Habitat Relations

Food Resource Availability for American Black Ducks Wintering in Southern New Jersey

DANE M. CRAMER,[1] *Department of Entomology and Wildlife Ecology, University of Delaware, 249 Townsend Hall, Newark, DE 19716, USA*

PAUL M. CASTELLI, *New Jersey Division of Fish and Wildlife, Nacote Creek Research Station, P.O. 418, Port Republic, NJ 08241, USA*

TINA YERKES, *Ducks Unlimited, Inc., 1220 Eisenhower Place, Ann Arbor, MI 48108, USA*

CHRISTOPHER K. WILLIAMS,[2] *Department of Entomology and Wildlife Ecology, University of Delaware, 253 Townsend Hall, Newark, DE 19716, USA*

ABSTRACT Midwinter waterfowl survey data indicates a long-term decline in the number of wintering American black ducks (*Anas rubripes*), potentially due to habitat limitations. In order for future estimates of carrying capacity to be determined, it is critical that regional food availability is estimated. We collected pairs of habitat core samples ($n = 510$) from 5 habitat types in southern New Jersey, USA, during October, January, and April 2006–2008 to estimate resource availability and variability. We collected upper gastrointestinal tracts from hunter-killed birds ($n = 45$) and late season collections ($n = 19$) to identify food items and limited our estimates of resource availability to only winter food items; thereby reducing the availability of seed foods found in our core samples by 38% and animal foods by 96%. We did not detect differences in years or sampling period, but did between habitat types. Mudflat habitat had the greatest availability of invertebrate and vertebrate food items and appeared to supply the bulk of energy to black ducks wintering in southern New Jersey. We suggest conservation efforts to be focused on restoring or enhancing mudflat habitat as an integral component of an ecologically functioning salt marsh to increase food availability. © 2011 The Wildlife Society.

KEY WORDS American black duck, *Anas rubripes*, food, habitat, winter.

Waterfowl populations are affected by the condition of wintering habitat throughout multiple stages of their life cycle (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1986). Wintering habitat may limit waterfowl populations either directly through poor physical condition and survival during the winter (e.g., Conroy et al. 1989), or indirectly during migration and the breeding season (e.g., Heitmeyer and Fredrickson 1981, Miller 1986) as well as in subsequent years (e.g., Haramis et al. 1986). The availability of wintering habitat, and food energy derived from it, may currently be a factor limiting waterfowl populations. The availability of food energy may be constrained due to poor habitat quality (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1986), severe weather conditions (Bergan and Smith 1993), or anthropogenic pressures such as disturbance (Morton et al. 1989a).

Midwinter waterfowl survey data indicates a long-term decline of American black ducks (*Anas rubripes*) with the greatest declines being realized in the Mississippi and southern Atlantic Flyways (North American Waterfowl Management Plan [NAWMP] Plan Committee 2004). The historic loss of coastal wetlands used as wintering habitat by black ducks has been severe (Dahl 1990) and their continued degradation (Dahl 2000, Dahl 2006) may limit the ability of the habitat to support wintering waterfowl (Morton et al. 1989b). The link between population objectives and habitat objectives is the fundamental concept by which the NAWMP functions to restore waterfowl populations through habitat conservation (NAWMP Plan Committee 2004, Runge et al. 2006).

Many regional joint ventures of the NAWMP estimate the energetic carrying capacity of waterfowl habitats in order to evaluate their ability to support migrating and wintering waterfowl populations (Reinecke et al. 1989). Bioenergetics modeling is used to calculate energetic carrying capacity in terms of duck-use days by estimating energetic demand and energetic supply. Recent examples of bioenergetics modeling of waterfowl habitats include the southeastern region of the United States (Foster et al. 2010), the Upper Mississippi River and Great Lakes region (Straub 2008), and the Rainwater Basin region in Nebraska (Bishop and Vrtiska 2008). Currently, estimates of food resource availability for wintering black duck habitat are limited to Long Island, New York (Plattner et al. 2010) and no such estimates of carrying capacity exist on the East Coast. This limitation has been identified as a research priority by the Black Duck Joint Venture (Black Duck Joint Venture

Management Board 2008). Estimates of carrying capacity are valuable assets for informing future habitat and harvest management goals and focusing conservation efforts at limiting segments of the annual cycle. The first step toward estimating carrying capacity is estimating food resource availability. Our objective was to estimate food resource availability and variability for black ducks wintering in southern New Jersey.
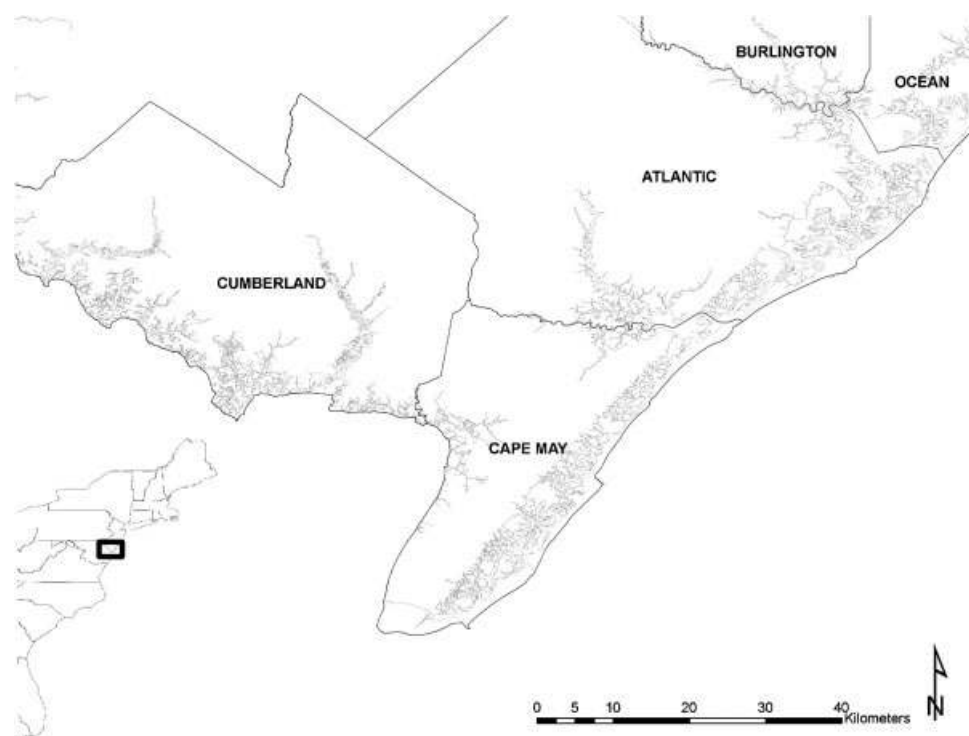
STUDY AREA

We estimated food resource availability in coastal wetlands in Atlantic, Cape May, Cumberland, and southern Ocean and Burlington counties in New Jersey, USA (Fig. 1). Based on midwinter waterfowl survey data, the highest density of wintering black ducks in North America occurred in the study area (U.S. Fish and Wildlife Service's Migratory Bird Data Center 2008). All 5 wetland and deepwater systems defined by the National Wetlands Inventory (NWI) existed in this area (i.e., marine, estuarine, palustrine, lacustrine, and riverine; Cowardin et al. 1979). Estuarine habitat is of particular importance to black ducks wintering in the Atlantic Flyway (Lewis and Garrison 1984). Within the estuarine system there are 4 commonly recognized habitat types which were categorized by the tidal regime and vegetative structure of each; high marsh, low marsh, mudflats, and subtidal waters (Tiner 1987). High marsh habitat was above the mean high tide line and therefore irregularly flooded and populated by the *Spartina patens* plant community (Tiner 1987, Collins and Anderson 1994). Pannes and quasi-tidal pools were additional features within the high marsh habitat type. Low marsh habitat laid between the mean high and low tide lines and was regularly flooded. Low marsh habitat was dominated by a single species of vegetation, tall form *S. alterniflora*, which was more salt tolerant than *S. patens* and its allies. Mudflat habitat was also regularly flooded and exposed. Mudflat habitat was characterized by the general lack of vegetation and accumulation of detritus, but could have experienced colonization by tussocks of *S. alterniflora*. Mudflat habitat occurred in 2 general forms: extensive flats in estuarine bays or narrow ribbons along tidal creeks and ditches that were exposed at low tide. Subtidal water was below the mean low tide line and was therefore irregularly exposed but was still within dabbling depth for black ducks. Additionally, freshwater (lacustrine and palustrine) water bodies and wetland habitat around their margins occurred within the study area. These environs were dominated by mixed hardwood overstory (e.g., sweet gum [*Liquidambar styraciflua*], red maple [*Acer rubrum*], and American holly [*Ilex opaca*]) and shrubby understory (e.g., highbush blueberry [*Vaccinium corymbosum*], common greenbrier [*Smilax rotundifolia*], and poison ivy [*Toxicodendron radicans*]; Collins and Anderson 1994).

METHODS

To quantify food resource availability and variability, we collected habitat core samples during 3 sampling periods (Oct, Jan, Apr) during each year of our study (2006–2007 and 2007–2008) among the 5 primary habitat types used by wintering black ducks to forage along the unglaciated

Figure 1. Map of study area, Cumberland, Cape May, Atlantic, and southern Ocean and Burlington counties, New Jersey, USA used to estimate energetic carrying capacity for American black ducks in October, January, and April, 2006–2008.

Atlantic coast (high marsh, low marsh, mudflats, subtidal waters, and freshwater). We only collected core samples to estimate food resource availability because Plattner et al. (2010) found that >99% of the invertebrate and seed biomass that they observed occurred in core samples. We annually established 85 random sampling locations and marked sites with a piece of 1.2-m reinforcing bar. Sampling locations were distributed in proportion to expected use based on previous winter habitat studies (Costanzo 1988, Morton et al. 1989a) during 2006–2007. Sampling location proportions were refined in 2007–2008 based on the previous year's radiotelemetry and behavioral observations (Cramer 2009; Table 1). During each sampling period, we visited sampling locations and collected a pair of core samples 51 mm in diameter by 120 mm long in randomly selected directions 2 m and 20 m from the sampling location. We placed individual core samples in 946 ml plastic bags and transported them to a laboratory for processing.

In the laboratory, we refrigerated samples for <3 days before sieving them with clean water through 2 mm (No. 10) and 500 μm (No. 35) screens. Sieved material was placed in a 150 ml specimen storage cup, fixed with 10% formalin buffer solution, and stained with Rose Bengal for a minimum of 7 days to aid in the sorting of seeds and invertebrates. Prior to sorting the material, we washed samples twice with clean water. We identified seeds to genus or species and invertebrates to the lowest taxonomic level possible, usually class, order, or family. We dried seeds and invertebrates in an oven at 50–55° C for 48 h and then weighed each sample to the nearest 0.0001 g. We recorded samples with masses of seeds and invertebrates <0.0001 g as zeros. Approximately one half of the samples collected during the first field season were sorted into 70% ethanol prior to identification. Although Anderson and Smith (1999) used this method, there was concern that invertebrate integrity might be adversely affected. Despite using 2 different methods of sample storage, we found no difference in the masses of seeds ($t_{50} = 0.368$, $P = 0.714$) stored in formalin ($n = 19$, $\overline{\chi} = 0.0145$ g $\pm$ SE 0.0051 g), and alcohol ($n = 33$, $\overline{\chi} = 0.0194$ g $\pm$ SE 0.0098 g) for samples with weights >0 (tested using Student's t-test assuming equal variances [separately tested for with Levene's test for equality of variances]). Additionally, we found no difference in the masses of invertebrates ($t_{45} = 0.450$, $P = 0.655$) stored in formalin ($n = 17$, $\overline{\chi} = 0.2513$ g $\pm$ SE 0.1915 g), and alcohol ($n = 33$, $\overline{\chi} = 0.4465$ g $\pm$ SE 0.3070 g). Although we found

no difference, as a precaution we discontinued storage in ethanol.

We averaged paired core samples to produce a single biomass estimate for each sampling location. We extrapolated resource availability in terms of biomass (i.e., kg/ha) by habitat type for each sampling period during both years. To increase the utility of our estimates for bioenergetics modeling, we also summarized resource availability in terms of energy (i.e., kcal/ha) by multiplying the biomass of seed and invertebrate items by true metabolizable energy (TME; kcal/g [dry]) values. To determine TME values for seed and invertebrates items, we conducted a literature review of published TME values (Cramer 2009). We used species specific values whenever possible and averages in instances where multiple published values existed. When TME values did not exist, we used the values for the closest related taxon so that all potential food items were included in the summation of energy estimates (see Table S1, available online at www.onlinelibrary.wiley.com). We tested for differences in energy separately from biomass because it was possible that misleading results could be produced after applying TME values to seed and invertebrate biomasses (e.g., scarce foods with high TME values versus abundant foods with low TME values).

The inclusion of potential food items too large to be consumed or accidentally ingested would lead to an overestimate of resource availability. We assembled a food taxa list by collecting upper gastrointestinal tracts from hunter-harvested black ducks during the open hunting season and targeted late season collections during the closed season. Hunter-harvested ducks may be biased towards foods from habitats where hunters focused their effort. For example, samples may not adequately reflect birds that fed on mudflats because of their difficulty to harvest in this habitat type. However, we felt that the sample size was adequate for our purposes of assembling a representative species richness list of food taxa. Upper gastrointestinal tracts were frozen within 8 h post-mortem until we could sort and identify contents. We sorted contents to the same taxonomic level described for core samples. Because we were compiling a taxa list of consumed foods and not an abundance or frequency measurement, we included all identifiable contents of both the proventriculus and the gizzard (see Baldassarre and Bolen 1994). We supplemented our taxa list with a literature review of black duck foods along the unglaciated coastal marsh. We used this taxa list to remove seed and invertebrate items that

Table 1. Distribution of random sampling locations sampled to estimate food resource availability for wintering American black ducks in southern New Jersey, 2006–2008.

Habitat type	2006–2007			2007–2008		
	Oct	Jan	Apr	Oct	Jan	Apr
Freshwater	9	9	9	12	12	12
High marsh	50	50	50	20	20	20
Low marsh	10	10	10	20	20	20
Mudflat	7	7	7	20	20	20
Subtidal	9	9	9	13	13	13
Total	85	85	85	85	85	85

black ducks were not documented to consume and tested for differences in food resource availability among years, sampling periods, and habitat types using an analysis of variance (ANOVA, $\alpha \leq 0.05$). We used protected Tukey's post hoc tests to identify significant variables within the ANOVA ($\alpha \leq 0.05$).

RESULTS

We collected 510 pairs of core samples among different sampling periods, years, and habitat types to estimate food resource availability and variability (Table 1). Habitat core samples identified 30 invertebrate, 1 vertebrate, and 54 seed taxa (Table S1, available online at www.onlinelibrary.wiley. com). We collected 45 upper gastrointestinal tracts from hunter-harvested black ducks and 19 from targeted late season collections. We supplemented our collections with diet information from Costanzo and Malecki (1989; $n = 40$) and B. Lewis, Southern Illinois University-Carbondale, unpublished data ($n = 50$). Our food taxa list included 13 invertebrate, 1 vertebrate, and 19 seed taxa (Table S1, available online at www.onlinelibrary.wiley.com). Because there was only a single vertebrate taxon (i.e., *Fundulus* spp.) and this item was not abundant in habitat core samples, we included it with invertebrate taxa in analyses. The largest bivalve recovered from an upper GI tract was a ribbed mussel (*Geukensia demissa*) 21.4 mm in length. Although a bivalve this size may not be indicative of the maximum consumable size, larger bivalves were abundant in core samples. Therefore, we assumed that bivalves exceeding 21.4 mm in length were not consumable. After removing items that we did not classify as black duck food from the total biomass and energy availability found in our core samples, seeds were reduced by up to 38%, and invertebrates and vertebrates up to 96% (Table 2).

We failed to detect differences in food resource availability (in terms of either biomass or energy) between years or sampling periods (Table 3). We were, however, able to detect differences in food resource availability between habitat types (Table 3). Because we did not detect differences between years and sampling periods, we combined years and sampling periods for further post hoc analysis of differences in habitat types. Post hoc tests indicated that the biomass of invertebrate and vertebrate food resources in mudflat habitat was greater than high marsh habitat ($P = 0.01$) and marginally greater than freshwater and low marsh habitats ($P = 0.06$ and $P = 0.07$, respectively). The energy of invertebrate and vertebrate food resources in mudflat habitat was greater than high marsh and freshwater habitats ($P < 0.04$) and marginally greater than low marsh habitat ($P = 0.09$). Both the biomass and energy of seed food resources in freshwater habitat was greater than all other habitat types ($P < 0.01$).

DISCUSSION

Our findings of black duck food availability in the core of their wintering range, in conjunction with DiBona (2007) and Plattner et al. (2010) further north, continue to refine the data necessary to ultimately build a spatially-explicit bioenergetics model to estimate carrying capacity along the Atlantic Flyway. Limiting our estimates to only the biomass and energy of taxa in the black duck diet made considerable reductions in the availability of resources, which we feel provides an accurate and conservative approach to estimating food resource availability.

Mudflat habitat had the greatest availability of invertebrate and vertebrate food resources whereas freshwater habitat had the greatest availability of seed food resources. Although the majority of studies modeling carrying capacity for wintering and spring migrating waterfowl focus on estimating the availability of moist soil seed and waste grain resources, >90% of the winter black duck diet is comprised of invertebrates (Costanzo and Malecki 1989). Because the greatest availability of invertebrate food resources exists on mudflat habitat, this habitat type appears to provide the bulk of food resources for black ducks wintering in southern New Jersey. In the Hackensack Meadowlands of northern New Jersey, DiBona (2007) reported mean invertebrate biomass on mudflat habitat in the range of 24–203 kg/ha. On Long Island, New York, Plattner et al. (2010) reported mean invertebrate biomass on mudflat habitat in the range of 85–1,204 kg/ha. Although our mean invertebrate and vertebrate biomass on mudflat habitat (1,516 kg/ha) exceeded estimates from both the Hackensack Meadowlands and Long Island (possibly helping to support the larger wintering population), it is important to recognize such energy densities are still below

Table 2. Estimates of resource availability and variability for wintering black duck habitat in Southern New Jersey 2006–2008 in terms of total biomass (kg/ha) and energy (kcal/ha) by habitat type as well as refined by black duck foods.

	Freshwater		High marsh		Low marsh		Mudflat		Subtidal	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Total biomass										
Invertebrate and vertebrate	25	6	1,011	346	4,365	1,344	3,318	1,472	1,469	736
Seed	442	61	34	7	35	6	36	12	58	32
Total energy										
Invertebrate and vertebrate	14,442	3,673	1,208,792	425,767	5,369,954	1,653,278	2,927,745	1,585,091	682,285	320,298
Seed	450,870	59,918	33,995	7,398	35,783	8,579	11,126	2,800	48,874	23,110
Black duck food biomass										
Invertebrate and vertebrate	12	2	81	18	163	46	1,516	898	413	338
Seed	399	58	27	5	31	5	34	12	56	36
Black duck food energy										
Invertebrate and vertebrate	6,936	1,376	95,614	24,675	242,023	70,470	1,183,090	666,283	222,683	151,185
Seed	364,121	49,505	21,090	3,234	26,490	6,877	7,659	2,033	46,399	21,565

Table 3. Summary of test statistics from analysis of variance comparing food resource availability in Southern New Jersey 2006–2008 in terms of both biomass and energy among years, sampling periods, and habitat types.

	Year[a]		Sampling period[b]		Habitat type[c]	
	F	P	F	P	F	P
Invertebrate and vertebrate biomass	1.82	0.18	0.17	0.85	3.01	0.02
Seed biomass	0.03	0.87	1.50	0.22	48.42	<0.01
Invertebrate and vertebrate energy	2.37	0.13	0.20	0.82	3.26	0.01
Seed energy	0.43	0.51	0.60	0.55	64.00	<0.01

[a] df = 1, 483.
[b] df = 2, 483.
[c] df = 4, 483.

those available to other dabbling ducks elsewhere in North America as suggested by Plattner et al. (2010).

Although we felt it important to provide estimates of food resource availability in terms of energy for the benefit of bioenergetics modeling, TME values for some important winter black ducks foods were largely nonexistent. In some cases, we were forced to use TME values from food items tested on birds from different avian orders. Determining accurate estimates of important winter foods such as fiddler crabs (*Uca* spp.), salt marsh snails (*Melampus bidentatus*), and killifish (*Fundulus* spp.) is needed. Although satisfactory for quantifying seeds and invertebrates, our habitat core sampling method was inadequate for quantifying highly mobile species such as killifish and fiddler crabs. Killifish have been found to be a critical food item in New Jersey during the winter and may be particularly crucial during periods of extensive ice cover when other foraging habitats are unavailable (Costanzo and Malecki 1989). Therefore, we encourage future research to develop methods that better estimate the food availability of these important food items.

As bioenergetic modeling of winter black duck carrying capacity moves forward, special consideration should be paid to accurately quantifying other variables in the model that may result in additional limitations to food availability. Specifically it is important to consider the possible effects of environmental stochasticity, competition, and human disturbance on the availability of food resources. First, stochastic events such as extensive ice cover have the potential to temporarily suspend the availability of food resources (Albright et al. 1983, Jorde and Owen 1988, Costanzo and Malecki 1989, Jorde et al. 1989) resulting in weight loss and winter mortality (Conroy et al. 1989, Jorde et al. 1989). Incorporating the periodicity and duration of freeze events as well as identifying foods critical to black duck survival through these resource bottlenecks should be components of bioenergetics models. Second, single species bioenergetics modeling may also come with its own suite of challenges. Although dabbling ducks sort into foraging niches (Pöysä 1986), quantifying the degree of overlap within Anatidae (and to taxonomic groups beyond) causing shared resource depletion, may prove especially challenging and have significant ramifications to extrapolating resource availability to the landscape scale. Sympatric species' concentrations and shared resource depletion may be further increased when large ice events reduce habitat availability (Pojar 1970,

Kozulin et al. 2001). Finally, human disturbance has the potential to both directly and indirectly affect the quantity of food availability. Accurate quantification of available habitat to which our estimates of food resource availability can be applied to is an essential component of carrying capacity estimation. Black ducks require habitats free from disturbance (Lewis and Garrison 1984, Morton et al. 1989*a*, Longcore et al. 2000) and disturbance may limit access to available food resources. The effects of disturbance and development may be particularly consequential along the highly developed Atlantic coastal wetlands within the core of the black ducks winter range. Further research should determine if refinement of such availability is biologically necessary for accurately representing available habitat.

MANAGEMENT IMPLICATIONS

Although mudflat habitat had the greatest availability of energy exploitable by black ducks, conservation efforts should not be limited to this habitat only, but rather as an integral component of an ecologically functioning salt marsh. Restoring full tidal exchange to formerly tidally restricted areas has the highest potential for conserving ecologically functioning salt marsh habitat along the mid-Atlantic coast. Impoundments, salt hay farms (Hinkle and Mitsch 2005), and dense stands of *Phragmites australis* (Roman et al. 1984) can be reverted to salt marsh-mudflat by removing impeding devices (e.g., tide gates and dikes; Boumans et al. 2002). Allowing full tidal exchange increases the intertidal zone, and hence, exposes a greater amount of mudflat habitat, promoting the growth of native plant communities and the invertebrate communities associated with them (Teal and Peterson 2005).

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