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Temporal and spatial abundance of wintering Common Eider *Somateria mollissima*, Long-tailed Duck *Clangula hyemalis*, and Common Scoter *Melanitta nigra* in shallow water areas of the southwestern Baltic Sea

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More than 76 000 Common Eiders *Somateria mollissima*, 5000 Long-tailed Ducks *Clangula hyemalis*, and 5000 Common Scoters *Melanitta nigra* usually spend the winter in the Baltic Sea of Schleswig-Holstein, FRG. Between November 1986 and April 1992 thirty-one aerial surveys were conducted to document their temporal and spatial abundance in the shallow water areas (< 10 m deep). All three species show strong differences in habitat use of offshore shallow waters and coastal shallow waters. Eiders and Long-tailed Ducks leave the offshore shallow waters in the second half of the winter. In contrast, they utilize coastal shallow waters throughout the winter, but especially as staging sites during spring migration. Common Scoters mostly pass through to spend the winter outside the study area; during spring migration they heavily use the offshore shallow waters. Finally the driving factors for the observed distribution patterns are discussed to describe the function of the Baltic Sea of Schleswig-Holstein for seaducks and its relation to other parts of the annual range of seaducks.

1. Introduction

The southwestern Baltic Sea serves as a moulting, wintering and staging area for seaducks (Joensen 1976, Bräger & Nehls 1987). The German parts are mainly utilized for wintering and staging on migration whereas many parts in the adjacent Danish Baltic Sea are also used for moulting by large numbers of seaducks (especially Common Eiders). Availability of food is an important criterion for wintering areas (Pehrsson 1984). For benthos-feeding seaducks this means a large stock of suitable macrofauna which is not likely to be covered by ice (Kirchhoff 1979). If the food supply is a major factor in shaping migration, competition for food is hypothesized to be important (see Pienkowski & Evans 1985 for review). Further criteria for choosing a wintering area are the distances to other parts of the annual range, and low frequencies of disturbance by man and predators (Bell & Owen 1990, Thiel et al. 1992).

The Baltic coast of Schleswig-Holstein (Fed. Rep. of Germany) serves mainly as a wintering area for the Common Eider *Somateria mollissima*, the Long-tailed Duck *Clangula hyemalis*, and the Common Scoter *Melanitta nigra* (Kirchhoff 1981, Kirchhoff et al. 1983, Bräger & Nehls 1987). Approximately 1–5% of their total Northwest European populations winter in this area (Laursen 1989) whereas other seaducks occur only in marginal numbers (e.g. Velvet Scoter *Melanitta fusca*). In this wintering area seaducks prefer shallow waters (< 10 m deep) for feeding. Two different categories of shallow waters can be distinguished: Mostly isolated offshore shallow waters (up to 10 km off the coast) and nearshore coastal shallow waters. As earlier studies emphasized the exceptional importance of the offshore shallow waters, it became of interest to what extent they are used in relation to the coastal shallow waters. Considering the differing utilization of the two different shallow water habitats by seaducks the question arose whether they differ in quality as wintering habitats.

2. Material and methods

Our study is based upon the results of 31 aerial surveys carried out during the wintering season of seaducks (October to April) on the Baltic Sea of Schleswig-Holstein, between November 1986 and April 1992 (n = 3 in Oct., 6 in Nov., 4 in Dec., 6 in Jan., 5 in Feb., 5 in March, and 2 in April). The winter of 1986/87 was exceptionally cold, with ice covering large parts of the southwestern Baltic Sea, whereas the five following winters were comparatively mild.

The study area is situated in Kiel Bay and in the northwestern part of Lübeck Bay (centre at 54°30′N / 10°40′E). The total area covers about 3000 km^2 (Babenerd & Gerlach 1987) and can be subdivided into three major categories. The first contains all deep waters (maximum depth is 32 metres), which were neglected in this study. The second category covered 97 km^2 of offshore shallow waters and, the third category consisted of 441 km^2 of coastal shallow waters. Both are less than ten metres deep and comprise the shallow waters of the study area. Together they constitute approximately 18% of the study area in the southwestern Baltic Sea. Our standard flight route mainly covered these shallow waters.

A twin-engine Cessna 336 was used for the surveys, flying at a speed of about 90 knots (170 km/h) and an altitude of approximately 500 feet (150 m). The numbers of observed seaducks were mapped simultaneously by three observers, and large flocks were photographed to improve the accuracy of the estimates. In the laboratory we counted the number of ducks on the photographs and compared them to the numbers estimated in the field. This revealed that even flocks of Eiders, which is the easiest species to count, were likely to be underestimated in the field (see also Follestad et al. 1988). Therefore, all numbers and densities given in the following should be considered as minimum values. A comparison with shore-based counts and excursions by ships revealed a relatively small deviation for numbers of Eiders whereas the numbers of Long-tailed Ducks and Common Scoters are always underestimated from the aircraft. Besides the detectability of the three species, weather conditions (especially visibility and wave-action) can also have a strong influence on the accuracy of the counts (see also Soikkeli 1976, Gaston & Smith 1984, Briggs et al. 1985a and b, Gaston et al. 1987, Conroy et al. 1988). Therefore, flights were conducted under favourable weather conditions.

The intensity of site use is described by calculating the number of birddays (i.e. the mean number of individuals of two subsequent counts multiplied by the number of days in between). The sum of average birddays spent on a single wintering site for the entire wintering period was then divided by the respective area size within the 10 m-depth-line. In doing this we were able to compare average densities of seaducks in coastal shallow waters versus offshore shallow waters, expressed as average birddays per km^2 and wintering period.

In order to examine, whether various parts of the wintering Eider population prefer different water depths, we reanalysed data collected from seaducks which had drowned accidentally in fishing nets (for details see Meißner & Bräger 1990 and Meißner 1992). Adult (≥ 3 years old) and immature (≤ 1 year old) Common Eiders from 14 different nets set in ten different water depths at 5–20 m were examined.

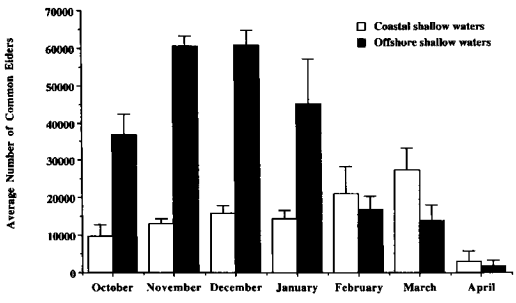

Fig. 1. Average numbers of wintering Common Eiders in the coastal shallow waters and offshore shallow waters of the Baltic Sea of Schleswig-Holstein. Numbers are based upon six consecutive wintering periods during 1986–1992 (October–April). The standard error is given for each monthly mean and shallow water habitat.

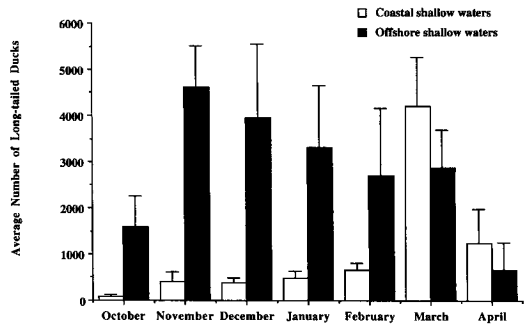

Fig. 2. Average numbers of wintering Long-tailed Ducks in the coastal shallow waters and offshore shallow waters of the Baltic Sea of Schleswig-Holstein. Numbers are based upon six consecutive wintering periods during 1986–1992 (October–April). The standard error is given for each monthly mean and shallow water habitat.

3. Results

3.1. Temporal abundance

On average seaducks spend about 7–13 million birddays in the study area annually. During the winters of 1986–1992 we registered 6–11 million birddays ($\bar{x}$ = 9.26) for Eiders, 0.5–1.1 million birddays ($\bar{x}$ = 0.71) for Long-tailed Ducks, and 0.3–1.0 million birddays ($\bar{x}$ = 0.71) for Common Scoters per winter.

3.1.1. Common Eider

The wintering stock increases from October until November. In November and December no large variations in Eider numbers were observed (Fig. 1). Maximum numbers are normally recorded in this period when the visible wintering stock appears to be stable (maximum about 100 000 individuals). A decline in numbers is first observed in January. The total wintering population drops to only 40 000 birds in February. A small peak in numbers, almost entirely in the coastal shallow waters, may appear in March during spring migration. The number of Eiders in coastal waters remains quite stable throughout the whole wintering period at a level of approximately 10–20 000 birds.

3.1.2. Long-tailed Duck

The numbers of wintering Long-tailed Ducks show a strong increase in in late autumn followed by a slow decrease until the end of February (Fig. 2). However, the numbers recorded are far lower (maximum 9–10 000 individuals) and appear in the study area somewhat later than Common Eiders. A second maximum is registered during spring migration in March, when numbers, for a short time, reach the same level as in early winter. In the winter the fraction of Long-tailed Ducks present in coastal waters is usually insignificantly small; high numbers of more than 5000 birds in coastal shallow waters can only be observed during spring migration.

3.1.3. Common Scoter

In winter the Common Scoter is recorded within the study area only in relatively small numbers (maximum 8–9000 individuals). The population increases slowly in the first half of the wintering period, decreases in February, and then suddenly increases during spring migration when most Common Scoter use the offshore shallow waters (Fig. 3). The peak in this period can greatly exceed the wintering population (maximum about 17 000 individuals on migration).

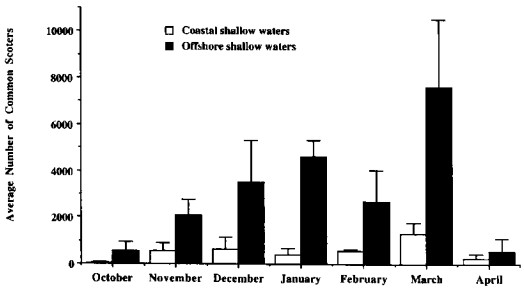

Fig. 3. Average numbers of wintering Common Scoters in the coastal shallow waters and offshore shallow waters of the Baltic Sea of Schleswig–Holstein. Numbers are based upon six consecutive wintering periods during 1986–1992 (October–April). The standard error is given for each monthly mean and shallow water habitat.

3.2. Utilization of different habitats

All three seaduck species use the shallow waters intensively during the winter period with highest numbers occurring in the offshore shallow waters (Figs. 4–6). For the Common Eider, more than 750 000 birddays were calculated for four different offshore shallow water sites each. Despite their large area the coastal shallow waters are only used by small numbers. In general the same utilization pattern is true for the other two seaduck species. Long-tailed Ducks spent more than 75 000 birddays only on two offshore shallow water sites, and for the Common Scoter the same number of birddays was also reached only on offshore shallow water sites.

Over the whole winter season, on average more than 72% of all birddays account for offshore shallow waters which is true for every one of the three seaduck species. Here the seaducks stay in concentrated flocks until January. In the second half of the wintering period such concentrations cannot be observed in the offshore shallow waters. In contrast, the much smaller flocks feeding in the coastal shallow waters stay there throughout the whole winter.

When relating the birddays to the size of the two different shallow water categories these differences in distribution patterns become even more obvious. The densities of each of the three seaduck species in offshore shallow waters are more than eleven times higher than those in coastal shallow waters (Table 1).

Young and old seaducks seem to favour different water depths for feeding. More than 66% of all immature Common Eiders (n = 105) which were caught accidentally in commercial setnets were foraging in waters 5–9 m deep. At the same time, more than 85% of all adult Common Eiders (n = 318) were caught in 9–20 m depth. On average, immature Common Eiders were foraging in significantly shallower waters ($\bar{x} \pm$ S.E. = 8.4 ± 0.33 m) than adult Eiders (11.2 ± 0.22 m; Mann-Whitney U-test: $P \leq 0.001$).

4. Discussion

4.1. Phenology and distribution

The results of this study indicate that the Schleswig-Holstein part of the Baltic Sea is an important staging and wintering area for parts of the Baltic or Northwest-European populations of the Common Eider, the Long-tailed Duck and the Common Scoter. From the end of October, the wintering seaduck populations build up in the Baltic Sea of Schleswig-Holstein. In November and December Eiders return from moulting in the Wadden Sea into the Kiel Bay, using the same bays and inlets they followed in summer (Nehls 1991, Meißner 1992, and pers. obs.). At this time of the season, both the coastal and the offshore shallow water areas are used intensively until the birds start to leave in January. From the beginning to the end of January, the total number of Common Eiders decreases by 50% which relates almost entirely to birds wintering in offshore shallow waters while the number of approxi-

Table 1. Average seaduck densities as number of birddays per km² and wintering season.

	Offshore shallow waters	Coastal shallow waters	Ratio
Common Eider	72 176	6 203	11.6
Long-tailed Duck	5 996	391	15.3
Common Scoter	6 763	231	29.3
Total	84 935	6 825	12.4

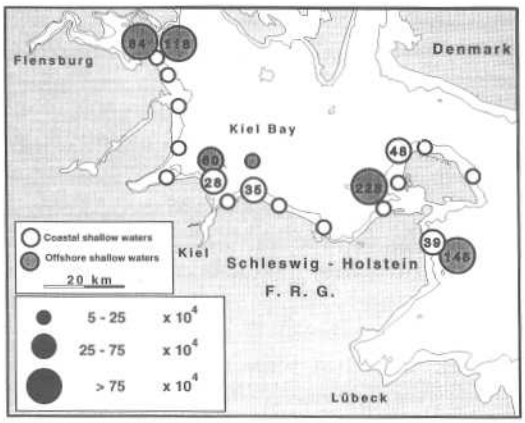

Fig. 4. Geographical distribution of average birddays of wintering Common Eiders in the Baltic Sea of Schleswig-Holstein. Results are based upon six consecutive wintering periods during 1986–1992 (October–April).

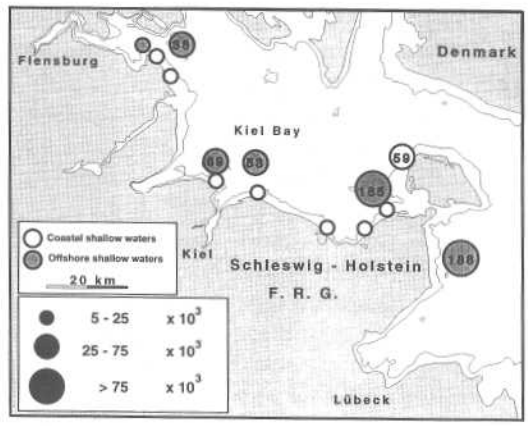

Fig. 5. Geographical distribution of average birddays of wintering Long-tailed Ducks in the Baltic Sea of Schleswig-Holstein. Results are based upon six consecutive wintering periods during 1986–1992 (October–April).

mately 15 000 Eiders in coastal waters remains almost unchanged throughout the entire wintering period. Guillemette et al. (1993) observed a similar decrease of Eider numbers in February and March in their study area in the Gulf of St. Lawrence. This decrease was due to the fact that the shallow reef areas with previously high densities of mussels were abandoned by large flocks. The same authors found that the preference for shallow waters by Eiders reaches a minimum in February and March and then increases again in April.

The disappearance of a large proportion of the wintering Common Eider population in January could mean that the ducks could either disperse and move to deep waters not covered by our aerial surveys or leave the study area altogether. Aerial surveys conducted in the adjacent Danish part of the Baltic Sea revealed a tendency of Eiders to move from many Danish parts of the Baltic Sea into the southern Danish waters around the island of Fyn by late January (Noer 1991). The 40 000 Eiders "missing" in the Baltic Sea of Schleswig-Holstein are suspected to have joined the 250–400 000 Eiders congregating in the southern Danish part. The rising numbers observed in March are likely to comprise birds on migration passing through the study area from the Wadden Sea (Swennen et al. 1989).

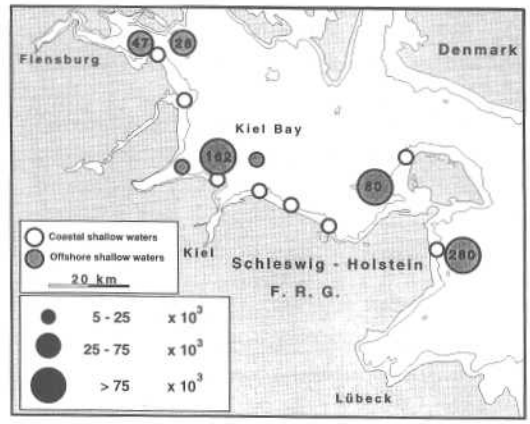

Fig. 6. Geographical distribution of average birddays of wintering Common Scoters in the Baltic Sea of Schleswig-Holstein. Results are based upon six consecutive wintering periods during 1986–1992 (October–April).

The migrational peak of the Common Scoter is made up by birds heading from the North Sea or the Atlantic ocean to the breeding grounds. During this time the flocks of Common Scoters occupy the offshore shallow waters again, while large numbers of Common Eiders and Long-tailed Ducks appear mainly in coastal shallow waters. Common Scoters, when using these sites

for staging, feed on different prey species than Eiders (Meißner & Bräger 1990). They still seem to be able to find sufficient food, even if the stock of benthic macrofauna has been depleted during the winter. By the end of April and the beginning of May, there are only few seaducks left in the investigation area.

Biotic factors influencing the temporal and spatial utilization of the study area by seaducks are the density and availability of benthic food (Kirchhoff 1979), and potential competition for food (Burger 1988, Milinski & Parker 1991). Shallow waters present a safe food resource for seaducks in the Baltic Sea of Schleswig-Holstein in autumn, as they are not exposed to the risk of oxygen depletion that occurs during summer (Weigelt & Rumohr 1986, Weigelt 1987). With the advance of winter there is a growing probability of storms destroying the epibenthic macrofauna, e.g. mussels *Mytilus edulis* and starfish *Asterias rubens* (Rees et al. 1977, Brey 1989, Meißner 1992). Since the continuing availability of mussel stocks is not guaranteed, it might be profitable for Common Eiders to exploit the resources in offshore shallow waters early in the season as long as they hold a high density of prey. The infauna, e.g. cockles *Cerastoderma edule* and clams *Mya arenaria*, which is consumed by Common Scoters (Meißner & Bräger 1990), is possibly less affected by hydrodynamical abrasion or, can even become more easily available to predators (Leipe 1985). Hence, the differential habitat use observed in springtime may be explained by the different feeding habits of Eiders and Common Scoters.

Musselbeds in coastal shallow waters within the study area have been described by Kirchhoff (1979) to supply a profitable food stock for seaducks. Consumption by waterfowl, fish, starfish, and crustaceans decreases the benthic biomass during winter (Arntz & Weber 1970, Kirchhoff 1979, Arntz 1980, Meißner 1992). In offshore shallow waters consumption of the foodstock by seaducks is considerably larger than in coastal shallow waters, since the density of seaducks is on average 12.4 times higher, even more so in the first half of winter. The stable numbers of seaducks in coastal shallow waters imply that food limition is not likely to occur there to the same extent as in offshore shallow waters. Whereas stocks of epibenthic molluscs may be destroyed completely or reduced below a profitable level in offshore shallow waters during winter (Meißner 1992), in coastal shallow waters their biomass usually decreases by only a small portion over the winter (Kirchhoff 1979). Therefore, coastal shallow waters can be used continuously until the onset of spring migration by comparably low densities of seaducks.

During winter seaducks are non-territorial and do not show aggressive guarding of resources. Flocking facilitates foraging on the feeding grounds (Guillemette et al. 1993). Resource competition among foraging seaducks may be of minor importance when food is abundant, but this could change with decreasing food stocks as winter progresses. Therefore, we consider the depletion of available food resources as well as endogenous factors related to the upcoming reproductive season to be responsible for the disappearance of the large Common Eider flocks from the offshore shallow waters. The formation of pair-bonds and mating by adult birds takes place in the second half of the winter. A high degree of intraspecific aggression can be observed between male seaducks during this time (Rutschke 1989), which seems to correspond with the decreasing density of Eider flocks seen in February and March (Guillemette et al. 1993, and pers. obs.).

Other endogenous factors are certainly also playing an important role in the geographical distribution of age classes of the three species. Different physiological abilities to cope with declining water temperatures during the winter and increasing diving depths off the coast may have an impact on the different utilization patterns. At least in the Common Eider, offshore shallow waters are preferred by adult birds, while coastal flocks mainly consist of immature Eiders as seen by field observations as well as found in Eiders accidentally drowned in fishing nets (Meißner & Bräger 1990). In some species juveniles may suffer more from competition for food through interference (e.g. Goss-Custard & Durell 1987). For immature seaducks this could mean that their diving abilities are not yet fully developed to compete with the adults for food in deeper waters. Thus there appears to be a general difference not only in the quality of the two types of studied

sites (i.e. coastal shallow waters and offshore shallow waters) but also in the "quality" of the ducks using these sites. The Eiders less able to compete successfully were probably seeking the habitat offering a stable but less profitable intake to improve their survival probability. This could compare to results of Guillemette et al. (1992), who found that individuals feeding in small flocks were in bad condition compared to individuals feeding in large flocks.

4.2. The function of the Baltic Sea of Schleswig-Holstein in the annual range of the seaducks

Shortly after the breeding season many waterfowl species migrate from the breeding areas to special moulting sites (Jehl 1990, Johnson & Herter 1990). The migration of the Eider in Schleswig-Holstein is well documented (Salomonsen 1968, Schafstall 1978, Moritz 1983, Schmidt 1983). From May until July the moult migration mainly of adult males to the Wadden Sea takes place without intermediate stops in our study area. The autumn migration starts in August and lasts until October. From September on the fraction of adult males that have moulted elsewhere in the Baltic Sea joins again the flocks migrating from the Baltic to the North Sea. In October, after these birds have migrated through the study area, the wintering stock of Eiders starts to build up. The study area has a unique key position for the migration to the Wadden Sea (see also Noer 1991), whereas as a wintering site it seems to correspond closely with the Danish waters. The geographical position at the southern border of the wintering range explains the increasing numbers of Eiders in times of cold temperatures when ice starts to form in the north (Nilsson 1984).

For the Long-tailed Duck the study area functions almost entirely as a wintering site. The population build-up of wintering Long-tailed Ducks resembles the one of the wintering Common Eiders. Peak numbers occurring during spring migration could result from a reconcentration prior to leaving the wintering area or from a southeastward migration through the Fehmarn-Belt towards the coast of Mecklenburg-Vorpommern (former GDR). In April when herring *Clupea harengus* are spawning, some 40–60 000 Long-tailed Ducks suddenly appear in the enclosed bay of the Greifswalder Bodden, 100 km east of the study area, where they feed on herring spawn (Leipe & Sellin 1983, Leipe & Scabell 1990, Sellin 1990).

During the summer moult migration Common Scoters behave similar to Common Eiders with thousands of predominantly male birds quickly crossing the study area (Lunau 1951, Salomonsen 1968, Schmidt 1976, Schafstall 1978, Nehls & Zöllick 1990). In contrast to Long-tailed Ducks, Common Scoters mainly use the study area for staging during autumn migration to the North Sea and the Atlantic Ocean, while only a minor portion of the population winters in this part of the Baltic Sea. The number of birds passing through the area on both migrations exceeds by far the number of wintering birds. This could be expected, since the main wintering areas of Common Scoters are situated much further southwest, causing similar migrational peaks in the Wadden Sea of Noord-Holland (Camphuysen & Van Dijk 1983).

Despite growing seaduck populations in Northwest-Europe, no increase in the wintering numbers was detected in the study area. In contrast to other nearby wintering areas (Laursen 1989), there has been no obvious increase in total Eider numbers at the Baltic coast of Schleswig-Holstein during 1986–1992. The rising numbers of Common Eiders in the German Wadden Sea, which were confirmed by comparable methods (Nehls et al. 1988, Nehls 1991), disprove the objection that the period of study considered here could have been too short to detect a remarkable increase. Short-term driving factors like the strength of the winters are presumably responsible for the annual variation between the respective months (see standard errors in Fig. 1–3). The relatively constant number of annually wintering Eiders could be based upon a limited carrying capacity of these wintering sites which determines the maximum numbers (Kirchhoff 1979, Goss-Custard 1985). Another possible explanation could be constant source populations, but very little is known about the breeding area and site fidelity of the seaducks visiting the southwestern Baltic Sea (Noer 1991). We hypothesize that the carrying capacity of

shallow waters is strongly limited by the food resources due to consumption or hydrodynamic abrasion possibly reinforcing each other. The limit of profitability seems to be reached quite early in the wintering period, when the seaducks search for food in deeper waters or leave the study area to spend the rest of the wintering period in other regions. Thus, even though Brey (1986) observed a sixfold increase in molluscan biomass in shallow waters of our study area from the 1960's to the 1980's, the seaduck populations do not seem to profit from this increase of their preferred prey species. The decrease in Eider and Long-tailed Duck numbers early in the winter suggests that the carrying capacity is limited by factors hampering the persistence and accessibility of the benthic food stock and not by its seasonal maximum.

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Selostus: **Lounainen Itämeri hahkojen, allien ja mustalintujen talvehtimisalueena**

Kirjoittajat tutkivat Itämeren lounaisosissa talvehtivia merilintuja vuosina 1986–1992. Schleswig-Holsteinin rannikolla tehdyissä lentokonelaskennoissa havaittiin vuosittain keskimäärin yli 76 000 talvehtivaa haahkaa, 5000 allia ja 5000 mustalintua. Haahkat ja allit jättivät talven loppupuoliskolla avomeren matalikot (< 10 m). Ne käyttivät rantamatalia läpi talven. Mustalinnut ovat yleensä läpikulkumatkalla Pohjanmeren talvehtimisalueille. Keväällä ne käyttävät runsaasti rantamatalia.

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