000). This pattern may either be a consequence of juveniles having higher nutritional demands related to body mass, growth or less developed gizzards, or be related to poor body condition (Bustnes et al. 2000; Merkel 2006). Some juveniles may behave as “risk-prone foragers” and seek the high-energy, but less predictable crustacean species to enhance their survival (Guillemette et al. 1992). For adult eiders, crustaceans may be important on a short seasonal basis (Pethon 1967;

Fig. 2 Spring diet composition (aggregate % fresh mass) among common eiders in the fjord ($n = 57$) and at coastal areas ($n = 57$) near Nuuk, Southwest Greenland. Only samples from March and April (2000–2002) are shown. Numbers next to columns indicate the number of species in each diet group. Asterisks show the level of significance from 0.05* to 0.001*** (two-sample t -test)

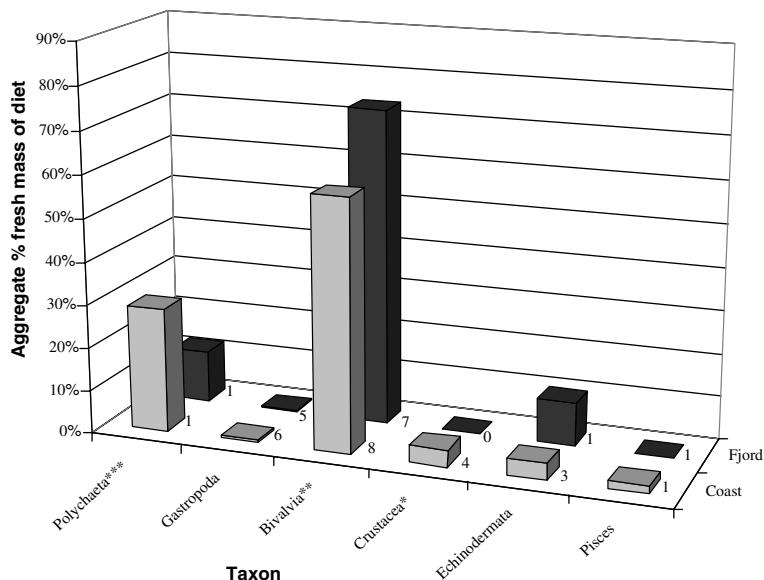


Fig. 3 The most important diet species (aggregate % fresh mass) for common eiders during mid-winter (December/January, $n = 34$) and late winter (March/April, $n = 37$) in the coastal area (Nepisat Sund) of Nuuk, Southwest Greenland. Asterisks show the level of significance from 0.05* to 0.001*** (two-sample t -test)

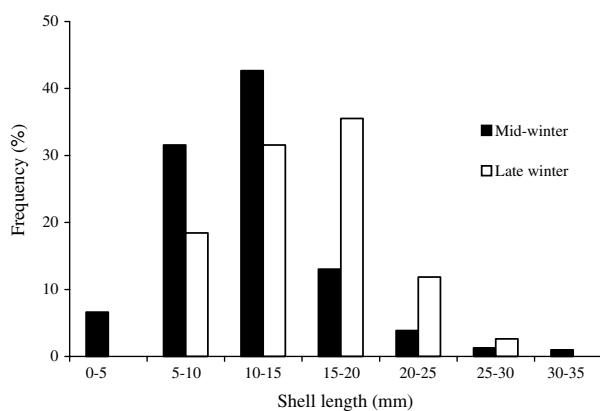
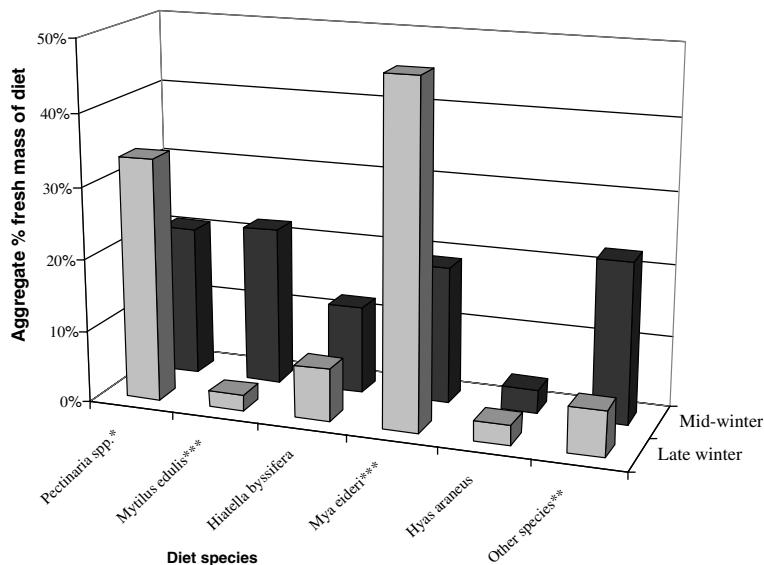


Fig. 4 The size frequency of blue mussels (*Mytilus edulis*) eaten by common eiders in mid-winter (December–January, 2001/2002, $n = 671$ mussels) and spring (March–April, 2002, $n = 76$) in Nuuk (Nepisat Sund), Southwest Greenland

Cantin et al. 1974; Bustnes and Systad 2001). In these studies, the occurrence of crustaceans in the diet peaked during autumn and early winter and may be important for maintenance of a waterproof plumage during moult (Pethon 1967).

Our study demonstrates the need to control for sampling parameters, such as time and location, when collecting diet samples. Prey selection by eiders can vary significantly only short distances apart (e.g. coast versus fjord, Table 2, Fig. 2) or between mid-winter and late winter at one specific location (Nepisat Sund, Fig. 3). To what extent the diet composition differed or changed due to diet preferences among birds, or simply because prey availability differed between locations and changed over time, is not clear (about prey depletion, see later). We suspect, however, that the less

diverse diet of fjord birds was a reflection of prey availability. In fact, we believe that the differences found are underestimated. Shallow waters are limited in the fjord and eiders often feed in the sublittoral zone of steep cliffs, which are heavily dominated by blue mussels (F. Merkel, personal observation). However, since all our fjord samples originate from lump sucker gillnets and since these are only put out on shallow waters, the “steep-cliff foragers” are probably not represented in our dataset. In contrast, we expect the shallow waters used for gillnetting in the coastal area to be largely representative of eider feeding habitats. They all represent high-density areas for common eiders in Nuuk and also typical diving depths for eiders (10–15 m).

Prey selection

Our study supports previous findings that the diets of large sea ducks, such as the common eider, are often dominated by few benthic prey species, whereas smaller sea ducks, such as the king eider, Steller’s eider, and long-tailed duck, normally have a more diverse diet with larger quantities of high-energy pelagic prey (Goudie and Ankney 1986; Bustnes and Erikstad 1988; Bustnes and Systad 2001; Jamieson et al. 2001). Goudie and Ankney (1986) found an inverse relationship between diet quality and body size in four sea duck species, and concluded that the higher energy requirements per gram live mass for the small duck species could not be met by low-energy benthic prey species. This finding supports the prediction by Bustnes et al. (2000) that some juveniles behave as “risk-prone foragers” and seek the high-energy crustacean prey. The relationship between energy requirements and body surface area is especially relevant at northern high latitudes since heat loss is highly linked to ambient temperature.

Blue mussels between 10 and 15 mm in size were most common selected in common eiders in our study and in northern Norway (Bustnes and Erikstad 1990). In Norway this length class had the lowest relative shell content, and thus the highest energy content (Bustnes 1998). Feeding on this size class may be an active energy maximization strategy which in the Norwegian case was supported by the fact that common eiders only ate the mussels with the lowest shell mass when given mussels of the same length-class, but with different shell morphology. We speculate that a similar relationship could explain the shift in mussel size consumed by the eiders in our study area. Towards spring, when mussels 15–20 mm long became more common in the diet than those 10–15 mm long, blue mussels might have become less profitable as a prey

item. We speculate that the blue mussels were substituted by the *Mya* clams in mid winter due to a gradual depletion over winter of blue mussels of the optimum size. In the Gulf of St. Lawrence, eastern Canada, Guillemette et al. (1995) found that common eiders substantially depleted blue mussel beds: from December to April, eiders removed 48–69% of the mussel biomass. According to Raffaelli et al. (1990) eiders may deplete preferred mussel beds by 80% over winter. We encourage direct observations on prey availability to further explore prey and habitat selection in our study area.

Acknowledgments This study was funded by the Greenland Institute of Natural Resources, the Danish National Environmental Research Institute, and the Danish Environmental Protection Agency as part of the Danish Cooperation for Environment in the Arctic (Dancea). We wish to thank Lotte Rasmussen and Kristian Wæver, Greenland Institute of Natural Resources, for laboratory assistance, and thanks to local hunters and fishermen from Nuuk, who made data collection possible. For guidance and verification of the eider diet, we are indebted to Godtfred H. Petersen and Tom Schiøtte, Zoological Museum, Copenhagen, and to Philip Lambert at the Royal British Columbia Museum, Victoria.

References

- Abraham KF, Finney GH (1986) Eiders of the eastern Canadian Arctic. In: Reed A (ed) Eider ducks in Canada. Canadian Wildlife Service Report Series No. 47, pp 55–73
- Bagge P, Lemmettyinen R, Raitis T (1973) Spring food of some diving waterfowl in the southwestern Finnish archipelago. Oikos 15:146–150
- Boertmann D, Lyngs P, Merkel FR, Mosbech A (2004) The significance of SW Greenland as winter quarters for seabirds. Bird Conserv Int 14:87–112
- Boertmann D, Mosbech A, Falk K, Kampp K (1996) Seabird colonies in western Greenland. National Environmental Research Institute (NERI). Copenhagen, Technical Report 170:98
- Bustnes JO (1998) Selection of blue mussels, *Mytilus edulis*, by common eiders, *Somateria mollissima*, by size in relation to shell content. Can J Zool 76:1787–1790
- Bustnes JO, Asheim M, Bjørn TH, Gabrielsen H, Systad GH (2000) The diet of Steller’s eiders wintering in Varangerfjord, Northern Norway. Wilson Bull 112:8–13
- Bustnes JO, Erikstad KE (1988) The diets of sympatric wintering populations of common eider *Somateria mollissima* and king eider *S. spectabilis* in northern Norway. Ornis Fennica 65:163–168
- Bustnes JO, Erikstad KE (1990) Size selection of common mussels (*Mytilus edulis*) by common eiders (*Somateria mollissima*): energy maximization or shell weight minimization. Can J Zool 68:2280–2283
- Bustnes JO, Systad GH (2001) Comparative feeding ecology of Steller’s eider and long-tailed ducks in winter. Waterbirds 24:407–412
- Cantin M, Bédard J, Milne H (1974) The food and feeding of common eiders in the St. Lawrence estuary in summer. Can J Zool 52:319–334

Foster NR (1991) Intertidal bivalves: a guide to the common marine bivalves of Alaska. University of Alaska Press, Alaska

Frimer O (1995) Comparative behaviour of sympatric moulting populations of common eider (*Somateria mollissima*) and king eider (*S. spectabilis*) in central West Greenland. *Wildfowl* 46:129–139

Frimer O (1997) Diet of moulting king eiders *Somateria spectabilis* at Disko Island, West Greenland. *Ornis Fennica* 74:187–194

Goudie RI, Ankney CD (1986) Body size, activity budgets, and diet of sea ducks wintering in Newfoundland. *Ecology* 67:1475–1482

Goudie RI, Robertson GJ, Reed A (2000) Common eider (*Somateria mollissima*). In: Poole A, Gill F (eds) *The Birds of North America*, no 546. The Birds of North America, Philadelphia, PA

Guillemette M, Himmelman JH, Barette C, Reed A (1993) Habitat selection by common eiders in winter and its interaction with flock size. *Can J Zool* 71:1259–1266

Guillemette M, Reed A, Himmelman JH (1995) Availability and consumption of food by common eiders wintering in the Gulf of St. Lawrence evidence of prey depletion. *Can J Zool* 74:32–38

Guillemette M, Ydenberg RC, Himmelman JH (1992) The role of energy intake rate in prey and habitat selection of common eiders *Somateria mollissima* in winter: a risk-sensitive interpretation. *J Anim Ecol* 61:599–610

Hutcheson K (1970) A test for comparing diversities based on Shannon formula. *J Theor Biol* 29:151–154

Jamieson SE, Gilchrist HG, Merkel FR, Diamond AW, Falk K (2005) Endogenous reserve dynamics of northern common eiders wintering in Greenland. *Polar Biol*. DOI 10.1007/s00300-005-0093-2

Jamieson SE, Robertson GJ, Gilchrist HG (2001) Autumn and winter diet of long-tailed duck in the Belcher Islands, Nunavut, Canada. *Waterbirds* 24:129–132

Just J (1980) Amphipoda (Crustacea) of the Thule area, Northwest Greenland: Faunistics and taxonomy. *Medd Grøn Biosci* 2:1–61

Laubitz DR (1972) The caprellidae (crustacea, amphipoda) of Atlantic and Arctic Canada. *Nati Mus Can Publ Biol Oceanogr* 4:1–82

Lubinsky I (1980) Marine bivalve molluscs of the Canadian central and eastern Arctic: faunal composition and zoogeography. Department of Fisheries and Oceans, Ottawa, Bulletin no. 207

Lyngs P (2003) Migration and winter ranges of birds in Greenland—an analysis of ringing recoveries. *Dansk Orn Foren Tidskr* 97:1–167

McPherson E (1971) The marine molluscs of Arctic Canada: prosobranch gastropods, chitons, and scaphopods. *Nati Mus Can Publ Biol Oceanogr* 3:1–149

Merkel FR (2004a) Evidence of population decline in common eiders breeding in western Greenland. *Arctic* 57:27–36

Merkel FR (2004b) Impact of hunting and gillnet fishery on wintering eiders in Nuuk, Southwest Greenland. *Waterbirds* 27:469–479

Merkel FR (2006) Common Eiders in Greenland—interactions between harvest, body condition and habitat use in winter. PhD dissertation, Greenland Institute of Natural Resources, Greenland and University of Copenhagen, Denmark

Merkel FR, Mosbech A, Boertmann D, Grøndahl L (2002) Winter seabird distribution and abundance off south-western Greenland, 1999. *Polar Res* 21:17–36

Mosbech A, Gilchrist HG, Merkel FR, Sonne C, Flagstad A (2006) Comparing spring and autumn migration of Arctic common eider based on satellite telemetry *Ardea* (in press)

Nehls G, Ketzenberg C (2002) Do common eiders *Somateria mollissima* exhaust their food resources? A study on natural mussel *Mytilus edulis* beds in the Wadden Sea. *Danish Rev Game Biol* 16:47–61

Petersen GH (1999) Five recent *Mya* species, including three new species and their fossil connections. *Polar Biol* 22:322–328

Pethon P (1967) Food and feeding habits of the common eider (*Somateria mollissima*). *Nytt Mag Zool* 15:97–111

Raffaelli D, Falcy C, Galbraith C (1990) Eider predation and the dynamics of mussel bed communities. In: Barnes M, Gibson RN (eds) *Trophic relations in the marine environment*. Aberdeen University Press, Aberdeen, UK, pp 157–169

Salomonsen F (1990) Grønlands fauna (The fauna of Greenland), 2nd edn. Gyldendal, Copenhagen

Sars GO (1895) *Amphipoda*. An account of the crustacea of Norway with short descriptions and figures of all the species. In: Abstracts Cammermeyer, Christiania and Copenhagen

Schoener TW (1970) Nonsynchronous spatial overlap of lizards in patchy habitats. *Ecology* 51:408–418

Squires HJ (1990) Decapod crustacea of the Atlantic coast of Canada. Department of fisheries and oceans, Ottawa, Ontario, Bulletin no. 221, p 532

Zar JH (1999) *Biostatistical analysis*, 4th edn. Prentice-Hall, Upper Saddle River, NJ