

## Articles

# The Food Preference Paradigm: A Review of Autumn–Winter Food Use by North American Dabbling Ducks (1900–2009)

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## Abstract

Studies describing food use (i.e., diet) of nonbreeding dabbling ducks *Anas* spp. are essential to understanding physiological needs of and recommending habitat management for these birds. We conducted a review of published autumn and winter food-use studies of dabbling ducks in North America to characterize the current state of knowledge and identify remaining research needs. We initiated our review to determine whether valuations of duck foods and the term “preference” commonly used by researchers and in waterfowl management guides (i.e., the food preference paradigm) were supported by available peer-reviewed literature. We analyzed peer-reviewed literature (1900–2009) on autumn–winter food use of dabbling ducks ( $n = 59$  studies). Most studies (68%) used methods known to contain substantial bias including data from gizzards and hunter-collected ducks. Only 5% of published articles reliably determined food selection by concurrently measuring food use and availability, and no study determined food use at a scale appropriate for winter home ranges of dabbling ducks. In some habitats commonly managed for waterfowl (e.g., agricultural lands), few if any collections of ducks are available to obtain data on food use. The limited geographic and habitat scope of unbiased food use and selection studies for dabbling ducks during autumn and winter suggests that the food-preference paradigm found in waterfowl management literature is not supported by empirical evidence and that managers must continue to use best judgment in managing foraging habitats for waterfowl. Researchers and conservation planners should aim to reduce uncertainty regarding the value of waterfowl foods by conducting contemporary food-selection studies using unbiased collection and processing methodologies. Further, we suggest future researchers conduct concurrent behavioral observations, habitat use, and food selection studies within winter home ranges of dabbling ducks to aid managers in meeting the nutritional requirements of dabbling ducks during autumn and winter in North America.

Keywords: dabbling ducks; diet; feeding ecology; food habits; food use; gizzard

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## Introduction

Food-use studies are useful in understanding basic ecology of animals and essential in determining food habits, feeding ecology, and energy budgets of waterfowl (Bartonek and Hickey 1969; Cornelius 1977; Baldassarre and Bolen 2006; Legagneux et al. 2007). Further, effective

management of waterfowl habitat depends on reliable information on food use and selection (Reinecke et al. 1989; Havera 1999; Bolen 2000). Land managers at migration stopovers and in wintering regions often create and manipulate foraging habitat for nonbreeding waterfowl to meet conservation goals consistent with the current state of knowledge of waterfowl food use



(Reinecke et al. 1989; Kross et al. 2008). Habitat management guidelines often encourage managers to produce high-energy foods (Nassar et al. 1993; Lane and Jensen 1999; Strader and Stinson 2005; Nelms 2007); however, true metabolizable energy of most waterfowl foods and selection tendencies of most species are unknown (Fredrickson and Taylor 1982; Dugger et al. 2007).

Avian botulism, lead poisoning, and other diseases prompted scientists to begin investigating waterfowl food use in the early–mid–1900s (Bolen 2000). Since that time, literature on food use has accumulated, but collection and processing methods may not have reliably or accurately characterized diets of dabbling ducks prior to important findings of Swanson and Bartonek (1970) and Sheeley and Smith (1989), who reported biases associated with using gizzard samples and hunter-collected ducks, respectively. Unbiased understanding of waterfowl food use and selection are necessary to accurately estimate and model ecological carrying capacity and predict food depletion (NAWMP 2007; NSST 2007; Greer et al. 2009). Joint Ventures, partnerships established under the North American Waterfowl Management Plan (NAWMP) to help conserve the continent's waterfowl populations and habitats, require reliable information on food selection by waterfowl (especially dabbling ducks) to accurately estimate the carrying capacities of landscapes and recommend efficient habitat conservation strategies (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986; Loesch et al. 1994). Herein, we describe the evolution in methodologies used and evaluate the extent of unbiased information available to conservation planners and habitat managers regarding autumn–winter food use and selection by dabbling ducks.

We assessed the current state of knowledge regarding food use and selection of autumn migrating and wintering migratory dabbling ducks (*Anas* spp.; i.e., excluding mottled ducks *A. fulvigula*) in North America. We reviewed information on dabbling ducks because this taxon is often a focus of habitat conservation initiatives (e.g., NAWMP, Wetlands Reserve Program, Migratory Bird Habitat Initiative) and food resources are considered a limiting factor during the nonbreeding season (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986; Loesch et al. 1994; Wilson and Esslinger 2002; Baldassarre and Bolen 2006; NAWMP 2007). We initiated our review because we observed habitat managers, conservation planners, and waterfowl scientists making value judgments of individual plant taxa (e.g., beneficial, important, undesirable, preferred) eaten by waterfowl, but seldom was empirical evidence presented to support such claims (i.e., the food preference paradigm [e.g., Fredrickson and Taylor 1982; Nassar et al. 1993; Lane and Jensen 1999; Miller and Miller 2005; Strader and Stinson 2005; Nelms 2007; IWMM 2010]). Literature on food use by waterfowl often refers to “preferred” foods of dabbling ducks (Forsyth 1965; Allen 1980; Paulus 1982; Tietje and Teer 1996), although few studies have determined preference as defined by Johnson (1980; see Barras et al. 1996). Inclusion of plant taxa avoided or failure to include taxa readily consumed by nonbreeding dabbling ducks could bias carrying capacity models found in planning docu-

ments and may result in inadequate habitat conservation or inefficient allocation of funding (Hagy 2010). We conclude with recommendations aimed at improving our understanding of feeding ecology of dabbling ducks during autumn–winter and better equipping conservation planners (e.g., Joint Ventures) responsible for determining foraging habitat needs of nonbreeding dabbling ducks.

## Methods

We conducted an extensive search of peer-reviewed, published literature to obtain all available food-use studies of autumn migrating and wintering dabbling ducks in North America, 1900–2009. We used popular waterfowl ecology texts (Bellrose 1980; Havera 1999; Baldassarre and Bolen 2006), journal databases, The Birds of North America series, and contacted colleagues to obtain all available published autumn–winter food-use studies (Table 1). We identified, reviewed, and quantified food-use studies by species, habitat type, frequency of studies (1900–2009), specimen collection methodology (i.e., hunter or experimental), and diet analysis methodology (i.e., proventriculus–esophagus or gizzard). We did not conduct meta-analyses because there were not a sufficient number of studies that had been conducted in similar habitats and regions to test for differences between food use studies pre- and postpublication of methodology biases (Swanson and Bartonek 1970; Sheeley and Smith 1989).

We used information from literature sources to build a matrix of study frequency by species and general habitat type to describe available food-use literature and identify research needs (Table 2; also see *Supplemental Material*, Table S1; <http://dx.doi.org/10.3996/102010-JFWM-038.S1>). We classified study habitats as “not identifiable” if we could not interpret the habitat type where ducks were collected or food types eaten by ducks from study site descriptions or methodology (see Table S1; <http://dx.doi.org/10.3996/102010-JFWM-038.S1>). For example, many published articles prior to 1980 did not describe the specific habitat where ducks were collected and often combined all food items from multiple species of ducks into a single table, resulting in unidentifiable habitat and food types. We categorized the method of diet analysis as crop (proventriculus–esophagus), gizzard, or both (crop and gizzard) and method of duck collection as either hunter or experimental (i.e., collection of actively foraging birds; Sheeley and Smith 1989) used in each publication and plotted frequency of each type of food-use study by decade. We calculated simple descriptive statistics to describe the change in study frequency over time and quantified the proportion of studies according to methodology. Lastly, when possible, we determined the relative scale at which studies were conducted (e.g., wetland, wetland complex, or winter home-range scales).

We searched websites of state, federal, and nonprofit natural resource agencies to identify and obtain management guides for autumn–winter waterfowl habitat to compare valuation of plant taxa with empirical evidence in autumn–winter food-use studies (Fredrickson and Taylor 1982; Nassar et al. 1993; Smith et al. 1994; Lane and Jensen 1999; Nelms 2001, 2007; Strader and Stinson



2005). We deemed a “valuation” made if language described a taxon’s value for waterfowl forage (e.g., good, desirable, excellent, exceptional, substantive, important, none, little, fair), but not if guides used language indicating only that waterfowl used taxa for food (e.g., “readily consumed,” “often occurred in diets”). We identified plant taxa in food-use studies that used unbiased methodologies to assess availability of empirical evidence for food selection (*sensu* Johnson 1980) by dabbling ducks during autumn–winter (Miller 1987; McKnight and Hepp 1998; Anderson et al. 2000). We calculated simple descriptive statistics to compare the number of plant taxa with valuations as waterfowl forage in management guides to taxa reported in food-use studies with unbiased methodology.

## Results

We obtained and reviewed 59 studies of dabbling-duck food use and identified 6 studies that investigated food selection (10% [Stoudt 1944; Miller 1987; Rollo and Bolen 1987; Tietje and Teer 1996; McKnight and Hepp 1998; Anderson et al. 2000]), 8 studies that made reference to food availability in the discussion (combined 24% [Dillon 1959; Conrad 1965; McGilvrey 1966; Landers et al. 1976; Allen 1980; Paulus 1982; Swiderek et al. 1988; Ballard et al. 2004]), and no studies that investigated food use or selection at scales likely used as home ranges by wintering dabbling ducks. We identified three studies (5%) that tested for food selection by experimentally collecting ducks, used only crop contents in analyses, and concurrently measured food availability (Miller 1987; McKnight and Hepp 1998; Anderson et al. 2000). We also noted a reduction in the use of gizzard samples from 1970 to 1990, following recommendations of Swanson and Bartonek (1970). From 1980 to 1989, 33% of food-use studies contained gizzard samples, whereas 9% did after 1990 (Figure 1).

We were not able to categorize habitat type for a large portion of food-use studies (42%; Table 2). Although we found many studies where ducks had consumed waste grain, no studies presented food use of ducks specifically collected from dry, harvested agricultural fields and only one study reported collecting one species in flooded agricultural fields (i.e., northern pintail *Anas acuta*; Miller 1987). Ducks collected in moist-soil wetlands included mallard *A. platyrhynchos*, gadwall *A. strepera*, northern pintail, cinnamon teal *A. cyanoptera*, blue-winged teal *A. discors*, and American green-winged teal *A. crecca*, but not American black ducks *A. rubripes*, American wigeon *A. americana*, or northern shoveler *A. clypeata*. Within emergent wetlands, food-use studies have been conducted for all ducks except cinnamon teal. Food-use studies of ducks collected in forested wetlands were common for mallards but lacking for American black duck, gadwall, American wigeon, northern shoveler, and green-winged teal. The majority of food-use studies within lacustrine habitats reported results only for gadwall, but also included mallard and a single diet study of northern shoveler foraging in manmade livestock-watering ponds and river oxbows. The food use of all dabbling duck species have been studied at

least once in saltwater habitats (i.e., coastal marshes, tidal flats, and estuaries), but not throughout the extent of their range in saltwater marshes.

We identified seven waterfowl-habitat management guides apparently available and used to guide waterfowl management activities. Guides described 177 different plant taxa using value terminology (e.g., good, desirable, excellent, exceptional, substantive, important, no, little, fair). We found that 24 plant taxa were described as selected or avoided in the three studies that appropriately tested for selection and used unbiased collection methodologies (Miller 1987; McKnight and Hepp 1998; Anderson et al. 2000). Twenty-one taxa of plant seeds and other parts were selected during some time period in autumn–winter, while three species were consistently avoided by dabbling ducks. However, two taxa were avoided when management guides indicated they were beneficial to waterfowl and one taxon was avoided when management guides indicated both positive and negative value. Thus, waterfowl management guides identify and value 20 of 177 taxa present in guides (11%). Overall, 89% of plant taxa judged by their quality as waterfowl foods in management guides have not been investigated in food selection or preference studies using unbiased methodologies.

## Discussion

### History and evolution of autumn–winter diet studies

McAtee (1918) and Mabbott (1920) pioneered research describing waterfowl food use, including mallard, American black duck, gadwall, American wigeon, northern pintail, cinnamon teal, blue-winged teal, and American green-winged teal diets. However, nearly 20 y lapsed before Martin and Uhler (1939) published “Food of Game Ducks in the United States and Canada” describing an analysis of approximately 8,000 duck diets. Unfortunately, characteristic of many early food-use studies, this early literature failed to report species-specific diets and food availability where ducks were obtained. These publications remained the few sources of waterfowl diet information until the 1950s, a lapse likely due to the Great Depression and World War II (McAtee 1922; Bolen 2000). Frequency of autumn–winter food-use studies of dabbling ducks increased in the 1950s, but subsequently declined for the following two decades (Figure 1). This decline coincided with increasing research of breeding waterfowl, including initiation of the Waterfowl Breeding Population Survey by the Fish and Wildlife Service in 1955 (predecessor to the U.S. Fish and Wildlife Service, which was established in 1956; Baldassarre and Bolen 2006). Growing evidence in the 1960s and 1970s suggested that conditions during the nonbreeding season might limit waterfowl populations (Lack 1966; White and James 1978; Fredrickson and Drobney 1979). Renewed interest in ecology and management of nonbreeding waterfowl resulted in a workshop held at Gaylord Memorial Laboratory in Missouri and culminated with a publication that outlined information needs for wintering waterfowl (Anderson and Batt 1983; Weller 1988). Subsequently, the number of food-use studies



**Table 1.** Sources used to develop the matrix of food-habits studies of North American dabbling ducks (*Anas* spp.) and diet analysis technique(s)<sup>b</sup> of each study<sup>a</sup>. (Table continued on next page.)

Source <sup>b</sup>	Author(s)	Year	Diet analysis technique <sup>c</sup>
1	McAtee	1918	Both
2	Mabbott	1920	Both
3	McAtee	1922	Both
4	Martin and Uhler	1939	Both
5	Stoudt	1944	Both
6	Schoffman	1947	Both
7	Mendall	1949	Both
8	Yocom	1951	Gizzard
9	Wingard	1952	Gizzard
10	Dillon	1957	Both
11	Gates	1957	Gizzard
12	Anderson	1959	Gizzard
13	Chamberlain	1959	Gizzard
14	Dillon	1959	Both
15	Kimble and Ensminger	1959	Gizzard
16	Wright	1959	Crop
17	Yocom and Keller	1961	Gizzard
18	Glasgow and Bardwell	1962	Crop
19	Glasgow and Junca	1962	Crop
20	Hall	1962	Both
21	Junca et al.	1962	Crop
22	Quay and Critcher	1962	Gizzard
23	Hartman	1963	Gizzard
24	Conrad	1965	Gizzard
25	Forsyth	1965	Crop
26	McGilvrey	1966	Gizzard
27	Rollo and Bolen	1969	Both
28	McMahan	1970	Both
29	Kerwin and Webb	1971	Gizzard
30	Wills	1971	Both
31	Landers et al.	1976	Both
32	Prevost et al.	1978	Both
33	Sell	1979	Crop
34	Allen	1980	Both
35	Connelly and Chesemore	1980	Crop
36	Perry and Uhler	1981	Gizzard
37	Paulus	1982	Crop
38	Jorde et al.	1983	Crop
39	Tabatabai et al.	1983	Gizzard
40	Delnicki and Reinecke	1986	Crop
41	Euliss and Harris	1987	Crop
42	Miller	1987	Crop
43	Swiderek et al.	1988	Both
44	Sheeley and Smith	1989	Crop
45	Gruenhagen and Fredrickson	1990	Crop
46	Euliss et al.	1991	Crop
47	Thompson et al.	1992	Crop
48	Migoya and Baldassarre	1993	Crop
49	Combs and Fredrickson	1996	Crop
50	Tietje and Teer	1996	Crop

**Table 1.** Continued.

Source <sup>b</sup>	Author(s)	Year	Diet analysis technique <sup>c</sup>
51	McKnight and Hepp	1998	Crop
52	Anderson et al.	2000	Crop
53	Dabbert and Martin	2000	Crop
54	Miller et al.	2000	Crop
55	Ballard et al.	2004	Crop
56	Wersal et al.	2005	Gizzard
57	Miller et al.	2009	Crop

<sup>a</sup> Stollberg (1950) and Singleton (1951) could not be included in Table 2 because duck species were not identified.

<sup>b</sup> Source numbers used in *Supplemental Material*, Table S1 (<http://dx.doi.org/10.3996/102010-JFWM-038.S1>).

<sup>c</sup> "Both" includes food items from proventriculus, esophagus, and gizzard; "Crop" includes food items from proventriculus and esophagus.

increased during the 1980s (Weller and Batt 1988), but then declined from the 1980s to present (Figure 1).

Several studies identified significant biases associated with collection and processing methodologies during the two ebbs in publication frequency (i.e., 1950s–1970s and 1980s–2000s; [Swanson and Bartonek 1970; Swanson et al. 1974; Sheeley and Smith 1989]). By the 1970s, scientists had advanced from the use of gizzard samples toward nearly exclusive use of proventriculus and esophageal samples (Swanson and Bartonek 1970). Swanson and Bartonek (1970) also suggested a bias in the analysis of hunter-collected waterfowl, but a change from these diet samples toward experimental collections did not occur until after the description of collection-method bias described by Sheeley and Smith (1989). Prior to Sheeley and Smith (1989), food-use studies often presented biased food-use data resulting from inclusion of gizzard samples and hunter- or nonexperimentally collected ducks. After 1989, 83% of studies report data from experimentally collected foraging ducks, thus reducing biased information of autumn–winter dabbling

duck food use. However, the biased literature before 1990 coupled with the recent decline in food-use studies could impact the ability of waterfowl managers to use available literature to adequately guide science-based management of food resources for waterfowl.

**Present state of food-use literature**

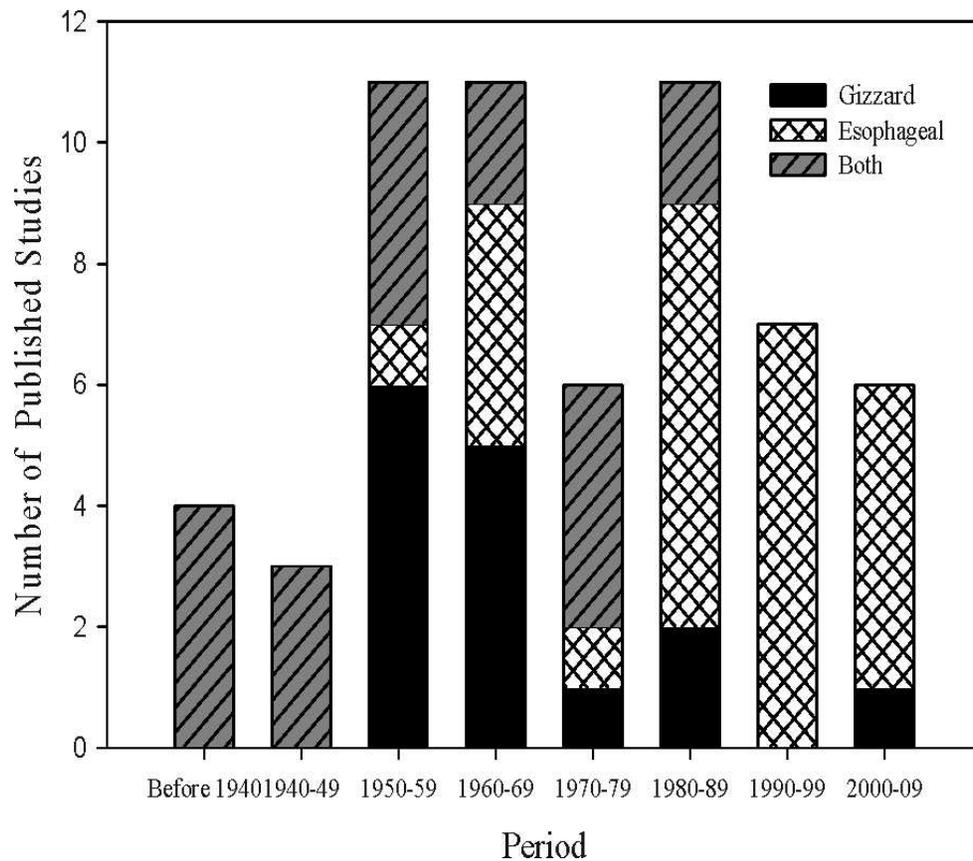
We identified only six studies that investigated food selection (Bellrose and Anderson 1943; Johnson 1980), an additional eight that discussed food availability compared to food use, and none that investigated foraging rates or food use of ducks at scales used by dabbling ducks in autumn and winter. In some cases, we continue to lack even baseline data on food use within managed habitats (e.g., dry and flooded agricultural fields) even though it is widely acknowledged that waterfowl feed extensively within these habitats (Bellrose 1980; Baldassarre and Bolen 1984; Ringelman 1990). The lack of unbiased food-use data for northern pintail in the Mississippi Alluvial Valley and American black ducks in the eastern United States was surprising, because both

**Table 2.** Frequency of food-use studies of North American dabbling ducks *Anas* spp. by species<sup>a</sup> (*n*) and foraging habitat type(s)<sup>b</sup> where ducks were sampled during autumn and winter, 1900–2009.

Species ( <i>n</i> )	Habitat type							
	Dry agriculture	Flooded agriculture	Moist soil	Emergent	Forested	Lacustrine	Salt	Not identifiable
MALL (36)	—	—	3	6	3	1	5	20
ABDU (12)	—	—	—	3	—	—	4	7
GADW (15)	—	—	1	2	—	1	2	9
NOPI (29)	—	1	5	4	—	1	9	11
AMWI (18)	—	—	—	3	—	—	3	12
NSHO (15)	—	—	—	2	—	2	4	8
CITE (4)	—	—	1	—	—	—	1	2
BWTE (16)	—	—	3	3	—	—	3	7
AGWT (22)	—	—	5	5	—	—	6	9

<sup>a</sup> MALL (mallard: *Anas platyrhynchos*), ABDU (American black duck: *A. rubripes*), GADW (gadwall: *A. strepera*), NOPI (northern pintail: *A. acuta*), AMWI (American wigeon: *A. americana*), NSHO (northern shoveler: *A. clypeata*), CITE (cinnamon teal: *A. cyanoptera*), AGWT (American green-winged teal: *A. crecca*), BWTE (blue-winged teal: *A. discors*).

<sup>b</sup> Habitat types defined as: Dry agriculture = harvested agricultural grain field that is not flooded; Flooded agricultural = harvested or unharvested agricultural grain field that is flooded either naturally or using manmade levees; Moist soil = seasonally flooded shallow manmade impoundments, river mudflat margins, and playa wetlands; Emergent = permanently flooded shallow water with emergent aquatic vegetation present; Forested = seasonally flooded bottomland hardwood forests and green-tree reservoirs; Lacustrine = permanently flooded open-water reservoirs, agricultural ponds, industry ponds, and large lakes that may or may not contain emergent vegetation; Salt = saline to brackish wetlands, tidal flats, and estuaries; Not identifiable = the habitat type could not be categorized from study site descriptions.



**Figure 1.** Frequency of food-use studies by decade and diet analysis methodology of North American dabbling ducks *Anas* spp. during autumn and winter, 1900–2009.

species have experienced long-term declines (Zimpfer et al. 2009). American black ducks commonly use forested wetlands and agricultural habitats (Bellrose 1980; Lewis and Nelson 1988; Madge and Burn 1988; Morton et al. 1989; Snyder 1993); however, no studies report food use or measure food selection in these habitats. Furthermore, winter flooding of agricultural fields, primarily rice, has been designated as a primary habitat provision strategy in wintering regions, but only one study has assessed northern pintail food use in rice fields (Loesch et al. 1994; Wilson and Esslinger 2002; CVJV 2006). These examples highlight our concern that habitat management and enhancement has preceded basic assessment of dabbling duck food use and selection.

We caution scientists and managers against assessing selection or preference of dabbling duck foods using literature published prior to the 1990s, most of which used hunter-collected ducks and gizzard samples to describe food use of dabbling ducks during autumn and winter. Our investigation of peer-reviewed literature indicates that reliable, unbiased information describing food selection and preference of dabbling ducks in autumn–winter in North America is lacking (sensu Johnson 1980; Sheeley and Smith 1989). Currently the majority of information on dabbling duck food selection and preference comes from the opinions of waterfowl managers and other professionals (see Dugger et al. 2007; Fleming 2010: 29–33). Recently published food-use

studies (i.e., post–1990) have supplemented and replaced some biased information gathered in previous decades, but our review suggests that these efforts have failed to provide a sufficient baseline of waterfowl food use, selection, or preference in many wintering and migration habitats for most species of dabbling ducks. Thus, waterfowl habitat managers and conservation planners are still required to use best judgments in writing management plans and assessing food values for waterfowl (Nassar et al. 1993; Lane and Jensen 1999; Miller and Miller 2005; Strader and Stinson 2005; Nelms 2007).

### The food preference paradigm

Valuations of plant taxa as foods for dabbling ducks are common in waterfowl habitat management guides. However, our review identified that 89% of plant taxa prescribed values in management guides have not been investigated in food selection or preference studies using unbiased methodology. Furthermore, we believe that other methods of justifying food values such as true metabolizable energy and results of previous studies that used biased methodologies do not supply sufficient evidence alone to support current food valuations in management guides and the waterfowl management community (Checkett et al. 2002; Kaminski et al. 2003; Dugger et al. 2007). Food selection may depend on many factors (van Eerden and Munsterman 1997; Gurd 2006)

and should be evaluated using unbiased methodologies at scales used by wintering dabbling ducks (Manly et al. 2002). Thus, we believe that clear evidence of the food preference paradigm in waterfowl management literature exists.

Early management guides used available information and expert opinion to classify plant taxa based on the potential to provide habitat, energy, or nutritive requirements (e.g., Fredrickson and Taylor 1982). Previously, unbiased diet studies were not available to provide empirical evidence of food selection; thus, value judgments of plant taxa were necessary. However, more recent management guides continue to make similar value judgments and only three food-use studies have provided empirical evidence of food selection by dabbling ducks. Given the decline in food-use study frequency and the current paucity of unbiased food-use and selection studies, habitat managers must continue to use best judgment in managing waterfowl habitats in winter. Researchers and conservation planners should aim to reduce uncertainty regarding the value of waterfowl foods by conducting food selection studies in major foraging habitats used by dabbling ducks throughout autumn and winter. We are not suggesting that current management of food resources by managers is incorrect, but rather that the current understanding of food resource use and selection by ducks contains significant information gaps and the use of the terms valuing foods in planning documents lack empirical support.

Dabbling ducks use a complex of habitats for feeding and other activities during winter, but diet analyses normally involved collection at a subsample of habitats (Dwyer et al. 1979; Ringelman et al. 1982; Fredrickson and Heitmeyer 1988; Fredrickson and Reid 1988; Baldassarre and Bolen 2006; Pearse 2007). Thus, management strategies would benefit from unbiased research on food availability and selection throughout the autumn and winter home ranges of dabbling ducks. Currently, there is insufficient information to characterize winter home ranges of dabbling ducks for all species and regions, and habitat selection depends on many factors (Moon and Haukos 2006; Fleskes et al. 2007; Davis et al. 2009). Only recently have scientists begun to quantify how waterfowl use multiple habitats within their winter home range to meet energy and fitness demands during winter (i.e., habitat complex). However, food habitat studies have not yet been published that examine food availability and waterfowl use in multiple habitats used by wintering dabbling ducks as a winter habitat complex. However, Pearse (2007) recently quantified composition of habitats most often used by wintering dabbling ducks in the Mississippi Alluvial Valley, which was an appropriate first step in describing winter home ranges of dabbling ducks. Future and ongoing habitat use and selection studies combined with descriptions of composition of winter complexes should guide researchers in selecting appropriate scales at which to sample foods and determine selection. We suggest that coordinated efforts by several researchers, facilitated through Joint Ventures and Landscape Conservation Cooperatives (i.e.,

conservation partnerships created through the Department of Interior; <http://www.fws.gov/science/shc/lcc.html>), could adequately and concurrently collect these data to benefit management strategies. Contemporary, unbiased food-use studies conducted in winter habitat complexes are essential for efficient allocation of funds and management efforts to conserve waterfowl habitats at a geographic scale used by wintering dabbling ducks.

Conservation planning documents often request review and refinement of assumptions and management approaches to strengthen the biological foundations used to derive regional habitat goals (CVJV 2006; NAWMP 2007: 66; ACJV 2009). However, without extensive, unbiased food-use data, assumptions and goals for nonbreeding waterfowl cannot be adequately addressed (NAWMP 2007). For example, food is considered limiting in most wintering regions and flooding of additional agricultural habitats has been targeted to mitigate low levels of food (Loesch et al. 1994; CVJV 2006; NAWMP 2007). However, few studies document food use in agricultural habitats and recent research indicated that waste grains were not an abundant or reliable source of food at southern latitudes (Stafford et al. 2006; Foster et al. 2010; Miller et al. 2010). Further, dabbling ducks often continue to forage in areas even when "preferred" foods are depleted below thresholds considered energetically profitable (van Gils et al. 2004; Havens et al. 2009; Hagy 2010), but the current lack of reliable information on food selection and preference precludes a reliable explanation for this foraging behavior. Furthermore, food selection may be dependent on current physiological requirements of ducks and future researchers should consider body condition of dabbling ducks when characterizing food use and selection (Fredrickson and Drobney 1979; Heitmeyer 2006; Fleskes et al. 2007; Morris and Mukherjee 2007). Without concurrent food-use data, full interpretation of food availability results are not possible and accurate management recommendations and habitat goals are difficult to develop.

### Management Implications

We encourage researchers conducting food availability and habitat suitability studies on nonbreeding dabbling ducks to incorporate experimental collection of specimens into methodology to address the current lack of unbiased food-use and selection information. Further, continued evaluation of dabbling duck food use and selection are essential to understand how climate and land-use change, genetic modification of crops, and introduction and range expansions of nonnative species affect foraging ecology of nonbreeding waterfowl (Nichols et al. 1995; Krapu et al. 2004). We recommend a multiscale approach, including 1) satellite- or radiotelemetry-monitored ducks to measure real-time habitat use and better characterize migration and winter home ranges, 2) determination of food use and selection by experimental collection of foraging ducks along with measurement of available food resources within specific habitat types, 3) focal observations of ducks in foraging



habitats to determine time spent foraging compared to food composition and abundance, and 4) implementation of stochastic spatial depletion models to better estimate food availability and carrying capacity in a variety of habitats and regions encountered during nonbreeding periods (van Gils et al. 2004; Hagy 2010). Results of new food-use studies could provide managers with the necessary information to evaluate food selection assumptions and strengthen the biological foundations used to develop landscape-scale management and strategic plans (e.g., Joint Venture scale, Landscape Conservation Cooperatives). A multistage sampling approach will assist researchers in determining the scale at which ducks select foods and how selected foods compare with others on the landscape (Manly et al. 2002: 7). We suggest that future researchers collaborate through Joint Ventures and Landscape Conservation Cooperatives to strategically implement habitat selection and food selection studies using contemporary methods to assess resource selection (Manly et al. 2002; Long et al. 2009).

### Supplemental Material

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**Table S1.** Food-use studies<sup>a</sup> of North American dabbling ducks (*Anas* spp.) by species<sup>b</sup> (*n*), food type(s) consumed<sup>c</sup>, and foraging habitat type(s)<sup>d</sup> where ducks were sampled during autumn and winters, 1900–2009.

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### References

- Allen CE. 1980. Feeding habits of ducks in a green-tree reservoir in eastern Texas. *Journal of Wildlife Management* 44:232–236.
- Anderson HG. 1959. Food habits of migratory ducks in Illinois. *Illinois Natural History Survey Bulletin* 27:289–344.
- Anderson JT, Smith LM, Haukos DA. 2000. Food selection and feather molt by nonbreeding American green-winged teal in Texas playas. *Journal of Wildlife Management* 64:222–230.
- Anderson MG, Batt BDJ. 1983. Workshop on the ecology of wintering waterfowl. *Wildlife Society Bulletin* 11:22–24.
- [ACJV] Atlantic Coast Joint Venture. 2009. Atlantic Coast Joint Venture strategic plan. Hadley, Massachusetts: U.S. Fish and Wildlife Service. Available: [http://acjv.org/documents/ACJV\\_StrategicPlan\\_2009update\\_final.pdf](http://acjv.org/documents/ACJV_StrategicPlan_2009update_final.pdf) (March 2011).
- Baldassarre GA, Bolen EG. 1984. Field feeding ecology of waterfowl wintering on the southern high plains of Texas. *Journal of Wildlife Management* 48:63–71.
- Baldassarre GA, Bolen EG. 2006. *Waterfowl ecology and management*. 2nd edition. Malabar, Florida: Krieger.
- Ballard BM, Thompson JE, Petrie MJ, Checkett M, Hewitt DG. 2004. Diet and nutrition of northern pintails wintering along the southern coast of Texas. *Journal of Wildlife Management* 68:371–382.
- Barras SC, Kaminski RM, Brennan LA. 1996. Acorn selection by female wood ducks. *Journal of Wildlife Management* 60:592–602.
- Bartonek JC, Hickey JJ. 1969. Food habits of canvasbacks, redheads, and lesser scaup in Manitoba. *Condor* 71: 280–290.
- Bellrose FC. 1980. *Ducks, geese and swans of North America*. Harrisburg, Pennsylvania: Stackpole.
- Bellrose FC, Anderson HG. 1943. Preferential rating of duck food plants. *Illinois Natural History Survey Bulletin* 22:417–433.
- Bolen EG. 2000. Waterfowl management: yesterday and tomorrow. *Journal of Wildlife Management* 64:323–335.
- Canadian Wildlife Service and U.S. Fish and Wildlife Service. 1986. North American waterfowl management plan. Washington, D.C: Canadian Wildlife Service and U.S. Fish and Wildlife Service. Available: <http://www.fws.gov/birdhabitat/NAWMP/files/NAWMP.pdf> (March 2011).
- [CVJV] Central Valley Joint Venture. 2006. Central Valley Joint Venture implementation plan—conserving bird habitat. Sacramento, California: U.S. Fish and Wildlife Service.
- Chamberlain JL. 1959. Gulf Coast marsh vegetation as food of wintering waterfowl. *Journal of Wildlife Management* 23:97–10.
- Checkett JM, Drobney RD, Petrie MJ, Graber DA. 2002. True metabolizable energy of moist-soil seeds. *Wildlife Society Bulletin* 30:1113–1119.
- Combs DL, Fredrickson LH. 1996. Foods used by male mallards wintering in southeastern Missouri. *Journal of Wildlife Management* 60:603–610.
- Connelly DP, Chesemore DL. 1980. Food habits of pintails (*Anas acuta*) wintering on seasonally flooded wetlands in the northern San Joaquin Valley, California. *California Fish and Game* 66:223–237.
- Conrad WB Jr. 1965. A food habits study of ducks wintering on the lower Pee Dee and Waccamaw Rivers, Georgetown, South Carolina. *Proceedings of the Annual Conference of Southeastern Association of Game and Fish Commissioners* 19:93–98.
- Cornelius SE. 1977. Food and resource utilization by wintering redheads on lower Laguna Madre. *Journal of Wildlife Management* 41:374–385.



- Dabbert CB, Martin TE. 2000. Diet of mallards wintering in greentree reservoirs in southeastern Arkansas. *Journal of Field Ornithology* 71:423–428.
- Davis BE, Afton AD, Cox RR Jr. 2009. Habitat use by female mallards in the lower Mississippi Alluvial Valley. *Journal of Wildlife Management* 73:701–709.
- Delnicki D, Reinecke KJ. 1986. Mid-winter food use and body weights of mallards and wood ducks in Mississippi. *Journal of Wildlife Management* 50:43–51.
- Dillon OW. 1957. Food habits of wild ducks in the rice-marsh transition area of Louisiana. *Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners* 12:114–119.
- Dillon OW. 1959. Food habits of wild mallard ducks in three Louisiana parishes. *Transactions of the North American Wildlife and Natural Resources Conference* 24:374–382.
- Dugger BD, Moore ML, Finger RS, Petrie MJ. 2007. True metabolizable energy for seeds of common moist-soil plant species. *Journal of Wildlife Management* 71:1964–1967.
- Dwyer TJ, Krapu GL, Janke DM. 1979. Use of prairie pothole habitat by breeding mallards. *Journal of Wildlife Management* 43:526–531.
- Euliss NH, Harris SW. 1987. Feeding ecology of northern pintails and green-winged teal wintering in California. *Journal of Wildlife Management* 51:724–732.
- Euliss NH, Jarvis RL, Gilmer DS. 1991. Feeding ecology of waterfowl wintering on evaporation ponds in California. *Condor* 93:582–590.
- Fleming KS. 2010. Effects of management and hydrology on vegetation, winter waterbird use, and water quality on Wetlands Reserve Program lands, Mississippi. Master's thesis. Mississippi State: Mississippi State University.
- Fleskes JP, Yee JL, Yarris GS, Miller MR, Casazza ML. 2007. Pintail and mallard survival in California relative to habitat, abundance, and hunting. *Journal of Wildlife Management* 71:2238–2248.
- Forsyth B. 1965. December food habits of the mallard (*Anas platyrhynchos* Linn.) in the Grand Prairie of Arkansas. *Proceedings of the Arkansas Academy of Science* 19:74–78.
- Foster MA, Gray MJ, Kaminski RM. 2010. Agricultural seed biomass for migrating and wintering waterfowl in the southeastern United States. *Journal of Wildlife Management* 74:489–495.
- Fredrickson LH, Drobney RD. 1979. Habitat utilization by postbreeding waterfowl. Pages 119–131 in Bookhout TA, editor. *Waterfowl and wetlands—an integrated review*. La Crosse, Wisconsin: La Crosse Printing.
- Fredrickson LH, Heitmeyer ME. 1988. Waterfowl use of forested wetlands of the southern United States: an overview. Pages 307–323 in Weller MW, editor. *Waterfowl in winter*. Minneapolis, Minnesota: University of Minnesota Press.
- Fredrickson LH, Reid FA. 1988. Waterfowl use of wetland complexes. Leaflet 13.2.1 in Cross DH, editor. *Waterfowl management handbook*. Washington, D.C.: U.S. Fish and Wildlife Service. Available: [http://www.nwrc.usgs.gov/wdb/pub/wmh/13\\_2\\_1.pdf](http://www.nwrc.usgs.gov/wdb/pub/wmh/13_2_1.pdf) (March 2011).
- Fredrickson LH, Taylor TS. 1982. *Management of seasonally flooded impoundments for wildlife*. Washington, D.C.: U.S. Fish and Wildlife Service Publication 148.
- Gates JM. 1957. Autumn food habits of the gadwall in northern Utah. *Proceedings of the Utah Academy of Arts, Letters, and Science* 34:69–71.
- Glasgow LL, Bardwell JL. 1962. Pintail and teal foods in south Louisiana. *Proceedings of the Annual Conference of Southeast Association of Game and Fish Commissioners* 16:175–184.
- Glasgow LL, Junca HA. 1962. Mallard foods in southwest Louisiana. *Proceedings of the Louisiana Academy of Science* 25:63–74.
- Greer DG, Dugger BD, Reinecke KJ, Petrie MJ. 2009. Depletion of rice as food of waterfowl wintering in the Mississippi Alluvial Valley. *Journal of Wildlife Management* 73:1125–1133.
- Gruenhagen NM, Fredrickson LH. 1990. Food use by migratory female mallards in northwest Missouri. *Journal of Wildlife Management* 54:622–626.
- Gurd DB. 2006. Filter-feeding dabbling ducks (*Anas* spp.) can actively select particles by size. *Zoology* 109:120–126.
- Hagy HM. 2010. Winter food and waterfowl dynamics in managed moist-soil wetlands in the Mississippi Alluvial Valley. Doctoral dissertation. Mississippi State: Mississippi State University.
- Hall DL. 1962. Food utilization by waterfowl in green timber reservoirs at Noxubee National Wildlife Refuge. *Proceedings of the Annual Conference of Southeast Association of Game and Fish Commissioners* 16:184–189.
- Hartman FE. 1963. Estuarine wintering habitat for black ducks. *Journal of Wildlife Management* 27:339–347.
- Havens JH, Kaminski RM, Davis JB, Riffell SK. 2009. Winter abundance of waterfowl and waste rice in managed Arkansas rice fields. *Proceedings of the Annual Conference of Southeast Association of Fish and Wildlife Agencies* 63:41–46.
- Havera SP. 1999. *Waterfowl of Illinois: status and management*. Urbana, Illinois: Illinois Natural History Survey Special Publication 21.
- Heitmeyer ME. 2006. The importance of winter floods to mallards in the Mississippi Alluvial Valley. *Journal of Wildlife Management* 70:101–110.
- [IWMM] Integrated Waterbird Management and Monitoring Program. 2010. *Integrated waterbird management and monitoring program of the Atlantic and Mississippi Flyways, habitat quality sub-team, waterfowl workshop summary proposal*. Laurel, Maryland: Patuxent Wildlife Research Center.
- Johnson DH. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology* 61:65–71.
- Jorde DG, Krapu GL, Crawford RD. 1983. Feeding ecology of mallards wintering in Nebraska. *Journal of Wildlife Management* 47:1044–1053.

- Junca HA, Epps EA, Glasgow LL. 1962. A quantitative study of the nutrient content of food removed from the crops of wild mallards in Louisiana. *Transactions of the North American Wildlife and Natural Resources Conference* 27:114–121.
- Kaminski RM, Davis JB, Essig HW, Gerard PD, Reinecke KJ. 2003. True metabolizable energy for wood ducks from acorns compared to other waterfowl foods. *Journal of Wildlife Management* 67:542–550.
- Kerwin JA, Webb LG. 1971. Foods of ducks wintering in coastal South Carolina, 1965–1967. *Proceedings of the Annual Conference of Southeast Association of Game and Fish Commissioners* 25:223–245.
- Kimble RB, Ensminger A. 1959. Duck food habits in southwestern Louisiana marshes following a hurricane. *Journal of Wildlife Management* 23:453–455.
- Krapu GL, Brandt DA, Cox RR Jr. 2004. Less waste corn, more land in soybeans, and the switch to genetically modified crops: trends with important implications for wildlife management. *Wildlife Society Bulletin* 32:127–136.
- Kross J, Kaminski RM, Reinecke KJ, Penny EJ, Pearse AT. 2008. Moist-soil seed abundance in managed wetlands in the Mississippi Alluvial Valley. *Journal of Wildlife Management* 72:707–714.
- Lack D. 1966. *Population studies of birds*. Oxford, United Kingdom: Clarendon Press.
- Landers JL, Johnson AS, Morgan PH, Baldwin WP. 1976. Duck foods in managed tidal impoundments in South Carolina. *Journal of Wildlife Management* 40:721–728.
- Lane JL, Jensen KC. 1999. Moist-soil impoundments for wetland wildlife. Washington, D.C.: U.S. Army Corps of Engineers Technical Report EL-99-11. Available: <http://el.erdc.usace.army.mil/elpubs/pdf/trel99-11.pdf> (March 2011).
- Legagneux P, Duhart M, Schricke V. 2007. Seeds consumed by waterfowl in winter: a review of methods and a new web-based photographic atlas for seed identification. *Journal of Ornithology* 148: 537–541.
- Lewis JC, Nelson M. 1988. Cover type relationships and black duck winter habitat. Pages 391–398 in Weller MW, editor. *Waterfowl in winter*. Minneapolis, Minnesota: University of Minnesota Press.
- Loesch CR, Reinecke KJ, Baxter CK. 1994. Lower Mississippi Valley Joint Venture evaluation plan. Vicksburg, Mississippi: North American Waterfowl Management Plan. Available: [http://www.lmvjv.org/library/NAWMP/evaluation\\_plan.pdf](http://www.lmvjv.org/library/NAWMP/evaluation_plan.pdf) (March 2011).
- Long RA, Muir JD, Rachlow JL, Kie JG. 2009. A comparison of two modeling approaches for evaluating wildlife-habitat relationships. *Journal of Wildlife Management* 73:294–302.
- Mabbott DC. 1920. Food habits of seven species of American shoal-water ducks. Washington, D.C.: U.S. Department of Agriculture Bulletin 862.
- Madge S, Burn H. 1988. *Waterfowl: an identification guide to the ducks, geese and swans of the world*. New York: Houghton Mifflin.
- Manly BFJ, McDonald LL, Thomas DL, McDonald TL, Erickson WP. 2002. *Resource selection by animals: statistical design and analysis for field studies*. 2nd edition. Dordrecht, The Netherlands: Kluwer Academic.
- Martin AC, Uhler FM. 1939. Food of game ducks in the United States and Canada. Washington, D.C.: U.S. Department of Agricultural Bulletin 634.
- McAtee WL. 1918. Food habits of the mallard ducks of the United States. Washington, D.C.: U.S. Department of Agricultural Bulletin 720.
- McAtee WL. 1922. Notes on the food habits of the shoveller or spoonbill duck (*Spatula clypeata*). *Auk* 39: 380–386.
- McGilvrey FB. 1966. Fall food habits of ducks near Santee Refuge, South Carolina. *Journal of Wildlife Management* 30:577–580.
- McKnight SK, Hepp GR. 1998. Diet selectivity of gadwalls wintering in Alabama. *Journal of Wildlife Management* 62:1533–1543.
- McMahan CA. 1970. Food habits of ducks wintering on Laguna Madre, Texas. *Journal of Wildlife Management* 34:946–949.
- Mendall HL. 1949. Food habits in relation to black duck management in Maine. *Journal of Wildlife Management* 13:64–101.
- Migoya R, Baldassarre GA. 1993. Harvest and food habits of waterfowl wintering in Sinaloa, Mexico. *The Southwestern Naturalist* 38:168–171.
- Miller JH, Miller KV. 2005. *Forest plants of the southeast and their wildlife uses*. Athens, Georgia: University of Georgia Press.
- Miller MR. 1987. Fall and winter foods of northern pintails in the Sacramento Valley, California. *Journal of Wildlife Management* 51:405–414.
- Miller MR, Burns EG, Wickland BE, Eadie JM. 2009. Diet and body mass of wintering ducks in adjacent brackish and freshwater habitats. *Waterbirds* 32:374–387.
- Miller MR, Garr JD, Coates PS. 2010. Changes in status of harvested rice fields in the Sacramento Valley, California: implications for wintering waterfowl. *Wetlands* 30:939–947.
- Miller OD, Wilson JA, Ditchkoff SS, Lochmiller RL. 2000. Consumption of agricultural and natural foods by waterfowl migrating through central Oklahoma. *Proceedings of the Oklahoma Academy of Science* 80:25–31.
- Moon JA, Haukos DA. 2006. Survival of female northern pintails wintering in the Playa Lakes Region of northwestern Texas. *Journal of Wildlife Management* 70:777–783.
- Morris DW, Mukherjee S. 2007. Can we measure carrying capacity with foraging behavior? *Ecology* 88:597–604.
- Morton JM, Kirkpatrick RL, Vaughan MR, Stauffer DF. 1989. Habitat use and movements of American black ducks in winter. *Journal of Wildlife Management* 53: 390–400.
- Nassar JR, Cohen WE, Hopkins CR. 1993. *Waterfowl habitat management handbook for the lower Mississippi Alluvial River Valley*. Mississippi State, Mis-

- Mississippi: Mississippi State University Extension Publication 1864.
- Nelms KD. 2001. Wetland management for waterfowl: a handbook. Stoneville, Mississippi: U.S. Department of Agriculture Natural Resources Conservation Service, Mississippi Fish and Wildlife Foundation; U.S. Fish and Wildlife Service, Ducks Unlimited, Delta Wildlife.
- Nelms KD. 2007. Wetland management for waterfowl: a handbook. Stoneville, Mississippi: Mississippi River Trust. Available: <http://www.ms.nrcs.usda.gov/technical/NRCS%20Wetland%20Mgt%20for%20Waterfowl.pdf>. (March 2011).
- Nichols JD, Johnson FA, Williams BK. 1995. Managing North American waterfowl in the face of uncertainty. *Annual Review of Ecology and Systematics* 26:177–199.
- [NAWMP] North American Waterfowl Management Plan. 2007. North American Waterfowl Management Plan continental progress assessment. Final Report of the Assessment Steering Committee submitted to the North American Waterfowl Management Plan Committee. Available: <http://www.fws.gov/birdhabitat/NAWMP/index.shtm> (September 2009).
- [NSST] NAWMP Science Support Team. 2007. North American Waterfowl Management Plan: desired characteristics for Joint Venture implementation plans, 17 July 2007. Available: <http://www.fws.gov/birdhabitat/NAWMP/NSST/files/NAWMPJVIPreviewcriteria.pdf> (September 2009).
- Paulus SL. 1982. Feeding ecology of gadwalls in Louisiana in winter. *Journal of Wildlife Management* 46:71–79.
- Pearse AT. 2007. Design, evaluation, and applications of an aerial survey to estimate abundance of wintering waterfowl in Mississippi. Dissertation. Mississippi State: Mississippi State University.
- Perry MC, Uhler FM. 1981. Asiatic clam (*Corbicula manilensis*) and other foods used by waterfowl in the James River, Virginia. *Estuaries* 4:229–233.
- Prevost MB, Johnson AS, Landers JL. 1978. Production and utilization of waterfowl foods in brackish impoundments in South Carolina. *Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies* 32:60–70.
- Quay TL, Critcher TS. 1962. Food habits of waterfowl in Currituck Sound, North Carolina. *Proceedings of the Annual Conference of Southeast Association of Game and Fish Commissioners* 16:200–209.
- Reinecke KJ, Kaminski RM, Moorehead DJ, Hodges JD, Nassar JR. 1989. Mississippi Alluvial Valley. Pages 203–247 in Smith LM, Pederson RL, Kaminski RM, editors. *Habitat management for migrating and wintering waterfowl in North America*. Lubbock, Texas: Texas Tech University Press.
- Ringelman JK. 1990. Managing agricultural foods for waterfowl. Washington, D.C.: U.S. Fish and Wildlife Service Leaflet 13.4.3. Available: [http://www.nwrc.usgs.gov/wdb/pub/wmh/13\\_4\\_3.pdf](http://www.nwrc.usgs.gov/wdb/pub/wmh/13_4_3.pdf) (March 2011).
- Ringelman JK, Longcore JR, Owen RB Jr. 1982. Breeding habitat selection and home range of radio-marked black ducks (*Anas rubripes*) in Maine. *Canadian Journal of Zoology* 60:241–248.
- Rollo JD, Bolen EG. 1969. Ecological relationships of blue and green-winged teal on the high plains of Texas in early fall. *The Southwestern Naturalist* 14:171–188.
- Schoffman RJ. 1947. Food of game ducks at Reelfoot Lake, Tennessee. *Journal of the Tennessee Academy of Science* 22:4–8.
- Sell DW. 1979. Fall foods of teal on the Texas High Plains. *Southwestern Naturalist* 24:373–375.
- Sheeley DG, Smith LM. 1989. Tests of diet and condition bias in hunter-killed northern pintails. *Journal of Wildlife Management* 53:765–769.
- Singleton JR. 1951. Production and utilization of waterfowl food plants of the east Texas Gulf Coast. *Journal of Wildlife Management* 15:46–56.
- Smith WD, Rollins GL, Shinn R. 1994. A guide to wetlands habitat management in the Central Valley. Sacramento, California: California Fish and Game and California Waterfowl Association. Available: <http://www.dfg.ca.gov/lands/waterfowl/docs/WetlandinCentralValley.pdf> (September 2010).
- Snyder SA. 1993. *Anas rubripes*. Fire effects information system. U.S. Forest Service. Available: <http://www.fs.fed.us/database/feis/> (April 2010).
- Stafford JD, Kaminski RM, Reinecke KJ, Manley SW. 2006. Waste rice for waterfowl in the Mississippi Alluvial Valley. *Journal of Wildlife Management* 70:61–69.
- Stollberg BP. 1950. Food habits of shoal-water ducks on Horicon marsh, Wisconsin. *Journal of Wildlife Management* 14:214–217.
- Stoudt JH. 1944. Food preferences of mallards on the Chippewa National Forest, Minnesota. *Journal of Wildlife Management* 8:100–112.
- Strader RW, Stinson PH. 2005. Moist-soil management guidelines for the U.S. Fish and Wildlife Service Southeast Region. Jackson, Mississippi: U.S. Fish and Wildlife Service, Division of Migratory Birds, Southeast Region Migratory Bird Field Office. Available: <http://www.fws.gov/columbiawildlife/MoistSoilReport.pdf> (September 2009).
- Swanson GA, Bartonek JC. 1970. Bias associated with food analysis in gizzards of blue-winged teal. *Journal of Wildlife Management* 34:739–746.
- Swanson GA, Krapu GL, Bartonek JC. 1974. Advantages in mathematically weighting waterfowl food habits data. *Journal of Wildlife Management* 38:302–307.
- Swiderek PK, Johnson AS, Hale PE, Joyner RL. 1988. Production, management, and waterfowl use of sea purslane, gulf coast muskgrass, and widgeongrass in brackish impoundments. Pages 441–457 in Weller MW, editor. *Waterfowl in winter*. Minneapolis, Minnesota: University of Minnesota Press.
- Tabatabai FR, Huggins JA, Smith RA. 1983. Mallard food habits in western Tennessee. *Journal of the Tennessee Academy of Science* 38:24–26.
- Thompson JD, Sheffer BJ, Baldassarre GA. 1992. Food habits of selected dabbling ducks wintering in

- Yucatan, Mexico. *Journal of Wildlife Management* 56: 740–744.
- Tietje WD, Teer JG. 1996. Winter feeding ecology of northern shoveler on freshwater and saline wetlands in south Texas. *Journal of Wildlife Management* 60:843–855.
- van Eerden MR, Munsterman MJ. 1997. Patch use upon touch: filter-feeding European teal (*Anas crecca*) have environmentally and socially determined foraging goals. Pages 165–185 in van Eerden MR, editor. *Patchwork: patch use, habitat exploitation and carrying capacity for water birds in Dutch freshwater wetlands*. Groningen, The Netherlands: Rijksuniversiteit Groningen.
- van Gils JA, Edelaar P, Escudero G, Piersma T. 2004. Carrying capacity models should not use fixed prey density thresholds: a plea for using more tools of behavioural ecology. *Oikos* 104:197–204.
- Weller MW, editor. 1988. *Waterfowl in winter*. Minneapolis, Minnesota: University of Minnesota Press.
- Weller MW, Batt BDJ. 1988. *Waterfowl in winter: past, present, and future*. Pages 3–8 in Weller MW, editor. *Waterfowl in winter*. Minneapolis, Minnesota: University of Minnesota Press.
- Wersal RM, McMillan BR, Madsen JD. 2005. Food habits of dabbling ducks during fall migration in a prairie pothole system, Heron Lake, Minnesota. *Canadian Field Naturalist* 119:546–550.
- White DH, James D. 1978. Differential use of fresh water environments by wintering waterfowl of coastal Texas. *Wilson Bulletin* 90:99–111.
- Wills D. 1971. Food habit study of mallards and pintails on Catahoula Lake, Louisiana, with notes of food habits of other species. *Proceedings of the Annual Conference of Southeast Association of Game and Fish Commissioners* 25:289–294.
- Wilson BC, Esslinger CG. 2002. North American waterfowl management plan, Gulf Coast Joint Venture: Texas Mid-Coast Initiative. Albuquerque, New Mexico: North American Waterfowl Management Plan. Available: <http://www.gcjv.org/docs/TXMidCoastpub.pdf> (March 2011).
- Wingard RG. 1952. Foods of some migratory waterfowl in Pennsylvania. *Journal of Wildlife Management* 16:228–230.
- Wright TW. 1959. Winter foods of mallards in Arkansas. *Proceedings of the Annual Conference of Southeast Association of Game and Fish Commissioners* 13:291–296.
- Yocom CF. 1951. *Waterfowl and their food plants in Washington*. Seattle: University of Washington Press.
- Yocom CF, Keller M. 1961. Correlation of food habits and abundance of waterfowl, Humboldt Bay, California. *California Fish and Game* 47:41–53.
- Zimpfer NL, Rhodes WE, Silverman ED, Zimmerman GS, Koneff MD. 2009. Trends in duck breeding populations, 1955–2009. Laurel, Maryland: U.S. Fish and Wildlife Administrative Report, July 1, 2009. Available: <http://www.fws.gov/migratorybirds/NewReportsPublications/PopulationStatus/Trends/Trend%20Report%202009.pdf> (October 2009).