Food Resources for Wintering and Spring Staging American Black Ducks

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Abstract

Habitat restoration and enhancement objectives for wintering waterfowl are typically derived by a bioenergetics modeling approach. This approach has been developed as a planning tool to identify the amount of foraging habitat required to meet North American Waterfowl Management Plan population objectives. Our objective was to provide the energetic supply component of the bioenergetics model at an important wintering area for American black ducks Anas rubripes in the Atlantic Flyway, the Eastern Shore of Virginia. We estimated food availability among four main wetland cover types used by overwintering American black ducks: brackish water, freshwater, mudflat, and salt marsh. Mudflat (221 ± 50 kg/ha) and salt marsh (728 ± 175 kg/ha) had the highest amounts of available invertebrate food density, and freshwater (42 ± 9 kg/ha) had the highest amounts of available seed biomass. Our results suggest that seed density found in freshwater wetlands on the Eastern Shore of Virginia is considerably lower than densities found in inland freshwater cover types used by dabbling ducks. We also found that levels of invertebrate density found in Virginia mudflat and salt marsh are considerably lower than levels on Long Island, New York, and in southern New Jersey. Lower levels of food density compared with both more inland and northern wintering areas suggest that American black ducks wintering in Virginia are more likely to be limited by forage availability than American black ducks and other dabbling ducks wintering both inland and in the northern portion of the wintering range.

Keywords: American black duck; Anas rubripes; foraging theory; invertebrate biomass; salt marsh; wetlands

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Introduction

Since the mid-20th century, the American black duck (hereafter black duck) Anas rubripes population has declined from an estimated 600,000 in the 1950s to an estimated 300,000 in the 1990s, with a disproportional decline occurring in the southern coastal areas such as Virginia (Steiner 1984; U.S. Fish and Wildlife Service [USFWS], unpublished data). This indicates the component of the population that historically wintered in the most southern portion of the range has disproportionately declined or redistributed to more northern wintering areas (Conroy et al. 2002). The population decline has resulted in a population half the historical size and far less than midwinter goals set by the North American Waterfowl Management Plan (NAWMP 2018).
Loss and degradation of wintering habitat is one of several possible explanations for this decline (Morton et al. 1989; Conroy et al. 2002). Thus, it is important to estimate the type and amount of coastal wintering cover required to support black duck population goals and identify factors that lead to variation in resource availability to inform bioenergetics models used for habitat restoration and enhancement objectives and better understand how resource availability during winter may influence manager’s ability to achieve NAWMP objectives.

Generally, reproductive output in dabbling ducks (Anas, Spatula, Mareca spp.) is most strongly influenced by processes on breeding areas (Hoekman et al. 2002; Coluccy et al. 2008), but carryover effects from conditions on wintering and staging areas may also influence their productivity (Heitmeyer and Fredrickson 1981; Kaminski and Gluesing 1987; Raveling and Heitmeyer 1989), social status, and population dynamics (Sedinger et al. 2011; Sedinger and Alisauskas 2014). Carryover effects have been attributed to the relationship between individual body condition over winter and reproductive success the following breeding season (Dubovsky and Kaminski 1994). Thus, the most likely way to influence reproduction outside of the breeding grounds may be by influencing the ability of dabbling ducks to acquire sufficient nutrients during winter and spring migration (Arzel et al. 2006; Stafford et al. 2014).

Habitat restoration and enhancement objectives for waterfowl in North America are typically derived from a bioenergetics modeling approach because food availability is thought to limit winter survival and have carryover effects on reproduction, thereby limiting populations (Atlantic Coast Joint Venture 2005). The bioenergetics approach has been developed as a planning tool to identify the amount of foraging habitat required to meet waterfowl population objectives of NAWMP and help identify priority areas for restoration, preservation, and management that lack adequate foraging habitat. Bioenergetics models used to inform NAWMP can be simplified into two major components: energetic demand and energetic supply. Energy supply is estimated by multiplying the foraging value of each cover type (the amount of food produced in each cover type as measured by its energetic value) by the total area of each cover type.

Our goal was to inform bioenergetics models used in conservation planning under the NAWMP by providing food density estimates among wintering cover types used by black ducks in coastal Virginia. Our objectives were to 1) estimate seed and macroinvertebrates food densities among four cover types commonly used by black ducks during winter in coastal Virginia (i.e., brackish water, freshwater marsh, mudflat, and salt marsh); 2) compare our estimates of food density to others in the Atlantic coast (Plattner et al. 2010; Cramer et al. 2012) to determine relative differences in food availability to black ducks during winter; 3) evaluate temporal and spatial variability in food densities available to black ducks during winter at our study sites; and 4) compare estimates of food density in coastal Virginia to estimates of food density available for waterfowl wintering in more inland cover types to provide insight as to how, in contrast to most other dabbling ducks in North America, current food availability during winter might be influencing black duck populations.

**Methods**

**Study area**

Our study area (Figure 1) was the Eastern Shore of Virginia, that is, the southernmost portion of the Delmarva Peninsula. The peninsula is 25,600 ha and is bordered on the western side by the Chesapeake Bay and on the eastern side by the Atlantic Ocean. The study area consisted of Accomack County to the north and Northampton County to the south and supports approximately 100,000 dabbling and diving ducks each winter (Steiner 1984; USFWS, unpublished data).

This region is a critical wintering area for migratory waterfowl in the Atlantic Flyway, primarily because of the diversity and abundance of wetland cover types, most notably expansive coastal salt marsh wetland ecosystems. Salt marshes and associated wetlands are delineated into several different cover types, including high marsh, low marsh, and mudflat (Cowardin et al. 1979). Low marshes are normally inundated twice daily during tidal movements, whereas high marshes are usually only inundated during periods of flood tides. Salt marsh vegetation predominantly consists of smooth cordgrass Spartina alterniflora, saltgrass Distichilis spicata, and needlerush Juncus spp. Although we recognize the substantial differences between low and high marsh ecosystems, a conservation planner’s ability to distinguish the difference between low and high salt marsh at a large geographic scale remains limited; thus, we combined low and high marsh samples into one category of salt marsh. An important associated cover in salt marsh ecosystems is the mudflat. We define mudflat as an area of more than one contiguous hectare exposed during low tides and flooded during high tides and lack the established vegetation of high and low marshes. These areas support extremely diverse and abundant animal communities, which are used extensively by black ducks during low tides. Inland from coastal cover types are tidal brackish water creeks and streams that eventually mix with inland freshwater resources. Further inland are freshwater wetlands that consist of ponds, swamps, and impoundments. These wetlands are not normally tidally influenced, and the primary source of water is precipitation (Cowardin et al. 1979). Tidal creeks and streams and freshwater wetlands provide food and are used as a freshwater source by black ducks (Morton et al. 1989).

We estimated food density by taking benthic core and nektonic sweep samples at 78 sites covering four dominant wetland types: salt marsh, brackish water, freshwater, and mudflat). Sampling sites (n = 78) were determined using a stratified random sample proportional to estimated coverage of the four available...
wetland types among the wildlife management areas, Wildlife Refuges, natural areas, and private lands in the area and generated by Ducks Unlimited Inc. Geographic Information System Department at their Great Lakes Atlantic Regional Office in Ann Arbor, Michigan (Figure 1). We collected samples from 1 November to 1 December, from 15 January to 15 February, and from 5 March to 30 March in 2006–2007 and 2007–2008 to estimate food densities for black ducks and other seed- and macroinvertebrate-eating waterfowl during three approximate periods: 1) arrival on wintering grounds, 2) timing of peak waterfowl abundance during winter, and 3) initiation of and during spring migration.

At each sampling site, we collected a 10-cm-diameter × 12-cm-deep core inside of a 1 × 1 m plot to sample for seed and macroinvertebrate biomass. These core samples represent a 1:123.35th ratio of a square meter. In addition, we used a 33-cm-diameter 500-μm mesh D-frame sweep net to sample standing water covering a square meter at all freshwater and brackish water sample sites. We rinsed core samples in a 600-lm sieve bucket and then placed them in polyethylene bags where a 10% buffered formaldehyde mixture was added to preserve

Figure 1. Map of study area, Accomack and Northampton counties, Virginia, and sampling locations used to estimate foods available for American black ducks Anas rubripes during the fall, winter, and spring of 2006–2007 and 2007–2008.
results of a repeated measures analysis of variance comparing seed density and invertebrate density among four cover types, two years, and four sampling sessions for overwintering American black ducks (*Anas rubripes*). There was significant variation in mean invertebrate density among cover types with no variation among sessions (Table 2; Data S3 and S4, Supplemental Material). Periwinkles (Littorinidae), ribbed mussels (Mytilidae), segmented worms (Oligochaeta), and bristle worms (Polychaeta) were the primary invertebrate foods that contributed to estimates of overall invertebrate biomass. Macr invertebrate density tended to vary between years ($F_{1,10} = 3.72; P = 0.08$), but this variation differed among cover types ($F_{1,10} = 3.06; P = 0.08$). From study year 1 to study year 2, available invertebrate density in brackish water, mudflat, and salt marsh decreased by 93, 66, and 88%, while invertebrate density in freshwater increased by 63% (Table 3). During the first year of our study, salt marsh had the highest amount of available invertebrate density (Table 3). Mudflat had the second highest level of invertebrate density followed by brackish water and freshwater (Table 3). In the second year of our study, salt marsh again had the greatest amount of available invertebrate biomass. Mudflat had the second largest level of invertebrate density followed by freshwater and brackish water (Table 3).

### Discussion

Freshwater had the highest amount of estimated seed density in our study area, whereas brackish, salt marsh, and approaching significance and worthy of discussion and content. We transported samples to Southern Illinois University–Carbondale for analysis.

In the laboratory, we filtered all samples through two sieves descending from a 1.0-mm mesh size to a 500-μm mesh size, allowing food biomass to be separated from larger nonfood materials. We then sorted animals and seeds from each sample and identified to the taxonomic level possible (typically family or order). We used field guides along with a previously identified seed catalog for identification and taxonomic classification of seeds and animals (Martin et al. 1961; Smith 2001; Voshell 2002; Merrit et al. 2008). After identification, we dried seeds and animals in an oven at 50°C until a constant mass (0.0001 g) was achieved (approximately 48 h). We weighed each taxonomic group individually to determine density in each sample. We one-quarter subsampled from the second field season to reduce sorting time. To standardize the subsampling process, all subsampling procedures were performed by the authors.

To provide unbiased estimates of cover type–specific food biomass, we reported cover type–specific arithmetic means and standard errors (SEs) of invertebrate and seed biomass. We used repeated measures to statistically analyze the variance in mean density among cover types, sampling session, and between years (Proc MIXED, SAS Institute Inc. 2013). This method was chosen because multiple samples were collected at each site, and this procedure is robust to multiple values of zero, which were present in our data. Data were log transformed to satisfy the assumptions of analysis of variance. We assumed statistical analysis to be significant at $\alpha = 0.05$ and approaching significance and worthy of discussion at $\alpha = 0.10$ (Murtaugh 2014).

### Results

Seed density did not vary seasonally (among sessions) or annually but was influenced by cover type. Freshwater cover had greater amounts of seed density than all other cover types. Brackish water had the second largest amount of seed density followed by salt marsh and mudflat (Table 1; Data S1 and S2, Supplemental Material). There was significant variation in mean invertebrate density among cover types. Brackish water (Table 1) had the greatest amount of available invertebrate density, whereas brackish, salt marsh, and mudflat had the second highest level of invertebrate density followed by freshwater and brackish water (Table 3). Mudflat had the second largest level of invertebrate density followed by freshwater and brackish water (Table 3).
and mudflat yielded estimates near or below those thought to provide resources adequate to support foraging dabbling ducks during winter (119 kg/ha; Table 1; Hagy et al. 2017). Even in freshwater, estimated seed density was lower relative to recent seed density estimates from areas used by inland wintering dabbling ducks. Bowyer et al. (2005) reported that seed densities in moist-soil wetlands in the Illinois River Valley varied from 329 to 1,231 kg/ha. Kross et al. (2006) estimated that seed abundance averaged 496.3 ± 62 kg/ha (mean ± SE) in moist-soil seed units in the Lower Mississippi Alluvial Valley. Osborn (2015) estimated that seed, tuber, and submerged aquatic vegetation abundance in moist-soil wetlands varied from 354.8 kg/ha in early winter to 201.2 kg/ha in late winter. By contrast, the average estimated seed density in freshwater wetlands in our study was 246 ± 24 kg/ha, a value similar to the 260 ± 47 kg/ha estimated by Plattner et al. (2010) for freshwater on Long Island, New York, and lower than that of Cramer et al. (2012) reported for southern New Jersey (442 ± 61 kg/ha).

Unlike seed biomass, which was much lower in wetlands of coastal Virginia than locations used by more inland wintering dabbling duck populations, coastal Virginia wetlands had much greater levels of invertebrate biomass. In forested wetlands in Mississippi, the largest amount of invertebrate density estimated by Wehrle et al. (1995) was 80.05 ± 5.9 kg/ha, whereas Foth et al. (2018) reported a maximum level of 19.23 ± 5.38 kg/ha on green tree reservoirs in southeastern Missouri, Arkansas, and Mississippi. In playa wetlands managed as moist-soil cover in the southern High Plains of Texas, the greatest amount of invertebrate density estimated by Anderson et al. (2000) was 35.22 ± 13.1 kg/ha. In moist-soil–managed impoundments at Noxubee National Wildlife Refuge in Mississippi, the largest amount of invertebrate density estimated by Gray et al. (1999) was 31.2 ± 5 kg/ha. In scrub-shrub wetlands of western Tennessee, the largest amount of invertebrate density estimated by Osborn (2015) was 46 ± 14.5 kg/ha. These results may explain why black ducks wintering near coastal cover types have adapted a more carnivorous diet during winter relative to sympatric dabbling ducks wintering more inland (Costanzo 1988; Jorde and Owen 1990; Lewis 2016).

Although seeds and plant vegetation are primary components in the diet of many species of dabbling ducks during the nonbreeding period (Paulus 1982; Jorde et al. 1983; Delnicki and Reineke 1986; Miller 1987; White et al. 1993; Miller et al. 2009), historical studies have shown that most of the diet of coastal wintering black ducks is composed of animal matter, specifically invertebrates (Costanzo 1988; Jorde and Owen 1990; Lewis 2016). Costanzo and Malecki (1989) and Jorde and Owen (1990) found that invertebrates comprised 66 and 96% of the aggregate dry mass of foods consumed by black ducks wintering in New Jersey and Maine, respectively. Results from a simultaneous diet study indicated animal matter accounted for 73% of the aggregate percent biomass of all foods consumed by black ducks wintering in Virginia (Lewis 2016). Similar to Plattner et al. (2010) and Cramer et al. (2012), we found mudflat (264.3 ± 66.0 kg/ha) and salt marsh (929.4 ± 230.2 kg/ha) provided the highest amount of invertebrate density. This may be why black ducks respond so strongly to tides by making daily foraging flights to mudflats during low tide (Morton et al. 1989). Brackish water and freshwater provided noticeably lower amounts of invertebrate density in year 1 and slightly lower levels of invertebrate density in year 2, compared with mudflat and salt marsh.

The level of annual variation in our study and temporal variation between our study and other studies make inference regarding latitudinal variation in resource availability among Long Island (Plattner et al. 2010), New Jersey (Cramer et al. 2012), and our current study difficult. It is likely however that winters with the lowest food availability would have the greatest effect on black duck populations; therefore, we compared the lowest amount of invertebrate density in each study within similar cover types in any year. When comparing minimum estimates of available invertebrate density among the three study sites, estimates were similar in freshwater and brackish water cover types on Long Island, New Jersey, and Virginia (Table 4). Alternatively, minimum annual invertebrate density in salt marsh and mudflat (the cover types most used by foraging black ducks in Virginia) was substantially lower in Virginia than density levels estimated on Long Island, New Jersey, and in New Jersey (Table 4). These results are consistent with observed declines in black duck populations and may reflect spatial and temporal factors that influence variation in black duck food abundance.

Although temporal variation among studies prevents conclusive inference regarding latitudinal variation in black duck food availability, our results are consistent with previous studies that have demonstrated latitudinal variation in primary productivity of salt marshes and the extensive work conducted on the susceptibility to thermal changes of salt marsh mollusks. Pennings and


<table>
<thead>
<tr>
<th>Cover type</th>
<th>LI 1</th>
<th>LI 2</th>
<th>NJ</th>
<th>VA 1</th>
<th>VA 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brackish water</td>
<td>21 ± 9</td>
<td>7 ± 2</td>
<td>NA*</td>
<td>33 ± 10</td>
<td>2 ± 0.5</td>
</tr>
<tr>
<td>Freshwater</td>
<td>30 ± 8</td>
<td>435 ± 304</td>
<td>25 ± 6</td>
<td>29 ± 6</td>
<td>78 ± 30</td>
</tr>
<tr>
<td>Mudflat</td>
<td>11,061 ± 3,994</td>
<td>1,051 ± 645</td>
<td>3,318 ± 1,472</td>
<td>264 ± 66</td>
<td>92 ± 2</td>
</tr>
<tr>
<td>Salt marsh</td>
<td>597 ± 291</td>
<td>1,073 ± 545</td>
<td>NA</td>
<td>929 ± 230</td>
<td>107 ± 54</td>
</tr>
</tbody>
</table>

* Delineations of brackish water and salt marsh habitat in the New Jersey study precluded a direct comparison to the New York and Virginia studies.
Bertness (1999) observed lower primary productivity in more southern salt marshes along the Atlantic Coast, presumably due to increased salinity levels caused by greater evapotranspiration and higher temperatures in the more southern region. In addition, salt marsh fauna, particularly mollusks, are acutely sensitive to thermal change, especially temperature increase (McMahon and Russell-Hunter 1981; Lerberg et al. 2000; Bilkovic et al. 2006; Hutchens and Walters 2006; Jost and Helmuth 2007). Because summer temperatures are normally higher in Virginia than in New Jersey and New York, mollusks in Virginia are likely nearer their thermal limit during summer and thus would be more susceptible to minor changes in temperature; thus, less of an increase in temperature would be necessary for temperatures to increase sufficiently to cause high mollusk mortality. Either lower primary productivity or higher ambient temperatures in Virginia than New Jersey and New York could explain the results we observed.

Although these results do not provide conclusive evidence that food availability during winter limits black duck populations, they are consistent with this hypothesis. Black ducks wintering in coastal areas are unique from other dabbling ducks in that they consume primarily invertebrates. Although these invertebrates are the most abundant foods available in this region, they are distributed in lower densities than foods in more inland and northern cover types important to wintering waterfowl. Lower amounts of available food density could result in the inability of coastal Virginia wintering areas to support comparable numbers of wintering black ducks and other dabbling ducks than more northern and inland wintering areas.

Salt marshes and associated estuarine cover types, specifically mudflats and freshwater pools within salt marshes, provide the most food resources for wintering black ducks. The high frequency of occurrence of these cover types and the stability of food resources within these cover types likely explain why coastal wintering black ducks are so reliant on salt marsh wetlands. Because of this reliance, the loss and degradation of these cover types could have negative effects on black duck populations and may explain why black duck populations have not responded as positively as other species of waterfowl to freshwater habitat restoration practices and continue to experience population trajectories below NAWMP goals. Thus, we encourage managers to focus future black duck habitat conservation efforts on the protection and restoration of these cover types.

**Supplemental Material**

Please note: The Journal of Fish and Wildlife Management is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

**Data S1.** Excel file containing all seed data from brackish water, freshwater, mudflat, and salt marsh during the fall, winter, and spring of 2006–2007 on the Eastern Shore of Virginia.

Found at DOI: [https://doi.org/10.3996/102018-JFWM-096.S1](https://doi.org/10.3996/102018-JFWM-096.S1) (856 KB XLS).

**Data S2.** Excel file containing all seed data from brackish water, freshwater, mudflat, and salt marsh during the fall, winter, and spring of 2007–2008 on the Eastern Shore of Virginia.

Found at DOI: [https://doi.org/10.3996/102018-JFWM-096.S2](https://doi.org/10.3996/102018-JFWM-096.S2) (319 KB XLS).

**Data S3.** Excel file containing all invertebrate data from brackish water, freshwater, mudflat, and salt marsh during the fall, winter, and spring of 2006–2007 on the Eastern Shore of Virginia.

Found at DOI: [https://doi.org/10.3996/102018-JFWM-096.S3](https://doi.org/10.3996/102018-JFWM-096.S3) (2.46 MB XLS).

**Data S4.** Excel file containing all invertebrate data from brackish water, freshwater, mudflat, and salt marsh during the fall, winter, and spring of 2007–2008 on the Eastern Shore of Virginia.

Found at DOI: [https://doi.org/10.3996/102018-JFWM-096.S4](https://doi.org/10.3996/102018-JFWM-096.S4) (301 KB XLS).


Found at DOI: [https://doi.org/10.3996/102018-JFWM-096.S5](https://doi.org/10.3996/102018-JFWM-096.S5) (7.51 MB PDF).


Found at DOI: [https://doi.org/10.3996/102018-JFWM-096.S6](https://doi.org/10.3996/102018-JFWM-096.S6) (17.45 MB PDF).


Found at DOI: [https://doi.org/10.3996/102018-JFWM-096.S7](https://doi.org/10.3996/102018-JFWM-096.S7) (479 KB PDF).


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References


