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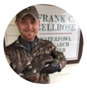

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Intrinsic and Extrinsic Factors Determining Diving Duck Condition and Habitat Quality during Spring Migration in the Upper Midwest

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ABSTRACT

The Illinois and Mississippi river corridors historically provide critical stopover habitat for spring-migrating diving ducks (Havera 1999). However, recent evidence suggests that wetlands associated with these river systems in the region provide limited seed and invertebrate biomass during spring (Straub et al. 2012). We evaluated habitat quality throughout the upper Midwest during springs 2014–2015 by sampling foods available to diving ducks and examining an index of daily lipid deposition of lethally collected lesser scaup and canvasbacks (DLDs; Anteau and Afton 2008*b*). We related habitat quality metrics to body condition, determined by proximate analyses, and habitat selection of diving ducks. Additionally, we estimated levels of the stress hormone, corticosterone, and bioaccumulated hepatic elements to describe physiological condition of lesser scaup at Midwest stopover locations. Our data indicate that regional differences in body condition, stress levels, nutrient acquisition, foraging patch selection, and foraging area selection were more important than other factors (e.g., food densities) during spring migration. We observed low food densities, diverse diets, and negative energy balances, suggesting that food may be limited for diving ducks during spring. In particular, lack of evidence for patch and area selection may indicate that diving ducks are often unable to differentiate foraging patches based on energetic value. Additionally, other stressors such as introduced parasites may be an emerging threat to lesser scaup populations and important contributors to the Spring Condition Hypothesis (England 2016).

INTRODUCTION

Background

Migratory waterbirds are assumed to be limited by habitat quantity and quality during non-breeding periods (Newton 2006, Abraham et al. 2007, Soulliere et al. 2007). During migration, waterbirds feed at stopover sites to replenish and accumulate lipids expended during migratory movements. Lesser scaup (*Aythya affinis*) and canvasbacks (*A. valisineria*) are two diving ducks considered in greatest need of conservation under the Illinois Wildlife Action Plan and are important species identified for conservation by the Upper Mississippi River and Great Lakes Joint Venture. Continental populations of both species have decreased significantly over the last 30–40 years, although lesser scaup breeding populations seem to have recently stabilized. The canvasback population reached a low of 373,000 in 1978 and concern remains over the future status of this species. Similarly, the continental breeding population of scaup was estimated at 8.0 million in 1972 but only 3.2 million in 2006 (Zimpfer et al. 2015). The “Spring Condition Hypothesis” may explain the lesser scaup decline, which indicates that foraging habitats in the midcontinent have declined in quality (e.g., abundance of food; Anteau and Afton 2004). If inadequate forage exists for lesser scaup during spring, these birds may delay, forgo, or risk reduced reproductive potential during the breeding season.

Identifying habitat quality of stopover sites can be difficult because traditional measures (e.g., mass of individuals) may be influenced by previously-used habitats, or “quality” metrics may not actually relate to habitat characteristics (Johnson 2007, Fleming 2010). Previously, scientists have measured abundance and behavior of focal individuals (Gawlik 2002, Hagy and Kaminski 2012*b*, Mittelhauser et al. 2008), physical habitat attributes (Bowyer et al. 2005, Brasher 2010, Straub et al. 2012) or juxtaposition of habitats (Webb et al. 2010) to indicate quality (UMRGLRJV 2007:35), but more direct measurements of stopover habitat influence on individual foragers have been less often used (e.g., diet, blood, nutrient reserves, metabolites; Badzinski and Petrie 2006, Johnson 2007, Anteau and Afton 2008*a*). While indirect measures of wetland quality for diving ducks may be valuable, measures of actual nutrient levels, or indicators thereof, provide a real-time assessment of habitat influence on body condition (Williams et al. 1999, Badzinski and Petrie 2006, Anteau and Afton 2011). However, nutrient composition of birds (e.g., fat and protein levels) may be influenced by habitats used in other areas (e.g., previously-used stopovers, wintering regions), life-history strategy, and sex, and may be highly variable among individuals (Badzinski and Petrie 2006). Several blood metabolites provide an index of body condition relative to recent lipid catabolism and deposition, (Williams et al. 1999; Anteau and Afton 2008*b*, 2011). Blood metabolite levels change rapidly in response to metabolic processes and provide a means to compare body condition at different points in time, in specific habitats, or during different activities (e.g., hyperphagia; Jenni-Eirmann and Jenni 1996, Williams et al. 1999).

In addition to blood metabolites, certain hormones may be produced in response to stressors, such as nutrient limitation, environmental pathogens, and anxiety (e.g., from capture and handling; Kitaysky et al. 1999, Sorenson et al. 2003). Long-term exposure to stress-induced hormones can result in disease, decreased reproductive potential, and immune system suppression (Romero and Butler 2007). Corticosterone (CORT) has been used extensively to measure stress related to experimental conditions of birds, but can rapidly change in blood and capture and handling biases can result (Broom and Johnson 1993). Thus, measuring CORT in fecal material can provide a better indicator of recent stress to individuals without incurring handling bias (Herring and Gawlik 2007) or being influenced by recent events, such as migration (Hartup et al. 2004). For instance, chronic stress related to food limitation or allostatic overload in migrating birds may increase stress hormone production (Kitaysky et al. 1999, McEwen and Wingfield 2003). Stress hormones can be used to measure metabolic response to food limitation and may be more efficient and accurate correlates of habitat quality than indirect measures (e.g., food abundance, diet composition), especially when combined with blood plasma metabolite indices.

Several elements (i.e., Arsenic [As], Cadmium [Cd] and especially Selenium [Se]) may interact with extrinsic factors during the annual cycle to reduce survival or productivity of lesser scaup in North America (Austin et al. 2006). Austin et al. (2000) identified examination of the effects of contaminants on lesser scaup as a critical research need and others have since identified the interactions of contaminant levels with foraging habitat and other extrinsic factors as possible mechanisms for the long-term population declines (Austin et al. 2006, Pollock and Machin 2009). Several studies have documented elevated concentrations of Se in scaup (Custer et al. 2000, 2003; Anteau et al. 2007; Petrie et al. 2007; Pillatzki et al. 2011); however, the impacts of such exposures together with other stressors, habitat quality, and body condition are relatively unknown (*cf.* DeVink et al. 2008, Pollock and Machin 2009). Pillatzki et al. (2011) reported elevated concentrations of Se and Cd in lesser scaup collected in the Prairie Pothole Region during spring migration and suggested that Se concentrations may be high enough to affect reproduction, although they noted the lack of information on Se toxicity in this species. DeVink et al. (2008) failed to demonstrate long-term effects of Se concentrations on body mass or reproduction in spring-staging scaup, but suggested that other contaminants accumulated during winter could have cross-seasonal effects. Anteau et al. (2007) found that Cd was negatively associated with lipid levels, suggesting that contaminants could be impacting scaup at a critical time in the annual cycle (i.e., during spring migration). Thus, considerable uncertainty exists regarding the possible interactions of contaminants with other intrinsic and extrinsic factors and subsequent effects on lesser scaup during spring migration. Although studies have documented exposure of lesser scaup to hydrocarbons wintering in contaminated sites (e.g., Indiana Harbor Canal [Custer et al. 2000], San Francisco Bay [Miles 1993]), there has been no examination of recent hydrocarbon exposure in northward migrating lesser scaup in the Midwest and the impacts that chronic exposure might have on condition during the spring. Although measuring hydrocarbons directly is expensive, certain elements (e.g., Nickel [Ni], Vanadium [V], Chromium [Cr], and Cd), may be more cost-effectively measured and used to indicate petroleum exposure. Thus, measuring a combination of elements can provide a chemical “profile” and act as a crude marker of potential hydrocarbon exposure (Michot et al. 1994, (Hobson et al. 1997, Dickerson et al. 2000).

Project Justification

The Illinois and Mississippi river corridors provide critical stopover habitat for migrating waterfowl, including diving ducks in spring (Havera 1999). Lesser scaup, a Joint Venture focal species, have experienced long-term declines, despite restrictive harvest and targeted research (Afton and Anderson 2001, Anteau and Afton 2008*a,b*). However, recent evidence suggests that wetlands associated with these river systems in the region provide limited seed and invertebrate biomass for waterfowl in spring (Straub et al. 2012). Moreover, recent data from the lower Great Lakes indicates that lesser scaup are in poor condition upon arrival and do not increase their nutrient resources during stopover there (Badzinski and Petrie 2006). Conversely, Anteau and Afton (2011) noted the condition of lesser scaup was substantially greater in the Pool 19 of the Mississippi River than other isolated wetlands of the upper Midwest. As wetlands along the Mississippi River and within the Illinois River receive substantial use by spring-migrating lesser scaup and canvasback and ducks move between and among these wetland complexes (Yetter et al. 2012), quality of these wetlands as foraging habitats for diving ducks should be quantified and compared with recent results from the Prairie Pothole Region and Pool 19 of the Mississippi River (Anteau and Afton 2011). Such comparisons are needed to evaluate specific objectives of the UMRGLR Joint Venture and assumptions regarding foraging habitat requirements and food availability for spring-migrating diving ducks (Arzel et al. 2006).

Anteau and Afton (2008*b*) developed an index of daily lipid dynamics to indicate body condition of lesser scaup during migration. They determined that wetlands north of Pool 19 of the Mississippi River in the Prairie Pothole Region may have been of low forage quality for lesser scaup during spring, which could negatively affect reproduction and overall fitness (Anteau and Afton 2009, 2011). However, previous researchers have not concurrently compared wetland type, behavior, abundance, and benthic and nektonic food availability to blood metabolites, contaminants, and stress hormones or concurrently examined these factors in relation to lesser scaup and canvasback abundance in the Joint Venture region. Identifying quality habitats and prioritizing wetlands and management regimes for conservation is critical to migrating ducks in spring (UMRGLRJV 2007, Straub et al. 2012). If current food availability estimates are not indicative of wetland quality for diving ducks, related conservation planning strategies based on those estimates must be revised and other models of wetland quality and habitat requirements must be developed.

Currently, the Joint Venture prioritizes habitat conservation based on the assumption that foraging habitat during spring migration may limit populations of many bird species (Soulliere et al. 2007:19). However, many factors in addition to forage biomass affect wetland quality and use by ducks, and measuring condition and success of foragers (e.g., ducks) using habitats may be a better determinant of wetland quality and should be assessed (Soulliere et al. 2007:19,27). Quantifying duck condition at discrete points in time would help meet several Joint Venture objectives, such as "Improve understanding of migration and wintering habitat selection, migration chronology, and human influences on migrating and wintering bird populations to better predict habitat needs and target conservation areas." Moreover, directly measuring the condition and nutrient acquisition of ducks during spring migration will assist the Joint Venture in assessing usefulness of parameters (e.g., total food biomass) used in carrying capacity models and used to prioritize habitat conservation, protection, and restoration measures at the state level (e.g., Illinois Wetland Campaign [Draft], Schultheis and Eichholz 2011). Currently, wetland conservation strategies are based on Joint Venture assumptions (e.g., UMRGLR Joint Venture Implementation Plan, Illinois Wetlands Campaign), and these must be validated using updated tools, technologies, and science.

Along with assessing habitat quality, recent researchers have indicated a need for increased banding data during multiple seasons of the year to improve the reliability of current survival estimates, especially during non-breeding periods (Koons et al. 2006). Additional band return data is needed to refine population dynamics models to target habitat conservation in areas most critical to survival and reproduction. Band returns establish linkages between migration stopover locations and other critical areas used during the annual cycle. Significant numbers of lesser scaup and canvasbacks have been banded along the Mississippi River, but very few have been banded along the Illinois River. As the Illinois River is a major fall and spring migration stopover location for ducks traveling to the Great Lakes and the Prairie Pothole Region (Havera 1999), additional banding data is needed to assess the relative importance of this region (Arnold et al. 2016). Moreover, limited evidence suggests that diving ducks may undertake east-west movements between the Illinois and Mississippi rivers during spring migration. Such movements can be identified using banding data from concurrent studies (e.g., A. Afton, Louisiana State University), and this information could be useful in current bioenergetics models. Additionally, banding data could help determine whether or not lesser scaup using the Illinois River migrate northward through the Great Lakes region or follow similar routes to lesser scaup using Pool 19 of the Mississippi River through the Prairie Pothole Region.

Objectives

Our goal was to concurrently measure abundance, behavior, food abundance, food use and selection, and levels of stress hormones, environmental contaminants, and blood plasma metabolites of lesser scaup and canvasbacks during spring migration through the Joint Venture region of Illinois and Wisconsin. Our objectives were to, at major spring-migration stopover locations of lesser scaup and canvasback in Bird Conservation Regions (BCR) 22 and 23 of the UMRGLR Joint Venture region, 1) compare blood plasma metabolite, environmental contaminant, and stress hormone levels with other measures of habitat quality (e.g., food abundance, behavior, wetland type, diet) to determine utility as indicators of habitat quality, 2) determine foraging habitat quality and energetic carrying capacity of emergent and riverine wetlands, 3) identify food use and selection, 4) evaluate the Joint Venture assumption that energetic carrying capacity is related to condition of foragers and a suitable surrogate for foraging habitat quality, 5) assess tissue concentrations of selected elements, and 6) identify linkages with subsequent breeding and wintering areas and determine apparent stopover duration by annually capturing and banding 1000 lesser scaup and 250 canvasbacks along the Illinois River.

Hypotheses

We hypothesized that: 1) blood metabolites and stress hormones would provide an accurate index of spring diving duck foraging habitat quality as determined by seed, tuber, and invertebrate abundances in diet samples (Anteau and Afton 2011); 2) habitat quality determined by assumed energetic carrying capacity would not be related to overall biomass of potential foods as currently assumed by the Joint Venture (Hagy and Kaminski 2012*a*); 3) emergent wetlands would be of greater foraging habitat quality than riverine or other wetland types, and plant foods may be selected in areas where invertebrate abundances are low (Strand et al. 2008, Yetter et al. 2012); 4) stress hormones would be elevated when food availability is low; and 5) significant numbers of diving ducks move between the Mississippi and Illinois rivers during spring migration.

SCOPE OF PROJECT

Study Area

In North America, the lesser scaup is the most abundant diving duck (USFWS, 2015) and constitutes approximately 89% of the continental scaup population (lesser and greater scaup [*A. marila*] combined; Austin et al. 2000). An estimated 75% of the continental scaup population travels through the Mississippi Flyway during spring and fall migrations. Regions of collection were categorized into 4 distinct areas post hoc based on latitude, physiography, and habitat type: Southern Illinois (SI [Rend Lake, Carlyle Lake]), the Illinois River (IR [Peoria Reach – Alton Reach]), the central Mississippi River (CMR [Pools 12 and 19]), and the upper Mississippi River (UMR [Pools 7 – 9]; Fig.1–7). We attempted to collect lesser scaup in other areas of southern Illinois, eastern Illinois, and eastern Wisconsin, but few samples were collected due to relatively low numbers of scaup using these areas, difficulty in accessing foraging locations, or lack of permission to collect samples. More than 700,000 lesser scaup were recorded on the upper Illinois River in 1949, INHS personnel counted nearly 12,500 lesser scaup at Emiquon Preserve in the IRV on 10 March 2007 and 350,000 lesser scaup and 20,000 canvasbacks on Pool 19 of the Mississippi River on 24 March 2008. Thus, wetlands of both rivers systems provided important stopover habitats during spring, a critically important time in the annual cycle of waterfowl.

Methods

We visited concentrations of lesser scaup and canvasbacks, identified by aerial surveys and located incidentally, and quantified behavior and food abundances at feeding and random locations. We targeted flocks where at least 25% of individuals were observed foraging to increase the probability that individual birds would be informed as to food densities in use locations. We used modified scan sampling whereby we located individual flocks (i.e., aggregations of ≥50 individuals) of lesser scaup and canvasbacks and quantified instantaneous behavior, species, and sex using 5–10 individual scans of each flock with a 5-minute waiting period between scans. Estimated time spent feeding by diving ducks is often biased low when using scan sampling because ducks underwater are missed (Baldassarre et al. 1988), and ducks in the inter-dive loafing period are misclassified as resting. Thus, our modified method included a slow scan of flocks to increase encounters with diving or surfacing individuals. When a bird that appeared to be resting was encountered, we observed it for 10 seconds, the approximate length of most inter-dive loafs (R. Smith, IDNR, *pers. comm.*). If the individual remained resting after that period or engaged in any other behavior (e.g., preening), we recorded the bird as resting, the originally encountered state. However, if the individual dove during that period, it was likely in the state of feeding and classified as such.

We lethally collected lesser scaup and canvasbacks from lakes and wetlands where they were observed foraging in large numbers. Within 10 minutes after collection, we obtained blood samples and upper digestive tracts (i.e., proventriculus and esophagus) from lesser scaup to measure blood-plasma metabolites (e.g., triglyceride [TRIG], β-hydroxybutyrate [BOHB]) and evaluate food use and selection (Anteau and Afton 2008*b*, 2011). We attempted to collect birds making multiple foraging dives to increase the likelihood of finding food in the digestive tract. We harvested ducks with a shotgun from shore or sneak boats, collected blood samples, obtained morphological measurements, necropsied carcasses to obtain digestive tracts and other tissues for later analysis, and preserved samples on ice or in liquid nitrogen until they could be transferred to long-term cold storage (-80°C). Immediately after collection, we used a cardiac puncture technique to obtain approximately 1 mL of blood for metabolite assays (Anteau and Afton 2008*c*, 2011). During field necropsy, the entire right lobe of the liver was removed from each lesser scaup collected using sterile techniques, immediately bagged, and transported on ice until it could be frozen at -20ºC. We obtained a 2-mL fecal sample directly from the cloaca, placed it into a cryovial, and flash froze the sample in liquid nitrogen for subsequent tests of the stress hormone corticosterone. In the laboratory, cryovials were stored at -80ºC (Herring and Gawlik 2009). Corticosterone extraction and assay protocol were conducted using Corticosterone EIA kits (Enzo Life Sciences, Farmingdale, New York, USA) following manufacturer instructions.

We estimated food density at all collection sites, behavior sites, and within random locations in wetlands where birds were collected or observed. Following bird or behavior collection, we collected 5 benthic core samples and 5 nektonic sweeps from each collection or foraging behavior site and 9 random samples across wetlands or portions of wetland used by diving ducks. Random samples were collected along 3 transects (3 equally spaced samples / transect) randomly allocated and spaced across portions of wetlands used by diving ducks to represent food availability and allow comparisons with food use (third order selection, *sensu* Johnson 1980). Samples were taken within 24 hr of bird collection or observation, but we collected random samples only once every two weeks and assumed significant depletion of foods would not occur over a two-week period (our data support this assumption). Each sample consisted of a vertical sweep-net (454 cm^2) and benthic-core (10-cm deep × 6-cm diameter) sample. Vertical sweep-net samples consisted of a vertical sweep through the water column using a standard D-frame net (500 µm mesh) at a right angle to an extended handle to estimate nektonic invertebrate density. Benthic core samples represented seed, tubers, and benthic invertebrate density. Samples replicates of a similar type (e.g., all 5 core samples) were combined from each collection site or random transect into a sieve bucket, rinsed to remove excess soil, and deposited into a labeled Ziploc bag containing a mixture of 10% formalin and rose bengal. Samples were transported to a laboratory and processed within 150 days. All seeds, tubers, and invertebrates were removed from samples by hand, dried at 60ºC, weighed by taxon (i.e., seeds to genus or species, invertebrates order or family), and extrapolated to kg(dry)/ha using standard protocols and correcting for diet and processing bias (Hagy et al. 2011, Hagy and Kaminski 2012*a*). We sub-sampled (up to ¼) by mass (dry benthic samples) or volume (nektonic samples using a Folsom plankton splitter) those samples with abundant food items (>200) to reduce processing time (Smith et al. 2012). At each food sample location, we also recorded water and Secchi depth.

We incorporated assay estimates of BOHB and TRIG into a predictive equation developed by Anteau and Afton (2008*b*) to infer daily lipid dynamics (hereafter, DLD), an estimate of the rate and direction of recent lipid change that can be used to index foraging habitat quality. Upper gastrointestinal tracts (i.e., proventriculi and esophagi) of diving ducks were thawed in the laboratory and all food items identified and enumerated by species (seeds) or family (invertebrates), oven-dried for ≤24 hr at approximately 60°C, and weighed to the nearest 0.1 mg. We present food use as percent occurrence and aggregate percentage dry mass along with rankings of availability and use (Swanson et al. 1974, Johnson 1980). We selected 130 lesser scaup from the larger sample of collected birds, due to monetary constraints, for liver element analysis based on the spatial distribution of collection sites and availability of other measures of health from the same bird. Subsequently, liver samples were prepared for analysis of elemental concentrations using a concentrated nitric acid digestion (EFGS-SOP-058 Teflon Concentrated Nitric Tissue Digestion), and subsequently analyzed for total recoverable elements by inductively-coupled plasma mass spectrometry in accordance with EFGS-SOP-054, a modified version of EPA 1638 (documents are available upon request). Elements of interest (detection limits in μg/g dry mass) were: arsenic (As, 0.04); cadmium (Cd, 0.001); calcium (Ca, 2); chromium (Cr, 0.02); cobalt (Co, 0.003); copper (Cu, 0.01); iron (Fe, 13); lead (Pb, 0.002); magnesium (Mg, 0.09); phosphorus (P, 52); selenium (Se, 0.06); strontium (Sr, 0.004); zinc (Zn, 0.02). Quality control samples included blanks, matrix spikes (MS) and duplicates (MSD), and laboratory control spikes (LCS) and duplicates (LCSD). All sample results were accepted based on the results of analyses of quality control samples. One blank had Zn (0.26) and 2 blanks had Cu (0.10; 0.39) contamination; however, these concentrations were a very small proportion of measured concentrations in samples. One blank had low Cd (0.013) contamination. The relative percent difference (RPD) between a MS recovery and a matrix spike duplicate MSD recovery averaged 10%. When RPD of a MS/MSD was above 25%, batch QC results were accepted based on acceptable LCS/LCSD. Matrix spikes recovered at 110%, on average. When matrix spike recoveries were outside of established guidelines, batch QC results were accepted based on acceptable LCS and LCSD recoveries. LCS and LCSD recovered well at 100%, on average. We compared observed values for elements in livers with avian toxicity thresholds and concentrations observed in other studies.

Aerial surveys and Use-days

We used fixed-wing aircraft to conduct aerial inventories of waterfowl and other waterbirds present at selected sites along the Illinois (Hennepin to Grafton, IL) and central Mississippi river (Pool 19) from ice-out in early March to the end of spring migration for most individuals in mid-April (Fig. 8; Havera 1999). One observer conducted all inventories from a single-engine, fixed-wing aircraft flying at an altitude of <450 ft and 150–160 mph (Havera 1999, Stafford et al. 2007). We recorded the number and species composition of waterfowl at each site, and survey methods mirrored previous years to maintain consistency with past inventories (Havera 1999). During each flight, we inventoried approximately 65 areas in each river system that typically host the majority of waterfowl in the region during spring migration (Havera 1999, Horath and Havera 2002). We computed waterfowl use-day estimates (Stafford et al. 2007) for diving ducks in the Illinois River (IR) and central Mississippi River (CMR) and compared use days to duck energy day estimates from core and sweep-net sampling. We assumed wetlands were no longer energetically beneficial at 200 kg/ha and subtracted this threshold from food estimates prior to DED calculations (Hagy and Kaminski 2015, Hagy et al. 2016).

We captured and banded lesser scaup and canvasbacks along the Illinois River using baited swim-in traps with captures occurring from early March through mid-April (Anteau and Afton 2008*b,c*, Yetter et al. 2012). For each bird captured, we recorded species and sex, obtained morphological measurements, and attached an incoloy leg band. Moreover, we monitored recaptures using swim-in traps at least 4 days/week to coarsely estimate apparent stopover duration in the Illinois River calculating a simple mean of days elapsed between initial capture and date of last capture.

Statistical Analyses

We used multivariate analysis of variance (PROC GLM in SAS v9.3; SAS Institute, Inc. 2010) to test for regional, species, and yearly differences in behaviors. We restricted analyses to foraging, resting, and locomotion as these behaviors represented >90% of observations. We designated $\alpha = 0.05$ and means were calculated from raw data (PROC MEANS in SAS v9.3).

We used separate linear models to test for differences of year and region on plant (i.e., seeds, tubers, and vegetative material), total invertebrate, and total food density (Proc MIXED in

SAS v9.3). We designated α = 0.05 and means were calculated from raw data (PROC MEANS in SAS v9.3). Additionally, we used an information theoretic approach based on Akaike's second order information criterion (AIC_c) to determine the relative effects of total food density (i.e., plant + invertebrate foods), region, species, and water and Secchi depth on the functional response (i.e. the proportion of time spent feeding) of lesser scaup and canvasback (PROC MIXED in SAS v9.3; Burnhan and Anderson 2002). We included year as a random effect and examined distribution of residuals to ensure model assumptions were met.

We used separate linear mixed models (PROC MIXED in SAS v9.3) to examine the effect of food density (total food, seeds and tubers, and invertebrates), region, sex, and diet composition (proportion plants, proportion animal) on body condition and fecal corticosterone concentrations in lesser scaup. A body condition index based on morphometrics (e.g., wing chord, mass, tarsus length) and proportion of carcass fat was positively correlated with post-necropsy body mass (i.e., eviscerated mass); hence, we used eviscerated mass as a surrogate measure of body condition of lesser scaup and canvasback (England 2016). We included year as a random effect.

In separate logistic models, we examined factors affecting foraging patch selection on experimentally collected ducks from 2014–2015 and factors affecting area selection by flocks of ducks observed foraging from 2012–2015. We modeled the proportion of samples where food density at foraging sites (1) was greater than random sites (0) by independent variables water depth, Secchi depth, region, species, and total food density (kg/ha; PROC LOGISTIC in SAS v9.3). We used an information theoretic approach based on AIC_c and ran all biologically plausible models, including two-way interactions. We included only total food density as it was highly correlated with benthic and plant food density, and nektonic food density contained many values of or near zero. We interpreted model results using log ratios.

We built and ranked separate linear models (PROC MIXED in SAS v9.3) to test for effects of species, sex, region, invertebrate foods, plant foods, and overall food resources on DLDs of diving ducks collected throughout the Midwest. We included year as a random effect. We used an information theoretic approach based on AIC_c and ran all biologically plausible models, including two-way interactions. Means and errors were calculated from raw data (PROC MEANS in SAS v9.3).

RESULTS

General

Our research was supported collaboratively by the U.S. Fish and Wildlife Service, Illinois

Department of Natural Resources, and the Illinois Natural History Survey at the University of Illinois at Urbana-Champaign and results have been previously reported in part in a Master's Thesis (Appendix 1) and a Final Report (Appendix 2) and will be included subsequently in a Final Report (IDNR-W-176-R). Herein, we combined data across regions, objectives, and funding proposals and present a comprehensive report on our research involving spring migration ecology of diving ducks in the Upper Midwest.

During February–April of 2012–2015, we collected 173 behavioral samples, 121 sets of random food density samples, 335 sets of foraging site food density samples, and 465 carcasses of diving ducks from Illinois and Wisconsin (Fig. 1–7). We processed approximately 2,764 core and nekton samples and conducted extensive laboratory work assessing health parameters of migrating diving ducks.

Behavior

Foraging, resting, and motion were the most common behaviors observed (>90%) and did not vary across species (Wilks's $\lambda = 0.708$, $F = 1.5$, $P = 0.213$). Across species, male (41%) and female (43%) diving ducks spent similar proportions of time feeding and this was consistently the dominant activity across years (Fig. 9; Table 1). Conversely, the proportion of individuals observed foraging was greatest in 2015 ($F = 11.3$, $P < 0.001$), resting was less in 2015 and 2014 than 2012 and 2013 ($F = 14.2$, $P < 0.001$), and birds observed in motion were greater in 2014 than other years ($F = 6.6$, $P < 0.001$). Both lesser scaup and canvasbacks spent the greatest percentage of their time foraging during spring 2015 when overall food availability (304.5 kg/ha) and benthic invertebrates (43.2 kg/ha) were least abundant (Table 2).

Foraging effort (i.e., functional responses) varied by water depth, Secchi depth, and species. Foraging decreased 1% for each 10 cm increase in water depth and increased 1% for each 10 cm increase in Secchi depth. Total food density was included in one top model, but confidence intervals overlapped zero indicating no true effect. Foraging effort was approximately 5% greater in canvasbacks compared to lesser scaup, but species was included in only one top model and weight was low ($\omega = 0.28$).

Food Density

Total food ($F_{3,116} = 2.65$, $P = 0.052$), seed ($F_{3,116} = 2.12$, $P = 0.102$), and invertebrate ($F_{3,116} = 2.38$, $P = 0.073$) biomass at foraging locations of diving ducks was similar across years of our study and was probably limited in most locations considering foraging thresholds and costs of foraging for diving ducks (Table 3; Fig. 10). Similarly, total food ($F_{3,115} = 0.79$, $P = 0.502$), plant ($F_{3,115} = 1.50$, $P = 0.219$), and invertebrate ($F_{3,115} = 2.44$, $P = 0.068$) biomass at foraging locations of diving ducks was similar across regions. Across years and regions, total food density for diving ducks was 317.3 kg/ha (SE = 63.6) and was comprised approximately equally of plants foods ($\bar{x}$ = 159.7 kg/ha, SE = 56.9) and invertebrates ($\bar{x}$ = 163.5 kg/ha, SE = 25.4). Nektonic invertebrates composed 3.5% of the total food density and likely contributed little to food availability for spring-migrating diving ducks. In 2012 and 2013, benthic invertebrates comprised most food density (57–90%) followed by plant foods (10–43%). However, in 2014 and 2015, when food selection and experimental collection activities occurred, benthic invertebrates comprised a small portion (14–16%) of food density compared to seeds and tubers (74–83%). Food densities at random locations were similar to foraging sites (Table 2).

Area and Patch Selection

Overall, area selection for increased food densities was limited and appeared similar between species at locations where flocks were observed foraging compared to random locations (Table 3). Area selection appeared to occur more often in the Illinois River when plant densities were greater than randomly available for both lesser scaup and canvasback. In the central Mississippi River, area selection occurred more often when invertebrate densities were greater for lesser scaup, but more often when plant densities were greater for canvasbacks. Neither canvasbacks nor lesser scaup consistently selected foraging areas with greater total food densities than random sites during our study and foraging area selection appeared random relative to total food densities (Table 3). The top logistic model of area selection included independent variables total food density and region (Table 4). Area selection increased 3.7% with each 10 kg/ha increase in food density and were approximately 33% less in the Central Mississippi River than and Illinois River.

Overall, patch selection for increased food densities was limited and appeared similar between species at locations where foraging birds were collected compared to random locations (Table 4). On average, less than half of diving ducks were observed foraging at locations with greater food density than at random locations across regions. However, the proportion of birds foraging at locations with greater food densities than at random locations was markedly different between regions. Lesser scaup and canvasbacks tended to select foraging patches with greater plant densities than randomly available more often in all regions, with the greatest selection tendencies occurring in the Illinois River for lesser scaup and in the central Mississippi River for canvasbacks. The odds of patch selection increased 1% with each 1.4 kg/ha increase in food densities at locations where ducks were foraging.

Diet and Food Selection

We analyzed food habits of 262 lesser scaup and 41 canvasbacks collected throughout the Upper Midwest. We limited diet analyses to birds observed foraging and having sufficient food in the esophagus for inference (>0.1 g / bird and >10 items). Generally, animal material was observed more frequently and at a greater percent aggregate mass than plant foods in diets of both species (Table 5). Similar trends were observed in both lesser scaup (Table 6) and canvasback (Table 7) diets, where invertebrates occurred more frequently (82% and 80%, respectively) and at a greater aggregate percent biomass (66% and 57%, respectively) than plant material. Notable food items of lesser scaup included dreissenid mussels, chironomids, sphaerid clams, amphipods, pondweed seeds, and millet seeds. Canvasbacks consumed principally animal matter, with mayflies, sphaerid clams, millets seeds, and wild celery tubers as the most common taxa.

Blood Metabolites

We observed a negative mean index of DLD for diving ducks in all regions of our study area (Table 8). Daily lipid dynamics of experimentally collected lesser scaup were negative in all regions (Table 9) and varied as a function of sex, region, invertebrate foods, and total food biomass (Table 11). Mean DLD was lower in lesser scaup females than males, and was greatest in the Illinois River ($\bar{x}$ = -7.9), followed by the central Mississippi River ($\bar{x}$ = -11.0), upper Mississippi River ($\bar{x}$ = -14.1), southern Illinois Reservoirs ($\bar{x}$ = -18.6), and Illinois/Mississippi River confluence ($\bar{x}$ = -26.2). The top regression model for DLD in lesser scaup included region and invertebrate and total biomass from core and sweep-net samples. The DLD index for lesser scaup increased by one unit for every 85-g increase in food density at collection locations and decreased one unit for every 99-g increase in invertebrate density (Table 11).

Daily lipid index of canvasbacks varied as a function of region, invertebrate foods, and total food biomass at collection locations according to top models (Table 11). Greatest mean DLD was observed in the upper Mississippi River ($\bar{x}$ = 27.4), followed by the Illinois River ($\bar{x}$ = -4.4), the Illinois/Mississippi River confluence ($\bar{x}$ = -7.0), the central Mississippi River ($\bar{x}$ = -11.8), and Southern Illinois Reservoirs ($\bar{x}$ = -28.4). The top regression model for DLDs in canvasbacks included region and invertebrate biomass from core and sweep samples. The DLD index for canvasbacks increased one unit for each 23-g increase in total food density and decreased one unit for every 7-g increase in invertebrate densities (Table 11). Mean DLD index for canvasbacks was negative across regions, with the exception of canvasbacks in the Upper Mississippi River ($\bar{x}$ = 27.4, Table 10).

Body Condition

Body condition, based on eviscerated mass of experimentally collected lesser scaup post necropsy, varied as a function of region, DLD, and proportion of plant material in the diet (Table 12). Eviscerated mass was greatest in the central Mississippi River ($\bar{x}$ = 614.3, SE = 19.3), followed by the Illinois River ($\bar{x}$ = 572.1, SE = 7.6), the Upper Mississippi River ($\bar{x}$ = 540.4, SE = 11.7), Southern Illinois Reservoirs ($\bar{x}$ = 523.6, SE = 15.0), and the Illinois/Mississippi River Confluence ($\bar{x}$ = 491.3, SE = 13.1). An increase in 0.7 grams of eviscerated mass resulted in an increase in 1 DLD unit in lesser scaup. The proportion of diet composed of plant material increased 1% for every 21.5 g decrease in mass.

Body condition of canvasbacks varied as a function of region, DLD, total food density, and proportion of plant material in the diet (Table 12). Eviscerated mass was greatest in the central Mississippi River ($\bar{x}$ = 1083.3, SE = 26.7), followed by the upper Mississippi River ($\bar{x}$ = 1044.0, SE = 54.2), and the Illinois River ($\bar{x}$ = 952.2, SE = 34.5). The Illinois/Mississippi river confluence was included in the Illinois River due to low sample size. Eviscerated mass decreased approximately 1 gram for every 4-g increase in total food density and 38.5 g for every 1% increase in the proportion of diet composed of plant material. Confidence intervals for DLDs overlapped zero indicating no true effect on mass in canvasbacks.

Stress

Long-term exposure to stress, as predicted by corticosterone levels in fecal samples taken from experimentally collected lesser scaup, varied by region, DLD, nektonic food density, and total food density (Table 12). Stress levels were greatest in southern Illinois reservoirs, followed by the Illinois River, the confluence of the Illinois and Mississippi rivers, the central Mississippi River, and the upper Mississippi River (Fig.12). Stress levels increased approximately 1 ng/mL for each increase in DLDs, but confidence limits for total food and nektonic food density overlapped zero indicating no true effect.

Hepatic Elements

Concentrations of the essential elements Fe, Co, Cr, Mg, P, and Zn were similar to concentrations observed previously in apparently healthy lesser scaup and other ducks, and the concentrations of non-essential elements that we observed in lesser scaup livers were within known avian toxicity thresholds (Table 13). Notably, concentrations of Se in 31% (37/120) of lesser scaup in our study exceeded 10 µg/g, and concentrations were greater than 33 µg/g threshold in four (3%) ducks.

Duck Use Days

During 2012–2015, total use days of diving ducks and mergansers averaged 3.9 million on the Illinois River and 5.9 million on Pool 19 of the Mississippi River (Table 14). Peak abundances averaged 225,200 on the Illinois River and 256,816 on Pool 19 of the Mississippi River (Table 15). Peak abundances and use days of lesser scaup, canvasback, and common goldeneye (*Bucephala clangula*) were greater along the Mississippi River whereas ring-necked duck (*A. collaris*) and ruddy duck (*Oxyura jamaicensis*) were more abundant and had more use days along the Illinois River. We counted 1,315,905 diving ducks and mergansers during spring 2015 on the Illinois River and Pool 19 of the Mississippi River. This estimate was 41% larger than ducks encountered (935,780) during spring 2014, but was 40% less than diving duck and merganser (mergini) numbers (2,184,795) counted in spring 2013. We excluded comparisons of spring diving duck counts in 2012 because only 3 flights were completed on each river in spring 2012 due to inclement weather. Along the Illinois River, Chautauqua National Wildlife Refuge and Emiquon Preserve accounted for approximately 21% of the total diving duck use days across years. Approximately 85% of the diving duck and merganser use days estimated from Pool 19 were observed from Keokuk, IA to Fort Madison, IA. The stretch of Pool 19 above Burlington, IA appeared to be of little value to spring diving ducks and mergansers during springs 2012 and 2015.

Along the Illinois River, actual use days exceeded energetic use day availability at 38% of locations in 2014 and 64% of locations in 2015 (Table 16). Overall, energetic use days exceeded actual use day requirements of diving ducks along the Illinois River, but diving ducks did not appear to distribute in an ideal free fashion according to energetic profitability. Interestingly, energetic deficits occurred at several notable spring stopover locations of diving ducks in the Illinois River, including Hennepin and Hopper Lakes (2014, 2015), Peoria Lake (2014), Chautauqua National Wildlife Refuge (2015), and Big Lake (2014).

Banding

We banded 7,535 lesser scaup and 44 canvasbacks during springs 2012–2015 (Table 17). Although we caught more canvasbacks (*n* = 21) during spring 2015 than in prior years (range: 3–12), canvasbacks failed to use baited sites and were seldom caught in traps. Even when specifically targeted, canvasbacks typically failed to use trap sites after deployment of swim-in traps. Conversely, lesser scaup were abundant and readily used baited sites and entered swim-in traps. Anecdotally, we noticed the proportion of apparent juvenile scaup increased as spring progressed each year. Likewise, we observed the proportion of captured female scaup increased throughout spring migration each year as indicated by declining sex ratios (male:female; Fig. 13). Similar to springs 2012–2014, the majority (88%) of banded lesser scaup in 2015 were male; likewise, 67% of captured canvasbacks were male. The overall sex ratio of banded scaup was 6.6 males per female. We recaptured 1,917 previously banded scaup at our trap locations in spring 2015. Based on recaptures, we estimated that apparent stopover duration of recaptured lesser scaup during spring 2015 was 38% longer than spring 2014; however, apparent time of stay was brief (9.8 days).

As of mid-April 2016, we have received reports of 223 encounters (3%) of lesser scaup extending from the Northwest Territories to the Gulf Coast (Fig. 14). Most scaup were recovered by hunters throughout the Mississippi Flyway (74%), but others were recovered in the Central (12%) and Atlantic (12%) Flyways. Most encounters were reported from Louisiana (29%), followed by Illinois (16%), and North Dakota (6%).

DISCUSSION

A major assumption of many conservation planners and habitat managers is that food density is a valuable proxy for habitat quality during non-breeding periods (i.e., fall migration, winter, and spring migration). Some conservation planning exercises include an assumption that food is limiting during one or more of these periods and that by increasing food density, fitness of individual foragers will increase and subsequent recruitment of individuals into the population will occur. During our study, lesser scaup and other diving ducks did not consistently select patches or areas with greater food densities than were randomly available, indicating that overall food density is probably not the only important indicator of habitat quality for these species (i.e., 3rd order selection; Johnson 1980). Although food density was the most important predictor of patch and area selection, birds more often than not foraged in areas with less plant and invertebrate density than was available at random locations. Moreover, we observed clear regional differences in patch selection among regions, but factors driving these regional differences apparently are only partially explained by water depth, water clarity, and food density. Foraging effort varied by water depth and clarity for both lesser scaup and canvasback. Ducks foraged less in deeper water and when clarity was low. Interestingly, foraging effort did not appear to vary by food density and we suspect diving ducks are unable to predict food densities without actively foraging.

An alternative explanation for a lack of overall patch and area selection is limited availability of food. Under food-limited conditions, foragers may act as energy maximizers and show limited selection for foraging patches. Birds may feed in any patch above a critical food density rather than select for the patch with the greatest energetic returns. Overall, forage density was relatively low and similar to previous studies in the region during spring (Straub et al. 2012). Random and foraging site food densities were similar, further indicating an opportunistic foraging strategy as opposed to optimal patch selection based on food density. Habitat and food availability may be restricted to the point where diving ducks must feed opportunistically and selective foraging would be detrimental to overall fitness. Recently, evidence has indicated that foraging thresholds exist near 200 kg/ha for dabbling ducks (Hagy and Kaminski 2015, Hagy et al. 2016). If energy acquisition costs are greater in diving ducks than dabbling ducks, foraging thresholds (e.g., critical food density) should also be greater. Given mean food densities <340 kg/ha in 3 of 4 years, forage densities in most locations used by diving ducks during spring may be near or below an energetic profitability level (i.e., critical food density).

Further evidence of ducks existing at a negative energy balance include mean negative DLD indices. Mean DLD values were below zero for most wetlands and regions indicating that birds existed in a negative energy balance while foraging in habitats sampled (Anteau and Afton 2011). The strongest predictors of DLD were region, sex, and food density, but the effect sizes for food densities were small and model uncertainty was high. The negative mean values of DLD across regions and lack of strong predictor variables, especially food density, may indicate low foraging habitat quality for diving ducks during spring migration which could result in reduced condition on the breeding grounds. Anecdotally, locations with positive DLD index values tended to be those that contained extensive moist-soil vegetation during the previous fall and were either hunted extensively or were not flooded until spring. A possible management approach to increase forage habitat value for spring-migrating diving ducks may be to flood managed wetlands in spring instead of fall (Greer et al. 2007). Further research should focus on cooperative management of wetland complexes for hunting activities during fall and provision of high-quality habitat for spring-migrating waterfowl.

Although evidence was limited for third-order selection of foraging patches based on food densities, lesser scaup and canvasbacks exhibited selection tendencies for several plant and animal taxa. Lesser scaup showed strong tendencies to select certain invertebrate taxa, including snails (Lymnaeidae, Physiidae), bivalves (Sphaeriidae), amphipods (Amphipoda), and isopods (Isopoda). Plant seeds were frequently consumed, but apparently were not selected. On the contrary, canvasbacks selected *Vallisneria americana* tubers and *Cyperus* spp. seeds and diets often contained other plant foods (e.g., millet [*Echinochloa* spp., smartweed *Polygonum* spp.]). For both species, no single diet item or taxonomic group was dominant and inter-individual variation suggests that both species were generalists by choice or necessity. While traditional diet items of lesser scaup (e.g., fingernail clams, amphipods) and canvasback (e.g., plant tubers) were certainly present in diets, a wide variety of plant and animal material was present and this omnivorous tendency may indicate food limitation.

Similar to other models, region tended to be the most consistent and important predictor of body condition and stress levels in diving ducks during spring migration. Interestingly, the proportion of plant material included in diets of individual ducks tended to be negatively associated with body condition. We noted the diversity of diet items previously, including large numbers of plant seeds, which are not traditionally considered important diet items of lesser scaup and canvasbacks. It is possible that limited availability of traditional foods has required diving ducks to diversify diets and may have resulted in lower body condition and nutrient acquisition during spring migration (Anteau and Afton 2008*a*). While overall food density may be an important metric of habitat quality for some migrating waterfowl, our data do not indicate that overall food density is related to increased nutrient acquisition or body condition of lesser scaup and canvasbacks. It is possible that food densities are limited in most stopover locations and birds are forced to feed on suboptimal diet items to maintain a positive energy balance or at least minimize loss of reserves.

Both the Illinois River and Pool 19 of the Mississippi River were major spring-migration stopover locations for diving ducks in Illinois with peak abundances >300,000 diving ducks on discrete areas of both river systems. However, use of Pool 19 by lesser scaup and canvasbacks was approximately 50% greater than use of the Illinois River. Use-days along the Illinois River in 2015 exceeded energetic carrying capacity in most wetlands surveyed. In some years, energy appears limited in midcontinent stopover locations of diving ducks (Anteau and Afton 2011). We noted longer stopover times in 2015 than 2014 when food density appeared to be limited. Increased stopover time or other strategies may be needed to offset energetic deficits encountered during spring migration.

Concentrations of the essential elements Fe, Co, Cr, Mg, P, and Zn were similar to concentrations observed previously in apparently healthy lesser scaup and other ducks (Table 12). Calcium levels were 63% less, on average, than reported by Petrie et al. (2007) for spring-migrating lesser scaup collected in the eastern Great Lakes. Zebra mussels (*Dreissena polymorpha*) and gastropods were major components of lesser scaup migrating through the eastern Great Lakes in spring (Badzinski and Petrie 2006), which could account for observed differences in Ca between studies. Breeding phenology and antagonism by other elements (cations, toxic elements [e.g., Pb]) can also affect Ca status. However, the timing of collection was similar to Badzinski and Petrie (2006) and well before egg formation. In addition, given the low (toxic elements) to normal (essential elements) concentrations of other elements we examined, these levels did not appear to be important factors in the ducks we examined. Mean hepatic Cu concentrations were greater than reported by Petrie et al. (2007; Table 13); however, ranges overlapped considerably, and ranges were much less than reported for Pb-intoxicated mallards (679 µg/g; Sanderson et al. 1997).

Selenium exposure and accumulation have been suggested as factors contributing to reduced health and productivity in lesser scaup in the Midwest (Anteau et al. 2007). Custer et al (2000) found that Se concentrations in livers of 88% of lesser scaup collected from an industrialized area of southern Lake Michigan were above the 10 µg/g threshold for reduced productivity, and 50% had concentrations greater than the 33 µg/g level associated with health effects. Concentrations in 31% (37/120) of lesser scaup in our study exceeded the 10 µg/g threshold, and concentrations were greater than 33 µg/g threshold in four (3%) ducks. The maximum value we observed was less than that observed in spring migrating female lesser scaup from the lower Great Lakes (56 µg/g, Petrie et al. 2007) and upper Midwest (Pillatski et al. 2010), but much greater than that reported for six states in the Mississippi Flyway (20 µg/g, Custer et al. 2003). However, the geometric mean we observed was similar to that reported by both Custer et al. (2003) and Pillatzki et al. (2010).

Generally, the concentrations of non-essential elements that we observed in lesser scaup livers were well within known avian toxicity thresholds. Concentrations of toxic elements As and Pb, and Sr were well below levels of concern (Table 13). Some researchers have noted elevated concentrations of Cd in lesser scaup (Custer et al. 2000, 2003; Pillatzki et al. 2010), but hepatic Cd concentrations were elevated in only 16% (19/120%) of lesser scaup in our study. Hepatic Cd concentrations were elevated in 44% of wintering lesser scaup collected in an industrialized area of southern Lake Michigan (Custer et al. 2000). In contrast to these findings, Petrie et al. (2007) did not detect Cd in liver (detection limits 0.15 µg/g) of spring-migrating lesser scaup. The geometric mean and maximum concentrations we observed were greater than reported by Custer at al. (2003) for the Mississippi Flyway (0.62, 3.3 µg/g) and our arithmetic mean concentration was nearly twice that of female lesser scaup from the Upper Midwest (Pillatzki et al. 2010). Our geometric mean concentration was less, though values in eight ducks were greater, than reported for male lesser scaup wintering in southern Lake Michigan (geometric means ~1.8, 2.0 and 3.0 µg/u, maximum 6.8 µg/g; Custer et al. 2000). Although elevated, the concentrations we observed were well below the threshold for Cd toxicity in birds

(167 µg/g, Furness 1996), those associated with cessation of egg-laying in adult female mallards (*Anas platyrhynchos;* 431 µg/g; White and Finley 1978), and kidney lesions in wood duck ducklings (*Aix sponsa*; 871 µg/g; Mayak et al. 1981).

IMPLICATIONS

Similar to England (2016), our data indicated that regional differences in body condition, stress levels, nutrient acquisition, foraging patch selection, and foraging area selection were more important than other factors (e.g., food densities) during spring migration. Given relatively low food densities compared to foraging thresholds for other species (Hagy and Kaminski 2015, Hagy et al. 2016), diverse diets, net negative energy balances (i.e., DLDs), and the lack of bird response to food densities in many different models, we suspect that diving ducks may have limited food availability during spring migration. In particular, lack of evidence for patch and area selection may indicate that diving ducks are most often unable to differentiate foraging patches based on energetic value. Additionally, other stressors such as introduced parasites may be an emerging threat to lesser scaup populations and important contributors to the Spring Condition Hypothesis (England 2016).

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Table 1. Mean ($\bar{x}$, ± SE) proportion of time spent in 5 behaviors where canvasback (*Aythya valisineria*) and lesser scaup (*A. affinis*) were observed foraging and proportional behavior quantified in the upper Midwest during springs 2014–2015.

Species/Year/Region	Feed		Rest		Social		Motion		Alert	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Canvasback	**46.2%**	**0.5%**	**23.4%**	**0.4%**	**1.1%**	**0.2%**	**21.4%**	**0.7%**	**1.1%**	**0.2%**
2012	50.3%	6.5%	24.0%	5.5%	1.0%	0.3%	16.8%	3.3%	0.0%	0.0%
2013	38.7%	5.2%	31.9%	4.9%	1.0%	0.3%	20.9%	4.0%	0.3%	0.1%
2014	37.2%	5.1%	29.2%	5.9%	2.2%	1.1%	20.7%	2.7%	2.7%	1.0%
2015	58.6%	7.2%	8.7%	4.0%	0.3%	0.2%	27.3%	5.7%	1.6%	0.6%
Central Mississippi River	62.9%	27.8%	10.2%	5.0%	1.1%	0.7%	17.2%	8.2%	1.9%	0.9%
Illinois River	45.5%	15.6%	22.9%	5.8%	0.6%	0.3%	23.7%	7.2%	2.0%	0.9%
Southern Illinois Reservoirs	0.2%	-	79.6%	-	1.6%	-	12.3%	-	3.2%	-
Upper Mississippi River	57.4%	36.6%	12.9%	7.0%	3.9%	2.9%	16.3%	4.7%	1.3%	0.4%
Lesser Scaup	**44.2%**	**0.2%**	**26.2%**	**0.4%**	**0.7%**	**0.1%**	**22.1%**	**0.1%**	**0.9%**	**0.1%**
2012	35.4%	4.0%	38.0%	3.8%	0.7%	0.2%	16.9%	1.7%	0.6%	0.1%
2013	36.5%	3.7%	34.7%	3.6%	0.4%	0.1%	22.7%	2.1%	0.3%	0.1%
2014	39.7%	3.4%	20.7%	2.5%	1.0%	0.2%	31.3%	2.3%	2.2%	0.6%
2015	65.1%	2.9%	11.2%	2.2%	0.9%	0.4%	17.6%	2.0%	0.4%	0.1%
Central Mississippi River	48.7%	11.4%	14.3%	5.2%	0.3%	0.2%	27.0%	5.7%	2.7%	0.8%
Illinois River	48.8%	10.7%	18.9%	4.5%	0.9%	0.5%	25.8%	5.8%	1.5%	0.7%
Southern Illinois Reservoirs	44.4%	-	15.9%	-	6.5%	-	26.4%	-	0.0%	-
Upper Mississippi River	37.8%	16.0%	23.8%	22.0%	2.4%	2.0%	26.9%	11.8%	0.8%	0.8%
Southeastern Wisconsin	35.3%	5.9%	19.4%	12.7%	2.3%	1.2%	32.6%	5.6%	2.0%	0.4%

Table 2. Mean ($\bar{x}$, ± SE) biomass (kg/ha) and proportion of total food biomass by food type at locations where diving ducks were observed foraging and proportional behavior was quantified and random locations in wetlands and portions of lakes nearby foraging flocks in the upper Midwest during springs 2012–2015.

Sample Type / Year	Benthic Invertebrate		Nektonic Invertebrate		Seeds & Tubers		Total	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Foraging Locations								
Food Density	171.6	36.7	11.1	2.4	186.8	9.7	369.2	26.7
2012	303.0	168.2	0.6	0.1	34.6	14.3	338.6	168.4
2013	285.9	91.4	2.6	0.8	212.9	52.7	501.4	98.3
2014	54.3	12.5	2.1	0.5	275.7	52.0	332.1	53.4
2015	43.2	17.0	38.9	10.1	224.0	54.0	304.5	57.1
Proportion	44.3%		3.5%		52.3%			
2012	89.5%		0.2%		10.2%			
2013	57.0%		0.5%		42.5%			
2014	16.4%		0.6%		83.0%			
2015	14.2%		12.8%		73.6%			
Random Locations								
Food Density	155.2	43.0	8.6	4.7	158.6	18.4	329.1	45.9
2012	197.7	65.9	2.3	1.5	63.0	17.7	263.0	66.2
2013	109.4	23.3	1.7	0.4	143.0	26.8	287.7	53.7
2014	216.2	126.2	0.3	0.1	275.5	44.4	492.0	127.6
2015	71.4	18.0	33.8	20.7	109.8	32.8	212.3	37.9
Proportion	47.1%		2.6%		48.2%			
2012	75.2%		0.9%		24.0%			
2013	38.0%		0.6%		49.7%			
2014	43.9%		0.1%		56.0%			
2015	33.6%		15.9%		51.7%			

Table 3. Proportion of feeding sites of flocks foraging (Area Selection) and individuals collected (Patch Selection) with greater food density (kg/ha) than random sampling sites for lesser scaup (*Aythya affinis*) and canvasback (*A. valisineria*) by food type (invertebrates, plants, and total) within the upper Midwest during springs 2012–2015.

Region		Patch Selection				Area Selection			
		Invert.	Plants	Total	*n*	Invert.	Plants	Total	*n*
Illinois River	Lesser scaup	31.9%	59.6%	51.1%	94	41.5%	53.7%	46.3%	82
	Canvasback	42.9%	47.6%	38.1%	21	29.0%	51.6%	45.2%	31
	Overall	33.9%	57.4%	48.7%	115	38.1%	53.1%	46.0%	113
Central Mississippi River	Lesser scaup	21.7%	56.5%	34.8%	23	44.1%	23.5%	14.7%	34
	Canvasback	9.1%	54.5%	63.6%	11	31.6%	36.8%	31.6%	19
	Overall	33.9%	57.4%	48.7%	34	39.6%	28.3%	20.8%	53
Upper Mississippi River	Lesser scaup	20.6%	35.3%	44.1%	34	25.0%	0.0%	0.0%	4
	Canvasback	18.8%	31.3%	18.8%	16	25.0%	75.0%	50.0%	4
	Overall	20.0%	34.0%	36.0%	50	25.0%	37.5%	25.0%	8
Illinois/Mississippi River Confluence	Lesser scaup	5.9%	14.7%	11.8%	18	-	-	-	-
	Canvasback	0.0%	0.0%	0.0%	1	-	-	-	-
	Overall	10.5%	26.3%	21.1%	19	-	-	-	-
Overall	Lesser scaup	24.2%	47.7%	44.7%	175	41.7%	43.3%	35.8%	120
	Canvasback	32.1%	39.6%	39.6%	53	29.6%	48.1%	40.7%	54
	Overall	28.9%	46.9%	44.3%	228	37.9%	44.8%	37.4%	174

Table 4. Important variables predicting patch and area selection of lesser scaup (*Aythya affinis*) and canvasback (*A. valisineria*) in the upper Midwest during springs 2014–2015 based on logistic regression models ranked according to Akaike's second order Information Criterion (AIC$_c$), the difference between the top model (ΔAIC$_c$), the log likelihood (£), and variance explained (R^2_{adj}).

Model Set / Variables	£	AIC$_c$	ΔAIC$_c$	R^2_{adj}
Area Selection				
Total food density + region	-82.6	171.4	0.0	0.30
Intercept Only	-114.0	233.0	61.6	0.00
Patch Selection				
Total food density + region	-100.8	214.0	0.0	0.52
Intercept only	-156.6	315.1	101.1	0.00

Table 5. Proportion of spring-migrating diving ducks (*Aythya affinis*, *n* = 262; and *A. valisineria*, *n* = 41) consuming individual food items (percent occurrence) and mean biomass per individual (aggregate biomass) of common food items in the upper Midwest during springs 2014–2015.

Taxa	Percent Occurrence	Aggregate Percent
Total Animal	81.6%	59.0%
Amphipoda	25.0%	1.0%
Bivalvia	42.0%	30.0%
Diptera	36.0%	4.0%
Ephemeridae	14.0%	7.0%
Gastropoda	44.0%	11.0%
Corixidae	6.0%	0.0%
Insecta Parts	5.0%	1.0%
Isopoda	13.0%	3.0%
Odonata	9.0%	1.0%
Oligochaeta	3.0%	1.0%
Total Plant	65.8%	41.0%
Amaranthus spp.	17.0%	0.0%
Cyperus spp.	27.0%	0.0%
Echinochloa spp.	18.0%	9.0%
Leersia oryzoides	15.0%	3.0%
Polygonum spp.	18.0%	1.0%
Potamogeton spp.	18.0%	1.0%
Vallisneria americana	4.0%	2.0%
Tubers	5.0%	25.0%

Table 6. Proportion of spring-migrating lesser scaup (*Aythya affinis*, *n* = 262) consuming individual food items (percent occurrence) and mean biomass per individual (aggregate biomass) of common food items with mean food availability (kg/ha) and rankings of dominant items in the upper Midwest during springs 2014–2015.

Taxa	Percent Occurrence	Aggregate Percent	Aggregate Rank	Food Availability	Availability Rank
Dreissena polymorpha	21.0%	13.0%	1	39.89	2
Chironomidae	37.0%	11.0%	2	11.21	7
Potamogeton spp.	19.0%	10.0%	3	27.62	4
Sphaeriidae	27.0%	8.0%	4	4.55	14
Echinochloa spp.	18.0%	8.0%	4	38.8	3
Physiidae	29.0%	7.0%	5	0.72	34
Polygonum spp.	19.0%	6.0%	6	20.2	5
Amphipoda	30.0%	5.0%	7	0.09	60
Leersia oryzoides	17.0%	5.0%	8	3.4	19
Isopoda	15.0%	4.0%	9	0.36	44
Lymnaeidae	7.0%	3.0%	10	0.26	50
Oligochaeta	3.0%	3.0%			
Cyperus spp.	30.0%	3.0%			
Quadrula	4.0%	2.0%			
Hydrobiidae	9.0%	2.0%			
Planorbidae	17.0%	2.0%			
Ephemeridae	9.0%	1.0%			
Valvatidae	7.0%	1.0%			
Viviparidae	10.0%	1.0%			
Corixidae	7.0%	1.0%			
Insecta Parts	6.0%	1.0%			
Odonata	11.0%	1.0%			
Amaranthus spp.	19.0%	1.0%			
Vallisneria americana tubers	2.0%	1.0%			
Cyperus escuelentus tubers	1.0%	0.0%			
Vallisneria americana	1.0%	0.0%			
Total animal	82.0%	66.0%			
Total plant	68.0%	34.0%			

Table 7. Proportion of spring-migrating canvasbacks (*Aythya valisineria*, *n* = 41) consuming individual food items (percent occurrence) and mean biomass per individual (aggregate biomass) of common food items with mean food availability (kg/ha) and rankings of dominant items in the upper Midwest during springs 2014–2015.

Taxa	Percent Occurrence	Aggregate Percent	Aggregate Rank	Food Availability	Availability Rank
Ephemeridae	44.0%	25.0%	1	2.09	22
Vallisneria americana tubers	20.0%	17.0%	2	6.22	12
Sphaeriidae	32.0%	16.0%	3	4.55	14
Echinochloa spp.	15.0%	10.0%	4	38.8	3
Potamogeton spp.	12.0%	7.0%	5	27.62	4
Chironomidae	34.0%	6.0%	6	11.21	7
Quadrula	12.0%	5.0%	7	1.19	28
Cyperus spp.	15.0%	4.0%	8	3.43	18
Dreissena polymorpha	12.0%	3.0%	9	39.89	2
Cyperus escuelentus tubers	2.0%	2.0%	10	10.2	9
Leersia oryzoides	5.0%	2.0%			
Amphipoda	2.0%	1.0%			
Physiidae	5.0%	1.0%			
Vallisneria americana	2.0%	1.0%			
Hydrobiidae	2.0%	0.0%			
Lamnaeidae	2.0%	0.0%			
Planorbidae	10.0%	0.0%			
Valvatidae	2.0%	0.0%			
Viviparidae	10.0%	0.0%			
Corixidae	2.0%	0.0%			
Insecta Parts	5.0%	0.0%			
Isopoda	2.0%	0.0%			
Odonata	0.0%	0.0%			
Oligochaeta	2.0%	0.0%			
Amaranthus spp.	7.0%	0.0%			
Polygonum spp.	7.0%	0.0%			
Total animal	80.0%	57.0%			
Total plant	56.0%	43.0%			

Table 8. An index of foraging habitat quality (daily lipid dynamics; DLD) and densities (kg/ha[dry]) of seeds and tubers (plant), invertebrates, and combined (overall) at experimental collection locations of lesser scaup (*Aythya affinis*) and canvasbacks (*A. valisineria*) in the upper Midwest during springs 2014–2015.

Region / Collection Location	DLD	*n*	Benthos	Nekton	Plant	Overall
Illinois River	**-7.6**	**198**	**102.7**	**18.7**	**228.1**	**349.5**
Anderson Lake SFWA	-10.0	9	30.0	4.6	426.5	461.1
Babb's Slough	-2.2	7	103.7	3.5	7.4	114.7
Bath Lake	-11.1	11	213.9	0.8	381.2	595.9
Big Lake	-3.0	6	219.8	7.9	82.7	310.4
Chain Lake	10.2	23	8.0	1.0	93.3	102.3
Chautauqua NWR	-15.7	29	250.2	7.3	97.2	354.7
Emiquon Preserve	-10.2	35	62.8	30.8	272.4	364.7
Peoria Lake	-12.1	13	41.6	82.0	49.8	173.3
Meredosia Lake	-10.0	4	54.1	2.3	22.6	79.0
Moscow Bay	17.4	5	337.9	63.2	258.0	659.1
Otter Lake/Cuba Island	-19.4	3	103.2	0.2	721.7	825.1
Quiver Creek	-10.3	14	134.5	20.2	151.6	306.2
Hennepin and Hopper Lakes	-5.9	17	34.4	37.2	251.5	323.1
Woodford/Marshall Co. SFWA	-33.0	8	128.3	2.6	10.6	141.5
Worley Lake	-6.0	5	61.3	1.0	543.0	605.3
Southern Illinois Reservoirs	**--19.5**	**30**	**7.5**	**20.5**	**1.1**	**29.2**
Carlyle Lake	-31.5	11	0.9	100.7	2.4	104.0
Rend Lake	-12.6	19	8.8	4.4	0.9	14.2
Illinois/Mississippi River Confluence	**-25.3**	**43**	**35.4**	**2.1**	**235.1**	**272.6**
Mississippi River SFWA-Fowler Lake	-30.7	6	58.4	0.9	151.5	210.7
Mississippi River SFWA-Fuller Lake	-29.6	11	41.4	0.5	335.9	377.8
Mississippi River SFWA-Godar Unit	-20.3	3	16.6	0.2	176.6	193.5
Swan Lake NWR	-22.6	23	25.2	6.6	276.5	308.3

Table 8 Continued.

Region / Collection Location	DLD	*n*	Benthos	Nekton	Plant	Overall
Central Mississippi River	**-11.3**	**86**	**25.5**	**2.0**	**73.0**	**100.4**
Pool 12	0.1	28	19.3	1.8	96.7	117.9
Pool 19	-16.8	58	29.7	2.1	56.9	88.5
Upper Mississippi River	**-11.1**	**97**	**26.6**	**36.2**	**172.4**	**235.2**
Pool 7	-12.2	38	20.1	80.6	173.1	273.9
Pool 8	-3.0	32	25.1	16.3	129.4	170.8
Pool 9	-19.2	27	36.0	3.0	216.9	256.0
Upper Midwest Summary	**-11.7**	**465**	**71.6**	**19.0**	**174.6**	**265.1**

Table 9. An index of foraging habitat quality (daily lipid dynamics; DLD) and densities (kg/ha[dry]) of seeds and tubers (plant), invertebrates, and combined (overall) at experimental collection locations of lesser scaup (*Aythya affinis*) in the upper Midwest during springs 2014–2015.

Region / Collection Location	DLD	*n*	Benthos	Nekton	Plant	Overall
Illinois River	**-7.9**	**171**	**86.6**	**18.8**	**186.9**	**292.2**
Anderson Lake SFWA	-14.6	8	35.8	5.0	374.8	415.6
Babb's Slough	-2.2	7	103.7	3.5	7.4	114.7
Bath Lake	-11.3	9	255.3	0.7	412.7	668.8
Big Lake	-3.0	9	219.8	7.9	82.7	310.4
Chain Lake	17.7	20	3.3	1.0	102.3	106.6
Chautauqua NWR	-16.0	27	70.6	7.6	105.8	184.1
Emiquon Preserve	-15.9	29	72.4	38.0	213.1	321.0
Peoria Lake	-12.7	11	41.6	82.0	49.8	173.3
Meredosia Lake	-10.0	4	54.1	2.3	22.6	79.0
Moscow Bay	23.9	3	761.9	1.8	143.5	907.2
Otter Lake/Cuba Island	-8.4	2	103.2	0.2	721.7	825.1
Quiver Creek	6.2	8	29.5	30.1	161.7	221.4
Hennepin and Hopper Lakes	-7.2	16	33.9	38.0	266.7	338.6
Woodford/Marshall Co. SFWA	-33.0	8	128.3	2.6	10.6	141.5
Worley Lake	-6.0	5	61.3	1.0	543.0	605.3
Southern Illinois Reservoirs	**-18.6**	**27**	**9.8**	**3.2**	**0.4**	**13.3**
Carlyle Lake	-31.5	11	0.9	100.7	2.4	104.0
Rend Lake	-9.7	16	9.8	3.2	0.4	13.3
Illinois/Mississippi River Confluence	**-26.2**	**41**	**34.5**	**3.2**	**291.3**	**328.9**
Mississippi River SFWA-Fowler Lake	-30.7	6	58.4	0.9	151.5	210.7
Mississippi River SFWA-Fuller Lake	-29.6	11	41.4	0.5	335.9	377.8
Mississippi River SFWA-Godar Unit	-20.3	3	16.6	0.2	176.6	193.5
Swan Lake NWR	-24.1	21	27.4	5.5	304.0	336.9

Table 9 Continued.

Region / Collection Location	DLD	*n*	Benthos	Nekton	Plant	Overall
Central Mississippi River	**-11.0**	**59**	**23.9**	**1.9**	**76.1**	**101.8**
Pool 12	-1.8	29	23.2	2.1	128.3	153.6
Pool 19	-19.9	30	24.2	1.8	47.6	73.6
Upper Mississippi River	**-14.1**	**90**	**26.6**	**36.2**	**172.4**	**235.2**
Pool 7	-17.2	33	7.5	134.1	253.1	394.8
Pool 8	-6.2	30	17.2	23.8	172.4	213.4
Pool 9	-19.2	27	34.0	4.2	310.6	348.8
Upper Midwest Summary	**-12.6**	**396**	**58.3**	**20.8**	**182.7**	**261.6**

Table 10. An index of foraging habitat quality (daily lipid dynamics; DLD) and densities (kg/ha[dry]) of seeds and tubers (plant), invertebrates, and combined (overall) at experimental collection locations of canvasbacks (*Aythya valisineria*) in the upper Midwest during springs 2014–2015.

Region / Collection Location	DLD	*n*	Benthos	Nekton	Plant	Overall
Illinois River	**-4.4**	**25**	**220.9**	**22.9**	**298.5**	**542.4**
Anderson Lake SFWA	26.6	1	3.9	2.9	659.1	665.9
Bath Lake	-18.4	1	7.0	1.1	223.7	231.8
Chain Lake	-39.5	3	54.8	0.1	4.1	58.9
Chautauqua NWR	-10.8	2	878.9	6.1	66.8	951.9
Emiquon Preserve	17.6	6	46.8	19.5	371.1	437.5
Peoria Lake	-8.7	2	44.4	0.9	29.6	74.9
Moscow Bay	7.7	2	19.9	109.3	343.8	473.0
Quiver Creek	-32.2	6	344.5	0.2	131.2	475.9
Hennepin and Hopper Lakes	14.2	1	37.0	33.1	167.9	238.0
Southern Illinois Reservoirs	**-28.4**	**3**	**4.4**	**44.7**	**2.2**	**51.4**
Rend Lake	-28.4	3	6.7	7.4	2.1	16.2
Illinois/Mississippi River Confluence	**-7.0**	**2**	**2.7**	**17.9**	**1.1**	**21.8**
Swan Lake	-7.0	2	2.7	17.9	1.1	21.8
Central Mississippi River	**-11.8**	**29**	**28.6**	**2.1**	**67.1**	**97.7**
Pool 12	38.3	1	14.2	1.5	54.7	70.4
Pool 19	-13.6	28	43.0	2.9	79.5	125.1
Upper Mississippi River	**27.4**	**7**	**40.0**	**1.7**	**43.5**	**85.1**
Pool 7	20.5	5	38.4	3.3	57.6	99.3
Pool 8	44.6	2	42.3	0.1	36.2	78.6
Upper Midwest Summary	**-6.1**	**67**	**109.7**	**13.8**	**151.8**	**275.1**

Table 11. Important variables predicting foraging habitat quality (daily lipid dynamics; DLD) of lesser scaup (*Aythya affinis*) and canvasback (*A. valisineria*) the upper Midwest during springs 2014–2015 based on mixed models ranked according to Akaike's second order Information Criterion (AIC_c), the difference between the top model (ΔAIC_c), the -2 log likelihood (£), and model weight (ω).

Model Set / Variables	AIC_c	ΔAIC_c	-2£	ω
Lesser Scaup				
Region + invertebrate food + total food	1670.7	0.0	1653.8	0.25
Invertebrate food + total food + sex*region	1673.1	0.3	1653.9	0.22
Region + total food	1671.2	0.5	1656.6	0.20
Region	1672.1	1.4	1659.6	0.13
Sex + total food + sex*region	1672.5	1.8	1646.6	0.10
Region + total food + sex*region	1672.5	1.8	1646.6	0.10
Intercept only	1682.1	11.4	1678.0	0.00
Canvasback				
Region + invertebrate food	280.4	0.0	264.5	0.57
Region	282.0	1.6	269.4	0.26
Region + invertebrate food + total food	282.8	2.4	263.4	0.17
Intercept only	292.1	11.7	285.1	0.11

Table 12. Important variables predicting body condition (mass) and stress (corticosterone) of lesser scaup (*Aythya affinis*) and canvasback (*A. valisineria*) the upper Midwest during springs 2014–2015 based on mixed models ranked according to Akaike's second order Information Criterion (AIC_c), the difference between the top model (ΔAIC_c), the -2 log likelihood (£), and model weight (ω).

Model Set / Variables	AIC_c	ΔAIC_c	-2£	ω
Mass				
Lesser Scaup				
Region + DLD + Plant Diet (%)	1997.6	0.0	1976.3	0.52
Region + DLD	1997.8	0.2	1978.7	0.48
Intercept Only	2022.5	24.9	2014.3	0.00
Canvasback				
Region + DLD	362.2	0.0	349.6	0.31
Region	362.4	0.2	349.8	0.28
Total food	363.5	1.3	353.8	0.16
Plant diet (%)	363.9	1.7	357.0	0.13
Intercept only	365.0	2.8	358.0	0.00
Corticosterone				
Lesser Scaup				
Region + DLD	173.2	0.0	155.2	0.60
Region	175.2	2.0	159.7	0.22
Region + nekton	176.8	3.6	158.8	0.10
Region + total	177.1	3.9	159.2	0.08
Null	190.3	17.1	184.0	0.00

Table 13. Arithmetic mean (standard deviation), minimum-maximum and geometric mean hepatic element concentrations (µg/g dw) from 120 female lesser scaup (*Aythya affinis*) collected in the upper Midwest during springs 2014–2015.

Elements	Mean (SD) Min-Max	Geometric Mean	Avian Toxicity Thresholds	Previously Reported For Waterfowl
Arsenic	0.26 (0.11) 0.02-0.84	0.23	33[a]	<1.5[a]
Cadmium	2.09 (2.90) 0.09-16.8	1.09	>3[b]; 167[v]	<0.15[c]; 3.3[d]; 6.8[e] 1.1[u]
Calcium	155 (77) 77-593	143	na	418, 178-9,340[f]
Chromium	0.32 (0.23) 0.01-1.01	0.24	na	<1.79[c]; <0.5[g]
Copper	0.15 (0.10) 0.00-0.71	0.07	679[h]	<0.10[c]
Cobalt	94 (33) 36-207	88	na	71, 27-221[f]; 55[i];
Iron	2,238 (1,063) 299-7,060	1,974	8,067[j]	2,200, 295-20,300[f]
Lead	0.20 (0.30) 0.00-2.40	0.11	8.33[k]	<1.3[c]; 0.5-5.0[l]
Magnesium	715 (88) 506-1,080	709	na	835, 621-1,050[f]
Phosphorus	11,982 (2,013) 8,159-20,500	11,182	na	13,183[m]
Selenium	14.3 (7.3) 4.4-47	12.6	10 repro impair.[n]; 33 health effects[o]	4-10[p]; 16, 1.77-56.4[f]; 3.2-20[q]; 4.2-11[r]; 14, 4.5-68[t]
Strontium	0.056 (0.062) 0.002-0.49	0.036	na	0.13-0.61[r]
Zinc	134 (30) 49-261	130	1,675[s]	131, 82-220[f]

[a] Goede 1985;

[b] DiGiulio and Scanlon 1984, elevated;

[c]Petrie et al. 2007, not detectable at this detection limit;
[d]Custer et al. 2003, maximum value for Mississippi Flyway LESC;
[e]Custer et al. 2000 max. s Lake Michigan;
[f] Petrie et al. 2007, mean, min-max spring migrating female LESC lower Great Lakes;
[g]Custer et al. 2003 Mississippi Flyway; not detected 5/6 locations;
[h]Sanderson et al. 1997; mean of Pb-dosed female game-farm mallards, converted to DW based on 76%;
[i]Vermeer and Peakall 1979, mean Greater Scaup (*Aythya marila*);
[j]Sanderson et al. 1997, mean of Fe-dosed game-farm mallards, converted to DW based on 76% moisture;
[k]Pain 1996, 2.0 in waterfowl, converted to DW based on 76% moisture;
[l]Scheuhammer 1987, background in birds;
[m]Sanderson et al. 1997, mean of control game-farm mallards, converted to DW based on 76% moisture;
[n]Heinz et al 1989, dosed mallards;
[o]Heinz 1996;
[p]Ohlendorf 1989;
[q]Custer et al. 2003 Mississippi Flyway, min-max 6 states; [r]Custer et al. 2003 Mississippi Flyway, range of geometric means by state;
[s]Levengood et al. 1999, mean concentration in Zn-intoxicated mallards (*Anas platyrhynchos*), converted to DW based on 76% moisture;
[t]Pillatzki et al. 2010, geometric mean, min-max male and female LESC upper Midwest converted to dry wt.;
[u]Pillatzki et al. 2010, arithmetic mean female LESC upper Midwest; converted to dry wt.;
[v]Furness 1996, toxicity threshold birds, converted to dry wt.

Table 14. Total and mean use-days ($\bar{x}$; ducks/ha/day) for diving ducks from aerially surveys of lakes and wetlands in the Illinois River and Pool 19 of the Mississippi River during springs 2012–2015.

Species	2012		2013		2014		2015		LTA	
	Illinois River	**Pool 19**	**Illinois River**	**Pool 19**	**Illinois River**	**Pool 19**	**Illinois River**	**Pool 19**	**Illinois River**	**Pool 19**
Bufflehead	30,588	24,245	38,453	80,945	36,928	28,473	60,448	103,985	41,604	59,412
Canvasback	320,520	859,435	452,625	3,775,168	926,288	1,160,618	167,863	1,170,206	466,824	1,741,357
Common goldeneye	20,493	50,570	79,575	202,500	28,560	49,048	18,785	100,535	36,853	100,663
Common merganser	---	---	157,478	347,780	48,095	37,435	49,773	48,563	85,115	144,593
Hooded merganser	---	---	10,408	0	675	115	640	0	3,908	38
Lesser scaup	565,523	1,416,750	1,625,980	5,429,655	2,392,308	3,328,283	1,495,233	4,743,316	1,519,761	3,729,501
Redhead	7,310	700	31,535	49,465	62,810	5,175	12,203	12,600	28,465	16,985
Ring-necked duck	436,743	9,250	2,030,138	120,280	1,588,020	104,628	607,863	42,250	1,165,691	69,102
Ruddy duck	725,260	56,915	723,270	140,233	384,468	122,110	444,760	226,296	569,440	136,389
Total	2,106,435	2,417,865	5,149,460	10,146,025	5,468,150	4,835,883	2,857,565	6,447,751	3,895,403	5,961,881

Table 15. Peak abundances of diving ducks and mergansers observed with the long-term average (LTA; 2012–2015) during spring migrations of 2012–2015 along the Illinois River and Pool 19 of the Mississippi River in Illinois.

Species and Regions		2012	2013	2014	2015	$\bar{x}$
Lesser scaup	Illinois River	33,530	97,645	124,710	83,295	84,795
	Pool 19	87,800	211,295	128,545	250,520	169,540
Ring-necked duck	Illinois River	42,910	152,215	93,750	40,470	82,336
	Pool 19	700	1,900	7,200	3,500	3,325
Canvasback	Illinois River	14,965	18,310	73,680	10,420	29,344
	Pool 19	78,510	98,300	94,670	79,420	87,725
Redhead	Illinois River	340	2,085	2,555	845	1,456
	Pool 19	100	2,770	450	1,350	1,168
Ruddy duck	Illinois River	42,295	58,555	12,400	28,080	35,333
	Pool 19	2,645	10,050	8,060	15,650	9,101
Common goldeneye	Illinois River	1,060	4,390	2,380	3,445	2,819
	Pool 19	2,860	4,530	3,675	9,070	5,034
Bufflehead	Illinois River	1,680	2,565	2,275	2,385	2,226
	Pool 19	1,310	5,970	1,765	6,910	3,989
Total diving ducks	Illinois River	103,275	333,975	312,100	151,450	225,200
	Pool 19	116,285	325,015	235,225	350,740	256,816
Common merganser	Illinois River	2,715	6,545	3,850	6,705	4,954
	Pool 19	6,210	7,440	2,360	4,170	5,045
Hooded merganser	Illinois River	245	365	30	70	178
	Pool 19	0	0	10	0	3

Table 16. Use-days (ducks/ha/day), duck energy days (DED), and estimated energy balance in wetlands surveys aerially during springs 2014–2015 in the Illinois River.

	2014			2015		
Location	DED/ha	UD/ha	Δ	DED/ha	UD/ha	Δ
Babb's Slough	0.0	73.3	-73.3	0.0	43.3	-43.3
Billsbach Lake	-	-	-	0.0	64.6	-64.6
Bath Lake	1620.8	961.4	659.4	-	-	-
Big Lake	0.0	351.5	-351.5	-	-	-
Anderson Lake	3075.9	106.4	2969.4	401.0	58.8	342.1
Chain Lake	0.0	44.9	-44.9	0.0	129.7	-129.7
Clear Lake	-	-	-	798.0	111.5	686.5
Chautauqua NWR	168.3	80.3	88.0	0.0	146.0	-146.0
Emiquon Preserve	998.2	184.9	813.2	7283.5	184.4	7099.1
Hennepin-Hopper Lakes	0.0	272.3	-272.3	0.0	260.0	-260.0
Spoon River Bottoms	6272.4	0.5	6271.8	-	-	-
Matanzas Lake	-	-	-	0.0	91.9	-91.9
Meredosia Lake	-	-	-	0.0	41.7	-41.7
Moscow	0.0	265.1	-265.1	0.0	101.1	-101.1
Otter Lake	6560.8	273.5	6287.4	-	-	-
Peoria lake	0.0	30.0	-30.0	5357.6	26.2	5331.4
Quiver Creek	3349.3	203.4	3146.0	-	-	-
Quiver Lake	88.2	147.6	-59.4	-	-	-
Spunky Bottoms	2545.8	252.9	2292.9	-	-	-
Swan Lake	377.0	145.0	232.0	3460.4	116.9	3343.5
Emiquon NWR-Wilder	6447.6	642.6	5805.0	-	-	-
Pekin Lake	4249.8	385.1	3864.7	-	-	-
Wightman Lake	-	-	-	0.0	46.4	-46.4
Total	**1986.3**	**245.6**	**1740.7**	**1235.7**	**101.6**	**1134.1**
Frequency of DED/ha > UD/ha			**61.1%**			**35.7%**

Table 17. Lesser scaup (LESC; *Aythya affinis*) and canvasbacks (CANV; *A. valisineria*) captured and banded at Emiquon Preserve and Chautauqua National Wildlife Refuge (NWR) along the Illinois River during spring 2014–2015 with mean apparent stopover duration (days).

Species	Year	Sex	*n*	Location	Dates	Recaptures	
						n	Days
LESC	2012	Male	823	Emiquon Preserve	2–8 Mar	---	---
		Female	174	Emiquon Preserve	2–8 Mar	---	---
		Total	**997**				
	2013	Male	368	Emiquon Preserve	9–14 Mar	---	---
		Female	31	Emiquon Preserve	9–14 Mar	---	---
		Male	578	Chautauqua NWR	12–14 Mar	---	---
		Female	52	Chautauqua NWR	12–14 Mar	---	---
		Total	**1,029**				
	2014	Male	1670	Emiquon Preserve	13 Mar–14 Apr	178	6.3
		Female	264	Emiquon Preserve	13 Mar–14 Apr	30	4.6
		Male	440	Chautauqua NWR	24 Mar–14 Apr	196	8.4
		Female	114	Chautauqua NWR	24 Mar–14 Apr	59	7.1
		Total	**2,488**			**463**	**7.1**
	2015	Male	1,607	Emiquon Preserve	10–29 Mar	967	9.3
		Female	210	Emiquon Preserve	10–29 Mar	143	9.7
		Male	1,062	Chautauqua NWR	21–29 Mar	741	10.8
		Female	142	Chautauqua NWR	21–29 Mar	65	9.0
		Total	**3,021**			**1,917**	**9.8**
CANV	2012	Male	4	Emiquon Preserve	2–6 Mar	---	---
		Female	4	Emiquon Preserve	2–6 Mar	---	---
		Total	**8**				
	2013	Male	7	Emiquon Preserve	9–12 Mar	---	---
		Female	5	Emiquon Preserve	9–12 Mar	---	---
		Total	**12**				
	2014	Male	3	Emiquon Preserve	13–14 Mar	1	---
		Total	**3**				
	2015	Male	9	Emiquon Preserve	10 Mar–11 Apr	1	---
		Female	2	Emiquon Preserve	10 Mar–11 Apr		
		Male	5	Chautauqua NWR	21–26 Mar	1	---
		Female	5	Chautauqua NWR	21–26 Mar	1	---
		Total	**21**			**2**	

Figure 1. Locations of foraging site and random food density samples, and collection locations of lesser of lesser scaup (*Aythya affinis*) and canvasbacks (*A. valisineria*) in the upper Midwest during springs 2012–2015.

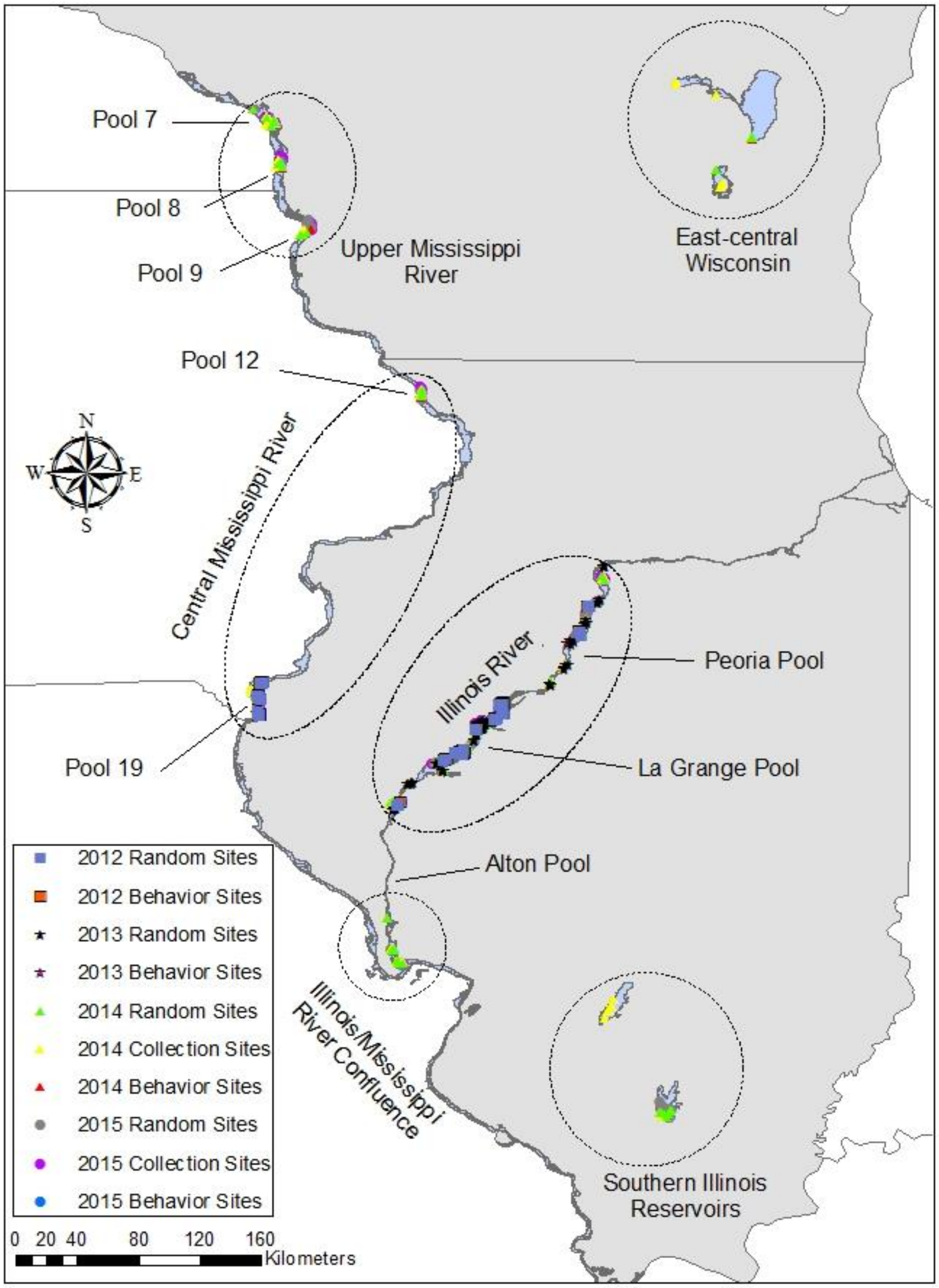

Figure 2. Locations of foraging site and random food density samples, and collection locations of lesser of lesser scaup (*Aythya affinis*) and canvasbacks (*A. valisineria)* in the Illinois River during springs 2012–2015.

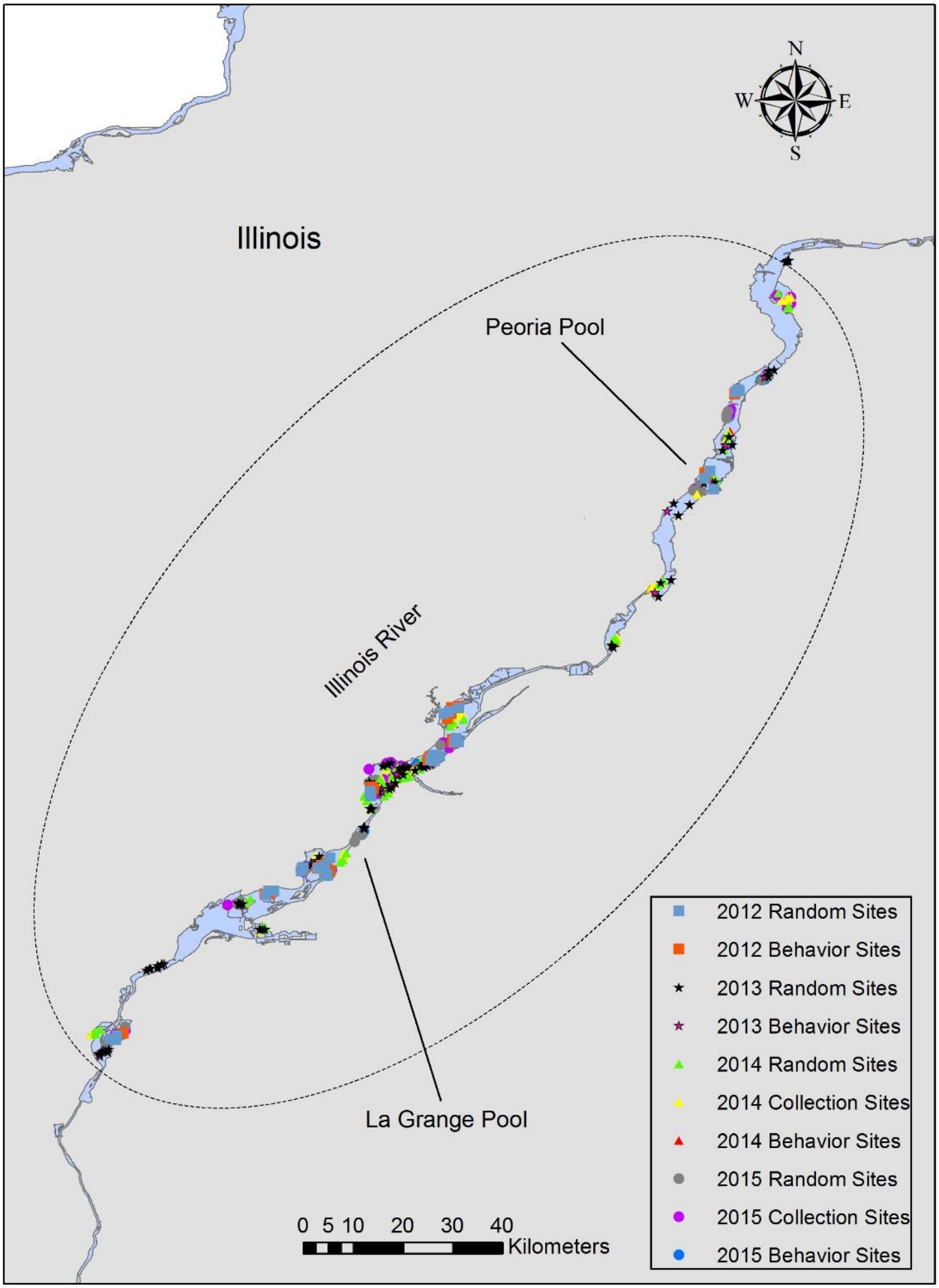

Figure 3. Locations of foraging site and random food density samples and collection locations of lesser of lesser scaup (*Aythya affinis*) and canvasbacks (*A. valisineria*) in reservoirs of southern Illinois during springs 2012–2015.

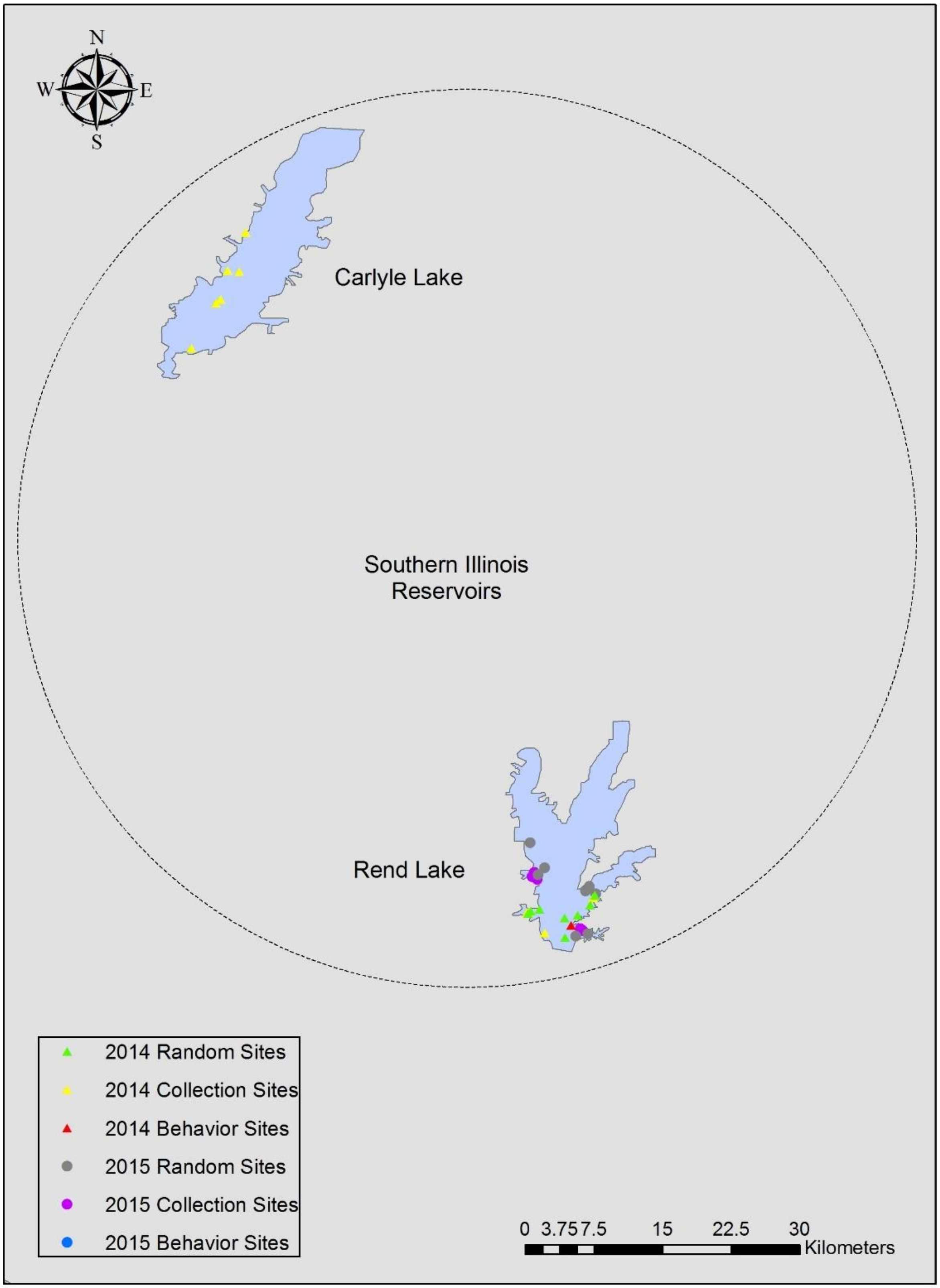

Figure 4. Locations of foraging site and random food density samples and collection locations of lesser of lesser scaup (*Aythya affinis*) and canvasbacks (*A. valisineria*) at the confluence of the Illinois and Mississippi Rivers during springs 2014–2015.

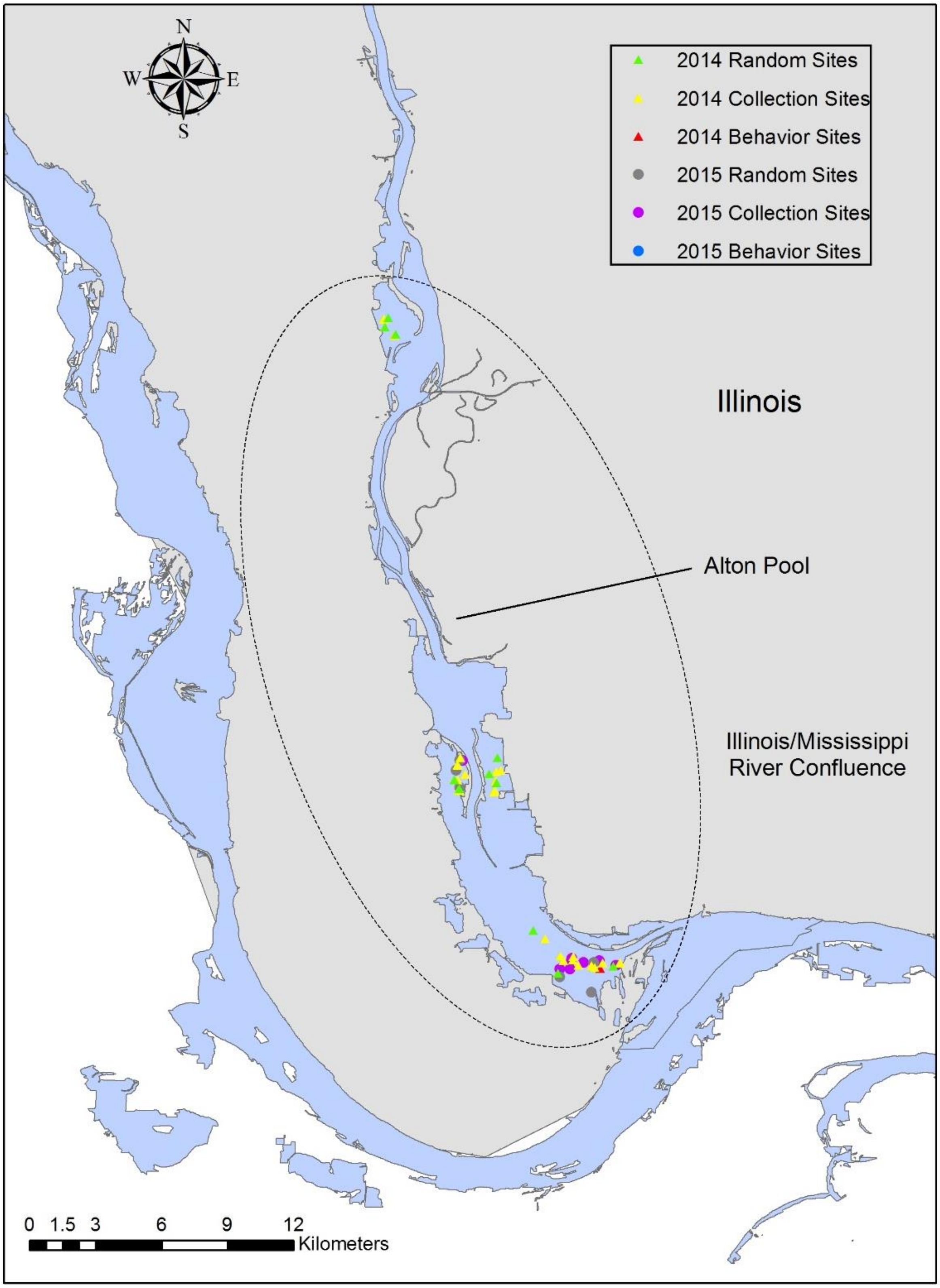

Figure 5. Locations of foraging site and random food density samples and collection locations of lesser of lesser scaup (*Aythya affinis)* and canvasbacks (*A. valisineria*) in the central Mississippi River during springs 2012–2015.

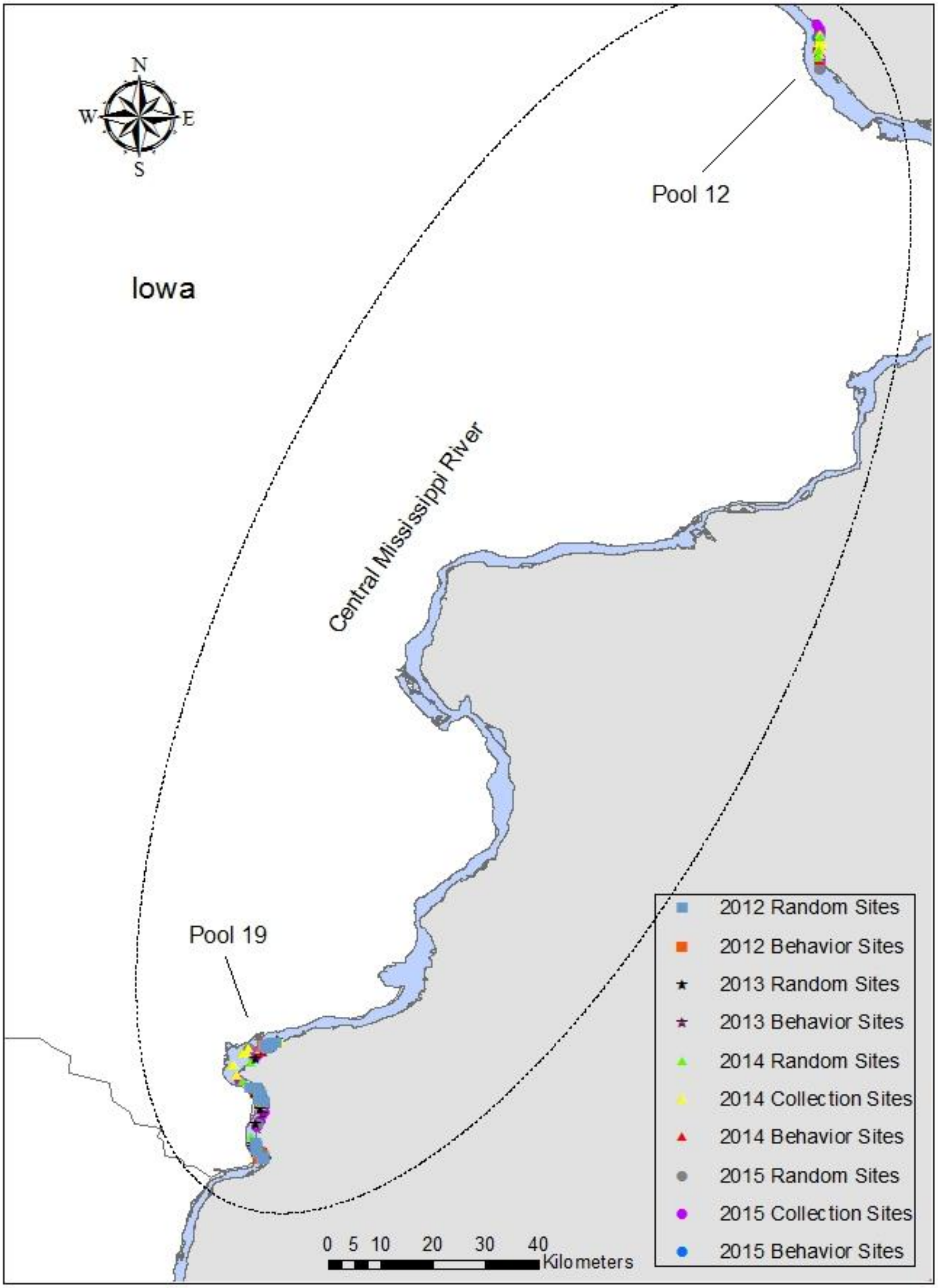

Figure 6. Locations of foraging site and random food density samples and collection locations of lesser of lesser scaup (*Aythya affinis*) and canvasbacks (*A. valisineria*) in the Upper Mississippi River during springs 2014–2015.

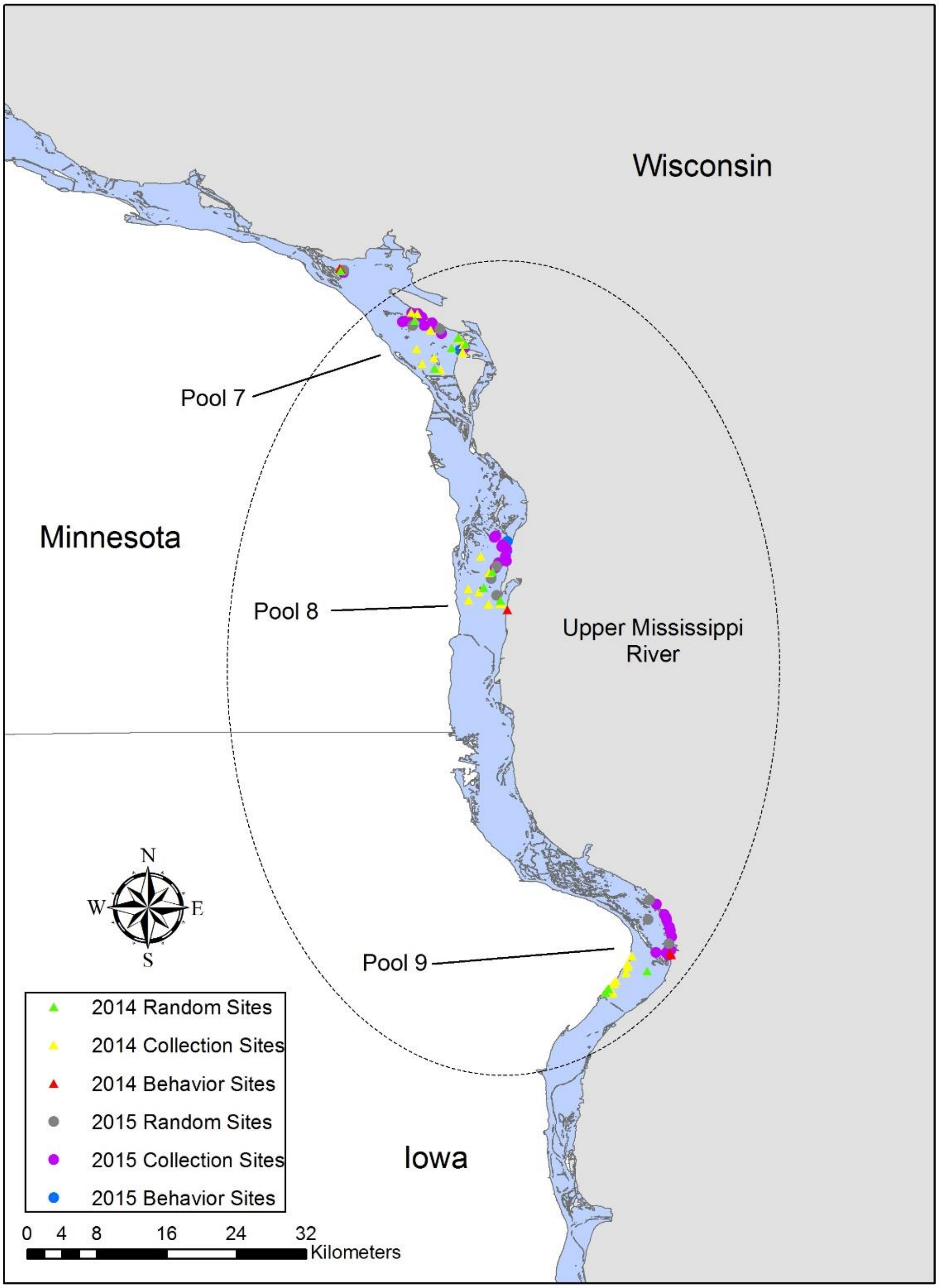

Figure 7. Locations of foraging site and random food density samples and collection locations of lesser of lesser scaup (*Aythya affinis*) and canvasbacks (*A. valisineria*) in the east-central Wisconsin during springs 2014–2015.

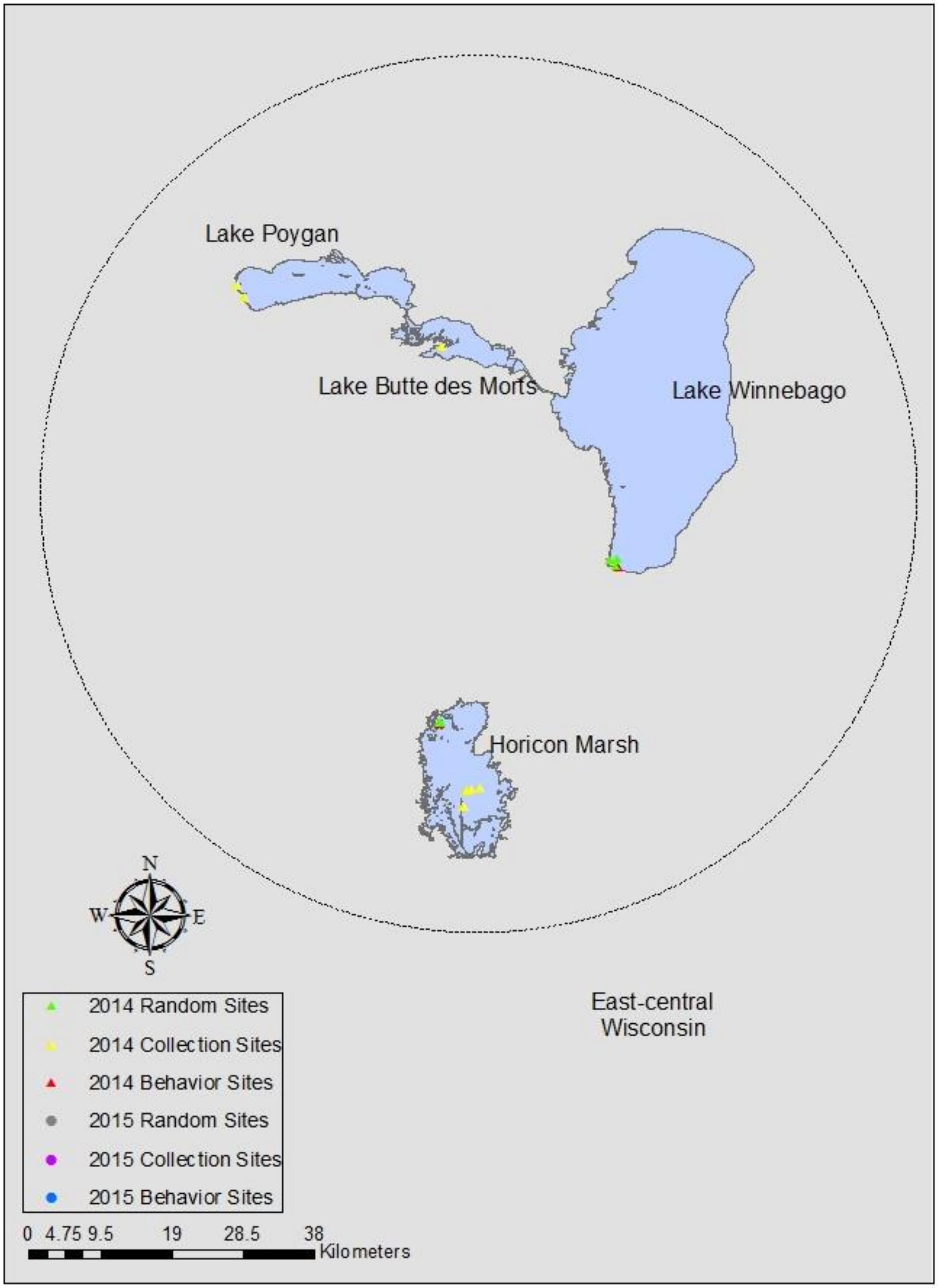

Figure 8. Locations in the Illinois and central Mississippi rivers aerially inventoried for diving ducks by the Illinois Natural History Survey during spring 2012–2015.

Figure 9. Mean (± SE) proportion of male and female lesser scaup (*Aythya affinis*) and canvasbacks (*A. valisineria*) engaged in behaviors in the upper Midwest during springs 2012–2015.

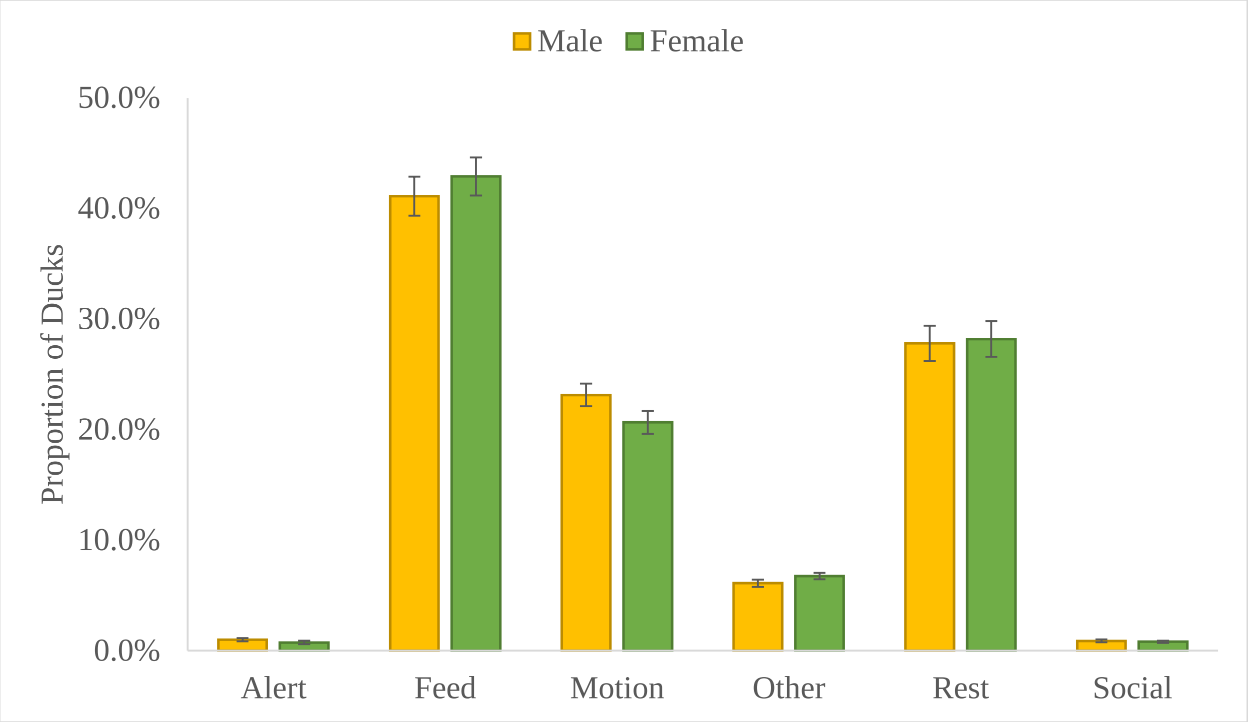

Figure 10. Mean (± SE) invertebrate, plant, and total food biomass from core and sweep-net samples collected in locations where lesser scaup (*Aythya affinis*) and canvasbacks (*A. valisineria*) were observed foraging and proportional behavior was quantified (foraging sites) and random samples collected throughout wetlands in the upper Midwest during springs 2012–2015.

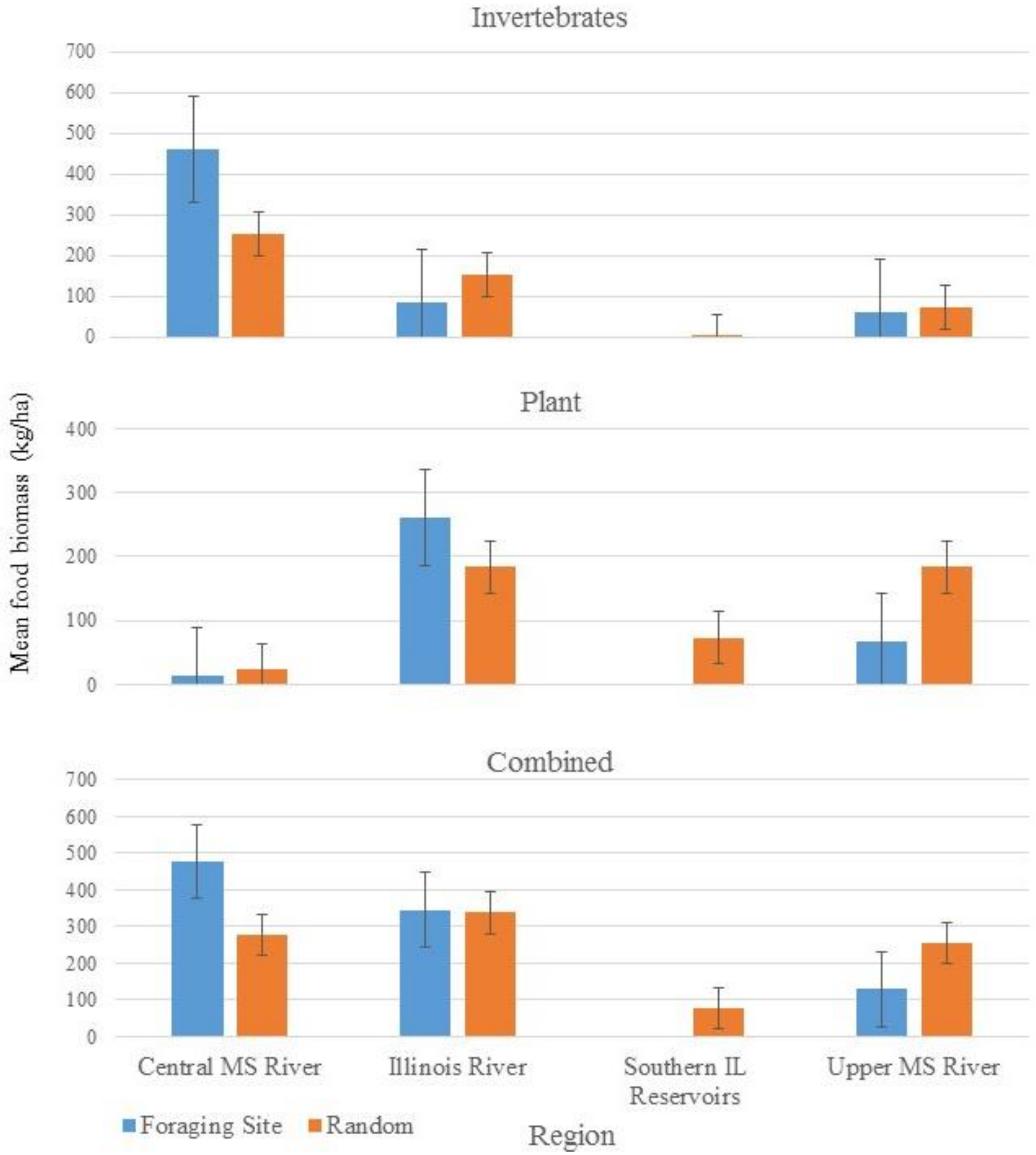

Figure 11. Mean ($\bar{x}$, ± SE) invertebrate, plant, and total food biomass from core and sweep samples collected randomly across wetlands where lesser scaup (*Aythya affinis*) and canvasbacks (*A. valisineria*) were observed foraging and proportional behavior was quantified in the upper Midwest during springs 2012–2015.

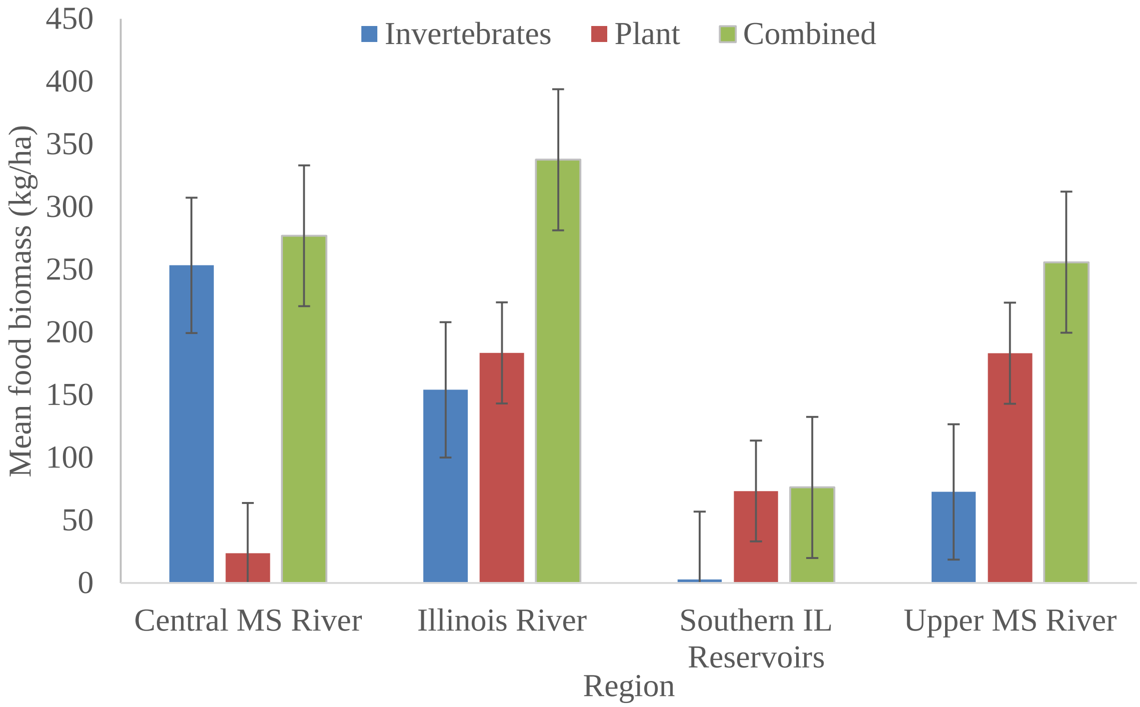

Figure 12. Mean (± SE) corticosterone concentrations in fecal material by region where lesser scaup (*Aythya affinis*) were lethally collected in the upper Midwest during springs 2014–2015.

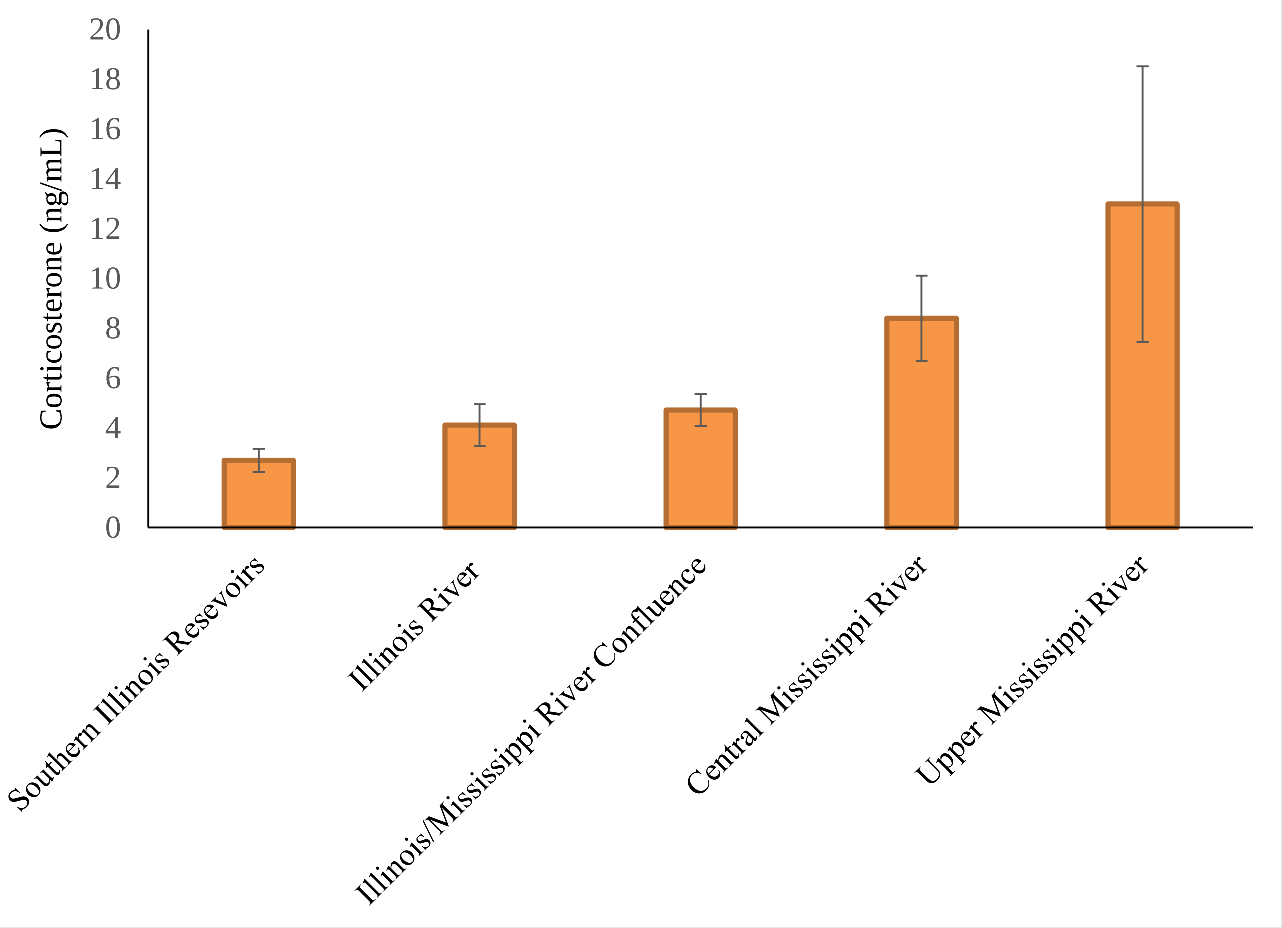

Figure 13. Trends in sex ratios (male:female) of lesser scaup (*Aythya affinis*) captured and banded along the Illinois River during springs 2014–2015.

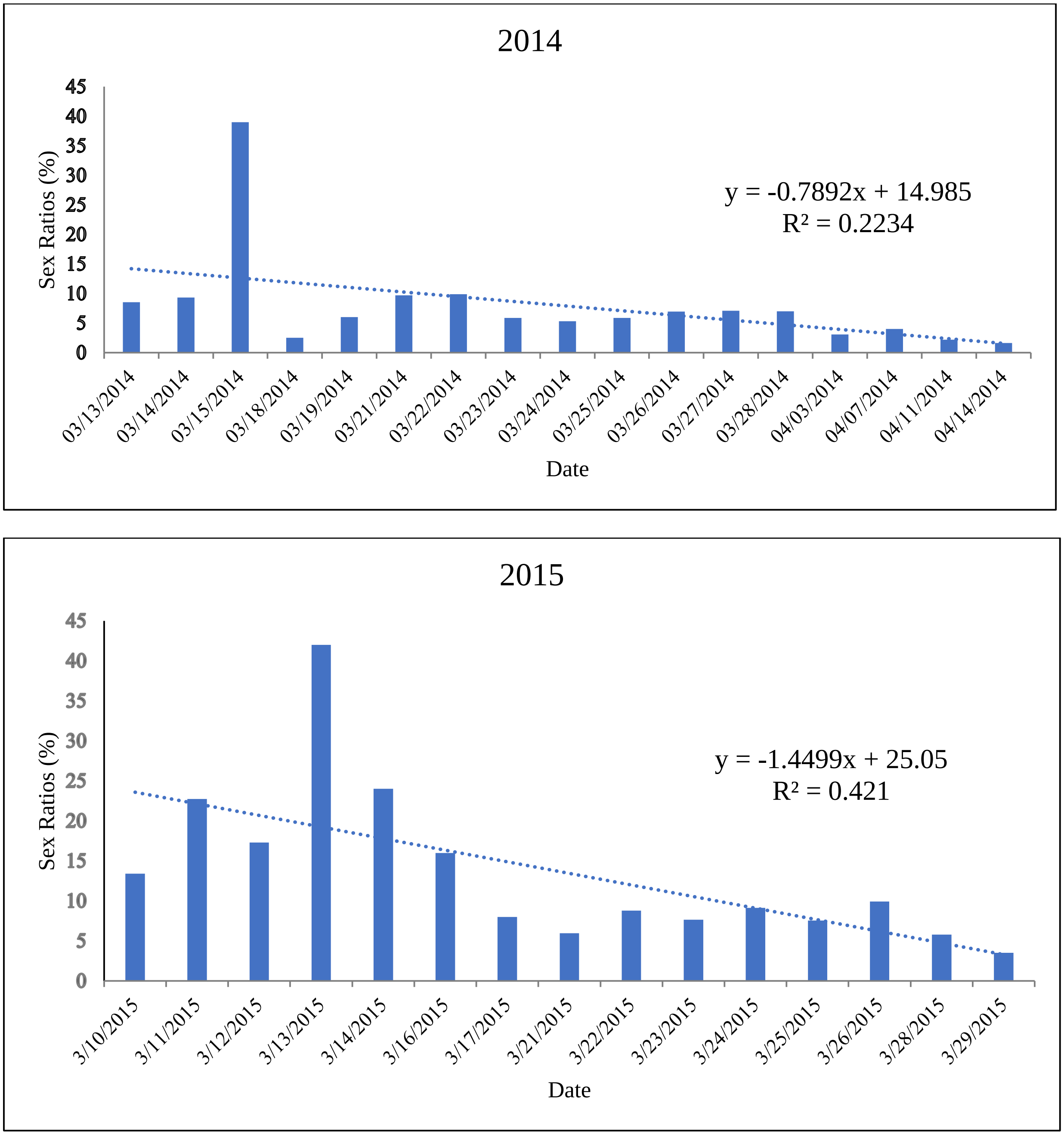

Figure 14. Distribution of leg-band recoveries of lesser scaup (*Aythya affinis*) banded along the Illinois River at Chautauqua National Wildlife Refuge and the Emiquon Preserve near Havana, Illinois, during spring 2012–2015.