FOOD OF JUVENILE COMMON EIDERS (*SOMATERIA MOLLISSIMA*) IN AREAS OF HIGH AND LOW SALINITY

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ABSTRACT.—In a comparative survey of the food selected by the Common Eider (*Somateria mollissima*) in coastal waters of the Skagerrak and the northern Baltic proper, waters of high and low salinity, we showed that *Mytilus edulis* was the most heavily utilized food type. In waters of high salinity, ducks did not select large mussels, though they were available, and apparently ducks preferred food items with a low seawater content, like crustaceans and gastropods. Large birds, however, consumed larger mussels than did smaller birds. These results support previously proposed hypotheses that mussel-feeding ducks can minimize salt intake by feeding on smaller mussels, by consuming other types of food, and by increasing the allowable intake by being larger. There were indications that the size and number of grit fragments swallowed were related to the type of food consumed. However, we were unable to determine whether grit fragments were consumed involuntarily during mussel gathering or swallowed intentionally to help in grinding food items. A decline in body size over a 1,000-year period in eiders from the Baltic compared with birds from the Swedish west coast implies an evolutionary adaptation to lower salinity. We also describe a method of mussel size reconstruction from shell remnants. *Received 2 January 1990, accepted 25 September 1990.*

THE DIET of the Common Eider (*Somateria mollissima*) varies with age in an area of high salinity (Pethon 1967). Young birds initially eat chiefly smaller crustaceans. With age, however, the proportion of bivalves in their diet increases steadily. The high saltwater content of bivalves has been suggested as the factor discouraging utilization of this type of food by young ducklings (Nyström and Pehrsson 1988). The seawater content of a mussel is positively correlated with its size, and the excretion of excess salt by the foraging bird imposes extra energetic costs that affect growth rate (Schmidt-Nielsen and Kim 1964, Peaker and Linzell 1975, Skadhauge 1981, Nyström and Pehrsson 1988). We performed a comparative study to determine whether the size of Common Mussels (*Mytilus edulis*) selected by juvenile eiders was affected by water salinity. We used study areas along the west and east coasts of Sweden that differed drastically in salinity levels.

METHODS

Food abundance and salt intake.—Outside Hållö on the Swedish Skagerrak coast (salinity ≈3.3%) (Fig. 1), *Mytilus edulis* and *Mya arenaria* were sampled at one station (Pengeskärsbåden) on 19 April 1987. We measured the length of mussels to the nearest 0.1 mm with a caliper square. Investigations by Kautsky (1982a) of the size distribution of *Mytilus* present in the northern Baltic proper (salinity 0.65–0.70%) have shown that the number of mussels ≥2 mm in length is fairly constant within as well as between years, and we use his data in this paper.

We estimated daily salt intake (SPUBW), expressed as salt (g) per unit body-weight (kg) by using equation 6 in Nyström and Pehrsson (1988):

$$\mathrm{SPUBW} = 9.568 \cdot L^{0.596} \cdot S \cdot W^{-0.3663}, \qquad (1)$$

where L = mussel length (mm), S = the proportion of salt in the water, and W = body mass (kg) of the duck. This daily salt intake (SPUBW) originates from the seawater locked up between the valves when a bird feeds on one size of mussels in sufficient quantities to maintain basal metabolic rate (BMR; King 1974).

Food analysis.—At six stations (Arholma, Grinda, Grönskär, Husarö, Nynäshamn, and Vaxholm) in the Stockholm archipelago (salinity 0.35–0.65%) (Fig. 1), birds were collected in September 1985 and October 1986. At Hållö corresponding collections were made

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Fig. 1. Study areas and salinity gradient (‰) from Skagerrak to the Baltic (Redrawn from McLusky 1971).

in October 1986. Whole birds were frozen on the day they were collected. We weighed birds from the Stockholm area in 1985 to the nearest 50 g and sorted them into weight classes (i.e. 1.2, 1.4, 1.6, and 1.8 kg). We measured the length of intact organisms and the diameter of grit found in the esophagus and gizzard to the nearest 0.1 mm. When possible, partly digested items or food remains were identified to taxon. Such items were not measured, nor was their frequency estimated. Instead, they were recorded as being present together with undamaged items on the list showing the composition of individual meals.

An index based on the length of each undamaged food item was established to approximate the relative utilization importance (I_t) of each taxon (t) in the food consumed by the birds:

$$I_t = 100(\Sigma L_t / L_{\Sigma t}), \quad (2)$$

where L_t = length of an individual belonging to a given taxon, and $L_{\Sigma t}$ = the sum of the lengths of all individuals belonging to all taxa.

Mussel size reconstruction.—We extracted shell fragments of *Mytilus* from gizzard contents of juvenile eiders of the Hållö area and sieved them through a 1.5 mm mesh screen. The thickness of the remaining shell fragments containing the intact or almost intact umbo was measured to the nearest 0.05 mm with a caliper square.

At Sälöfjorden, on the Swedish Skagerrak coast, we sampled *Mytilus* at one station (Lekskär) on 15 September 1988. The mussel length was measured. One shell-half of each mussel was then broken into pieces,

TABLE 1. Frequency and relative importance, I_t (Eq. 2) of undamaged food items obtained from Common Eider juveniles in the Stockholm archipelago (n = 98) and the Hållö area (n = 13).

	Stockholm			Hållö		
Taxon	No.	%	I_t	No.	%	I_t
Mollusca	621	73.7	80.9	71	85.5	78.1
Gastropoda	7	0.7	0.17	14	16.9	8.4
Littorina littorea	1	0.1	0.02	14	16.9	8.4
Hydrobia ventrosa	3	0.3	0.06			
Bithynia tentaculata	3	0.3	0.09			
Bivalvia	614	73.0	80.7	57	68.6	69.7
Mytilus edulis	612	72.8	80.5	46	55.4	58.1
Cardium glaucium	2	0.2	0.2			
Mya arenaria				11	13.2	11.6
Crustascea	208	24.8	18.7	11	13.2	19.3
Cirripedia						
Balanus improvisus	12	1.4	0.6			
Isopoda						
Mesidothea entomon	40	4.8	9.2			
Idothea sp.				1	1.2	0.6
Unidentified sp.	1	0.1	0.1			
Amphipoda						
Gammarus sp.	152	18.1	8.0			
Decapoda	3	0.4	0.8	10	12.0	18.7
Astacus fluviatilis[a]	3	0.4	0.8			
Carcinus maenas				9	10.8	17.6
Cancer pagurus				1	1.2	1.1
Insecta	11	1.2	0.49			
Odonata	1	0.1	0.03			
Trichoptera (larvae)	1	0.1	0.1			
Hemiptera/Heteroptera	2	0.2	0.06			
Hymenoptera						
Formicidae	7	0.8	0.3			
Echinodermata						
Asterias rubens				1	1.2	2.6

[a] Originating from human waste.

similar in size to those found in eider gizzards, and the thickness of each was measured in the same way.

RESULTS

Composition of food items.—The frequency of undamaged food items indicated no difference between sites in the utilization importance indices of Bivalvia and Crustacea (Table 1). However, gastropods were utilized relatively more by juveniles in the Hållö area than by those in the Stockholm area ($z = 2.6334$, $P < 0.005$, z-test; Dixon and Massey 1969). Also, juvenile eiders in the Hållö area tended to include more crustaceans in their diet when preying upon bivalves than did juveniles of the Stockholm archipelago. Similarly, fewer birds preyed solely on bivalves at the former site (Table 2).

TABLE 2. Number of Common Eider juveniles feeding on Bivalvia and Crustacea.

	Stockholm (n = 98)			Hållö (n = 13)	
	No.	%	P[a]	No.	%
Solely on Bivalvia	65	66.8	<0.001	2	15.4
Solely on Crustacea	19	19.4	NS	4	30.8
Solely on Bivalvia and Crustacea	8	8.2	<0.05	4	30.8

[a] P = probability from Chi-square test that numbers differ by chance (NS = not statistically significant).

Mussel size reconstruction.—Thirty seven shell halves ($\bar{x}$ = 31.7 mm, SD = 14.7, range = 9.3–56.0 mm) were broken into pieces. In each, the thickest piece originated from the umbo. There was a significant correlation between the shell-half length, L (mm), and the thickness, T (mm):

$$T = 0.02146L - 0.1417 \quad (3)$$

($r = 0.93$, $t = 15.2918$, df = 35, $P < 0.0001$).

In the gizzard contents of the Hållö juveniles,

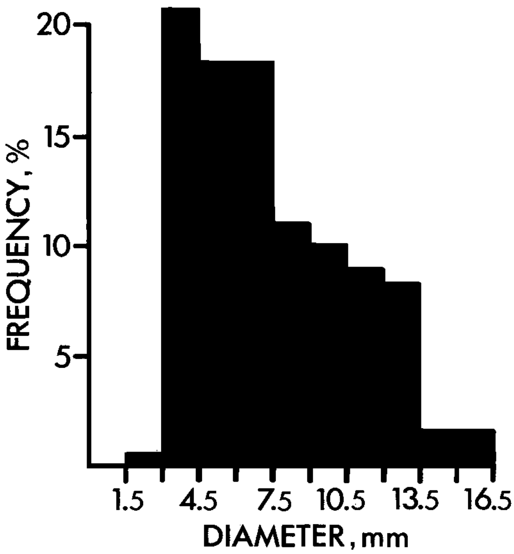

Fig. 2. Size distribution of 179 grit fragments found in the gizzards of 33 Common Eider juveniles from the Stockholm archipelago in October 1986 ($\bar{x}$ = 7.1 mm, range = 3.0–16.0).

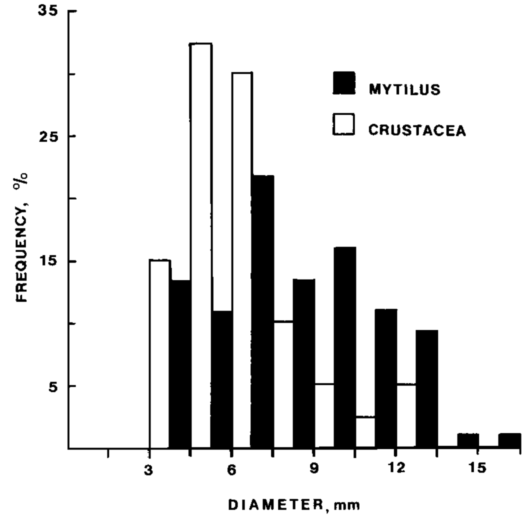

Fig. 3. Size distribution of 83 grit fragments ($\bar{x}$ = 8.7 mm, range = 3.4–15.9) found in the gizzards of 21 Common Eider juveniles in the Stockholm archipelago in 1986 when preying solely on *Mytilus edulis*, and, superimposed, 40 grit fragments ($\bar{x}$ = 6.7 mm, range = 3.2–12.8) in 7 juveniles preying solely on Crustacea in the same area.

we found no significant difference (t = 0.1084, df = 71, P = 0.91) between the mean length estimated for damaged mussels ($\bar{x}$ = 17.4 mm, SD = 8.4, maximum length = 41.6 mm, n = 27 mussels or 53 umbos) and the mean length of undamaged mussels ($\bar{x}$ = 17.2 mm, SD = 7.1, maximum length = 34.2 mm, n = 46) (Table 3).

Grit utilization.—Of 115 juveniles, 54.8% had grit in their gizzards (57.8% of 102 individuals in the Stockholm archipelago, 30.8% of 13 individuals in the Hållö area). In the Stockholm area, the mean number of grit fragments per bird was 5.5 (range = 1–51) for 51 juveniles in which grit was counted.

Of the birds listed in Table 2, 50.7% of the 67 juveniles feeding solely on Bivalvia and 73.9% of the 23 juveniles feeding solely on Crustacea contained grit. There was no significant difference between the number of birds in the two food-item groups found with grit in their gizzards (χ^2 = 2.8583, df = 1, 0.05 < P < 0.10). The size distribution of grit fragments was skewed in favor of smaller sizes (Fig. 2), and larger grit items were used when birds preyed on Bivalvia than when they preyed on Crustacea (t = 3.6198, df = 121, P = 0.0004) (Fig. 3).

Mussel size selection in relation to body mass.—The mean body mass of 35 juveniles in the Stockholm archipelago in 1985 was 1.79 kg (range = 1.10–2.60), and there was a positive

TABLE 3. Mean size (mm) of undamaged *Mytilus edulis* consumed by Common Eider juveniles.

	1985			1986			
Locality	n	$\bar{x}$ ± SD	Range	n	$\bar{x}$ ± SD	Range	P[a]
The Baltic	315	17.8 ± 4.0	6.6–30.0	297	16.5 ± 3.9	4.8–31.0	***
Arholma	132	17.5 ± 3.9		160	17.3 ± 3.4		NS
Grinda	80	20.9 ± 3.7		13	16.8 ± 6.6		***
Grönskär	8	14.1 ± 4.2					
Husarö	26	19.0 ± 4.2		11	20.1 ± 5.6		NS
Nynäshamn	69	14.9 ± 4.2		160	14.9 ± 3.4		NS
Skagerrak				46	17.2 ± 7.1	2.8–34.2	

[a] P = probability from t-test that mean sizes differ by chance (*** = P < 0.001, NS = not statistically significant).

correlation between juvenile body mass ($n = 17$ birds representing 6 weight classes) and mean size of the mussels consumed ($n = 228$ mussels, $r = 0.96$, $t = 7.4262$, df = 4, $P = 0.002$).

Mussel size selection in relation to salinity.—In the Stockholm area, the mean size of *Mytilus* selected was significantly larger in 1985 than in 1986 (Table 3). This difference in size was obvious in the Grinda subarea. In the other three subareas, there was no significant difference between years.

The mean mussel size per meal (1985: $\bar{x} =$ 16.9 mm, SD = 2.85, $n = 18$; 1986: $\bar{x} = 18.2$ mm, SD = 4.95, $n = 17$) for juveniles in the Stockholm area did not differ significantly between years ($t = 0.9591$, df = 33, $P = 0.34$). Thus, although the observed difference between 1985 and 1986 in mean length (1.3 mm) of *Mytilus* consumed was statistically significant, it was of little practical importance because the calculated daily salt intake (SPUBW, Eq. 1) values were similar (0.28 [$L = 17.8$, $S = 0.0065$, $W = 1.79$] in 1985, and 0.27 g/kg [$L = 16.5$, $S = 0.0065$, $W = 1.79$] in 1986). Consequently, the samples were pooled.

The sizes of *Mytilus* eaten in the high salinity area of Hållö ($\bar{x} = 17.2$ mm) were similar (Table 3) to those of *Mytilus* consumed in the low salinity area of the Stockholm archipelago ($\bar{x} =$ 17.2 mm). There was no significant difference ($t = 1.6063$, df = 37, $P = 0.12$) in the mean size of *Mytilus* per meal between the areas (Hållö: $\bar{x} = 14.1$ mm, $n = 4$; Stockholm: $\bar{x} = 17.5$ mm, $n = 35$). At Hållö, the calculated SPUBW values were 1.39 g/kg (17.2-mm mussels), 2.12 g/kg (35-mm), and 2.63 g/kg (50-mm) ($S = 0.033$, $W = 1.79$). The corresponding SPUBW values in the Stockholm area were 0.27 g/kg (17.2-mm mussels), 0.42 g/kg (35-mm), and 0.52 g/kg (50-mm) ($S = 0.0065$, $W = 1.79$). Thus, when feeding on the 17.2 mm-size, the eiders ingested >5 times more salt on the Swedish west coast than in the Stockholm archipelago.

Mussel size selection in relation to available stock.—In the Stockholm archipelago, eider juveniles selected all sizes of *Mytilus* available. However, in the Hållö area, of the mussels available in 1987 ($n = 62$), there was a preference for sizes up to approx. 42 mm in length, even though mussels reached a maximum length of 110.6 mm. A similar preference for smaller individuals ($t = 3.5748$, df = 25, $P = 0.001$) was found when eider juveniles of Hållö fed on another mussel, *Mya arenaria* (available: $\bar{x} = 22.8$ mm, range = 12.5–32.3, $n = 16$; in esophagus and gizzard: $\bar{x} = 14.3$ mm, range = 9.3–19.1, $n = 11$).

DISCUSSION

Along a decreasing salinity gradient in Scandinavia (Fig. 1), *Mytilus* (where it occurs) is the food most heavily utilized by the Common Eider (Pethon 1967, Madsen 1954, Kirchhoff 1979, Bagge et al. 1973, Segerstråle 1947). Its use is higher in the Baltic than in more saline areas even though several other food types are available. The secondmost utilized group is the Crustacea, of which *Carcinus*, living in waters of higher salinity, is replaced by *Mesidothea* and *Amphipoda* in brackish areas. Gastropods and *Asterias* are heavily utilized in saline waters only, though gastropods—but not *Asterias*—also occur in brackish waters. In areas with a surface water salinity <0.6%, freshwater insects are consumed.

The proportion of bivalves and gastropods in the diet of the Common Eider juveniles at Hållö corresponds well with the proportion of these groups in the diet of 8- to 10-week-old eiders in the highly saline outer Oslo fjord and even better with adults in September (Pethon 1967).

Grit may be consumed accidentally, when eiders gather mussels, but they may also actively search for grit to facilitate the grinding of food items in the gizzard. Player (1971) noted a higher occurrence of grit in eiders feeding mainly on crustaceans than in those eating mollusks. We had a similar finding, where grit fragments were also significantly smaller in ducks feeding on crustaceans. Large grit may be needed to crack larger, less fragile mussels. Although small grit fragments are of little use for that task, a larger number of small grit fragments may increase the grinding effect, which helps to digest crustaceans with more tenacious shells.

Mussel size reconstruction proved that shell remnants found in the gizzard represent the size distribution of mussels consumed equally as well as undamaged mussels found in the esophagus. Therefore, this method may also be used when analyzing shell fragments found in feces.

In the Stockholm archipelago, the mussel size range selected by feeding eiders coincides closely to the range of available stock. In the

Hållö area, however, eiders selected approximately the same sizes that they selected in the Stockholm area, though considerably larger mussels were available and despite the fact that eiders on the Swedish west coast seem to be larger than eiders on the east coast (Ericson 1986, 1987: tables 47–50). The largest *Mytilus* ever recorded in a Common Eider was 80 mm (Madsen 1954), but the largest mussel consumed at Hållö was only half that size. According to Nyström and Pehrsson (1988: eqs. 2, 4, 5), an eider at this locality ingests 2.6 times more salt, when feeding on 50-mm mussels (1.65 g) than when feeding on 10-mm mussels (0.64 g) to obtain 10 g dry-weight mussel meat. This supports the theory that foraging eiders, especially young birds, select small mussels in areas of high salinity (Nyström and Pehrsson 1988).

Our results also support the hypotheses that larger birds can utilize larger mussels than smaller birds (Nyström and Pehrsson 1988), and that in water of high salinity ducks minimize salt intake by including more nonmussel food that lacks locked-in seawater, such as crustaceans and gastropods (cf. Cantin et al. 1974). Immature birds may also select small mussels and crustaceans, because their gizzards are not yet capable of handling larger bivalves. When dissecting adults and immatures in September, we found no visual difference in the digestive organs between the groups.

Morphometrical comparisons of 1,000-year-old eider bones from archaeological excavations in the Stockholm area with bones from the present population have shown that the mean body size of eiders has decreased. This decrease has accelerated since the turn of the present century (Ericson 1987). One thousand years ago, the salinity was considerably higher in this area, and during the present century there has been an enormous increase in the number of breeding eiders in the inner part of the Stockholm archipelago (Andersson et al. 1978), where salinity is lower. In this low-salinity environment there is no positive selection against large body size (Nyström and Pehrsson 1988). On the contrary, the available, small, low-salinity mussels may be used more efficiently by smaller birds (Nyström and Pehrsson 1988).

We studied young birds, some of which were not fully grown. The fact that adult birds wintering in Danish waters need larger (30–40 mm) mussels (Madsen 1954) explains why eiders leave the more brackish parts of the Baltic as soon as they are full-grown (Joensen 1974), even though the common mussel forms a large part of the hard-bottom biomass (80% in some areas; Jansson and Kautsky 1977). Although the mussels are too small to be used effectively by yearling and adult eiders, the region is of great importance as a rearing area where growing ducklings can effectively utilize small mussels (Nyström and Pehrsson 1988).

Weight loss in *Mytilus edulis* after spawning (mid-May until early June) is substantial (38–52% of the meat dry-weight in 10- to 30-mm mussels) due to the release of gametes. Weight increases during March to May the year after (Kautsky 1982b). Because the low salinity in the Baltic results in dwarf mussels (Remane and Schlieper 1971), there are few mussels >30 mm available on which grown eiders can prey. This low yield to adult eiders during feeding is compounded by the reduced (meat) weight of mussels after spawning. Therefore, 10- to 30-mm mussels afford good energetic and nutritional value in spring but poorer value in autumn, which may also explain why eiders do not wait for the ice cover to form before they migrate.

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