Body condition of American black ducks (Anas rubripes) wintering in Atlantic Canada using carcass composition and a scaled mass index

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Abstract

Body condition is commonly used in ecology to assess the physiological health of an organism or population, and can be used to predict individual survival or breeding success. Waterfowl have been the focus of much research on body condition, and we studied body condition via carcass composition and using a scaled mass index (SMI) in American black ducks (Anas rubripes) wintering in coastal, agricultural, and urban areas of Atlantic Canada. Carcass composition varied between sexes and body mass decreased through winter as fat reserves depleted. Carcass composition was compared to black ducks wintering in the United States, and black ducks wintering in Atlantic Canada were structurally smaller yet proportionally fatter than those wintering in the United States, likely as a mechanism to survive Atlantic Canada’s harsher winters. SMI did not differ between coastal, agricultural or urban black ducks, indicating that despite known differences in the diets of the ducks from these three areas, they can maintain similar body conditions capable of surviving the winter. We show that the SMI is a non-destructive alternative to study body condition in waterfowl. Our research highlights the adaptability and hardiness of black ducks at the northern limit of their winter range.
Keywords

American black duck

Anas rubripes

Body condition

Carcass composition

Scaled mass index

Atlantic Canada
Introduction

Body condition is commonly used in ecological research to assess the physiological health of an organism or population, and can act as a proxy to predict individual survival or breeding success (Peig and Green 2010; Guillemain et al. 2013a). There are a variety of definitions for body condition, but it is generally considered as a measure of the energetic reserves (usually fat and protein) of an animal, and the parameters that determine body condition can widely vary (Stevenson and Woods 2006; Peig and Green 2010). Body condition is often poorly defined, and many studies have employed different methods of determining body condition, ranging from using body mass alone to analyses of carcass components and macromolecules, which can make comparing results among studies difficult (Schamber et al. 2009; Peig and Green 2010).

Body condition has been thoroughly studied in waterfowl, and extensively in American black ducks (Anas rubripes), a widespread species with a long history of harvest and conservation management in eastern North America (Reinecke et al. 1982; Morton et al. 1990; Robb et al. 2001; Barboza and Jorde 2002). Atlantic Canada forms the northern limit of black duck winter range, and winter at higher latitudes is an energetically-stressful time for waterfowl due to increased energetic costs of thermoregulation and a general reduction in food abundance (Kricher 1975; Albright et al. 1983; Conroy et al. 1989; Mason et al. 2007). Species that forage in the intertidal zone (e.g., black ducks) are further challenged through winter due to ice and snow cover which can restrict access to foraging habitats (Albright et al. 1983). Pair-bonding for black ducks also occurs during winter, resulting in energetically-demanding agonistic
interactions and courtship behaviours as black ducks compete for mates (Brodsky and Weatherhead 1985; Hepp 1986).

Through winter, body mass (a strong indicator of body condition) in waterfowl tends to decrease as fat reserves are catabolized for thermoregulation (Hepp 1986; Barboza and Jorde 2002; Mason et al. 2007). Black ducks exhibit an endogenous regulation of body mass through winter (Hepp 1986), with a pattern of body mass decline similar to other ducks (Barboza and Jorde 2002). Direct sampling of fat tissue requires destructive techniques, and various non-destructive methods of determining body condition are available, which are normally calculated based on a regression of a particular morphometric measurement ($L$) with body mass ($M$) (Peig and Green 2010). Most body condition studies on waterfowl have required destructive sampling, which is undesirable when studying species of ecological concern, and also prevents study of how body condition relates to the subsequent performance of the individual.

Peig and Green (2009) developed a non-destructive method of determining body condition: the scaled mass index (SMI). This method has been proposed to be more biologically relevant than other methods because SMI accounts for a changing relationship between $M$ and $L$ as body size changes during growth (Peig and Green 2010). SMI has been successfully applied to a variety of species including waterfowl (Champagnon et al. 2011; Guillemaud et al. 2013a), and when compared to other non-destructive methods of determining body condition, studies show that SMI is a better measure of relative size and energy reserves (Peig and Green 2010; Bokony et al. 2012; Kelly et al. 2014; Maceda-Veiga et al. 2014).

We analyzed carcass composition and body condition of wintering American black ducks in coastal, agricultural, and urban sites in Atlantic Canada. These sample sites were near the northern limit of the species’ wintering range (Longcore et al. 2000), where winter temperatures...
should be colder than in the core wintering area for black ducks in the United States, and days with freezing temperatures would be common (Environment Canada, 2015), hence freezing over freshwater sites that might provide food (e.g., beaver ponds). We compared carcass composition of ducks in our study to black ducks wintering in the United States (data from Reinecke et al. 1982; Morton et al. 1990), and anticipated that ducks in northern areas may have greater thermoregulatory costs and consequently would experience greater losses in body mass, reducing their winter body condition more than birds sampled in the United States. Moreover, due to known variation in the diets of ducks sampled from coastal, agricultural, and urban locations (English et al. 2017) we expected that ducks exploiting anthropogenic food resources in the agricultural and urban sites would exhibit better body condition through winter than ducks using natural coastal habitats. Body condition was assessed using Peig and Green’s (2009) scaled mass index, and effects of sex, location, and time were investigated.

Methodology

Black duck collection and processing

Seventy-four American black ducks (38 males, 36 females) were collected for this study, with 37 collected opportunistically by hunters in coastal saltmarsh habitat of Nova Scotia and New Brunswick from 26 Nov 2013 to 27 Mar 2014, and 37 collected and euthanized by cervical dislocation by Environment and Climate Change Canada employees in an urban freshwater pond in St. John’s, Newfoundland and Labrador (47.528 N; 52.746 W), from 11 Feb 2014 to 15 Apr 2014. All ducks were sent to Acadia University, where they were stored frozen at -18° C until being sent to the Avian Energetics Laboratory (Long Point, Ontario), where full carcass
processing occurred using standardized methods. Briefly, ducks were partially thawed and plucked. The entire gastrointestinal tract was removed, emptied, and weighed wet prior to returning it to the carcass for drying. Dry masses were obtained after the carcass and components were freeze dried for approximately 48 hr. For full details see Reinecke et al. 1982 or Morton et al. 1990.

Data on winter black duck wet mass and body morphometrics were gathered in 2014 and 2015 as part of regular banding operations. Banding occurred at the agricultural (Oulton’s farm) site (44.968 N; 64.141 W) from 9 Feb 2014 to 9 Mar 2014, and from 30 Jan 2015 to 9 Apr 2015 using a drop-door trap (trapping methods described in Bub 1996). Oulton’s farm is a livestock farm which raises domestic geese among other livestock. The geese winter in a small spring-fed pond on the farm which remains open through winter, and wild black ducks have been wintering in this pond and exploiting the feed provided to the geese for many years. Additional banding using bait traps occurred in coastal areas of Grand Manan, New Brunswick (44.770 N; 66.765 W), and a coastal area in Cole Harbour, Nova Scotia using a net-cannon (44.618 N; 63.444 W) (Figure 1). Black ducks caught in Grand Manan were sampled from 14 - 16 Jan 2015, and Cole Harbour was only sampled 12 Feb 2015. Urban birds (i.e., those banded in St. John’s Newfoundland) were captured from 18 Nov 2013 to 15 Apr 2014 (Table 1). All trapping and handling of waterfowl for this research was pre-approved by Acadia University (Animal Care Permit 02-14) and Environment and Climate Change Canada (Scientific Permit ST2785).

**Carcass composition analysis**

Carcass components of interest (total fat, total ash, total protein [ash free lean dry mass], carcass water, and carcass dry mass) were compared between coastal and urban black ducks
collected during overlapping time periods (i.e. between January and late March) and between sexes using a two-way ANOVA. Because no duck carcasses from the agricultural area were collected, carcass composition data are unavailable for this location. Results of the two-way ANOVA comparison were used to inform whether or not to pool urban and coastal black ducks and sexes, or to keep them separate for subsequent analyses.

Winter was divided into three periods: early (end of November to December), mid (January and February) and late (March to mid-April), similar to Palm et al. (2013) and Mason et al. (2007). Carcass component masses were compared between sex and winter period using ANOVA with Tukey Honest Significance Difference (HSD) tests for post-hoc testing. All statistical analyses were done using R v. 3.2.3 (R Development Core Team 2015).

**Comparison with black duck winter body composition from core wintering area**

Our data on carcass composition were compared to those from black ducks wintering in more southern regions of their range, using previously published research in Maine (Reinecke et al. 1982) and Virginia (Morton et al. 1990). Both studies separated their duck collections into different parts of the year, so we only compared data from the mid-winter period in both studies (January – February). Due to the low number of ducks that were collected in our study from January and February, we combined our coastal and urban black ducks collected from 30 Jan 2014 to 15 Apr 2014 for this comparison.

We used unpaired t-tests (Welch corrected) or ANOVA (with Tukey HSD tests) based on summary data (Graphpad Software Inc 2009) to compare three aspects of carcass composition among Atlantic Canada birds and those from the United States: 1) mean total fat (based on dry mass); 2) mean ingesta-free wet mass (as dry mass was not available from Morton et al. 1990);
and 3) mean total ash (a proxy for structural size of the ducks). We calculated fat proportion (mean total fat / mean ingesta-free wet mass) as an index of body condition to compare across studies (e.g., as per Ringelman and Szymczak 1985).

**Body condition determination**

Body condition was determined for each individual duck by developing a scaled mass index (SMI) as per Peig and Green (2009). This method standardizes body mass to a specific fixed linear measurement of the organism based on the scaling relationship between mass and length using the equation:

$$ SMI = M_i \left( \frac{L_0}{L_i} \right)^{b_{SMA}} $$

where $M_i$ and $L_i$ are the body mass and linear measurement, respectively, of individual $i$; $b_{SMA}$ is the scaling exponent estimated by the standardized major axis (SMA) regression of $\ln(M_i)$ on $\ln(L_i)$; $L_0$ is an arbitrary value of $L$ (e.g., the arithmetic mean value for the study population); and SMI is the predicted body mass for individual $i$ when the linear body measure is standardized to $L_0$.

Following Peig and Green (2009), we looked for outliers based on body mass, and one duck with a wet mass of 1840 g was removed as determined from Grubb’s test ($G = 3.595$, $U = 0.927$, $p = 0.023$). For the black ducks in this study, we took the following linear measurements: wing chord, total head length, culmen length, and total tarsus length. Data were ln-transformed and then Pearson correlations were used on the ln-transformed data to see which measurement ($L$) was the best predictor for body mass, and scaling exponents ($b_{SMA}$) were calculated by fitting a SMA regression line to the ln-transformed data. A $b_{SMA}$ value close to 3 is desirable on
a ln-ln scale because the assumption of isometric growth is valid for many, but not all, species (Stevenson and Woods, 2006).

Factors affecting body condition

Due to known structural differences between male and female black ducks (Longcore et al. 2000), we were first interested in seeing the general temporal trend in SMI for all ducks regardless of location or year of sampling for both sexes over winter, which we analysed using ANCOVA using date of sampling as the covariate and sex as the factor. If the interaction between sex and date of sampling was not significant, both sexes were pooled for subsequent ANCOVAs. Because black ducks were sampled both in the winters of 2013-2014 and 2014-2015, the potential effect of the year of sampling on SMI was tested using a one-way ANOVA. If the effect of year was significant, then direct comparisons between SMI and the different locations at which the ducks were sampled were only possible within years. Black ducks from all locations were sampled in winter of 2013-2014, and SMI of these ducks was compared among the three locations using a one-way ANOVA. When comparing SMI among locations, coastal and urban ducks that were sampled in November and December of 2013 were excluded, so that only birds sampled during overlapping time periods (i.e., mid to late winter) were compared. A regression analysis between SMI and date was performed to see if it was linear or nonlinear, and then appropriate regressions were applied to SMI through winter at each site to detect shifts in SMI. Direct comparisons between temporal trends in SMI at the three locations could
not be conducted due to non-uniform temporal sampling at each site in this study. Reliable age data can be challenging to collect during winter banding operations (Ashley et al. 2006), and thus we chose not to include age as a factor. Significance levels were $p < 0.05$.

**Results**

**Carcass composition analysis**

Males on average were structurally larger and contained higher masses of different carcass components than females\(^a\) (ANOVA: all $p \leq 0.02$), except fat, which did not differ between sexes ($p = 0.51$; Figure 2). Carcass composition did not differ between coastal and urban ducks (all $p \geq 0.08$), except that ducks from coastal areas contained more water than urban ducks ($p < 0.001$).

Given that both sexes of coastal and urban ducks had similar carcass composition within the periods that they overlapped, we assumed that their carcass composition was similar before and after this overlapping period, and thus pooled data from all sites to assess overall temporal patterns of body composition of male and female black ducks in winter. Carcass compositions of both sexes were similarly affected by period as all interactions between sex and period were not significant at $p \geq 0.14$ (Figure 2).

Females had significant mass loss from early to late winter in both carcass dry mass (Tukey HSD: $p = 0.017$) and total fat ($p = 0.012$), while carcass composition did not vary in mid versus late winter. In males, carcass dry mass was significantly lower in the late winter than the early ($p < 0.001$) and mid-winter ($p = 0.007$). Fat followed the same trend in males, being significantly lower in late winter than early ($p = 0.002$) and mid-winter ($p = 0.016$). Protein

\(^a\)Supplementary data have been made available online with this manuscript.
declined significantly from the early to late winter in males ($p = 0.037$). In both sexes, ash ($p = 0.54$) and carcass water ($p = 0.28$) did not vary through winter (Figure 2).

**Comparison with black duck winter carcass composition from core wintering range**

Female black ducks wintering in Atlantic Canada had significantly lower body mass than those wintering in Maine and Virginia ($F_{2,36} = 30.67$, $p < 0.001$; each group different from each other, Tukey HSD tests, all $p < 0.05$). The mass of ash in female carcasses differed geographically ($F_{2,36} = 5.27$, $p = 0.001$), with females from Atlantic Canada having less ash (meaning that they were structurally smaller) than those in Virginia (Tukey HSD, $p < 0.05$). However, females from all sites had similar masses of fat ($F_{2,36} = 0.77$, $p = 0.47$).

Male black ducks wintering in Atlantic Canada had lower body mass than those wintering in Maine ($t$-test: $t_{25} = 10.24$, $p < 0.001$), but mass of fat was similar between these two locations ($t_{25} = 0.39$, $p = 0.70$) as was the mass of ash ($t_{10} = 1.37$, $p = 0.20$) (Table 2). Given that male and female black ducks from Atlantic Canada had lower body mass and less ash but similar levels of fat, the proportional sizes of their fat reserves were larger (Table 2).

**SMI determination**

Head length was the best predictor of body mass ($r_{140} = 0.54$; $p < 0.001$), and had a $bSMA$ value of 3.349, so it was used as the linear measurement in calculating SMI ($L_0 = 112.5$ mm). The closest $bSMA$ value to 3 was that of wing chord ($bSMA = 2.732$), however, this measurement did not predict body mass as well as head length ($r_{130} = 0.49$; $p < 0.001$). Culmen length ($r_{140} = 0.36$; $p < 0.001$) and tarsus length ($r_{140} = 0.16$; $p = 0.051$) did not correlate strongly with body mass.
Factors affecting SMI

Females maintained a higher SMI than males through winter ($F_1 = 5.10, p = 0.025$), and both sexes were similarly affected by date of sampling, as both sexes exhibited declines in SMI through winter ($F_1 = 0.41, p = 0.524$). The interaction between date of sampling and year was significant ($F_1 = 19.59, p < 0.001$), and so for the comparison of SMI between the three locations, only ducks sampled in 2013 - 2014 were considered. Since all sites sampled in 2013 - 2014 were not sampled continuously, ducks sampled in early winter in the coastal and urban site were removed so that SMI was only compared among the three sites during the same period of the same winter. With year and date of sampling controlled for, SMI did not vary among sites sampled in the mid to late winter of 2013 – 2014 for females ($F_2 = 0.29, p = 0.745$); however, site had a significant effect on male SMI ($F_2 = 8.84, p < 0.001$), with agricultural males exhibiting a higher SMI than urban males (Tukey HSD; $p < 0.001$).

Nonlinear regressions on SMI through time were not significant and were not considered further. SMI did not detectably decline in coastal female ($r^2 = 0.080, F_{18} = 2.68, p = 0.119$) and male black ducks ($r^2 < 0.001, F_{15} < 0.01, p = 0.993$); however it did decline through winter in male ($r^2 = 0.634, F_{15} = 28.73, p < 0.001$) and female ($r^2 = 0.389, F_{15} = 11.17, p = 0.004$) agricultural black ducks, and male ($r^2 = 0.367, F_{47} = 28.79, p < 0.001$) and female ($r^2 = 0.203, F_{23} = 7.11, p = 0.014$) urban black ducks (Figure 3).

Discussion
We examined body condition using carcass composition and a scaled mass index of American black ducks in Atlantic Canada, near the northern limit of their winter range. We expected that our northern black ducks would have more difficulty meeting energetic needs and thus, we predicted that body condition of these birds would be lower than for black ducks wintering farther south in the core of their winter range. However, contrary to our prediction, body condition (as indexed by fat reserves, the key component fuelling winter survival; Ankney et al. 1991; Blums and Clark 2004) was similar to that of black ducks wintering farther south, and in fact, fat reserves were proportionally larger in birds from Atlantic Canada. When we further partitioned our data by wintering habitat, we found minimal differences in the body condition of ducks wintering in coastal, agricultural or urban habitats in Atlantic Canada. Collectively our data suggest that black ducks wintering throughout Atlantic Canada maintain a similar body condition, which is better than the body condition of black ducks wintering farther south. However, the ducks in our study were caught through bait trapping or were shot by hunters, and ducks sampled in these methods exhibit a condition bias and may not be representative of the population as a whole (Weatherhead and Ankney 1984). We also could not examine the effect of age on body condition (reliable age data were not available). Ashley et al. (2006) developed a method to age black ducks in late winter and early spring which relies on examining the shape and structure of certain feathers. This method can fail if feathers are not dry or are excessively worn during the time of capture, and this method can be misleading as a small proportion of some age-sex cohorts exhibit the same traits as other age-sex cohorts (Ashley et al. 2006). In general, juvenile black ducks tend to be smaller and in worse condition than adults (Longcore et al. 2000), but Hepp (1986) found no difference in the percentage of weight change through winter in juvenile and adult captive black ducks.
Carcass composition

The endogenous regulation of carcass composition in black ducks has been previously described by Hepp (1986), and Barboza and Jorde (2002), which we corroborate with our study. Black ducks and other species of waterfowl accumulate fat reserves in the fall and fat levels normally peak in early winter, so that they have sufficient fat reserves to catabolize for winter thermoregulation (Hepp 1986; Barboza and Jorde 2002; Mason et al. 2007; Palm et al. 2013). In our study, body mass declined through winter as a result of fat loss in both sexes, and protein reserves remained relatively stable through winter, indicating that these black ducks maintained sufficient fat reserves for thermoregulation and did not need to catabolize muscle. This interpretation should be treated with caution because our analysis contained a pooled sample of black ducks wintering in two separate habitats, and these birds were not sampled concurrently through winter. We were not able to sample urban birds in the early portion of the winter, but we pooled samples based on a lack of differences in carcass composition through the mid- and late winter in both groups, and we assumed that both groups of birds would be regulating their body mass in similar fashions.

Comparison with black duck winter body condition from core wintering area

We expected that black ducks in Atlantic Canada would have a lower body condition than those wintering in core areas in the United States. However we observed the opposite; black ducks in Atlantic Canada were in better condition than those wintering farther south, when using the ratio of fat:body mass as the metric for body condition (Ringelman and Szymczak 1985). This higher fat proportion may be a result of the black ducks in our study being structurally
smaller than those farther south, requiring a lower absolute mass of fat reserves to have a proportionally fatter bird. Proportionally higher fat reserves may be a mechanism to cope with the higher thermoregulatory costs of wintering farther north, and building up fat reserves may serve as an insurance risk against extreme winter weather (Fox et al. 2013). These results should be cautiously interpreted since our measure of body condition did not standardize fat proportion to a morphometric measurement, and over 30 years separate these studies with our current study. Carcass processing methods may have differed from those in our current study. It is also worth noting that trends in body condition over large temporal scales (e.g. decades) have been detected in waterfowl, and some research suggests winter body condition has been improving as a result of climate change (discussed in Guillemain et al. 2013b).

**SMI as a metric for body condition, and factors affecting SMI**

The scaled mass index method developed by Peig and Green (2009) was a suitable metric of body condition for the black ducks in our study, and to our knowledge, is the first time SMI has been applied to black ducks. Using SMI as a metric for body condition was reliable based on its accuracy as a predictor of carcass composition, and is simple to implement in field operations due to only requiring two measurements from each individual bird. The results from the SMI and carcass composition analyses were similar, however, SMI is a non-destructive method of evaluating body condition, which is desirable when studying species at risk or when studying ecological relationships with body condition. Another advantage of using SMI is when the $L_0$ value is provided, researchers can easily compare SMI values in different study populations.

Coastal black duck SMI did not decline in either sex through winter, which was unexpected due to the known endogenous reduction of fat reserves through winter in black ducks
This may be a result of the irregular, opportunistic sampling of coastal black ducks in winter of 2013-2014, which would make detecting temporal trends difficult due to large temporal gaps in the sampling. No coastal ducks were sampled in April, and this sampling gap likely excluded ducks with the lowest SMI, since April is when SMI was lowest in agricultural and urban ducks.

The difference in body condition in agricultural birds in the winters of 2014 and 2015 is likely a result of differing intensities of those winters, since the winter of 2015 was an unusually severe winter in Atlantic Canada (The Weather Network, 2015). Out of the three sites we examined, males and females in the agricultural site both exhibited the sharpest declines in body condition through winter, suggesting they were under increased stress at this site in 2015 compared to the coastal and urban ducks in 2014. Negative correlations between body condition and ambient temperature have been documented in a variety of waterfowl, including black ducks (Albright et al. 1983; Robb et al. 2001; Mason et al. 2007; Palm et al. 2013), and Guillemain et al. (2013a) recorded inter-annual variation in SMI in Eurasian teal (Anas crecca) in response to environmental conditions. It should also be noted that between 200 – 400 ducks could be present in the ~50 m² pond at our agricultural site, which would likely lead to increased intraspecific and interspecific (with mallards, Anas platyrhynchos) agonistic interactions during pair bonding (Brodsky and Weatherhead 1985).

Agricultural males exhibited a higher SMI than urban males in the mid to late winter of 2014, which may be attributed to a small sample size, and also a bias in the sampling. The black ducks which were banded at the agricultural site in 2014 were used in a tracking study and had satellite platform terminal transmitters attached to them (English et al. unpub data), so ducks that appeared to be large and healthy were sampled, which may have artificially inflated SMI in
agricultural ducks. Studies where tracking devices are attached to birds tend to favour birds that appear to be healthier and larger than the true representation of the population, which may cause biased results with these studies (e.g., Fife et al. 2015).

Petrie (2005) examined body condition in white-faced whistling ducks (*Dendrocygna viduata*) in South Africa, and observed that ducks wintering in agricultural areas contained higher fat reserves in spring than those wintering in more natural coastal areas due to increased food availability (maize) through winter in the agricultural site. The black ducks at the agricultural site we studied did not differ in body condition from those wintering in coastal areas, despite known differences in diets (English et al. 2017).

Studies on the body condition of urban populations of waterfowl are limited. Figley and VanDruff (1982) compared masses of urban mallards in the fall and winter to those of wild mallards and found that urban mallards were considerably heavier than wild ducks; however, we were unable to document any difference between the body condition of urban and coastal black ducks. Body condition in urban ducks steadily declined through winter, which has been shown in wild (Reinecke et al. 1982) and captive black ducks (Hepp 1986; Barboza and Jorde 2002), indicating that these urban black ducks are physiologically similar to those wintering in more natural habitats. Furthermore, results of the SMI and carcass composition analyses showed that urban ducks can maintain a similar body condition to wild ducks through winter, which further suggests that urban habitats may be important to black ducks at the northern limit of their wintering range. Emerging research is highlighting the attraction of various bird species to anthropogenic habitats due to food subsidies (e.g., Fischer and Miller 2015; Walker and Marzluff 2015; English et al. 2017), an attraction which northern wintering black ducks appear to display.
Recently, Williams et al. (2014) and Ringleman et al. (2015) mapped food supplies and Beatty et al. (2015) examined energetic carrying capacity models for black ducks, and these large-scale studies found little support for the hypothesis that food supplies or habitats were limiting for black duck wintering habitats in eastern North America. Collectively, similarities in carcass composition among studies (this study, Reinecke et al. 1982; Morton et al. 1990) despite the variability in food supplies from those regions (Coluccy et al. 2016; English et al. 2017), the fact that black ducks lose mass in winter even when fed *ad libitum* (Hepp 1986), and the lack of support for a food supply – wintering population link for black ducks suggests that a threshold body condition is met in the fall or early winter, which the ducks try to maintain above some minimum level before spring arrives. These studies therefore suggest that black ducks are able to exploit whatever food resources are available to them to maintain energetic reserves capable to survive winter at the northern limit of their wintering range.

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Oral Presentation presented at the 7th North American Duck Symposium, Annapolis, MD.


Graphpad Software Inc. 2009. GraphPad. La Jolla, California: Graphpad Software Inc.


Table 1: Black duck (*Anas rubripes*) sample sizes by sex and year for all sites during the winters of 2013-2014 and 2014-2015.

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<td>-</td>
</tr>
</tbody>
</table>
Table 2: Comparisons between the carcass composition of black ducks (*Anas rubripes*)

wintering in Atlantic Canada, Maine and Virginia. Note the study from Maine only includes data on female black ducks.

<table>
<thead>
<tr>
<th>Location</th>
<th>Sex</th>
<th>n</th>
<th>Mean ingesta-free wet mass (g) ± SE</th>
<th>Mean total fat (g) ± SE</th>
<th>Mean total ash (g) ± SE</th>
<th>Fat proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic Canada</td>
<td>M</td>
<td>31</td>
<td>999 ± 20</td>
<td>139 ± 11</td>
<td>45 ± 1</td>
<td>13.9</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>22</td>
<td>868 ± 19</td>
<td>128 ± 13</td>
<td>38 ± 1</td>
<td>14.7</td>
</tr>
<tr>
<td>Maine&lt;sup&gt;a&lt;/sup&gt;</td>
<td>F</td>
<td>11</td>
<td>989 ± 28</td>
<td>128 ± 18</td>
<td>42 ± 2</td>
<td>12.9</td>
</tr>
<tr>
<td>Virginia&lt;sup&gt;b&lt;/sup&gt;</td>
<td>M</td>
<td>11</td>
<td>1311 ± 23</td>
<td>132 ± 14</td>
<td>52 ± 5</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>6</td>
<td>1200 ± 46</td>
<td>159 ± 24</td>
<td>46 ± 3</td>
<td>13.3</td>
</tr>
</tbody>
</table>

<sup>a</sup> data from Reinecke et al. (1982)
<sup>b</sup> data from Morton et al. (1990)
Figure captions

**Figure 1:** Map of Atlantic Canada showing the coastal (circles) agricultural (triangle) and urban (square) sampling sites used in this study.

**Figure 2:** Mean ± SD of different carcass components of female (top) and male (bottom) wintering black ducks (*Anas rubripes*) collected in the early, mid, and late periods of winter 2014. Letters above the error bars represent significant differences as detected by a Tukey HSD test.

**Figure 3:** Temporal trends in scaled mass index (SMI) in female (circles) and male (triangles) black ducks (*Anas rubripes*) wintering in three separate habitats (coastal, agricultural, and urban). Lines are based on linear regressions; shaded area indicates 95% CI. The stars indicate significant linear regressions for both sexes. Note that the coastal and urban ducks in this figure were sampled in 2013-2014, and the agricultural ducks were sampled in 2014-2015. The masses of the ducks are standardized to a head-length value ($L_0$) of 112.5 mm.
Figure 1:
Figure 2:
Figure 3: