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Abstract:	<p>The Mississippi Flyway supports millions of waterfowl during spring migration as individuals replenish vital nutrients en route to breeding locations. Green-winged teal <i>Anas crecca</i> consume natural plant and animal foods in shallow wetlands during autumn and winter, but little information is available to describe food use and selection during spring migration. We experimentally collected green-winged teal and quantified food use and availability to determine selection in the Illinois River Valley during February–April 2016–2018. We removed, dried, and weighed (± 0.1 mg) food items by taxa from the upper digestive tract (proventriculus and esophagus) of birds and core samples for comparison. Additionally, we evaluated retention of common diet items between small (#60; 250 μm) and medium (#35; 500 μm) sieves and the effect of processing sieve size on selection coefficients. Seeds of moist-soil vegetation occurred in all green-winged teal diets, while invertebrates and vegetative material occurred in 67.4% and 25.8% of diets, respectively. Green-winged teal consumed 85.8% (CI95 = 81.2–90.3%) plant material and 14.2% (CI95 = 9.6–18.7%) invertebrates based on aggregate dry biomass. We failed to find support for selection of either plant or animal foods in general, but green-winged teal selected <i>Cyperus</i> spp., <i>Ammannia</i> spp., <i>Leptochloa</i> spp., and <i>Potamogeton</i> spp. and avoided <i>Amaranthus</i> spp., <i>Ipomoea</i> spp., <i>Echinochloa</i> spp., and <i>Oligochaeta</i> individual taxa. We found no support for a difference in selection ratios between sexes, but selection ratios differed among years and wetland connectivity regimes with changes in food availability. Sieve size had minimal impact on rank and selection intensity of most food items, but only small sieves captured <i>Ammannia</i> spp., which was an important diet item. We found no evidence that green-winged teal selected invertebrates in our mid-latitude migration study area as has been speculated for dabbling ducks in general during spring migration (i.e., spring diet-shift hypothesis). We encourage managers to provide shallowly flooded wetlands with desirable plant taxa (e.g., <i>Cyperus</i> spp., <i>Ammannia</i> spp., <i>Leptochloa</i> spp.) for green-winged teal by maintaining actively-managed moist-soil wetlands that are made available during spring migration.</p>

Food selection by spring-migrating green-winged teal

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Abstract

The Mississippi Flyway supports millions of waterfowl during spring migration as individuals replenish vital nutrients en route to breeding locations. Green-winged teal *Anas crecca* consume natural plant and animal foods in shallow wetlands during autumn and winter, but little information is available to describe food use and selection during spring migration. We experimentally collected green-winged teal and quantified food use and availability to determine selection in the Illinois River Valley during February–April 2016–2018. We removed, dried, and weighed (± 0.1 mg) food items by taxa from the upper digestive tract (proventriculus and esophagus) of birds and core samples for comparison. Additionally, we evaluated retention of common diet items between small (#60; 250 μ m) and medium (#35; 500 μ m) sieves and the effect of processing sieve size on selection coefficients. Seeds of moist-soil vegetation occurred in all green-winged teal diets, while invertebrates and vegetative material occurred in 67.4% and 25.8% of diets, respectively. Green-winged teal consumed 85.8% (CI₉₅ = 81.2–90.3%) plant material and 14.2% (CI₉₅ = 9.6–18.7%) invertebrates based on aggregate dry biomass. We failed to find support for selection of either plant or animal foods in general, but green-winged teal selected *Cyperus* spp., *Ammannia* spp., *Leptochloa* spp., and *Potamogeton* spp. and avoided *Amaranthus* spp., *Ipomoea* spp., *Echinochloa* spp., and *Oligochaeta* individual taxa. We found no support for a difference in selection ratios between sexes, but selection ratios differed among years and wetland connectivity regimes with changes in food availability. Sieve size had minimal impact on rank and selection intensity of most food items, but only small sieves captured *Ammannia* spp., which was an important diet item. We found no evidence that green-winged teal selected invertebrates in our mid-latitude migration study area as has been speculated for dabbling ducks in general during spring migration (i.e., spring diet-shift hypothesis). We encourage managers to provide shallowly flooded wetlands with desirable plant taxa (e.g., *Cyperus* spp., *Ammannia* spp., *Leptochloa* spp.) for green-winged teal by maintaining actively-managed moist-soil wetlands that are made available during spring migration.

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Introduction

Availability and accessibility of food resources at spring stopover sites are important factors affecting the condition of many species of waterfowl (Arzel et al. 2006; Stafford et al. 2014; Klimas et al. 2020). Waterfowl use stopover sites to replenish fat reserves for subsequent migratory movements and in preparation for nest initiation upon breeding ground arrival. During spring, waterfowl may encounter conditions that limit nutrient uptake such as low food abundances, adverse weather conditions (e.g., ice coverage, cold temperatures), and increased energy expenditures involved with courtship and pair bonding (Anteau and Afton 2009; Straub et al. 2012; Janke et al. 2019). Inability to acquire sufficient food resources along spring migration routes can negatively influence body condition in some species of waterfowl, and spring habitat resource quality has been linked to subsequent breeding success in some species (i.e., cross-seasonal effects; Sedinger and Alisauskas 2014; Klimas et al. 2020). Some waterfowl that reach the breeding grounds with increased nutrient and lipid reserves can exhibit greater breeding success and recruitment (Devries et al. 2008).

Outside of the breeding season, food availability is assumed to be an important environmental factor affecting subsequent recruitment for most waterfowl populations and is

commonly used as a basis for conservation planning (Central Valley Joint Venture 2006; Edwards et al. 2012; Soulliere et al. 2013). Many Joint Ventures established by the North American Waterfowl Management Plan (2012) calculate habitat objectives for waterfowl populations using bioenergetics models that include energetic availability and demand (Stafford et al. 2014; Williams et al. 2014; Soulliere et al. 2017). Energetic carrying capacity estimates require information on diets, daily energetic demands, food availability, and metabolizable energy of consumed food items (Williams et al. 2014). Recent quantification of food availability in the Upper Mississippi / Great Lakes Region Joint Venture revealed that spring migrants encounter many areas with limited food resources (Straub et al. 2012). Food resources are depleted through consumption by autumn-migrating and overwintering waterfowl, consumption by other wildlife, and decomposition (Foster et al. 2010; Hagy and Kaminski 2012a,b). Additionally, changing environmental conditions, land-use practices, and competing management interests can limit initial food production and availability during spring for waterfowl (Hagy et al. 2017).

Information on food selection provides insights into the basic ecology of a species, as well as informing conservation planning efforts and guiding habitat management (Callicutt et al. 2011). Migratory waterfowl depend on disparate food types throughout their annual cycle as a function of changing geography, availability, and seasonal shifts in physiological needs (Hitchcock 2008). In particular, studies of food use and selection during late winter and spring migration are uncommon, especially for species other than mallard *Anas platyrhynchos* and northern pintail *A. acuta*. Previous research suggests dabbling ducks tend to consume diets high in carbohydrates during the non-breeding season and protein-rich diets during the breeding season (Krapu 1974; Reinecke and Owen 1980; Krapu and Reinecke 1992). Even though the timing of diet shifts in relation to the annual cycle is relatively unstudied, it is hypothesized that ducks increase invertebrate consumption prior to their arrival on the breeding grounds (e.g., spring diet-shift hypothesis; Manley et al. 1992; Hitchcock 2008; Tidwell et al. 2013; Hitchcock et al. 2021).

Green-winged teal *Anas crecca* (hereafter teal) are common across all four North American flyways, have extensive breeding and wintering ranges, and are a socioeconomically important species comprising the second most harvested duck in North America (Baldassarre

2014; Raftovich et al. 2018). Teal are the smallest dabbling duck in North America and forage in shallow water (0–12 cm) and on mudflats where they access small seeds and invertebrates with little competition from heterospecifics (Baldassarre 2014; Johnson et al. 2020). Due to their small size, teal likely use a combination of stored fat reserves and food resources obtained on the breeding grounds to meet energetic requirements of reproduction, a trait common in most dabbling ducks (Paquette and Ankney 1998; Klaassen et al. 2006). Additionally, Arzel et al. (2007) characterized teal as income migrants, utilizing energy obtained at stopover locations to fuel subsequent migratory movements. As income migrants, teal are likely to have an increased reliance on local food sources throughout spring migration and the breeding season. Therefore, inadequate food availability could result in decreased body condition during migration and upon arrival to breeding areas which can have consequences for recruitment (Devries et al. 2008).

Although teal are omnivorous, plant materials, especially small seeds, have been documented as a mainstay of teal diets during the autumn and winter periods in Alaska, California, Illinois, and Texas (Sell 1979; Hughes and Young 1982; Euliss and Harris 1987; Havera 1999; Anderson et al. 2000; Collins et al. 2017). Conversely, some researchers have found teal to use animal material during winter and spring periods (DeRoia 1989; Vest and Conover 2011). Furthermore, many researchers reference a hypothetical shift in waterfowl diets during late winter and spring from seeds and other relatively high carbohydrate foods to aquatic invertebrates, which may have higher relative protein levels (Taylor 1978; Miller 1987; Manley et al. 1992; Tidwell et al. 2013; Hitchcock et al. 2021). Unfortunately, few of these previous works used unbiased methodology (Callicutt et al. 2011) or analytical techniques (*c.f.* Anderson et al. 2000; Collins et al. 2017), and none analyzed food use or selection by teal at stopover locations during spring migration.

An important aspect of quantifying diet selectivity is ensuring that sampling devices and processing methods capture a representative sample of resources that were available to foraging individuals prior to collection (Johnson 1980; Manley et al. 2002). Much of the previous duck diet selection and food availability research obtained nektonic and benthic food items via coring device or sweep net and rinsed environmental samples through a 500- μ m sieve (e.g., Hagy and Kaminski 2012b; Straub et al. 2012) or did not specify if or which sieve size was used in methodology (e.g., Collins et al. 2017). Teal lamellar spacing is approximately 670–750 μ m

(Nudds and Bowlby 1984; Nudds et al. 1994; Mateo et al. 2000) suggesting that a 500- μ m sieve would provide adequate spacing to retain selectable seeds. However, some plant seeds (e.g., *Ammannia* spp.) previously identified as potential diet items of teal and other dabbling ducks (Miller 1987; Collins et al. 2017) pass through a 500- μ m sieve undetected; thus, an evaluation of sieve size effects on food selection analysis of teal is warranted.

We used contemporary, unbiased methods to quantify food selection of spring-migrating teal within a migration stopover region in the Midwest, USA. Consistent with the spring diet-shift hypothesis (Klimas et al. 2020; Hitchcock et al. 2021), we hypothesized that teal would select invertebrates within the Illinois River Valley during spring migration. Additionally, we hypothesized that selection of food items would be impacted by wetland to river connectivity due to the influence of floodplain inundation on vegetative communities during the growing season. Separately, we evaluated the impact of processing sieve size on food availability estimates and their impact on food selection. This research provides an unbiased insight into food use and selection of spring-migrating teal to aid and inform conservation planners and wetland managers.

Study Site

The Illinois River Valley (IRV) provides habitat resources during spring and autumn migration for millions of migratory waterfowl and other waterbirds annually (Havera 1999). The IRV has been impacted by multiple anthropogenic stressors including floodplain wetland drainage, channelization, installation of locks and dams, pollution, increased base-flow, and increased flood frequency and amplitudes following the completion of the Chicago sanitary and ship canal in 1900 (Bellrose et al. 1979; Havera 1999; Lemke et al. 2017). Anthropogenic changes have influenced vegetation communities and wetland quality for waterfowl in areas with a continued connection to the main channel of the Illinois River (Bellrose et al. 1979; Havera and Bellrose 1985; Stafford et al. 2010; Blake-Bradshaw et al. 2020). Our study encompassed federal, state, and private wetlands within the Alton, La Grange, and Peoria reaches of the Illinois River (river miles 0–231; Figure 1). These reaches contain a historically wide floodplain with relatively low gradient and soft substrate (Mills et al. 1966). Mean temperatures during the study ranged from -1° C in February to 11° C in April with mean precipitation of 7–10 cm (Illinois State Water Survey; isws.illinois.edu). The 74,000 ha IRV floodplain contains diverse

waterfowl habitat resources, including open water, aquatic vegetation beds, mudflats, emergent marsh, floodplain forest, and seasonally flooded agricultural fields (Havera 1999; Bowyer et al. 2005; Stafford et al. 2010).

Methods

Field collections

During February–April 2016–2018, we collected teal at wetlands (~40–2000 ha) in the IRV. We identified wetlands where teal were abundant through ground surveillance and spring waterfowl aerial inventory data from the Illinois Natural History Survey (Stafford et al. 2007; Klimas et al. 2020). Teal were observed foraging for ≥ 10 minutes to increase the likelihood of ingesta upon dissection and then lethally collected with a shotgun and non-toxic shot (Swanson and Bartonek 1970). Immediately after collection (< 5 min), we retrieved individuals and preserved food items in the upper digestive tract (i.e., proventriculus and esophagus; Swanson and Bartonek 1970). We injected a 10% buffered formalin solution stained with rose bengal into the upper digestive tract and restricted food items to the esophagus and proventriculus by placing zip ties at the throat and junction of proventriculus and gizzard. We preserved upper digestive tract tissues and food items in a 10% formalin solution and froze (-18°C) until processing (30–130 days later). Additionally, we recorded age and sex classes using wing plumage characteristics following Carney (1992) or additional internal bird morphology. All avian collection methods and protocols were approved by the University of Illinois Institutional Animal Care and Use Committee Protocol (15032). Permits for lethal collection included U.S. Fish and Wildlife Service Scientific Collection Permit (MB145466-4, MB145466-0, MB145466-2) and Illinois Department of Natural Resources Scientific Collecting (W16.4071, W17.6079, W18.6079) and Research permits (SS16-030, SS17-030, SS18-030).

To quantify food availability (kg/ha) at foraging locations, we collected benthic (i.e., soil and associated bottom material) and nektonic samples (i.e., water column atop benthic sample; hereafter, core samples) within 24 hr of a teal collection event. We sampled benthic and nektonic foods at 3 random locations within the general area in which we had watched teal forage prior to collection (i.e., foraging patch). Although the size of the foraging patch varied according to behavior of individual birds, patches were generally $< 25\text{ m}^2$. The three core

samples (5-cm diameter \times 10-cm depth; Rickly Universal Core Sampler; Rickly Hydrological Company; Columbus, OH) were homogenized in a 500- μ m (#35 sieve; 2016 and 2017) or 250- μ m (#60 sieve; 2018) mesh sieve bucket in the field to partially remove excess water, debris, and soils. We transferred the field-washed sample into a polyethylene bag and added a 10% formalin solution stained with rose bengal until all material was saturated by the preservative. Samples were stored at room temperature in the preservative until processing (60–160 days later).

Laboratory processing

In the laboratory, upper digestive tracts were thawed for ~4 hr and cut lengthwise with scissors to access diet items. The contents were subsequently washed through a 250- μ m sieve to remove preservative, after which the diet items were transferred to a petri dish for identification to the lowest practical taxonomic classification using a dissecting microscope. We dried diet samples at 60° C for ~24 hr and then enumerated and weighed diet items by taxa to the nearest 0.1 mg (Swanson et al. 1974). In 2016–2017, we washed core samples through a 500- μ m sieve in the field to remove excess soil, water, and fine particulate matter before transportation to the laboratory for subsequent processing. However, when sorting core samples from these first 2 years of the study, we noted an absence of small food items (e.g., *Ammannia* spp.) that occasionally occurred in teal diets during 2016–2017. Thus, in 2018, we washed core samples through a 250- μ m sieve in the field to ensure that small items were retained. Subsequently in the laboratory, we rinsed cores from 2018 through a 500- μ m sieve, first, and secondly through a 250- μ m sieve to quantify the amount and type of food items that were potentially not captured from using only the larger 500- μ m sieve in previous years. In all years, core samples that contained large amounts of soil after the initial rinse were soaked in hydrogen peroxide for \leq 2 min and re-rinsed (Hagy and McKnight 2016).

We transferred wet material from core samples to a petri dish and removed and identified invertebrates and aquatic vegetation to the lowest practical classification using a dissecting microscope. We then air dried remaining material for >24 hr to prepare samples for seed removal. Dried samples were again passed through a series of sieves (#18 [1.0 mm] and #35, 2016 and 2017; #18, #35, #60, 2018) to remove residual soil/detritus and separate seeds based on size. From these samples, we removed seeds using a dissecting microscope and subsampled (\leq 25%) small and medium seed samples (#60 and #35 sieves, respectively) with abundant food

items (e.g., >500) to save time and labor costs (Hagy et al. 2011; Stafford et al. 2011; Livolsi et al. 2014). For subsampling, we obtained the weight of the full sample, homogenized the sample, and removed a random portion of the sample equal to the weight of the desired subsample (25% or 50% of the sample) for analysis. All food items from cores were dried to constant mass separately by the lowest taxonomic level practical (genus or species for seeds and vegetation, family or class for invertebrates), enumerated, weighed by taxon using published protocols, and extrapolated to kg/ha (Hagy et al. 2011; Hagy and Kaminski 2012b).

Data analysis

To quantify diet composition, we calculated proportional occurrence and aggregate percent dry biomass across all food items found in the esophagus and proventriculus (Swanson et al. 1974). Individuals containing insufficient amounts of food (<5 items or <0.001 g) were removed from analyses. We determined food selection using a rank comparison of use and availability (Johnson 1980). We selected this method because it is relatively insensitive to the inclusion of questionable items or when true resource availability is not straightforward and results in ordering of food items that allows relative statements of resource selection (Johnson 1980; Alldredge and Griswold 2006; Tidwell et al. 2013).

We calculated proportional occurrence and aggregate percent biomass for diets and core samples for comparison (Swanson et al. 1974). We combined seed masses of all congeners as well as invertebrate taxa into logical groupings (i.e., Family–Class) for analyses due to limited samples sizes of many individual species. We included diet items for selection analysis based on their aggregate percent biomass values, using the most common items from both diet and core samples in subsequent analysis. We recalculated aggregate percent biomass values for top items in each diet and core sample using only the top seven items and ranked each item according to Johnson (1980). We removed one food item from this analysis (*Ammannia* spp.) because it was not detected in any of the 39 foraging site core samples collected during 2016 and 2017, indicating possible sampling error and probable selection bias. We calculated a selection coefficient t_{ij} for each individual teal (j) and diet item (i) combination by subtracting the rank of availability from the rank of usage. We performed the same calculations with overall plant and animal material for each bird to generate selection values between the two food sources.

We tested for differences in overall selection of plant and animal material using Wilcoxon signed-rank test due to non-normal distributions of data. Selection intensity values of top diet items were also not normally distributed; however, we used multivariate analysis of variance (MANOVA) because the *F*-test is robust to deviations from normality (Lindman 1974). We tested for differences in selection intensity among age, sex, year, migratory period, and wetland connectivity variables. To control for potential differences in body condition during the spring migration period (Klimas et al. 2020), we identified the average peak spring migration date (~15 March) for teal in the IRV using eBird data from 2016–2018 and classified collections as early (before 15 March) or late (on or after 15 March; eBird 2019). We categorized wetland connectivity with the main channel of the Illinois River as 1) directly connected or influenced by the Illinois River below flood stage (connected), 2) influenced by the river at or above moderate flood stage (partially connected), and 3) disconnected via surface water and mostly uninfluenced by the Illinois River (isolated; Lemke et al. 2017). We used a Hotelling's T^2 -test to evaluate hypotheses and used the corresponding Wilks' Lambda measure to test the null hypothesis (Tidwell et al. 2013). For independent variables with a significant effect, we further evaluated selection rates of individual diet items using a Waller-Duncan multiple comparisons procedure recommended by Johnson (1980).

Sieve size comparison

We analyzed differences in seed retention between 500- μ m and 250- μ m sieves for 2018 core samples. We identified the seven highest ranked items from diet and core samples and calculated availability estimates (kg/ha) for both sieve samples, but unlike the previous analysis, we retained *Ammannia* spp. because it was captured and was present in the 250- μ m sieve. We used a paired sample t-test to identify differences in seed retention between the 500- μ m and 250- μ m sieve of each food item in our analysis ($\alpha = 0.05$). We censored paired samples if no seeds of the target taxa were recorded in the 250- μ m sieve. To identify how differences in seed retention affected selection, we calculated individual selection for each taxa between sieves. We followed aforementioned protocols for calculating selection intensity and performed Waller-Duncan multiple comparisons procedure on both data sets to identify individual taxa selection and quantify variation in selection intensities with different food availability estimates (Johnson 1980).

Results

Diet and food selection

During February–April 2016–2018, we collected 95 after-second-year (6 female, 89 male) and 71 second-year (38 female, 33 male) teal from 13 wetlands in the IRV. We censored 27 teal (16 male, 11 female; 16%) from analyses because they contained insufficient ingesta, issues occurred during preservation or processing resulting in incomplete diet or core samples, or the diet did not contain any of the top diet items included in selection analysis. Diet analyses was conducted on 79 after-second-year (5 female, 74 male) and 60 second-year (29 female, 31 male) teal collected from 59 foraging patches with associated core samples.

We identified 128 unique food items in the diets of teal, including 80 plant taxa and 48 invertebrate taxa. Mean aggregate percent biomass of plant and animal material comprised 85.8% ($CI_{95} = 81.2\text{--}90.3\%$) and 14.2% ($CI_{95} = 9.6\text{--}18.7\%$) of diets, respectively. Additionally, plant and animal material occurred in 100.0% and 67.4% of diets, respectively. Plant items that comprised >5% of mean aggregate percent biomass included seeds of sedges *Cyperus* spp., smartweeds *Polygonum* spp., pigweeds *Amaranthus* spp., sprangletop *Leptochloa* spp., panic grass *Panicum* spp., and toothcup *Ammannia* spp. The only animal item comprising >5% of aggregate biomass was aquatic worms (Oligochaeta). Vegetation shoots comprised <1% of aggregate biomass (Table 1).

Mean food availability across foraging locations was 450.8 kg/ha ($CI_{95} = 347.8\text{--}554.4$ kg/ha; range: 46.5–2,359.9 kg/ha, $n = 59$). Mean aggregate percent biomass for plant and animal availability was 79.5% ($CI_{95} = 73.6\text{--}85.4\%$) and 20.5% ($CI_{95} = 14.6\text{--}26.4\%$), respectively. Items comprising >5% of aggregate biomass included *Polygonum* spp., *Ipomoea* spp., Oligochaeta, *Cyperus* spp. tubers, *Amaranthus* spp., *Echinochloa* spp., and *Potamogeton* spp. (Table 1).

Spring-migrating teal consumed overall plant and animal material in proportion to availability in locations where they occurred and foraged in the IRV ($Z = 0.29$, $P = 0.18$); however, they selected certain food items disproportionate to availability among years (Wilks' $\lambda = 0.52$, $F_{2,131} = 5.90$, $P < 0.01$) and wetland connectivity classes (Wilks' $\lambda = 0.61$, $F_{2,131} = 4.35$, $P < 0.01$) but not by age, sex, or migratory period (Wilks' $\lambda > 0.91$, $F_{1,131} \leq 1.38$, $P \geq 0.21$).

Selection varied among years for all food items ($F_{2,136} \geq 3.3$, $P \leq 0.04$) except *Potamogeton* spp.

($F_{2,136} = 1.05$, $P = 0.35$). Selection varied among wetland connectivity classes for *Cyperus* spp. ($F_{2,136} = 3.88$, $P = 0.02$), *Leptochloa* spp. ($F_{2,136} = 15.90$, $P < 0.01$), and *Potamogeton* spp. ($F_{2,136} = 4.81$, $P = 0.01$). Multiple comparisons tests revealed variation in selection intensity among top food items among years and connectivity measures (Table 2).

Sieve size comparison

We captured four diet taxa in the 250- μ m sieve, including *Ammannia* spp., *Amaranthus* spp., *Cyperus* spp., and *Panicum* spp. We were unable to find evidence of a difference between mass of seeds captured by each sieve size for *Amaranthus* spp. and *Panicum* spp. ($P \geq 0.05$; Table 3). The 250- μ m sieve captured >6 times more *Cyperus* spp. seeds than the 500- μ m sieve ($P = 0.004$) and *Ammannia* spp. was captured only by the 250- μ m sieve. Greater seed retention in the 250- μ m sieve altered the availability ranking of some diet items leading to a general decline in selection intensity for those items, which had increased availability and increased selection intensity for the remaining diet items in the 250- μ m sieve analysis (Table 3). Ultimately, *Polygonum* spp. was the only diet item that switched from selection with a 500- μ m sieve to avoidance with a 250- μ m sieve, but confidence intervals in both analyses overlapped zero.

Discussion

Diets of spring-migrating teal in the IRV were comprised primarily of plant seeds. In contrast with the spring diet-shift hypothesis, we found no evidence for selection of animal material in diets during spring migration and low occurrence and biomass of invertebrates in diet relative to studies in winter (e.g., Euliss and Harriss 1987; Manley et al. 1992). Moreover, teal avoided the only invertebrate food item that ranked in the top diet and available items (i.e., Oligochaeta). While teal diets were primarily composed of seeds, we failed to find evidence that they were generally selecting seeds in greater proportion than availability within foraging patches. Teal selected for small (i.e., *Cyperus* spp.) and medium (i.e., *Leptochloa* spp., *Potamogeton* spp.) sized seeds and avoided large seeds (i.e., *Ipomoea* spp., *Echinochloa* spp.) and invertebrates (Oligochaeta). Four individual seed taxa were consumed in greater proportion than availability at foraging sites among years, including *Cyperus* spp., *Leptochloa* spp., *Potamogeton* spp., and *Ammannia* spp., indicating localized selection in spite of annual

variability in abundance and other environmental conditions. Selection of small seeds may be advantageous to teal, as they exhibit high lamellar density (i.e., 13 lamellae/cm) allowing for selection of small items relative to larger-bodied dabbling ducks (Nudds and Bowlby 1984; Armstrong and Nudds 1985).

Previous food habits studies of teal during autumn migration in Illinois reported consumption of plant material totaling >80% of the total biomass and similarly found *Cyperus* spp. to be the most important diet item for teal during spring migration (Anderson 1959; Havera 1999). *Cyperus* spp. is common in moist-soil wetlands in the Midwest (Bowyer et al. 2005, Smith 2007; Hitchcock 2008; Dugger and Feddersen 2009), is valued as a good food for waterfowl based on a moderate true metabolizable energy value (Ballard et al. 2004; Strader and Stinson 2005), and responds well to mid- and late-season drawdowns (Fredrickson and Taylor 1982), which are typically the most practical to achieve within connected and partially connected floodplain wetlands in the region (Bowyer et al. 2005; Lemke et al. 2017). In particular, flooding events during the middle of the growing season (i.e., June–July) can limit seed production or altogether destroy emergent vegetation leaving little food for migrating waterfowl in connected and partially connected floodplain wetlands (Bowyer et al. 2005; Lemke et al. 2017, 2018). However, *Cyperus* spp. can respond vigorously after a mid-summer flood and produce abundant food for teal even after the window for many other larger-seeded plant species has closed (Chu et al. 2019). Although selection tendencies for some food items varied by wetland connectivity classes, taxa for which coefficients were relatively large (i.e., *Cyperus* spp., *Leptochloa* spp., *Potamogeton* spp., *Echinochloa* spp., *Oligochaeta* spp.) did not vary directionally within wetland connectivity class or year. Thus, for strongly selected and avoided diet items, tendencies were similar across wetlands and time.

The lack of overall selection tendencies for seeds or invertebrates and variation in selection of some taxa among years implies some degree of plasticity in diet relative to availability (Euliss and Harris 1987). Mean food availability at teal collection sites (~450 kg/ha) was substantially greater than estimates during spring across the upper Midwest (Straub et al. 2012) and surpasses thresholds for profitable forage acquisition (Krapu and Reinecke 1992; Hagy and Kaminski 2015; Hagy et al. 2017), which likely enable selection for individual taxa or sizes of taxa (Smith et al. 2012). Given the variation in diets across their range (Rollo and Bolen

1969; Manley et al. 1992; Anderson et al. 2000; Collins et al. 2017), we suspect that teal diets are driven mostly by local resource availability with spatially and temporally dynamic selection tendencies as opposed to fixed selection across portions of the annual cycle (Euliss and Harriss 1987; Krapu and Reinecke 1992).

Variation in seed selection tendencies among years was likely related to abiotic factors that influence vegetation communities and wetland availability in the IRV (Hagy et al. 2017). Production of moist-soil plant seeds can vary substantially among years in the IRV due to flooding patterns during the growing season and subsequent autumn and winter periods when migrating waterfowl are present (Bowyer et al. 2005; Stafford et al. 2011; Lemke et al. 2017). Differences in wetland drawdown rate, drawdown timing, and summer precipitation can affect vegetation composition and seed production (Fredrickson and Taylor 1982; Bowyer et al. 2005; Dugger and Feddersen 2009). For example, flooding during the growing season can limit growth of or destroy moist-soil plant communities in connected or partially connected floodplain wetlands (Lemke et al. 2018). Moreover, river levels during migration can provide access to or make mostly unavailable foods that were produced in the previous growing season (Lemke et al. 2017). For example, a major flood event in March 2018 inundated a large portion of the IRV floodplain and allowed spring migrants to access resources in wetlands not available to autumn migrants or wintering waterfowl. Additionally, some wetland obligate taxa were absent from connected and partially connected wetlands in the IRV due to flooding frequencies during the growing season (i.e., *Potamogeton* spp.), which likely influenced selection intensity among connectivity types (Stafford et al. 2010; Hine et al. 2017; McClain et al. 2019).

Common diet items like *Cyperus* spp., *Ammannia* spp., and *Amaranthus* spp. were underestimated or completely absent from samples rinsed through a 500- μ m sieve in our study. These taxa are common in moist-soil wetlands in the United States (Strader and Stinson 2005; Dugger and Feddersen 2009; Schummer et al. 2012) and important food items to some waterfowl species (Euliss and Harris 1987; Anderson et al. 2000; Hitchcock 2008; Tidwell et al. 2013; Collins et al. 2017). Previous research that measured food availability with 500- μ m sieve likely underestimated the availability of small seeds, which can comprise a large amount of the overall food biomass in moist-soil wetlands (Stafford et al. 2011). Although we noted differences in seed retention and selection intensities among taxa between 500- μ m and 250- μ m sieve samples,

overall selection trends remained similar for nine of ten diet items. *Polygonum* spp. was the only item to switch between selection and avoidance with differing food availability estimates; however, those estimates overlapped zero in both analyses, indicating no selection or avoidance. Although using a 500- μ m sieve in diet and food availability processing resulted in some bias against small seeds, the overall differences in food selection were relatively small in our study. However, use of 250- μ m sieves for food availability studies would maximize retention of small seeds from all taxa and further eliminate bias.

To our knowledge, Anderson (2000) performed the only previous food selection analysis on teal, revealing selection for invertebrates during autumn and early winter periods in the southern High Plains of Texas. Food selection results for other species during spring migration are variable with mallards selecting for (Smith 2007) or avoiding (Tidwell et al. 2013) moist-soil seeds. Blue-winged teal *Anas discors* selected for invertebrates during spring in Louisiana (Manley et al. 1992) and Nebraska (Tidwell et al. 2013), but blue-winged teal likely consume a high dietary portion of invertebrates year-round (Hitchcock et al. 2021; Rohwer et al. 2020). Although a number of studies have documented an increase in consumption of invertebrates during winter and spring for northern pintail (Ballard et al. 2004), blue-winged teal (Manley et al. 1992), and mallard (Hitchcock et al. 2021), it is unclear if trends are related to changing food availability (Hagy and Kaminski 2012b; Osborn et al. 2017) or birds' response to physiological needs. Heitmeyer (1985) described an increase in dietary invertebrates for mallards during pre-basic molt in late winter, but after molting they shifted back to a high carbohydrate diet immediately before spring migration. Gammonley (1995) found differences in invertebrate consumption during various reproductive periods in female cinnamon teal *Spatula cyanoptera*, although invertebrate consumption did not differ from that of pre-breeding individuals.

The spring diet-shift hypothesis purports that dabbling ducks increase selection for invertebrates prior to and during spring migration in preparation for the breeding season (Tidwell et al. 2013; Hitchcock et al. 2021). Our study failed to provide evidence of invertebrate selection or substantial invertebrate consumption by spring-migrating teal in the IRV. Pearse et al. (2011) reported similar findings for northern pintail in the rainwater basin of Nebraska. While there currently exists a paradigm with many wetland managers that the consumption of invertebrates by migrating ducks increases from winter through spring to support nutrient requirements

associated with egg formation or feather replacement (e.g., Taylor 1978; Miller 1987; Manley et al. 1992; Ballard et al. 2004; Hitchcock et al. 2021), few studies have provided empirical evidence to support the spring diet-shift hypothesis using true food selection methodologies employed across the majority of the late winter – spring migratory period. Interestingly, literature that is routinely cited when referencing the spring diet-shift hypothesis does not provide compelling evidence of tangible shifts in food selection prior to the breeding period for most dabbling ducks (e.g., Heitmeyer 1985; Gammonley 1995; Hohman et al. 1996). Additionally, the methods and timescale of most previously published diet studies do not allow for an appropriate test of the hypothesis. At minimum, studies must examine food availability simultaneous with diet during spring migration to differentiate food use with actual selection. Furthermore, a more appropriate test of this hypothesis would need to be performed over subsequent months from winter to the breeding season to obtain invertebrate consumption rates on the wintering grounds, during spring migration, and for breeding individuals while controlling for food availability both temporally and spatially. The latter is critical to ensure that a potential diet shift is not simply due to increasing invertebrate availability as temperatures warm and birds move northward towards breeding grounds where animal foods are more common (Euliss and Harriss 1987; Krapu and Reinecke 1992). Testing of this hypothesis in greater detail and with expanded efforts may increase our knowledge of energetics and food selection during a relatively understudied period in the annual cycle of waterfowl (Arzel et al. 2006).

Recommendations

We recommend active moist-soil management (i.e., annual water level manipulation, periodic disking, or other disturbances) within wetland complexes that provide a diversity of annual plants rather than producing a monoculture of large-seeded species (e.g., millet, agricultural crops) for teal (Tidwell et al. 2013). Managing a complex of different wetlands through cooperative partnerships with adjacent landowners will allow variation in drawdown date, vegetation communities, and general habitat resource conditions that benefit a wide range of waterfowl and other waterbird species dependent on many different food taxa (Pearse et al. 2012; Yetter et al. 2018; McClain et al. 2019). To provide these resources during spring

migration, wetland managers can forego flooding of some wetlands until late winter or early spring, which will make available new resources for spring migrants (Greer et al. 2007).

Supplemental Material

Data S1. Microsoft Excel file containing the mass (g) of diet items recovered from esophageal samples of green-winged teal *Anas crecca* experimentally-collected in the Illinois River Valley during February–April 2016–2018. Samples are identified by a 'Diet ID' value which can be combined with data in the covariates (Data S4) and core mass (Data S3) datasets to replicate diet selection analysis. Similarly, the 128 diet items identified in columns B:DY can be categorized into food item types using the food item type dataset (Data S5).

Data S2. Microsoft Excel file containing the count of each diet item recovered from esophageal samples of green-winged teal *Anas crecca* experimentally-collected in the Illinois River Valley during February–April 2016–2018. Each sample is uniquely identified by the 'Diet ID' column.

Data S3. Microsoft Excel file containing mass (g) of seeds, tubers, and aquatic invertebrates recovered from core samples taken from wetlands where green-winged teal *Anas crecca* were experimentally-collected in the Illinois River Valley during February–April 2016–2018. Unique samples are identified by a 'Core ID' and can be paired with diet mass (Data S1) and covariates (Data S4) datasets. The data included in this tab represents food items recovered from a #35 (500 μ m) sieve.

Data S4. Microsoft Excel file containing covariates used in diet selection analysis of green-winged teal *Anas crecca* experimentally-collected in the Illinois River Valley during February–April 2016–2018. Data can be used to pair diet mass (Data S1), diet number (Data S2), and core sample mass (Data S3) by “Diet ID” and “Core ID” columns. Diet ID: Unique identifier of teal diet. Core ID: Unique identifier of collection site core sample. Area: General location of where the green-winged teal and environmental sample were collected. Age: (SY - Second Year; ASY - After Second Year). Assigned age of collected green-winged teal. Assigned based on wing plumage characteristics using Carney (1992; Species, age and sex identification of duck wings using wing plumage, USFWS Report). Sex: Assigned sex of collected green-winged teal. Assigned similar to Age. DOY: Day of year (day 1 = January 1) when collection occurred. Migperiod: Assigned migration period (prior to March 15 = Early, March 15 and later = Late).

Connect: Connectivity of wetland where green-winged teal was collected to the Illinois River. A metric that represents a collection site's susceptibility to flooding. (1 = directly connected or influenced by the Illinois River below flood stage; 2 = influenced by the Illinois River at or above moderate flood stage; and 3 = disconnected via surface water and mostly uninfluenced by the Illinois River.

Data S5. Microsoft Excel file containing a classification type (i.e., seed, aquatic invertebrate, or vegetation) for all food items encountered in diets and/or core samples from wetlands where green-winged teal *Anas crecca* were experimentally-collected in the Illinois River Valley during February–April 2016–2018.

Data S6. Microsoft Excel file containing the mass (g) of food items recovered from esophageal samples of green-winged teal *Anas crecca* experimentally-collected in the Illinois River Valley during February–April 2018. Core samples were first rinsed through a #35 (500 µm; or large sieve) and next rinsed through a #60 (250 µm; or small sieve). Individual samples are identified by 'Core ID' and 'Sieve Size' columns. This data was used to compare the retention of seeds between sieve sizes and its impact on diet selection analysis.

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Table 1. Mean aggregate percent biomass (\bar{x}) and mean percent occurrence (f) of food items found in green-winged teal *Anas crecca* diets ($n = 147$) and average aggregate percent biomass and average total biomass of food items at foraging sites ($n = 64$) for the 20 most commonly encountered food items consumed in the Illinois River Valley during February–April 2016–2018. Items averaging less than 0.1% aggregate percent biomass were noted as trace (*tr*).

Taxa	Diet		Availability	
	\bar{x}	f	\bar{x}	f
Total Seeds	84.5	72.9	308.0	68.9
<i>Cyperus</i> spp.	18.8	76.9	2.8	6.8
<i>Ipomoea</i> spp.	--	--	12.2	73.6
<i>Polygonum</i> spp.	11.3	53.1	14.1	55.6
<i>Amaranthus</i> spp.	8.2	49.7	8.0	22.7

<i>Leptochloa</i> spp.	6.8	21.1	--	--
<i>Panicum</i> spp.	6.5	33.3	3.7	13.3
<i>Ammannia</i> sp.	5.4	23.8	--	--
<i>Potamogeton</i> spp.	4.3	17.0	5.8	44.0
<i>Leersia oryzoides</i>	3.9	17.7	2.7	18.0
<i>Eleocharis</i> spp.	3.1	21.1	1.3	4.8
<i>Abutilon</i> spp.	--	--	3.0	14.6
<i>Echinochloa</i> spp.	2.1	16.3	6.5	25.4
<i>Leptochloa</i> spp.	--	--	1.4	3.8
<i>Chenopodium</i> spp.	--	--	1.0	4.0
<i>Setaria</i> spp.	--	--	1.0	4.5
Total Invertebrates	14.2	23.0	20.5	52.8
Oligochaeta	5.6	23.1	9.2	19.5
Chrionomidae	3.0	32.7	1.5	2.6
Sphaeriidae	1.4	4.1	1.4	3.0
Gastropoda	0.9	13.6	--	--
Physidae	--	--	2.0	8.6
Glossiphoniidae	--	--	0.9	2.9
Egg Mass	0.6	10.9	--	--
Ostracoda	0.6	23.1	--	--
Nematoda	0.5	5.4	--	--
Hemiptera	0.5	7.5	--	--
Diptera	0.3	10.9	--	--
Unknown Invertebrate	0.2	1.4	--	--
Total Vegetation	1.3	4.1	89.9	10.6
<i>Lemna</i> spp.	1.0	24.5	2.2	13.3
<i>Wolffia</i> spp.	0.3	4.1	--	--
<i>Elodea</i> spp.	<i>tr</i>	0.7	--	--
<i>Ceratophyllum demersum</i>	<i>tr</i>	2.0	--	--
<i>Cyperus</i> spp. tubers	--	--	8.4	76.3

Table 2. Variation in selection intensity by year (Annual) and river connectivity (connected [C], partial [P], isolated [I]) to the main channel of the Illinois River of top items consumed and available to spring-migrating green-winged teal *Anas crecca* during February–April 2016–2018 in the Illinois River Valley.

Taxa	Annual ^{a, b}				River Connectivity ^{a, b}			
	All	2016	2017	2018	All	C	P	I
Plant	0.0 _A	0.0 _A	0.0 _A	-0.1 _A	0.0 _A	-0.1 _A	0.0 _A	-0.1 _A
Animal	0.0 _A	0.0 _A	0.0 _A	0.1 _A	0.0 _A	0.1 _A	0.0 _A	0.1 _A
<i>Cyperus</i> spp. seed	-2.7 _A	-1.5 _A	-3.9 _A	-2.6 _A	-2.7 _A	-4.3 _A	-2.4 _A	-2.8 _A
<i>Leptochloa</i> spp.	-1.2 _B	-1.6 _A	-2.6 _B	-0.3 _{BC}	-1.2 _B	-0.9 _{AB}	-0.6 _B	-3.1 _A
<i>Potamogeton</i> spp.	-1.1 _B	-1.0 _A	-1.4 _{BC}	-0.9 _B	-1.1 _B	-1.0 _{AB}	-1.4 _{AB}	-0.3 _B
<i>Panicum</i> spp.	0.1 _C	-0.1 _A	0.9 _{DE}	-0.2 _{BCD}	0.1 _C	-0.8 _B	0.2 _{BC}	0.3 _{BC}

<i>Amaranthus</i> spp.	0.5 _{CD}	1.8 _C	0.0 _C	0.0 _{CD}	0.5 _{CD}	1.7 _B	0.4 _{BC}	0.1 _{BC}
<i>Polygonum</i> spp.	0.6 _{CE}	0.2 _{AB}	1.7 _E	0.1 _{CD}	0.6 _{CE}	1.5 _B	0.4 _{BC}	0.5 _{CD}
<i>Ipomoea</i> spp.	1.1 _E	-0.3 _A	2.5 _F	1.0 _E	1.1 _E	-0.2 _B	1.1 _C	1.6 _E
<i>Oligochaeta</i> spp.	1.3 _E	1.1 _{BC}	0.6 _{CD}	1.9 _E	1.3 _E	1.7 _B	1.1 _C	1.8 _{DE}
<i>Echinochloa</i> spp.	1.4 _{DE}	1.4 _C	2.2 _{EF}	1.0 _{DE}	1.4 _{DE}	2.2 _B	1.1 _C	1.9 _E

^a Negative selection intensities indicate selection for the diet item, whereas, positive values indicate avoidance.

^b Taxa sharing a letter within a column exhibited similar selection intensity, whereas those not sharing a letter displayed different selection intensity at the $\alpha = 0.05$ level.

Table 3. Mean aggregate biomass (%) of taxa in esophageal (Diet) and availability (Core) samples, comparison of mean food selection intensity (T_i) calculated using proportional availability from 500- μ m (#35) and 250- μ m (#60) mesh sieves, and mean percent difference (Δ) in mass of top food items at foraging locations with P -values from paired t-tests comparing mass retained by sieve sizes for spring migrating green-winged teal *Anas crecca* collected in the Illinois River Valley, Illinois, USA during February–April 2018.

Taxa	Diet	# 35 Sieve		# 60 Sieve		$\Delta^{d,e}$	P^d
		Core	T_i^b	Core	$T_i^{b,c}$		
Plant	96.3	86.1	0.02 _A ^c	87.4	0.02 _A	-	-
Animal	3.7	13.9	-0.02 _A	12.5	-0.02 _A	-	-
<i>Cyperus</i> spp. seeds	25.3	2.1	-2.68 _A	6.0	-1.18 _A	661.5	0.004
<i>Ammannia</i> spp.	5.6	0	-1.68 _{AB}	1.7	-0.95 _A	- ^f	- ^f
<i>Potamogeton</i> spp.	5.9	7	-0.72 _C	6.8	-0.98 _A	0.0	-

<i>Panicum</i> spp.	15.3	8.1	-0.12 _{CD}	6.7	-0.55 _{AB}	0.8	0.168
<i>Leptochloa</i> spp.	11.5	13.9	-0.12 _{BCE}	10.0	-0.63 _{AB}	0.0	-
<i>Amaranthus</i> spp.	20.6	19.1	0.05 _{CF}	24.0	0.18 _{BC}	13.0	0.056
<i>Polygonum</i> spp.	9.2	7.6	0.15 _{DEF}	6.6	-0.3 _{AB}	0.0	-
<i>Echinochloa</i> spp.	4.1	7.4	1.26 _{DG}	6.4	0.95 _{CD}	0.0	-
<i>Ipomoea</i> spp.	2.5	12.1	1.37 _G	11.9	1.08 _D	0.0	-
<i>Cyperus</i> spp. tubers	0	22.7	2.49 _F	19.8	2.39 _E	0.0	-

^b Negative selection intensities indicate selection for the diet item, whereas, positive values indicate avoidance.

^c Taxa sharing a letter within sieve sizes exhibited similar selection intensity, whereas those not sharing a letter displayed different selection intensity at the $\alpha = 0.05$ level.

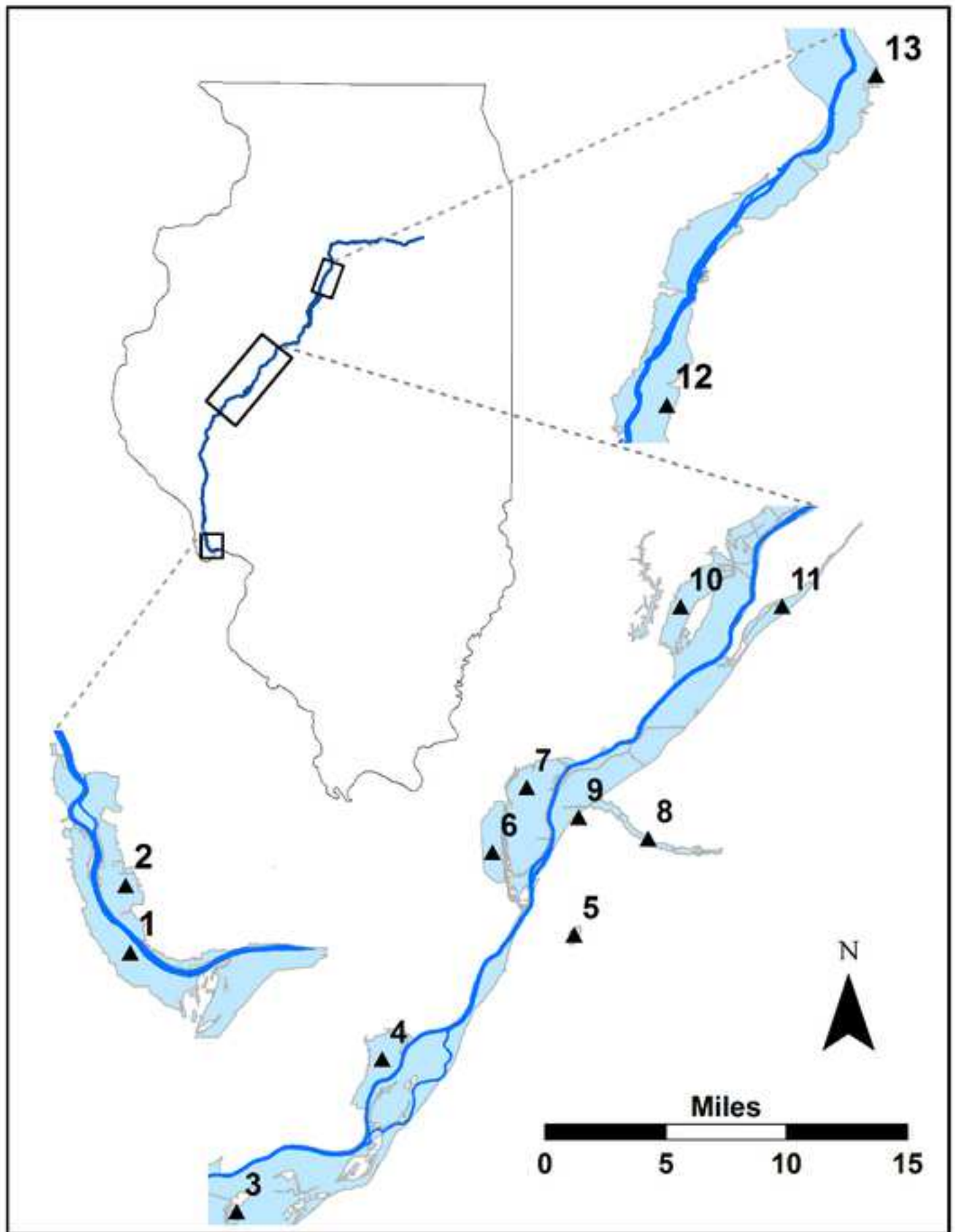
^d Symbol (-) indicates test was not performed on the taxa or data not available.

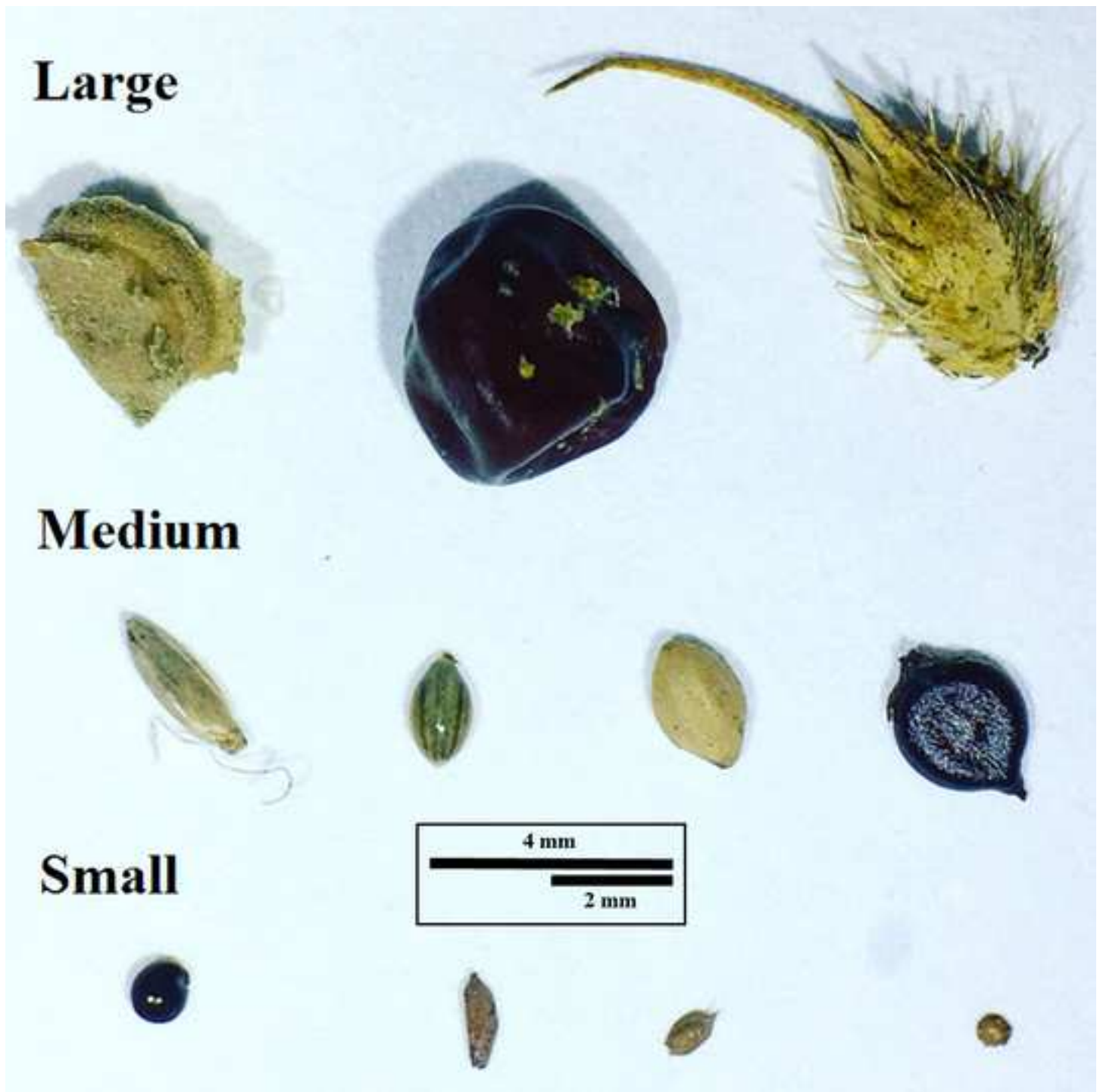
^e Estimates include only samples where seeds were present in both sieves.

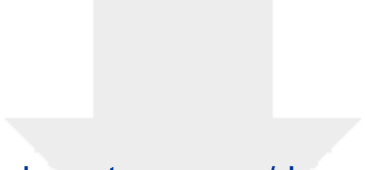
^f Insufficient sample size for analysis and seeds only present in the #60 sieve.

Figure 1. Collection locations of foraging green-winged teal *Anas crecca* during spring migration (February–April 2016–2018) in the Illinois River Valley, Illinois, USA. 1-Two Rivers National Wildlife Refuge (NWR); 2-Mississippi River State Fish and Wildlife Area (SFWA); 3-Sanganois SFWA; 4-Anderson Lake SFWA; 5-Sand Lake; 6-Emiquon NWR; 7-Emiquon Preserve; 8 Quiver Creek; 9-Chautauqua NWR; 10-Rice Lake SFWA; 11-Spring Lake SFWA; 12-Marshall SFWA; 13-Swan Lake Club.

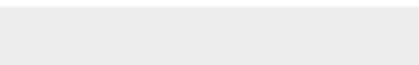

Figure 2. Visual depiction of the general size classes of common moist-soil seeds occurring in diets of spring-migrating green-winged teal *Anas crecca* in the Illinois River Valley, Illinois, USA. In order from left to right. Top row: *Potamogeton* spp., *Ipomoea* spp., *Echinochloa crus-galli*; middle row: *Leptochloa fusca*, *Panicum dichotomiflorum*, *Setaria* spp., *Polygonum lapathifolium*; bottom row: *Amaranthus* spp., *Cyperus odoratus*, *Cyperus erythrorhizos*, *Ammannia* spp.








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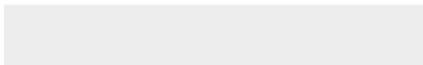




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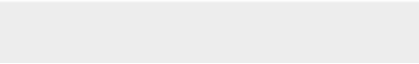


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