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Changes in the body composition of Velvet Scoters (*Melanitta fusca*) wintering in the Gulf of Gdańsk

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Abstract

Body mass and body composition of 27 adult Velvet Scoters (*Melanitta fusca)* were studied. These birds were collected from January to March in the Gulf of Gdańsk, Poland. Body mass, fat, and protein contents of both males and females decreased significantly between mid and late winter, possibly because of a physiological process or a result of worsening environmental conditions. In mid-winter, the mean body mass of males and females did not differ significantly, whereas in late winter the difference in body mass between sexes became prominent. There was no difference in fat mass between the sexes, but females had higher lipid indexes despite their smaller size. The lack of expected fat mass increase in late winter may be due to the spring migration strategy of Velvet Scoters, which apparently opt to fly short distances rather than make long non-stop flights after departure from the Gulf of Gdańsk. Body mass was the best predictor of fat mass accumulated by Velvet Scoters wintering in the Gulf of Gdańsk.

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INTRODUCTION

The main endogenous sources of energy for birds are lipids stored in adipose tissue and proteins stored in skeletal and heart muscles. These stores are accumulated before migration, providing energy during migratory flight and during winter, allowing survival through periods of negative energy balance caused by limited food availability (Blem 1990). Fat is the most important source of energy for birds, because its isocaloric value is twice as high as proteins or carbohydrates (Blem 1990). Hence, the possibility of assessing fat stores from easily obtained measurements in the field without time-consuming dissections and laboratory carcass analyses is essential for determining the nutritional status of birds and the impact of the environment on their body condition (Whyte and Bolen 1984, Ringelman and Szymczak 1985, Whyte et al. 1986, Boos et al. 2000, DeVault et al. 2003).

The amount of energy birds are able to store during winter has a great influence on waterfowl overwinter survival (Haramis et al. 1986, Bergan and Smith 1993), pairing chronology (Hepp 1986), and reproductive potential (Raveling 1979, Krapu 1981, Esler and Grand 1994). Thus, quantifying carcass composition during winter is a widely used methodology for studying different aspects of duck ecology (e.g. Miller 1986, Whyte et al. 1986, Thompson and Baldassarre 1990, Hohman 1993, Lovvorn et al. 2003, Ballard et al. 2006). In contrast to dabbling ducks (*Anas* spp.), body mass and composition are poorly documented for seaducks due to difficulties in obtaining specimens for laboratory analysis. There are only a few papers concerning this group of birds and all but one are from North America (Leafloor et al. 1996, Lovvorn et al. 2003, Bond and Esler 2006, Jamieson et al. 2006, Fox et al. 2008). In particular, studies of the body composition of Velvet Scoters *(Melanitta fusca)*, a seaduck species of conservation concern mentioned in The Bird Directive (Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds), are lacking. Even knowledge of the body mass of this species is very limited and the only data available on single specimens exist in old literature sources (Bauer and Glutz von Blotzheim 1969, Cramp and Simmons 1977). The Baltic Sea is the most important wintering area for the Velvet Scoter in Europe. Almost 930 000 Velvet Scoters were recorded here, approximately 93% of the entire European wintering population of this species (Durinck et al. 1994). Two populations of Velvet Scoters spend the winter in the Baltic: migratory birds from the White Sea and northern Russia and local breeding populations from Estonia, Finland, and Sweden (Paakspuu 1989).

The purposes of this paper are to report changes in body composition in Velvet Scoters in the Gulf of Gdańsk during their wintering period and to develop a non-invasive method for estimation of fat content without euthanizing birds for fat extraction.

MATERIALS AND METHODS

Body mass and composition were studied on 27 adult Velvet Scoters (16 males and 11 females) collected between January and March of 2007-2009. Ducks were aged and sexed by plumage characteristics (Boyd et al. 1977). All birds in this study had drowned entangled in fishing nets in the Gulf of Gdańsk. The majority of them were taken from Krynica Morska harbour, though single birds were also obtained from Mechelinki and Gdynia-Oksywie (Fig. 1). Velvet Scoters were collected about 3-4 nautical miles offshore from these ports. After retrieval, birds were transported to the laboratory and frozen within 48 hours. After thawing, birds were dried with a hair dryer and weighed to the nearest 1 g to obtain total body mass. Total head length, bill length, and keel length (after dissection) were measured to the nearest 0.1 mm with callipers. Tarsus with middle toe and wing length (maximum chord) were measured to the nearest 1 mm using a stopped ruler (Meissner 2000). Before dissection, birds were plucked and dried with paper towel. Not all measurements were taken simultaneously on all birds, thus the sample sizes in different analyses were not equal. Due to possible changes in body composition during the wintering period the sample was divided into mid-winter and late winter subsamples consisting of birds from January and those collected between mid-February and late March, respectively.

Fig. 1. Velvet Scoter collection locations, showing the number of Velvet Scoters collected in each harbor.

The carcass, minus head, feet, and parts of the wings (removed from the carpal joint), and without digestive tract contents, was ground four times using a commercial meat grinder and mixed thoroughly after each grinding. A sample of approximately 30 g of homogenate was used to determine carcass composition. The sample was dried in a lab dryer at 80°C to a constant mass. Dry residue was subtracted from wet sample mass to establish carcass water content. To determine the amount of lipids, the dry sample was extracted in a Soxhlet apparatus for about 10-15 h using petroleum ether as a solvent. After extraction, the sample was dried for 25 min at 60°C to remove the solvent. Lipid content was calculated by subtracting the mass of the extracted sample from the dry mass. The lean dry subsample of about 5 g was then combusted in a muffle furnace at 600°C for 6 h to determine ash content. Ash weight was subtracted from the lean dry mass of the analysed subsample to determine the ash-free lean dry mass, a measure of total body protein. The proportion of lipid and protein in each subsample was multiplied by the dry mass of the total carcass to calculate the total mass of protein and of lipid in each bird. Since the body mass data were not normally distributed, they were log transformed (ln) before analysis to normalise this variable. The amount of fat was expressed either as a lipid index (percent of fat in relation to total body mass) or total mass of fat (in grams) estimated from the fat index and total body mass of a given bird.

Total body mass and mass of proteins (a component of body mass) are both correlated with the structural size of the bird (Alisauskas and Ankney 1987). To account for variation in size among individuals the correlation matrix from total head, tarsus with toe, wing and keel lengths was used in principal components analysis (PCA) of all birds combined. Bill length was omitted in this analysis, because of the strong intercorrelation between this measurement and total head length and a lack of this measurement in three males. Scores obtained for each bird along the first component axis (PC1) were used as an index of structural size (Alisauskas and Ankney 1987). PC1 accounted for 77% of variation in the measurements, with a corresponding eigenvalue of 3.11. PC1 scores for individual birds were used as covariates in analyses of covariance (ANCOVA) comparing body mass and protein dry weights between sexes and between mid-winter and late winter periods. To estimate fat mass, multiple regression equations were derived based on total body mass and linear morphological measurements. Other statistical methods followed Zar (1996). All analyses were conducted using STATISTICA 9.1 software (StatSoft Inc. 2010).

RESULTS

Males were larger in all measurements than females (Table 1). The absolute difference between means was greatest in bill length, being 7.7% larger in males. For other measurements, males were 4.0 to 4.9% larger than females (Table 1).

Table 1

Comparison of mean measurements of Velvet Scoter adult males and females.

Measurement [mm]	Males			Females			t-Student (t) or Cochran-Cox (t') test	
	Mean	SD	N	Mean	SD	N	t or t'	p
Total head length	115.82	1.73	16	110.81	5.38	11	t'= 2.98	0.0001
Bill length	45.98	1.47	13	42.69	2.31	9	t = 4.10	0.0006
Tarsus plus toe length	134.1	4.20	16	128.9	4.78	11	t = 2.96	0.0067
Wing length	286.3	6.11	16	273.0	5.18	11	t = 5.91	<0.0001
Keel length	107.39	2.11	16	103.14	3.01	11	t = 4.32	0.0002

Body mass of both males and females decreased significantly between mid and late winter (ANCOVA, $F_{1.22}$=20.60, p=0.0002) (Fig. 2). In mid-winter mean body mass of males and females did not differ significantly, whereas in late winter difference in body mass between sexes became prominent (Fig. 2).

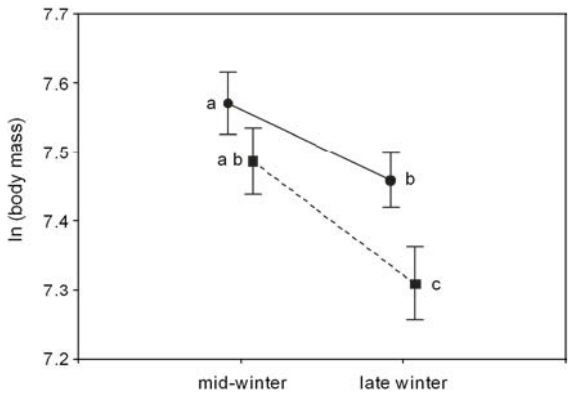

Fig. 2. Differences in body mass in male (circles, thin line) and female (squares, dashed line) Velvet Scoters in mid-winter and late winter periods in the Gulf of Gdańsk. Symbols show the mean, whiskers show 95% confidence intervals. Letters designate means not significantly different from each other (Tukey post hoc test, p>0.05).

The amount of fat accumulated by Velvet Scoters varied between 83 and 415 g, comprising from 5% to 21% of the total body mass. The mean fat index for the entire study period was significantly higher for females (16%, SD=2.9, N=11) than for males (13%, SD=3.5, N=16) (two-way ANOVA, $F_{1.23}$=5.23, p=0.032). Fat mass in males and females decreased significantly between mid and late winter (two-way ANOVA, $F_{1.23}$=4.52, p=0.045) and did not differ between sexes (two-way ANOVA, $F_{1.23}$=0.81, p=0.379) (Fig. 3).

Protein mass decreased during the winter (ANCOVA, $F_{1.22}$=10.39, p=0.004) both in males and females (Fig. 4). In both winter periods the mean protein mass of males and females differed significantly, being larger in males (Fig. 4).

Body mass was the best predictor of fat mass accumulated by Velvet Scoters wintering in the Gulf of Gdańsk (Table 2). Linear measurements had no significant influence on estimated fat mass. However the predictive value of the model was reasonable only in the case of females, whereas in males predictive ability was rather low (Table 2).

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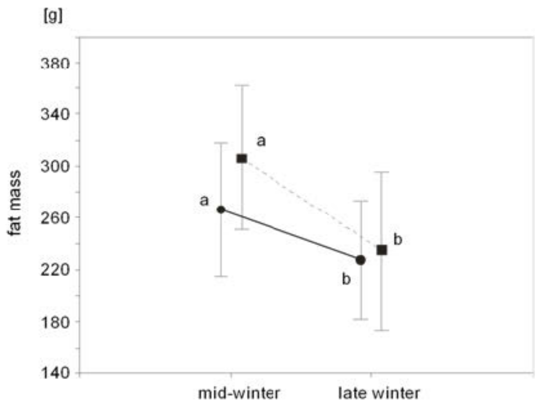

Fig. 3. Differences in fat mass in male (circles, thin line) and female (squares, dashed line) Velvet Scoters in mid-winter and late winter periods in the Gulf of Gdańsk. Symbols show the mean, whiskers show 95% confidence intervals. Letters designate means not significantly different from each other (Tukey post hoc test, p>0.05).

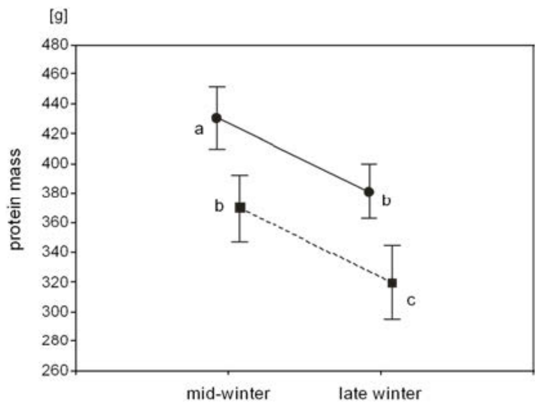

Fig. 4. Differences in protein mass in male (circles, thin line) and female (squares, dashed line) Velvet Scoters in mid-winter and late winter periods in the Gulf of Gdańsk. Symbols show the mean, whiskers show 95% confidence intervals. Letters designate means not significantly different from each other (Tukey post hoc test, p>0.05).

Table 2

Regression functions for estimating fat mass (F in g) from body mass (BM) in male and female Velvet Scoters wintering in the Gulf of Gdańsk. Coefficient of determination (R^2) assesses the amount of variation explained by the particular model.

Sex	N	Linear regression equation	R^2
Males	16	F = 0.281BM – 269.138	0.27
Females	11	F = 0.239BM – 122.153	0.43

Discussion

Patterns of changes in the body mass of ducks during winter may vary geographically within a given species depending on local environmental conditions (Perry et al. 1986, Hohman and Weller 1994, Olsen and Cox 2003). Usually levels of energetic stores in ducks decline throughout the winter and then increase again prior to spring migration (e.g. Peterson and Ellarson 1979, Whyte et al. 1986, Bond and Esler 2006). Studies on carcass composition suggest that an endogenous mechanism controls changes in body mass in winter (Reinecke et al. 1982, Perry et al. 1986, Thompson and Baldassarre 1990). However, some authors have suggested that environmental conditions such as declining food supply or temperature cause the observed patterns (Kaminsky and Ryan 1981, Whyte et al. 1986). It is known that seaduck predation has a significant effect on the abundance of bivalves, leading to subsequent changes in community structure and decreasing densities of bivalves (Guillemette et al. 1996, Hamilton 2000, Lewis et al. 2007). Stempniewicz (1995) estimated that the most common seaduck wintering in the Baltic, the Long-tailed Duck *(Clangula hyemalis)*, takes about 6350 tons of bivalves yearly in the western part of the Gulf of Gdańsk. Over-exploitation of mussel populations, which constitute the main food for seaducks, including Velvet Scoters (Stempniewicz 1996), is probably one of the reasons for the observed shifts in bird distributions during winter (Kube and Skov 1996, Meissner 2010). In other words, Velvet Scoters can abandon one feeding area when foraging becomes less profitable and move to a new one. However, it remains unknown whether the decrease in body mass, lipid stores, and proteins observed in Velvet Scoters wintering in the Gulf of Gdańsk is a typical physiological process or the result of worsening of feeding conditions.

Body mass and fat mass both decreased in late winter (mid-February and late March), indicating that Velvet Scoters wintering in the Gulf of Gdańsk did not start fattening for migration before April. The amount of energetic reserves stored before migration depends on the migration strategy. Birds following an energy minimization strategy depart with small fat reserves and engage in short distance, non-stop flights (Alerstam and Lindström 1990). The migration strategy used by Velvet Scoters is unknown, but large flocks of this species passing the north-eastern Baltic coasts have been observed in

May (Buzun 1998, Noskov and Smirnov 1998), when only a few birds remained in the study area (Meissner et al. 2009, 2010). Birds departing in spring from the Gulf of Gdańsk might be heading to their breeding area in the northern Baltic, or to stop-over sites in the eastern and northern Baltic, where these ducks concentrate in large numbers in early May prior to dispersal to breeding grounds situated in northern European Russia and Siberia (Saurola 1976, Durinck et al. 1993). In both cases, the distance to these sites is short and birds do not need to accumulate substantial energetic reserves to conduct one non-stop flight. On the other hand, the last samples for this study were collected in March, when birds still had more than one month for fattening before departure towards Arctic breeding grounds, so they may not have initiated migratory fattening during our study period.

Protein is not normally metabolized as an energy source unless an individual is under extreme nutritional stress (Blem 1990). However, pectoral muscle size (the largest protein store in birds) rapidly tracks body mass changes (Lindström et al. 2000), so it might explain the observed parallel decreases in body mass, fat mass, and protein reserves in Velvet Scoters between mid and late winter. A similar situation was found in the Black Duck *(Anas rubripes)*, where variation of body weight within and among seasons was strongly correlated with protein and fat content (Reinecke and Stone 1982).

Predictive equations for assessing the amount of accumulated fat in Velvet Scoters may be used for both living and dead birds, eliminating the need for laboratory analyses. However, our predictive equations should be used only for birds wintering in the Baltic, because the proportion of fat and non-fat components may differ within a given species seasonally and geographically (Miller 1989, DeVault et al. 2003).

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