



## Original Article

# Body Composition Dynamics of Common Eider During Winter: An Application of the Deuterium Dilution Method

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**ABSTRACT** The nearshore and offshore waters of southern New England provide some of the most important wintering habitat for sea ducks in North America. Understanding changes in sea duck body composition during winter could provide insights into current habitat quality and potential effects of anthropogenic disturbances on the body condition of sea ducks. We used the deuterium dilution method, a nonlethal approach, to investigate intraseasonal variation and differences between genders in body composition of 86 adult common eiders (*Somateria mollissima*) during winter (2011 and 2012) in southern New England. Both male ( $n=39$ ) and female ( $n=47$ ) eiders increased fat mass by 75% in late winter compared with early winter. Wet lean mass of males remained constant throughout the winter, while that of females decreased by 10%. These seasonal increases in fat stores of eider suggest that birds were able to secure adequate resources to improve their body condition over winter. Our estimates of body composition of eider during winter in southern New England can be used as a baseline when conducting future research to evaluate effects of anthropogenic disturbance and disease. © 2016 The Wildlife Society.

**KEY WORDS** body composition, common eider, deuterium dilution, *Somateria mollissima*, southern New England, winter.

Understanding seasonal changes in body composition of migratory birds is important because individuals with less nutrient stores can have reduced annual survival rates and increased vulnerability to diseases (Brown 1996). In addition, the amount of nutrient stores in female waterfowl during winter and spring migration can affect their reproductive investment (Korschgen 1977, Ankney et al. 1991). However, most studies of waterfowl body condition during winter have focused on dabbling and diving ducks, geese, and swans (e.g., Campbell and Leatherland 1980, Reinecke and Stone 1982, Baldassarre et al. 1986, Bêty et al. 2003, Badzinski et al. 2011). Much less is known about inter- or intraseasonal changes in body condition of sea ducks despite recent declines in many sea duck populations that may be related to their ecology and condition (Caithamer et al. 2000, Goudie et al. 2000, Jamieson et al. 2006a, Schummer et al. 2012).

There is also a pressing need to understand how body condition of wintering sea ducks is affected by displacement from offshore wind-energy developments (Langston 2013) and potential anthropogenic disturbances (Merkel et al. 2009, Schwemmer et al. 2011, Klimstra and Padding 2012). Efforts to develop 2 offshore wind-energy projects (i.e., a 5-turbine facility and a 200-turbine facility) are advancing adjacent to Rhode Island, USA (Grilli et al. 2013, Musial et al. 2013), intensifying the need to understand the potential effects of offshore wind-energy facilities on sea duck body composition in southern New England. Available evidence from Europe suggests that offshore wind-energy developments may alter body composition of sea ducks because these facilities displace birds from selected habitats (Petersen et al. 2006), causing at least short-term avoidance of the area near turbines (Larsen and Guillemette 2007, Petersen and Fox 2007).

North America's largest species of sea duck, the common eider (*Somateria mollissima*; hereafter, eider), is widespread and abundant during winter in northeastern North America (Goudie et al. 2000, Silverman et al. 2013), and thus is an ideal species for investigating changes in body composition throughout winter. Thousands of American common eider (*S. m. dresseri*) winter nearshore in southern New England

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(Klimstra and Padding 2012, Silverman et al. 2013) where individuals are exposed to harvest by hunters (Raftovich et al. 2011), habitat loss and degradation (Goudie et al. 2000, Thrush and Dayton 2002), inclement weather, and novel diseases (Pello and Olsen 2013) including Wellfleet Bay Virus, a newly described, emerging regional disease (Allison et al. 2015). Although body composition of eiders likely influences their response to anthropogenic disturbance and disease risk, the only baseline study of the body composition dynamics of eider during winter was conducted on the smaller northern common eider (*S. m. borealis*; Jamieson et al. 2006b) that winters in more northern latitudes.

We used a recently validated nonlethal method for estimating body composition of common eider to document seasonal variation in their body composition during winter in southern New England (Beuth et al. 2016b). The specific objectives were to assess changes in body composition of adult male and female American common eiders in southern New England during winter. We also compared the body composition dynamics of male and female American common eiders with that documented from previous studies of the northern subspecies of eider during winter.

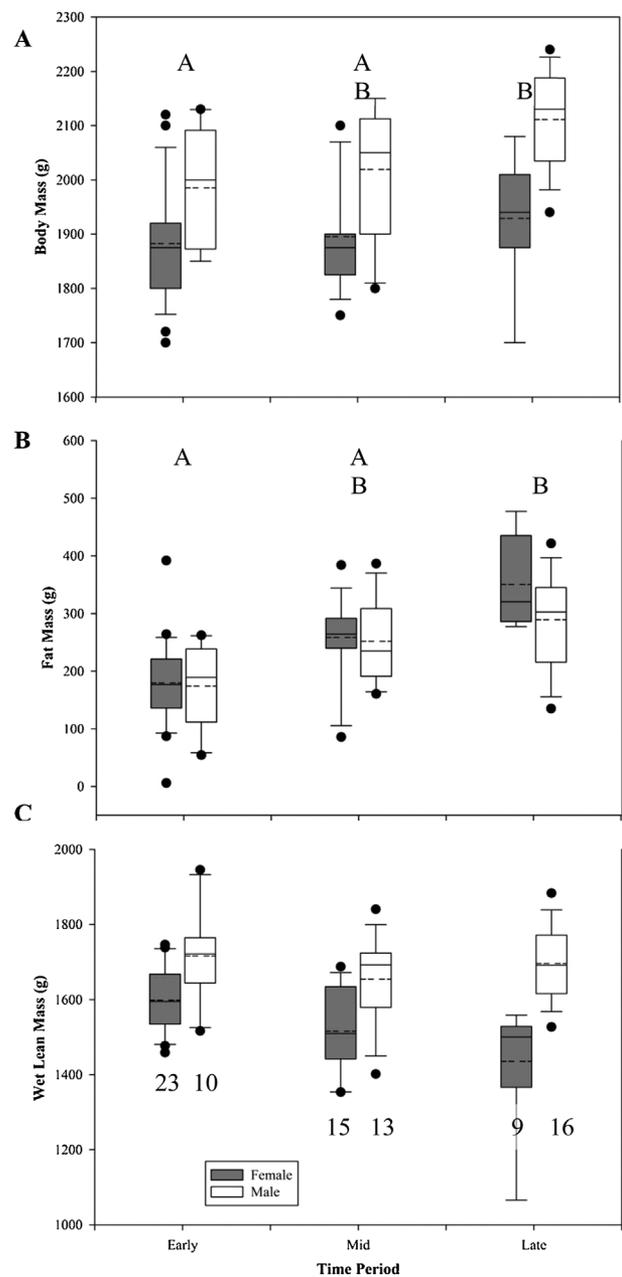
## STUDY AREA

We captured eiders in the nearshore and offshore waters of southern New England, which we defined as all waters extending east from Montauk Point, Long Island, New York (41.0383°N, 71.9506°W) to Cape Cod and Cape Cod Bay, Massachusetts (41.6800°N, 70.2000°W; fig. 1 in Beuth et al. 2016b) in the United States. Rocky reefs and sporadic mussel beds in southern New England provide eiders with excellent foraging opportunities for benthic invertebrates (Theroux and Wigley 1998), such as blue mussels (*Mytilus edulis*) and green crabs (*Carcinus maenas*; Loring et al. 2013), which were foods selected by eiders inhabiting these habitats (Ydenberg and Guillemette 1991). The nearshore waters of southern New England are generally shallow, with increased depth gently sloping seaward (Theroux and Wigley 1998, Eakins et al. 2009) that provides extensive habitat for eider and other sea ducks because they prefer to forage in water depths up to 20 m (Goudie et al. 2000). As such, southern New England supports the greatest relative densities of wintering sea ducks on the western Atlantic Coast (Silverman et al. 2013).

## METHODS

### Measuring Body Composition

**Field methods.**—To estimate seasonal variation in body composition of eiders, we used floating mist nets and decoys (Brodeur et al. 2008) to capture approximately 30 adult eiders during each of 3 winter periods (early winter, just after birds arrived to southern New England, 13 Nov–14 Dec 2011,  $n = 35$ ; midwinter, 6–16 Feb 2012,  $n = 29$ ; late winter, 1 month prior to spring migration, 15–19 Mar 2012,  $n = 26$ ; Beuth et al. [2016a] reported the migration phenology of this population of common eider). We determined age and sex of captured eiders using wing plumage characteristics (Carney



**Figure 1.** Comparison of (A) body mass, (B) fat mass, and (C) wet lean mass of 86 adult common eiders captured in Rhode Island and Massachusetts, USA, during early winter (13 Nov–14 Dec 2011), midwinter (6–16 Feb 2012), and late winter (15–19 Mar 2012). Box-and-whisker plots represent the 10th, 25th, 75th, and 90th percentiles, the mean of each group is represented by a dashed line and the median is represented by the solid line. Sample sizes are given in the bottom panel. For body mass and fat mass, time periods with the same letters were not different (Tukey's *post hoc* multiple-comparison test). For wet lean mass, the results of the multiple-comparison tests are not reported because we detected no difference between time periods after we removed one outlier, a female caught in late winter with an unusually low wet lean mass.

1992). We captured 144 adult and 71 juvenile (first- and second-year) eiders during winter 2011–2012 off the coast of Rhode Island and 4 adult and 4 juvenile eiders in November 2012 in Wellfleet, Massachusetts. We used 90 of the 144 adult eiders captured during fieldwork in Rhode

Island for inclusion in this study of body composition dynamics. In addition, we captured and retained 21 adult eiders, including the 4 adult birds captured in Wellfleet, for the validation of the deuterium dilution method (Beuth et al. 2016b). We immediately released after banding the other 37 adults that were captured, as well as all 75 juvenile eiders captured during fieldwork. We included more adult eiders during early winter because this project was part of a larger satellite telemetry study for which we estimated body composition of eiders when transmitters were deployed (Beuth et al. 2016a).

To assess deuterium concentrations in the blood of sampled birds, we followed methods described in Beuth et al. (2016b). In brief, we injected on average  $1,066 \pm 4.5$  mg and  $3,148 \pm 34.3$  mg of 99.9% deuterium oxide (Sigma-Aldrich, St. Louis, MO, USA) into the pectoral muscle of each adult eider captured in Rhode Island ( $n = 107$ ). We weighed birds ( $\pm 10$  g) immediately following injection, except for 5 birds we could not weigh because of unfavorable field conditions. We housed birds in pet crates for approximately 90 min to allow deuterium oxide to reach equilibrium (Eichhorn and Visser 2008); and then, 97 min ( $\pm 9$  min) after injection, we collected approximately 200  $\mu$ L of blood from the medial metatarsal vein. We immediately released the 90 adult eiders used in this body composition study after collecting these postinjection blood samples. All methods were approved by the University of Rhode Island Institutional Animal Care and Use Committee (Protocol no. AN 11-09-004).

*Estimating body composition using deuterium dilution.*—We used the predictive models developed by Beuth et al. (2016b) to estimate the body composition of 90 adult eiders ( $\sim 30$  each seasonal period) that we injected with deuterium, bled approximately 100 min after injection, and then released. We used analysis of variance with Tukey's multiple comparisons to compare body mass, estimated wet lean mass, estimated fat mass, and test for interactions between male and female eiders across the 3 winter time periods (SAS Institute, Inc., Cary, NC, USA). We used  $\alpha = 0.05$  for all statistical tests.

## RESULTS

### Body Mass of Captured Eider and Number Used to Estimate Body Composition

Mean body mass of the 143 adult eiders was 1,934.8 g (range = 1,420–2,320 g), whereas that of the 90 adult eiders used for this body composition study was 1,960.1 g (range = 1,520–2,320 g). Two of the 90 eiders had predicted total-body-water levels that were biologically unreasonable ( $< 50\%$  or  $> 80\%$  of body mass; McWilliams and Whitman 2013), and 1 eider was lighter and another heavier than those used in the validation. Thus, we used 86 adult eiders to assess changes in body composition of male ( $n = 39$ ) and female ( $n = 47$ ) eiders throughout the winter.

### Seasonal Changes in Body Composition of Male and Female Eider

Body mass varied across the 3 winter periods ( $F_{2, 80} = 4.39$ ,  $P = 0.02$ ) and differed between males and females ( $F_{1, 80} = 32.62$ ,  $P < 0.001$ ), but the interaction between sex and

winter period was not significant ( $F_{2, 80} = 0.93$ ,  $P = 0.40$ ). On average, male eiders ( $2,048.3 \text{ g} \pm 18.7 \text{ SE}$ ) were 153.0 g heavier than females ( $1,895.3 \text{ g} \pm 15.2$ ). Eiders in late winter ( $2,045.6 \text{ g} \pm 25.9$ ) were 132.0 g heavier than birds in early winter ( $1,913.6 \text{ g} \pm 20.4$ ; Fig. 1A).

Fat mass increased across the 3 winter periods ( $F_{2, 80} = 22.98$ ,  $P < 0.001$ ), did not differ between males and females ( $F_{1, 80} = 2.07$ ,  $P = 0.16$ ), and we failed to detect an interaction between sex and winter period ( $F_{2, 80} = 1.09$ ,  $P = 0.34$ ). On average, eiders in late winter ( $311.4 \text{ g} \pm 16.9$ ) averaged 133.4 g more fat than eiders in early winter ( $178.0 \text{ g} \pm 12.7$ ; Fig. 1B).

Wet lean mass declined across the 3 winter periods ( $F_{2, 80} = 5.32$ ,  $P = 0.007$ ) and differed between males and females ( $F_{1, 80} = 49.91$ ,  $P < 0.001$ ), with a significant interaction between sex and winter period ( $F_{2, 80} = 3.12$ ,  $P = 0.05$ ). On average, males ( $1,687.0 \text{ g} \pm 17.2$ ) had 146.2 g more wet lean mass than females ( $1,540.8 \text{ g} \pm 18.0$ ). The wet lean mass of males in late winter ( $1,695.5 \text{ g} \pm 24.1$ ) did not differ from males in early winter ( $1,716.0 \text{ g} \pm 36.7$ ). In contrast, females in late winter ( $1,435.5 \text{ g} \pm 53.5$ ) averaged 163.0 g less wet lean mass than females in early winter ( $1,598.5 \text{ g} \pm 17.5$ ; Fig. 1C). The sex and winter period interaction was not significant when the female with the lowest wet lean mass during late-winter was removed from the analysis.

## DISCUSSION

### Changes in Body Composition of Eider During Winter

Body mass and fat mass of male and female eiders increased during late winter in southern New England, suggesting that birds were able to secure adequate resources to improve their body condition over the course of the winter period. This interpretation assumes that this population of common eider resides in southern New England throughout the winter as shown with eiders implanted with satellite transmitters (Beuth et al. 2016a). In contrast, body mass of male northern common eiders in Scotland did not change over winter, although body mass of females significantly increased in late winter (Milne 1976). Guillemette et al. (1992) detected no changes in body mass of male and female common eiders during winter in the Gulf of St. Lawrence. In general, female and male American common eiders during winter in southern New England had more fat mass ( $\bar{x} = 232$  and 242 g, respectively) than eiders during winter in Maine ( $\bar{x} = 175$  g; Korschgen 1977), Scotland ( $F \sim 160$  g,  $M \sim 170$  g; Milne 1976), Quebec, Canada ( $M = 17$ –170 g; Guillemette et al. 1992), and Greenland ( $F = 205$  g,  $M = 221$  g; Jamieson et al. 2006a, Merkel et al. 2006), although these comparisons do not account for body size differences.

In our study, male and female American common eiders had more fat in late winter than they did in early winter and this accounted for the majority of the increase in body mass over winter. Milne (1976) monitored annual variation in body composition and reported an increase in fat prior to breeding by female northern common eiders, and minor fluctuations throughout the year in fat for males with lowest levels from June to September during molt. Merkel et al.

(2006) assessed total carcass lipids during late winter (19 Feb–18 Mar) and early spring (19 Mar–18 Apr). They detected a decrease in fat from late winter to early spring during 2 years for both male and female eiders residing along the coast, whereas they documented a decrease during 1 year and an increase the next year for eiders utilizing fjords (Merkel et al. 2006). Future research should aim to identify the environmental and anthropogenic drivers responsible for this overwinter variation in eider body composition among populations and subspecies; the deuterium dilution method used here provides an accurate and precise, nonlethal technique for doing so (Eichhorn and Visser 2008, McWilliams and Whitman 2013, Beuth et al. 2016*b*).

Male American common eiders had more wet lean mass than females throughout winter, which is similar to the gender differences in body protein reported in northern common eiders by Jamieson et al. (2006*a*). The decrease in wet lean mass of female American common eiders during late winter that we documented was not observed in the northern subspecies (Milne 1976, Jamieson et al. 2006*a*), whereas all studies of common eider to date detected that wet lean mass of males did not change during winter (Milne 1976, Jamieson et al. 2006*a*, our study). Loss of wet lean mass during winter has been observed in other waterfowl (Ballard et al. 2006, Meissner et al. 2012) and may be related to local environmental conditions and different migration or breeding strategies. However, given that the late-winter decrease in wet lean mass of females in our study was sensitive to the inclusion of one very lean female, we encourage cautious interpretation of this pattern, and further study.

Previous studies on waterfowl body-composition dynamics suggest that body mass and reserves peak in early winter before decreasing throughout the winter, likely because of temperature or food availability (Peterson and Ellarson 1979, Blem 1990, Gates et al. 2001). Blem (1990) hypothesized that fat storage is linked to photoperiod and during the shortest days, birds would store the most fat to survive the longest nights. However, eiders in southern New England during winter did not follow these trends, possibly indicating that food availability was sufficient to maintain body reserves throughout the winter. Body reserves were likely not required for thermoregulation because this period (Oct 2011–Mar 2012) was the warmest on record for southern New England (NOAA 2012). Eiders are sensitive to hunting disturbance (Bell and Owen 1990) and hunting-related disturbance during the early winter hunting season (8 Oct 2011 through 22 Jan 2012) may have decreased time spent foraging and displaced birds from preferred foraging sites (Gaston 1991, Laursen and Frikke 2008, Merkel et al. 2009). This may have prevented eiders from attaining maximum reserve levels when hunting occurred during early winter, whereas thereafter eiders were able to increase their reserves. Additional studies over multiple years that measure hunting pressure, time budgets, environmental factors and body composition would provide further insights into the factors driving body composition changes of eiders in southern New England.

There is a possibility that the eiders we captured by the use of decoys near mist nets provided a biased subsample of birds in poorer physiological condition than the general population (Weatherhead and Greenwood 1981, Weatherhead and Ankney 1985, but see Burnham and Nichols 1985). Numerous studies of waterfowl species have documented a condition bias for birds shot by hunters over decoys (see review by McCracken et al. 2000), although other studies found no evidence that waterfowl captured using decoys were in poorer condition (e.g., Reinecke and Shaiffer 1988, Morez et al. 2000). We attempted to reduce the potential for such a condition bias by capturing a relatively large number of individuals ( $n=148$  ad, 75 juv) and selecting for study of body condition only 90 adult eiders that represented the full range of body masses. Entirely avoiding condition bias associated with capturing birds over decoys is not possible in a study such as ours that uses a nonlethal method to assess body condition.

## MANAGEMENT IMPLICATIONS

Our estimates of body composition of eiders during winter in southern New England can be used as a baseline when conducting future research to evaluate effects of anthropogenic disturbance and disease. For example, monitoring of body composition dynamics of wintering eider may enable managers to predict the severity of die-offs from Wellfleet Bay Virus and the potential for population-level effects. As offshore wind developments become more prevalent in the coastal waters of the eastern United States, managers can assess the potential effects of habitat displacement on body condition of eider by measuring changes in body composition of eiders before and after construction with appropriate consideration of natural, annual variation in body composition.

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