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Effect of habitat management on dabbling ducks during spring migration in southwest Indiana

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EFFECT OF HABITAT MANAGEMENT ON DABBLING DUCKS DURING SPRING MIGRATION IN SOUTHWESTERN INDIANA

by

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Historically, management for migratory waterfowl was focused around providing hunting opportunity each fall. More recently habitat during spring migration has received attention as a potentially limiting factor for some species of waterfowl, considering the carry-over effects that have been observed in both capital and income breeders. Habitat needs have been compounded by the flashy flood events that now occur in the highly modified landscape. The discovery of carry-over effects has led to an increase in habitat management actions and a diversification of available management strategies. In my study I hoped to identify the best management strategies for spring migratory waterfowl. I also wanted to identify how quickly waterfowl can respond to flood events. In 2012 and 2013, I examined the effect of habitat management on dabbling duck behavior and distribution during spring migration in southwest Indiana. I investigated three management options for wetlands: active management, passive management, and agricultural food plots. Actively managed wetlands are wetlands where the hydrology is managed and controlled. In passively managed wetlands and agricultural food plots; the hydrology is provided naturally. I surveyed both duck behavior and abundance on 14 wetlands on the Patoka River National Wildlife Refuge and Management Area. I also surveyed short-lived wetlands to determine the response rate of waterfowl to inundation following rain events. The agricultural food plot areas had the lowest estimates of food availability followed by the actively managed areas with the passive managed wetlands having the highest estimate. Waterfowl abundances

were highest on the actively managed wetlands with the food plots coming in second and the passive wetlands coming in a distant third. The passive wetlands had the highest proportions of time spent feeding followed by the active and food plot wetlands. Dabbling ducks were not distributing themselves relative to food density but are feeding in the highest proportions in these areas. Waterfowl use was recorded less than 24 hours after inundation on 14 of 21 short-lived wetlands. Short-lived wetlands may be important to migratory waterfowl. Conservation prioritization of passively managed areas would provide larger areas for dabbling ducks to feed, but active management provides habitat regardless of climatic variability. Moving forward, wetland complexes encompassing diverse wetland management approaches would be the best option for spring migrating waterfowl as these complexes can provide high quality habitats and buffer against uncontrollable climactic conditions.

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GENERAL INTRODUCTION

Many birds nesting in temperate and arctic areas migrate to regions with a more favorable climate following the breeding season (Bell 2005, Rappole and Jones 2002). The timing of migration can be adjusted in response to weather or phenology of snow melt and ice breakup (Marra et al. 2005). Waterfowl have adapted to take advantage of food resources made available by flood events that occur during migratory periods, therefore, migratory waterfowl often follow large river systems, such as the Mississippi, Missouri, and Illinois for activities such as feeding and resting (Bellrose 1957, Bellrose 1980, Korschgen 1989). This, along with band return data, helped identify the flyway systems used by waterfowl to travel between their breeding and wintering areas and helps target areas for habitat management and research.

Spring migration is a crucial time for waterfowl as it is immediately followed by the breeding period, having direct effects upon reproductive success and recruitment (Heitmeyer and Fredrickson 1981, Krapu 1981, Raveling and Heitmeyer 1989, Afton and Anderson 2001, Anteau and Afton 2004, Arzel et al. 2006, Sedinger and Alisauskas 2014, Stafford et al. 2014). The importance of spring migration is further compounded because it happens during a time of the annual cycle where food densities are usually low (Arzel et al. 2006, Newton 2006). Food availability during spring migration is thought to be the most limiting factor for waterfowl outside the breeding season by the Upper Mississippi River and Great Lakes Region Joint Venture (Soulliere et al. 2007). Thus, managing for migrating waterfowl now focuses on providing areas with high densities of quality waterfowl food during the winter and spring migratory seasons prior to reproduction.

Reproduction for waterfowl requires a large amount of nutrients. Nutrient acquisition and investment of animals has historically been categorized into two strategies: income and capital breeding (Drent and Daan 1980). Capital breeders are those organisms that acquire the nutrients used for offspring production prior to the initiation of reproduction while income breeders acquire nutrients during the reproductive period. More recent research suggests, instead of a categorical relationship, acquisition of resources used for reproduction is found on more of a continuum, with larger bodied waterfowl such as geese and swans being found near the capital breeding end and smaller bodied waterfowl such as dabbling ducks on the intermediate region of the continuum (Drent and Daan 1980, Bonnet et al. 1998, Krapu and Reinecke 1992 Arzel et al. 2006, Sedinger and Alisauskas 2014). Because of the need to acquire at least some reproductive nutrients prior to breeding, Anatidae generally spend more time feeding during spring than in winter (McLandress and Raveling 1981, Paulus 1988). For this reason, appropriate spring habitat at staging sites important to the fitness of migrating ducks (Ankney et al. 1991, Alisauskas and Ankney 1992, Klaasen 2002).

Lipid reserves have been found to be positively correlated to clutch size in waterfowl (Krapu 1981). Lipid accumulation occurs during migration on stopover habitats where Anatidae feed, rest, and participate in courtship activities (Guillemain et al. 2004). Spring water conditions such as water level and abundance of wetlands have been shown to be important to the breeding success of ducks (Krapu et al. 1983) and some authors have suggested loss of available food resources during spring migration has affected reproductive success of some species of ducks (Afton and Anderson 2001, Anteau and Afton 2004, 2006, 2008, and 2009). Thus, habitat management goals usually work towards providing high quality areas for birds to use while migrating.

While large scale planning documents such as those provided by the USFWS Joint Ventures provide general guidance as to what resources should be provided for waterfowl at the larger regional scale, understanding and guidance as to the most efficient implementation practices to produce those resources at the more local level is still limited (Loesch et al. 1994, Soulliere et al. 2007). For example, larger scale planning documents identify the total amount of resources needed to support waterfowl within the region. There is little guidance available as to how those resources should be distributed or what implementation approaches are most efficient at providing those resources. Thus, it is up to local implementation agencies, such as individual USFWS refuges, to identify the most cost-efficient approach of providing those resources. As previously mentioned, in the case of migratory waterfowl, food resources are assumed to be the most limiting resource outside the breeding grounds, so local implementation agents emphasize providing food for waterfowl when providing habitat. Local habitat managers can supply food resources for waterfowl using a variety of approaches that vary in both the amount of money invested and the amount of food produced on a dollar per acre investment. For example, managers can restore and maintain what are commonly referred to as "intensively managed" wetlands, where the hydrology of the wetland is closely monitored and controlled to maximize the level of resources produced for waterfowl (Pankau 2008). While these wetlands tend to more consistently provide waterfowl resources than less intensively managed wetlands, the level of resources produced for use by waterfowl may not be greater and the cost per ha is typically much greater than for less intensive approaches (Pankau 2008). Alternatively, managers could use less intensive, and thus less expensive, approaches to restoring and managing wetlands, such as planting food plots in flood prone areas or simply securing and protecting natural and agricultural habitat in flood prone areas. The level of resources produced and the use of these resources, however, may be inadequate to justify even the lesser expense. Therefore, better information is needed by managers to most efficiently provide waterfowl resources in non-breeding regions.

In Chapter 1 of this thesis, I compare resource productivity, migratory waterfowl distribution, and migratory waterfowl behavior among wetlands being managed with different levels of intensity at Patoka National Wildlife Refuge. This information can be used by refuge biologists to help determine what level of management activity most cost-efficiently meets their objectives.

Availability of those resources produced could also have a strong impact on resource acquisition by waterfowl. Although waterfowl have adapted to exploit ephemeral habitats during spring migration, the timing and longevity of these habitats has changed dramatically during the last 50 years due to anthropogenic modifications of riverine ecosystems. What used to be gradual overbank flooding, with gradual inundation and dewatering of ephemeral riparian wetlands is now much more “flashy”, with much more frequent but less predictable flood events of shorter duration. The ability of waterfowl to exploit resources produced in these less predictable, more ephemeral habitats has been questioned to the extent that some large scale management plans do not include resources provided in these habitats when developing habitat management objectives (e.g., Loesch et al. 1994). In Chapter 2 of this thesis, I tested the assumption that resources provided by ephemeral, riparian wetlands inundated mainly through over-bank flooding are too short-term to allow migratory waterfowl the opportunity to locate and exploit them.

CHAPTER 1

EFFECT OF HABITAT MANAGEMENT ON DUCK BEHAVIOR AND DISTIBUTION DURING SPRING MIGRATION

INTRODUCTION

Historically, habitat management for migratory waterfowl emphasized providing hunting opportunity. More recently, habitat managers have emphasized the provision of adequate resources to waterfowl during both the spring and fall migratory periods (Soulliere et al. 2007). Strategies to improve migratory habitat include active management, passive management, or leaving areas unmanaged after acquisition and protection.

Moist-soil units are wetlands enclosed by an earthen levee that allows managers to actively control hydrology using a variety of water control structures, thereby affecting the soils and vegetation present on the wetland (Fredrickson and Taylor 1982, Gray et al. 1992). Moist-soil units are often inundated by gravity flow from an impoundment or river; they can also be filled by actively pumping groundwater or surface water (Lane and Jensen 1999). Actively managed wetlands are expensive with initial construction costs ranging from \$500 - \$37,000 per hectare plus ongoing mechanical and maintenance costs (Lane and Jensen 1999, Pankau 2008). Ability to control the water level ensures that managers have control over hydrologic conditions regardless of environmental conditions. Typically, these areas are drawn-down (drained) in the spring and summer to allow moist-soil vegetation to grow and mature, followed by flooding in the fall to provide habitat to migrating and wintering waterfowl (Fredrickson and Taylor 1982). Wetlands are drawn down to stimulate the growth of early successional plants. These plants are usually annuals that produce abundant seeds; providing a food source to migrating and wintering waterfowl during times of the annual cycle when food densities are lower (Arzel et al. 2006).

Other options available to land managers for providing habitat to migratory waterfowl are to manage an area passively or not to manage at all. These options are generally much cheaper than active management over the long haul as most cost is tied up with the conservation of these lands (Lane and Jensen 1999, Pankau 2008). Passively managed lands are areas that depend on natural water level fluctuations for inundation; however, these areas may have low levees that hold water after initial inundation (Brasher et al. 2007, Pankau 2008, Stafford et al. 2011). These areas can be agriculturally manipulated; planted into row crops, seed producing perennials, or a combination of the two. Keeping the land in agriculturally managed prevents succession of woody plants and shrubs typical of many passively managed areas. Inundation of passively managed wetlands results in the creation of large foraging areas. Wetlands that go unmanaged are areas where no restoration work has occurred and water level and food abundances are rarely anthropogenically altered (Lane and Jensen 1999, Pankau 2008). Both passive and unmanaged wetlands may depend on unreliable water sources making them less seasonally predictable as a habitat for migrating waterfowl than actively managed wetlands (Brasher et al. 2007, Pankau 2008, Stafford et al. 2011).

The quality of habitat for migratory waterfowl is often quantified to help establish management strategies for a given area. Directly measuring food density and other determinants of habitat quality is labor intensive relative to monitoring the distribution of animals; therefore, animal use or distribution is often used by managers as an index of habitat quality (Brasher et al. 2007, Pankau 2008). Bird distribution, however, may not reliably indicate habitat quality (Morrison 2001, Johnson 2007). For example, because food availability is assumed to be the most limiting resource for waterfowl during spring migration, waterfowl are thought to distribute themselves based primarily on the distribution of food (Soulliere et al. 2007). However, factors other than food density such as predator avoidance, inter- and intraspecific competition, and microclimate also influence bird distributions (Pulliam 2000, Scott et al. 2002). These other factors may cause waterfowl to select habitat with lower food density (Morrison 2002). The selection of suboptimal habitat can lead to lower fitness (Schlaefer et al. 2002, Battin 2006). Bock and Jones (2004) suggested that birds can fail to recognize suboptimal habitats if they are inhabiting habitat different from that in which they evolved. The North American landscape has been drastically altered, and it is unknown how migratory waterfowl may be affected by this change. An alternative explanation as to why suboptimal habitats are being selected is that habitat quality is being inappropriately defined. For example, waterfowl may avoid areas with extremely high densities of food because of extremely high predation pressure or high exposure to unfavorable microclimate conditions.

It is unclear how waterfowl choose cover types during spring migration in relation to food availability (Soulliere et al. 2007, Stafford et al. 2014). Density of an animal and habitat quality are not always positively correlated (Van Horne 1983, Gates and Gysel 1978, Pidgeon et al. 2003, Ries and Fagan 2003). Therefore, behavioral studies can be used as an alternative to measuring waterfowl distribution to indicate the quality of available habitat.

Migratory animals attempt to identify habitats of high quality, considering aspects such as predation risk and food density when selecting resting and foraging sites during migration. Foraging animals undergo a constant trade-off between vigilance and feeding behavior (Brown 1999). During an individual foraging bout, the proportion of time an individual spends feeding relative to being vigilant likely depends on both forage density and perceived predation risk (Schoener 1971, Hill and Ellis 1984, McNamara and Houston 1994, Verdolin 2006, Bednekoff 2007). Because direct assessment of food availability and predation risk is difficult, many bird species use habitat characteristics, such as cover, to judge the predation risk and potential food density of a habitat, and therefore the quality of that habitat (van der Wal et al. 1998, Rowcliffe et al. 1999). Davis (1973) suggested that cover prevents predators from successfully catching prey, while Underwood (1982) suggested that cover can facilitate predation by keeping predators concealed from their prey. With variable effects of cover on predation risk, understanding how management actions influence both distribution and behavior can provide insight as to which management actions are most beneficial for the intended organisms. Behaviors can be recorded in the form of an activity budget that can be used to understand how waterfowl use different habitats (Rave and Baldassarre 1989). Activity budget studies are intensive compared to distribution studies. However, they can provide information that would not be detectable during a basic distribution survey such as whether individuals are using the site for foraging or loafing. Behavioral observations may be particularly useful for migratory populations whose numbers are variable and where scheduled bird counts may miss large influxes of birds (Webster et al. 2002).

Waterfowl eat a variety of foods during migration including invertebrates, natural seeds, plant fragments, and waste grain (Straub et al. 2011, Pearse et al. 2011). Food availability is typically estimated by sampling from the water column and substrate of a wetland during inundation. Estimates of food abundances in moist-soil units range from 431 kg/ha to 1629 kg/ha (Table 1.1). Previous literature suggests that natural, unmanaged wetlands provide less food relative to managed wetlands. Straub et al. (2011) studied wetlands in the Upper Mississippi River and Great Lakes Region, finding an average food availability during the spring migratory period of 208 kg/ha for shallow semi-permanent and deep marshes. This value is close to the Upper Mississippi River and Great Lakes Region Joint Venture's estimate for food availability of 188 kg/ha (Soulliere et al. 2007), which is used to help establish habitat objectives in the region for migrating waterfowl. Most available food estimates are from research conducted in the fall; however, food depletion may occur by birds during the fall and winter, leaving lower food densities during spring migration (Stafford et al. 2006, Greer et al. 2009). This depletion leaves habitat managers unsure food abundances and ideal management strategies for spring stopover habitat.

My objective was to increase our understanding of how local management actions influence quality of habitat for migratory waterfowl. I tested the hypothesis that more intensive management actions lead to higher quality habitat by comparing the behavior, distribution, and food availabilities of spring migratory waterfowl across wetlands being managed with 3 levels of intensity. I predicted that the actively managed wetlands would have higher food densities than passively managed wetlands. I also predicted that, because waterfowl are thought to be limited by food availability during spring migration, waterfowl would be most abundant and feed most intensively on actively managed sites, where I predict food will be most abundant.

METHODS

Study Area

Patoka River National Wildlife Refuge and Management Area was established in 1994 as the 502nd refuge in the National Wildlife Refuge system. It was the 2nd refuge in the state of Indiana and is located in the southwestern part of the state, including Pike and Gibson counties. It currently sits at 2,671 ha with an ultimate acquisition boundary of 9,094 ha. The Patoka River has an extensive history of hydrologic alterations (USFWS 2008). In the 1920s, an attempt was made to drain 40,000 hectares of forested wetlands adjacent to the river. This was known as Houchin’s Ditch and replaced 58 km of natural meanders with 27 km of dredged, straightened river channel (USFWS 2008). The other significant alteration event in the Patoka River system is the creation of Lake Patoka in the late 1970s. Lake Patoka is a 3,200 ha impoundment managed by the United States Army Corps of Engineers. These two alterations have contributed to the Patoka River having very flashy flood events that inundate large tracts of the refuge for varying periods of time (Heath Hamilton, USFWS, pers.comm.).

I conducted research for this chapter entirely on properties owned by the Patoka River National Wildlife Refuge and Management Area managed by the United States Fish and Wildlife Service. I monitored 14 wetlands over a 453 km^2 area. These wetlands take on one of three categorizations based on cover type and management action: (1) actively managed wetlands also known as moist-soil units, (2) passively managed wetlands, and (3) agricultural food plot wetlands.

I surveyed six actively managed wetlands. Four of these wetlands total 78 ha within the 197 ha Cane Ridge Wildlife Management Area. This area is traditionally known as a migratory pathway and wintering area for waterfowl because of its centralized location between the confluences of the White, Patoka, and Wabash Rivers (USFWS 2008) and its proximity to Gibson Lake, a cooling lake for Gibson Generation Station. Also, two wetlands were monitored at Dillin Bottoms, a moist-soil complex designed by Ducks Unlimited, totaling 25 ha on the east end of the refuge.

The 3 passively managed wetlands I surveyed were flow-through wetlands directly connected to the Patoka River prior to its channelization (Heath Hamilton, USFWS, pers.comm.). Currently, these wetlands are affected during flood events but maintain water levels independent of flooding. These wetlands have been conserved to allow a chance to revert to a naturally functioning wetland complex without major intervention.

The 5 agricultural food plot wetlands I surveyed were located close to a channelized portion of the river and were prone to winter and spring inundation. These areas were planted under a cooperative farming agreement between the United States Fish and Wildlife Service and a local area farmer, who plants a harvestable human food crop such as corn or soybeans on refuge property and leaves a ¼ share food plot on the landscape. The share is split between leaving 1/8 of the field in the standing human food crop while the other 1/8 will have a Japanese millet (*Echinochloa spp.*) and buckwheat (*Fagopyrum spp.*) stand that is planted by drilling. Once inundated, these areas can provide food for migrating and wintering waterfowl.

Research Design

At each wetland, I surveyed waterfowl once weekly during a randomly selected period (morning, midday, or afternoon) to prevent time-associated bias in observed behaviors. Evening surveys were avoided to prevent lower detection probabilities cased by low light levels and shadows. Each survey consisted of a scan behavioral survey for ducks (Altmann 1974) and a total waterfowl count.

Scan behavioral surveys were conducted every 10 minutes for one hour to total seven sampling intervals per survey period. Each survey followed a 30-minute rest period to allow the ducks to return to a state of normalcy if ducks were alerted to my presence while getting into survey position. I used a variable 20-60X power spotting scope to scan across the wetland and recorded the species, sex, and behavior of every duck present on the water body. A direction to scan, right to left or left to right, was chosen randomly prior to the initiation of the first survey. Surveys were done from the vehicle if possible to prevent behavior bias in observed birds as vehicle travel around the refuge is common. The spotting scope was attached to a window mount to scan the wetland from the roadway. If surveying from a vehicle was not feasible, a vantage point was chosen that concealed the surveyor and allowed for a broad view of the wetland. If large concentrations of ducks were present, I sub-sampled by dividing the wetland extent from the observer's vantage point into quarters and randomly selecting two of those quarters (Hepworth and Hamilton 2001). If ≥ 500 ducks appeared to be present, I divided the wetland extent into eighths and randomly selected two of those eighths for sampling.

The behaviors were recorded into 11 different categories: (1) feeding on surface, (2) feeding with the head underwater, (3) feeding by up-ending, (4) feeding by diving, (5) resting, (6) courtship, (7) swimming, (8) self-maintenance, (9) aggression, (10) alert, and (11) flying (Pöysä 1983a,b, 1987; Lovvorn 1989; Guillemain et al. 2002; Arzel and Elmberg 2004). Scan samples have been known to underestimate the amount of time that diving ducks spend feeding (Baldassarre et al. 1988), so time budgets were created and analyses were conducted using only the data from eight dabbling duck species that were most prevalent: American black duck (*Anas rubripes*), American wigeon (*Anas americana*), blue-winged teal (*Anas discors*), gadwall (*Anas strepera*), green-winged teal (*Anas crecca*), mallard (*Anas platyrhynchos*), northern pintail (*Anas acuta*), and northern shoveler (*Anas clypeata*).

Waterfowl were counted immediately following the scan survey. If extensive emergent vegetation was not present on the wetland, ducks were counted from the survey location. On wetlands with extensive emergent vegetation, ducks were counted by flushing to account for ducks obscured by the emergent vegetation (Pöysä and Nummi 1992).

Soil cores were collected at five random locations in each wetland at the beginning of the 2013 field season. Each core had a diameter of 10.2 cm and was 10 cm deep. I used cores with a larger diameter than the cores used in most other studies to minimize the variance associated with sampling from a population with a clumped distribution (Behney et al. 2014). Core samples were washed through a 500 µm mesh sieve bucket in the field and preserved with 10% buffered formalin. In the lab, I washed samples through 750 and 500 µm sieves, and invertebrates and seeds were separated. Invertebrates and seeds were dried at 60° C for 48 h, and weighed to the nearest 0.1 mg to determine dry mass.

To test the prediction that food density is greater in more actively managed plots I used the linear mixed effects model package in Program R with dried mass of seeds and invertebrates of each core as the dependent variable, plot as the random variable, and management type as the fixed effects variable. To test the hypothesis that spring migratory ducks distribute themselves relative to food density, (i.e., there would be a positive relationship between duck abundance and food density), I used the linear mixed effects model package in Program R with average dabbling ducks encountered by visit as the dependent variable, year and size of the wetland as the random effects variables, and management type and food density as independent fixed variables. This resulted in a model set that included a null model, a model that had management type as an independent fixed variable, and a model that had food density as an independent fixed variable. Wetland size was a random effect to account for the variance of size of each wetland based on hydrologic conditions. I ran models that grouped all dabbling duck species together in addition to running each model set for each individual duck species. For these models the average number of birds encountered during each wetland visit per year was used to test differences between species. The linear mixed effects models were compared using AIC corrected for small sample size (AIC_C).

To test the hypothesis that birds behave differently on actively managed sites, I tested the prediction that there would be a positive relationship between proportion of time spent feeding and management intensity, with a predicted higher food density in actively managed sites, using the generalized linear mixed effects model package in Program R. Proportion of time spent feeding was the dependent variable with wetland and year as the random effects variables. Species, sex, date, management type, and food density were the independent fixed variables. Generalized linear mixed effects models were compared using Akaike's Information Criterion (AIC) in an Information-Theoretic approach (Burnham and Anderson 1998).

RESULTS

Over the spring 2012 and 2013 field seasons I recorded 48,753 observations of dabbling duck behavior on Patoka River National Wildlife Refuge and Management Area. Northern shovelers were the most numerous duck surveyed (12,644 observations) followed by mallard (12,452), northern pintail (8,599), green-winged teal (7,384), gadwall (5,548), American wigeon (1,075), blue-winged teal (783), and American black duck (268).

The number of dabbling ducks observed during counts was 64,997 combined over both years. In 2012, 125 bird counts were conducted, 27 of which were flush counts. In 2013 I conducted 96 bird counts, 23 of which were flush counts. Mallards were the most numerous duck recorded (18,203), followed by northern pintail (15,405), green-winged teal (13,535), Northern Shoveler (9,512), gadwall (6,285), blue-winged teal (1,022), American wigeon (753), and American black duck (282).

Food availability varied by management activity as the model incorporating management action had a lower AIC_C than the null model (Table 1.2). In contrast to my prediction, point estimates from this model indicated passively managed wetlands had the highest estimated food density (813.8 ± SD 159.6 kg/ha, figure 1.1) followed by actively managed wetlands (717.9 ± SD 112.9 kg/ha) and agricultural food plot wetlands (575.7 ± SD 123.6 kg/ha).

The 3 candidate distribution models ranked similarly for all species. Distribution of each species was most affected by management action (Table 1.3). The null model was the second most competitive model for each species and the food model is least supported for each species. The American black duck was the only species to have a model weight below 90% with a model weight of 87% for the management action model. Duck species distributed themselves differently with respect to management, with the American wigeon being more common in the passively managed wetlands and gadwall and northern pintails being more numerous in agricultural food plot wetlands (Table 1.4). The remaining five species of dabbling ducks were most prevalent in the actively managed wetlands. The most supported model for the behavior of ducks during spring migration included only species and sex (Table 1.5). A model that included management action was also competitive, but I found no evidence that food availability influenced behavior (Table 1.5). Model estimates separated by species and sex indicated females fed more intensively than males of each of the selected species (Figure 1.2). Northern shovelers fed most intensively with around 70% of their time dedicated to foraging activities for both sexes. American black ducks fed the least intensively with males feeding around 31% of their time and females feeding around 41% of their time. Out of the 8 dabbling duck species I monitored, all but the green-winged teal and northern pintail fed most intensively in the passively managed areas (Table 1.6). The pintails fed most intensively in the food plot areas and the green-winged teal fed most intensively in the actively managed moist-soil units.

DISCUSSION

Current theory predicts individual organisms should select habitat that allows them to maximize fitness. If food availability has the greatest impact on fitness by directly influencing either survival or reproductive success, then waterfowl should select sites that allow them to maximize food intake. In general, habitat managers have accepted the paradigm that the distributions of spring migratory waterfowl correspond to food resources, with food availabilities being the most limiting factor for ducks during the migratory period (Soulliere et al. 2007, Stafford et al. 2014). My results suggest that spring migrating dabbling ducks using the Patoka River National Wildlife Refuge and Management Area are distributing themselves according to management action and not solely on food availability. I can identify several reasons why waterfowl may not be distributing themselves relative to the availability of food.

Waterfowl may be inept at locating food rich patches. Because waterfowl food resources are typically found in the benthic layer of wetlands, they are obscured by both the water column and the wetland substrate. Thus, foods are likely difficult to locate by sight. Waterfowl likely use structure of vegetation or other feeding individuals as cues to the availability of food. Although these cues may be of general use, they may be only weakly correlated to actual food availability, leading to suboptimal habitat selection by waterfowl. Alternatively, as demonstrated by their ability to navigate to extremely well-concealed nest sites both within and among years, waterfowl have a very refined spatial memory (MacInnes & Dunn 1988, Gautier 1990, Öst et al. 2011). One adaptation that has likely evolved in waterfowl is the ability to remember and relocate safe, resource-rich, foraging patches. Because the moist soil units in my study are on a protected part of the refuge, waterfowl concentrate on those units during the fall and winter hunting season. Thus, waterfowl might concentrate on those areas during spring simply because they have provided resources and protection from predation (hunters) during the fall migration and winter. This may be a successful long-term strategy of species for which patch richness is not easily assessed.

Alternatively, the assumption that food availability is limiting to the point that it drives habitat selection may not be appropriate. Susceptibility to predation, ability to form and maintain pair bonds, or cover from inclement weather may influence survival and reproductive success to a greater extent than food availability. Thus, food availability may play only a small role in habitat selection of migratory ducks during spring (Stafford et al. 2014).

Although food availability appeared to have little influence on the distributions of ducks in my study, ducks fed most intensively in plot types with the greatest food density (passively managed wetlands). The lack of a direct linear relationship between my measure of food density and feeding intensity suggests feeding intensity may not be directly related to food density. Theoretically, the intensity at which waterfowl feed (proportion of a given amount of time when their head is down and they are actively feeding during a feeding bout) should be determined by the tradeoff between the level of reward gained by feeding and the risk taken (Lima and Bednekoff 1999). Theory predicts individuals, while seeking food resources, should increase feeding intensity with an increase in food density or a perceived decrease in predation risk (Lazarus and Symonds 1992). In my study, waterfowl in unmanaged wetlands fed more intensively. While passive wetlands had slightly greater food availability, I found no direct relationship between food availability and feeding intensity in my study. Thus, it's possible that waterfowl perceived the passively managed wetlands as being more safe from predation. Although I did not formally estimate vegetation structure or density, passively managed wetlands appeared to be more open. Waterfowl may have perceived this more open habitat as more safe because they could detect predators at a greater distance (Lazarus and Symonds 1992, Poysa 1994, Behney 2014). Food in actively managed wetlands could be more desirable compared to the passively managed wetlands. If the food was more desirable, migratory waterfowl could choose the higher perceived risk associated with these wetlands to forage on the desired forage.

The lack of a direct relationship between food density and waterfowl distribution and feeding intensity suggests either waterfowl are inept at locating the most food-rich foraging patches or food is not the most sought resource during spring migration. In my study, ducks appeared to select habitat according to management action and not following food availabilities possibly due to past experience. Because my food sampling protocol provided point estimates with limited precision, it's possible ducks were actually choosing plots with the greatest amount of food. Even if the true food abundance for the actively managed moist soil units was near the upper end of the 95% confidence interval and actual food abundance for passively managed sites was near the lower end if it's 95% confidence interval, the difference in food availability would be inadequate to explain the 2 to 25-fold difference in duck abundance observed between management types for species of ducks observed at greater abundances in the actively managed moist soil unit sites. Thus, I suggest an increased emphasis should be placed on conservation activities as opposed to investing resources into high priced, actively managed moist-soil units. If refuge staff maintain high food availabilities on lands that are cheaper to manage, i.e., agricultural food plot wetlands and passively managed wetlands, then funding can be better allocated to optimize seasonal bird use. Actively managed wetlands do, however, hold increased value during times of drought or seasonal variability (Pankau 2008), so complexes of both actively and passively managed wetlands should be maintained to provide quality habitat regardless of climatic variability and the exact timing of migration.

Currently, the refuge is able to manage complexes of all wetland types and I suggest the refuge, as well as other land management agencies and organizations should maintain these suite of wetland types as they move forward and continue to acquire land through fee-title acquisition agreements. Areas close to the river that are prone to seasonal flooding could be managed as agricultural food plot wetlands and passively managed wetlands, utilizing flooding regimes that are unnaturally flashy as a management tool. This can provide large areas of habitat to migrating waterfowl especially northern pintail, a species of conservation priority, because pintails were most numerous in my study on agricultural food plot areas. Pintails potentially chose this habitat because migrating pintails could select areas of sparse cover to increase the detection of local predators. The agricultural food plot wetlands were generally in open areas where approaching predators could be easily seen, compared to passive and actively managed wetlands where stands of trees were closer to the wetlands. If this is the case, pintails may require large, expansive tracts of open land to thrive during all parts of the annual cycle, increasing the importance of creating and preserving large, shallow wetland complexes.

It is possible that food is not limiting for spring-migrating waterfowl. This could lessen importance of areas managed for high food densities occurring in actively managed wetlands and their associated higher costs. Previous literature indicates food resources during spring have been declining for diving ducks (Afton and Anderson 2001), but these same declines may not be occurring for dabbling ducks. A variety of characteristics, such as bill morphology and ideal feeding depth, has allowed several species of dabbling ducks to use the same general areas, especially in areas with variable water depths as the result of flooding regimes. Dabbling ducks are able to use areas prone to flash flooding that result in shallow water. Diving ducks might be more limited to historical, permanent water bodies during migration that have been degraded as a result of human action. This makes diving ducks ideal candidates to test ideal free distribution because dabbling ducks may be experiencing a plethora of food-rich patches during migration.

In general, dabbling ducks I studied were affected more by management action and cover type than by food availability, but habitat selection differed among species. Northern pintail as well as gadwall were most numerous on food plots. American wigeon were the only dabbling duck species that was most numerous in the passively managed wetlands, likely a result of aquatic macrophytes present on these areas. The other five species (mallard, American black duck, northern shoveler, green-wing teal, and blue-wing teal) all were most numerous in the actively managed wetlands. These varied selection patterns further strengthen the argument for managers to diversify wetland complexes, providing preferred habitat for all species of dabbling ducks.

CHAPTER 2

RESPONSE RATE OF WATERFOWL TO INUNDATION

INTRODUCTION

Spring habitat at staging sites is important to the fitness of migrating ducks, providing nutrients and energy for reproduction and migration (Ankney et al. 1991, Alisauskas and Ankney 1992, Klaasen 2002). Most Anatidae use stopover sites at some point on migration to feed, rest, and participate in courtship activities (Guillemain et al. 2004). Lipid reserves have been found to be positively correlated to clutch size and lipid accumulation can occur during migration on stopover habitats (Krapu 1981). Breeding and migratory water conditions such as water level and abundance of wetlands have been shown to be important to the breeding success of some species of ducks (e.g. Mallard (*Anas platyrhynchos*) Krapu et al. 1983). Loss of available food resources during spring migration has also been suggested to greatly affect reproductive success of other species (e.g. Lesser Scaup (*Aythya affinis*) Afton and Anderson 2001, Anteau and Afton 2004, 2006, 2008, and 2009). Based on the assumption that food is the most critical resource during spring migration, managers often assume migratory waterfowl follow a food based ideal free distribution.

Under an ideal free distribution spring migratory waterfowl would distribute themselves based on characteristics that would result in the highest fitness (Fretwell and Lucas 1969). Lack of information, predator avoidance, and disturbance, in addition to other factors, can alter waterfowl behaviors resulting in a distribution less than ideal or free. Waterfowl management actions are often based on the assumptions underlying an ideal free scenario (i.e. if a food source is available the birds will find it and freely use it); however, it is likely that the factors preventing an ideal free distribution decrease use of available habitat. Factors preventing an ideal free distribution must be better understood to determine what is limiting waterfowl access to resources during important times of the annual cycle, such as spring migration, where flooded habitats are frequently used by waterfowl.

Flood events have been shown to provide important habitats to waterfowl where they can take advantage of shallow flooded areas and the abundant, easily accessible food they provide (Heitmeyer 2006). Waterfowl may also abandon areas as deep water restricts or prohibits effective foraging (Sherman et al. 1995). Waterfowl move great distances during large precipitation events (Cox and Afton 2000, Fleskes et al. 2002). It is believed that they redistribute during precipitation events to use any newly flooded areas that appear on the landscape (Dugger 1990, Reinecke et al. 1992). Waterfowl, however, adapted to use natural flood scenarios that are very different from the flooding regimes experienced today.

Anthropogenic hydrologic modifications appear to result in floods that are less beneficial to migratory waterfowl (Junk et al. 1989). Examples include river channelization, river damming, and diking of rivers with the creation of levees. Rivers are channelized to improve transportation and reduce flooding in the surrounding uplands. This practice has negative influences on the productivity of the floodplain ecosystem (Junk et al. 1989, Poff et al. 1997, Thoms 2003, Watkins et al. 2010, Jordan et al. 2012). Dams can alter the timing of flows and associated flooding, changing sediment and nutrient characteristics, resulting in economic and ecological impacts, and altering productivity (Bergkamp et al. 2000). Levee systems are created to help contain flood water within the river channel and narrow floodplain. Losing the connection between the main river channel and the full floodplain results in floodplains and backwaters that turn from aquatic to terrestrial habitat; losing ecological value and the ability to provide the ecosystem services wetlands provide such as carbon sequestration, groundwater recharge, and water purification (Gore and Shields 1995, Ward and Stafford 1995, USGS 1999). Floodplains are a crucial migratory waterfowl habitat and it is unclear how these impacts are being felt and how they affect migratory patterns and site selection.

The timing, occurrence, and severity of flood events have changed due to anthropogenic influences on river systems important to waterfowl, such as the Missouri and Mississippi Rivers (Criss and Kusky 2009). In lower order rivers than the Mississippi and Missouri, river channelization and wetland drainage have combined to create seasonal floods that rise rapidly and recede gradually (Rhoads and Herricks 1996). Because the water reaches such high levels, areas not prone to flooding before human settlement get inundated for highly variable periods of time before recession. This leaves birds a small window of time to use these areas before water recession.

Indirect changes to the river hydrologic pattern have also altered flooding such as drained wetlands in the uplands, invasive and non-native species, and higher sediment loading of rivers. People primarily drain wetlands to benefit agricultural activities by overland ditching or subsurface tiling. In areas such as the lower mid-western states (Illinois, Missouri, Indiana, Ohio, Kentucky, and Iowa), wetland loss is > 80% with total losses across the conterminous United States at 54% (Tiner 1984, Dahl 1990, Brinson and Malvarez 2002). More recently, wetland drainage has increased wetland losses (Watmough and Schmoll 2007). Wetland drainage may increase the frequency and magnitude of downstream floods (Campbell and Johnson 1975) resulting in flashy flood events in areas where long, drawn-out inundations used to occur naturally. The flow of water from subsurface tile into drainage ditches has created new water connections in areas where wetlands were previously isolated, resulting in inundation where it would not naturally occur (Westbrook et al. 2011).

Currently, waterfowl habitat management for the spring migration period emphasizes providing high densities of food that can be used by waterfowl leading up to the breeding season (Soulliere et al. 2007). Quality of some wetlands, however, has been altered due to anthropogenically induced modifications to the hydrologic cycle, causing more frequent flood events that are often of higher magnitude but of shorter periods than historic flooding.

Frequently habitat managers are asked to estimate the amount of available habitat. Flood events may make it hard to obtain accurate estimates. Some managers include flooded agricultural fields or the active floodplain between a rivers levees, knows as batture wetlands in habitat estimates (Soulliere et al. 2007). These areas are prone to frequent and variable inundations providing resources to migratory waterfowl. Other managers assume that only long inundations provide appropriate waterfowl habitat, not including short-term habitats in their wetland habitat estimates or modeling methodology (Twedt et al. 1997). This may underestimate habitat amounts if waterfowl are able to use short-lived wetlands. To manage lands for spring migrating waterfowl most cost efficiently, accurate habitat estimates must be obtained, ensuring habitat goals and objectives are met but not exceeded.

The objective of my study was to gather information on the ability of waterfowl to respond to flood events. I attempted to estimate the response rate of waterfowl to inundation. For the purpose of this study, response rate is how quickly waterfowl locate new habitat and begin to exploit it. I also identified types of habitat used by waterfowl during short duration flood events. I predicted that waterfowl would respond to short-term flooding within two days, because these areas may have higher concentrations of food compared to areas that have been subject to longer inundations.

METHODS

Study Area

All wetlands studied were located in Pike and Gibson counties in southwestern Indiana near or within the boundaries of Patoka River National Wildlife Refuge and Management Area (Figure 2.1). This area receives little use by fall migrating waterfowl but is used extensively by spring migrating waterfowl (Heath Hamilton, USFWS, pers. comm.). Patoka River National Wildlife Refuge and Management Area was established in 1994 as the 502nd refuge in the National Wildlife Refuge system and the 2nd refuge in the state of Indiana. The Patoka River has an extensive history of hydrologic alterations (USFWS 2008). In the 1920s, an attempt was made to drain 40,000 ha of forested wetlands adjacent to the river. This was known as Houchin's Ditch and replaced 58 km of natural meanders with 27 km of dredged, straightened river channel (USFWS 2008). The other significant alteration event in the Patoka River system is the creation of Lake Patoka in the late 1970's. Lake Patoka is a 3,200 ha impoundment managed by the United States Army Corps of Engineers. The combination of these events plus extensive use of subsurface drain tiling in the surrounding agriculture fields resulted in a drastic change to the hydrology of the river as it runs through the refuge. Currently, flood events rise rapidly with inundation length of the floodplain dependent upon severity of the flood (Heath Hamilton, USFWS, pers.comm.).

Prior to precipitation events, I identified areas prone to short-term inundation near the Patoka River or near drainage ditches that feed into the river. A preliminary visit assured that these areas were free of inundation. After large rain events, each pre-identified area was checked for inundation and river gauge data were monitored. If an area was inundated, I surveyed it to determine the presence or absence of waterfowl less than 24 hours after initial inundation. I scan surveyed for waterfowl (Altmann 1974) using a 20-60x variable power spotting scope from an adjacent vantage point or right of way, trying to minimize disturbance to waterfowl. I also recorded the basic cover type of the flooded area. If birds were present during the initial visit, the date of visit was recorded and no additional visits to the wetland occurred. If waterfowl were not present during the initial visit, the wetland was systematically rechecked starting with the second day followed by every other day (i.e., Days 1, 2, 4, 6, 8, etc.) until waterfowl were observed there or water receded to the point of exposing the substrate.

RESULTS

During the spring of 2013, two substantial precipitation events inundated pre-targeted areas. The first event occurred 26 February 2013 with an average of 1.73 cm of rain falling over the region (www.ncdc.noaa.gov). This resulted in the Patoka River rising 0.61 meters to 5.64 meters on 27 February 2013 at the Princeton, IN water gauge (http://water.weather.gov/). The second event occurred 17 March 2013 and resulted in the Patoka River rising 2.43 meters to 6.68 meters on the same day. These two events created 21 short-lived wetlands (Table 2.1, Figure 2.2), one during the first event and 20 during the second event. Seventeen were flooded agricultural fields, three idle grassland fields, and one woodlot. With results pooled across both events, 14 of 21 wetlands had waterfowl use less than one day after inundation (Figure 2.3), comprising 11 flooded agricultural fields and 3 idle grassland fields. Waterfowl appeared at two additional wetlands within two days: one flooded agricultural field and one new growth woodlot.

After four days of inundation, waterfowl were present on one additional flooded agricultural field. By the fourth day of inundation, every wetland either had documented waterfowl use or inundation had receded. Of the four wetlands from which water receded before being used by waterfowl, one receded after < 2 days of inundation and water from the other three wetlands receded after < 4 days resulting in an average of 3.5 (SD=1) days of inundation for wetlands that did not receive bird use. Totaled, 17 of the 21 wetlands had documented use with a median of one day of inundation before use by waterfowl and with percentiles of: 50th =1.8 days, 75th =2.2 days, and a 95th =2.52 days.

DISCUSSION

My data indicate spring migrating waterfowl in southwestern Indiana can respond within one day of inundation, supporting my prediction that migratory waterfowl would be able to respond to newly inundated areas within two days. With one visit per day I was able to detect waterfowl use on 81% of wetlands before water recession. The majority of my wetlands (81%) occurred in flooded agricultural fields with most receiving bird use prior to recession (76%). The response rate I recorded may be a result of migratory birds trying to locate feeding areas with more food and less competition by exploiting newly available habitat, allowing them to increase per capita feeding rate. I had limited data for cover types other than flooded agriculture, but those that were studied were used by birds prior to water recession indicating that a variety of cover types are used by waterfowl during flood events.

Migrating waterfowl often follow riparian areas during migration, likely adopting the ability to respond to the newly flooded habitat. These newly flooded areas are likely higher in resources than previously exploited areas. Even though these birds are encountering areas that they are not familiar with (Moore et al. 1990, Németh and Moore 2007) they may still be able to recognize these flood prone areas and use them soon after inundation.

Migrating waterfowl responding within one day to inundation in this study suggest that previous estimates of available habitat that excluded “short-lived” wetlands may have underestimated available wetlands, especially inundated agricultural fields created by both overland and out of bank flood events. Wetlands that are present on the landscape for as little as one day, such as batcher lands, appear to be used by waterfowl, thus these areas need to be accounted for when estimating habitat availability. This study indicates waterfowl respond quickly and can exploit wetlands even when only inundated for very short periods of time, an occurrence that is common with the current modifications to river hydrology. Management actions should continue to focus on providing areas with high food densities for use by migratory avifauna; however, questions related to response rate to flood events during both the fall and spring migratory periods should be further investigated.

CONCLUSIONS

Loss of breeding habitat continues at a rate that is worrisome for future waterfowl populations (Stephens et al. 2008), while migratory habitat used prior to and immediately following the breeding season has to a large extent already been lost (LMVJV 2007). The loss of migratory habitat has potentially influenced waterfowl populations through cross-seasonal effects (Sedinger and Alisauskas 2014). Thus, maintaining waterfowl populations requires management of habitat throughout the entire annual cycle. I found that migrating waterfowl can respond to new habitat less than 24 hours after becoming available. Frequently these new patches occur in agricultural fields where abundant large seeds can provide food (Soulliere et al. 2007).

Areas such as the Mississippi Alluvial Valley have already been targeted as high-priority areas for migrating waterfowl (LMVJV 2007). Secondary, and lesser known, areas are still being identified and frequently these are the habitats that link the known, high-priority sites. Habitat complexes, such as Patoka River National Wildlife Refuge and Management Area, are important stepping stones to wintering areas like the Mississippi Alluvial Valley. Birds migrating down the Mississippi and Illinois river valleys frequently head southeast towards the Wabash and Patoka River regions of eastern Illinois and western Indiana as indicated by weather radar (O'Neal et al. 2010). The Patoka River region is devoid of wetlands, outside of conserved habitat or hunting preserves, increasing the need for continued and intensified restoration targets and plans.

During my research I encountered high densities of migrating dabbling ducks in an area with little previous waterfowl research. This study along with other studies at Southern Illinois University and the University of Illinois occurred concurrently in the Wabash river region in eastern Illinois and western Indiana including the Patoka River National Wildlife Refuge and Management Area. Currently, organizations and agencies in the area are working collaboratively to protect what little is left and to restore new tracts. This area contains diverse wetlands that collectively provide habitat for a plethora of migrating birds and effective management and conservation is crucial to achieve and maintain optimal bird use.

This study prompts further questions regarding response rate of waterfowl. Part of my research addressed the timing of response to new inundation by spring migrating waterfowl. Additional questions, such as how does depth and length of inundation affect response rate of waterfowl, still need to be addressed. Gaining insight into the habitat selection process of waterfowl will enable habitat managers to more accurately provide resources. Behaviors and food availabilities in these short-lived wetlands are another area of research need. Fall migratory birds could also be examined to see what kind of influence, if any, hunting pressure has on response rate. Once more information is gathered on how waterfowl can respond to flood events, managers can then work towards habitats that provide waterfowl places to rest and feed during migratory periods and these areas can be perpetually protected.

Table 1.1. Moist soil unit food availability studies with their food estimates (kg/hectare).

Author(s)	Year	Food Estimate
Fredrickson and Taylor	**1982**	**1629**
Reinecke et al.	**1989**	**450**
Moser et al.	**1990**	**613**
Haukos and Smith	**1993**	**590**
Gray et al.	**1999**	**444**
Naylor	**2002**	**430.56-824.72**
Penny	**2003**	**611**
Bowyer et al.	**2005**	**790**
Reinecke and Hartke	**2005**	**603**
Kross et al.	**2008**	**496**
Stafford et al.	**2011**	**691**

Table 1.2. Modeling food abundance based on management action at Patoka River National Wildlife Refuge and Management Area.

Model	D.F.	AIC	AICC	Delta AIC_C	Likelihood	Weight
Cover	5	1043.46	1044.3975	0	1	**0.99997552**
Null	3	1065.269	1065.6326	21.23513636	2.44821E-05	**2.4482E-05**

Table 1.3. Models investigating dabbling duck species specific distribution responses to food resources and management action (cover) during spring migration on Patoka River National Wildlife Refuge and Management Area.

Model	DF	AIC	AICc	Δ AIC$_C$	Log Likelihood	w
All Species Combined						
Cover	6	373.02	377.02	0	1	0.999982417
Null	4	397.48	399.2191	22.19913043	1.51189E-05	1.51186E-05
Food	5	400.12	402.8473	25.82727273	2.46422E-06	2.46417E-06
ABDU						
Cover	6	128.74	132.74	0	1	0.836632436
Null	4	134.27	136.0091	3.269130435	0.195037152	0.163174407
Food	5	146.76	149.4873	16.74727273	0.000230874	0.000193157
AMWI						
Cover	6	187.7	191.7	0	1	0.952646401
Null	4	195.99	197.7291	6.029130435	0.049067164	0.046743658
Food	5	203.68	206.4073	14.70727273	0.00064026	0.000609941
BWTE						
Cover	6	200.69	204.69	0	1	0.954338042
Null	4	209.04	210.7791	6.089130435	0.047617011	0.045442725
Food	5	218.72	221.4473	16.75727273	0.000229723	0.000219233
GADW						
Cover	6	299.54	303.54	0	1	0.998200387
Null	4	314.52	316.2591	12.71913043	0.001730119	0.001727005
Food	5	319.87	322.5973	19.05727273	7.27387E-05	7.26078E-05
GWTE						
Cover	6	315.51	319.51	0	1	0.999841086
Null	4	335.37	337.1091	17.59913043	0.000150799	0.000150775
Food	5	340.22	342.9473	23.43727273	8.14068E-06	8.13939E-06
MALL						
Cover	6	310.47	314.47	0	1	0.999811836
Null	4	330	331.7391	17.26913043	0.000177851	0.000177817
Food	5	334.7	337.4273	22.95727273	1.03488E-05	1.03469E-05
NOPI						
Cover	6	316.99	320.99	0	1	0.998920806
Null	4	333	334.7391	13.74913043	0.001033747	0.001032631
Food	5	338.21	340.9373	19.94727273	4.66128E-05	4.65624E-05
NSHO						
Cover	6	280.83	284.83	0	1	0.999867611
Null	4	301	302.7391	17.90913043	0.000129146	0.000129129
Food	5	307.37	310.0973	25.26727273	3.26048E-06	3.26005E-06

Table 1.4. Estimated average ducks encountered per visit by habitat management action broken down into species on Patoka National Wildlife Refuge, Indiana.

	Active (SE)	Food Plot (SE)	Passive (SE)
ABDU	2.36 (0.52)	0.66 (0.40)	0.06 (0.04)
AMWI	1.14 (0.42)	3.49 (1.34)	7.54 (3.37)
BWTE	7.75 (2.79)	2.34 (1.06)	1.84 (0.77)
GADW	6.31 (2.34)	54.34 (18.01)	30.86 (11.33)
GWTE	111.72 (35.44)	32.41 (10.94)	4.70 (1.34)
MALL	105.59 (20.14)	82.84 (36.90)	33.30 (15.88)
NOPI	54.93 (26.57)	111.25 (42.33)	32.44 (14.45)
NSHO	63.10 (8.68)	28.07 (8.89)	25.16 (8.44)
Total	352.91 (16.46)	315.39 (14.40)	135.09 (5.21)

Table 1.5. Models investigating the effect of management action on duck behavior during spring migration on Patoka National Wildlife Refuge, Indiana.

Model	AIC	Δ AIC	K	Log Likelihood	Weight
Species*Sex	21101.99	0	18	1	**0.369146**
Species*Sex + Date	21102.44	0.45	19	0.798516219	**0.294769**
Species*Sex + Management Ac.	21103.22	1.23	21	0.540640895	**0.199575**
Species*Sex + Food	21103.98	1.99	19	0.369723445	**0.136482**
Species + Sex	21122.78	20.79	11	3.0585E-05	**1.13E-05**
Species + Sex + Date	21123.71	21.72	12	1.92115E-05	**7.09E-06**
Species + Sex + Management Ac.	21124.02	22.03	14	1.6453E-05	**6.07E-06**
Species + Sex + Food	21124.77	22.78	12	1.1308E-05	**4.17E-06**
Species	21239.64	137.65	10	1.28731E-30	**4.75E-31**
Temp	22972.11	1870.12	4	0	**0**
Sex	23084.47	1982.48	4	0	**0**
Date	23117.17	2015.18	4	0	**0**
Null	23151.45	2049.46	3	0	**0**
Log(Food)	23153.45	2051.46	4	0	**0**
Management Action	23153.71	2051.72	6	0	**0**
Management Ac. + Log(Food)	23155.68	2053.69	7	0	**0**

Table 1.6. Estimated average proportion of time feeding by habitat management action and species on Patoka National Wildlife Refuge, Indiana.

	Active (SE)	Food Plot (SE)	Passive (SE)
ABDU	0.409 (0.031)	0.188 (0.101)	0.600 (0.122)
AMWI	0.454 (0.036)	0.429 (0.027)	0.501 (0.021)
BWTE	0.511 (0.025)	0.485 (0.031)	0.589 (0.043)
GADW	0.437 (0.016)	0.432 (0.009)	0.478 (0.012)
GWTE	0.550 (0.007)	0.250 (0.012)	0.536 (0.025)
MALL	0.446 (0.007)	0.493 (0.008)	0.581 (0.010)
NOPI	0.561 (0.008)	0.664 (0.008)	0.596 (0.016)
NSHO	0.759 (0.005)	0.489 (0.010)	0.775 (0.009)
Average	0.516 (0.003)	0.429 (0.004)	0.582 (0.005)

Table 2.1. Information on selected study sites in southwestern Indiana, 2013, including cover type, management action, water source, and ownership.

Wetland Number	Cover Type	Management Action	Water Source	Ownership
1	Agriculture	Passive	Patoka River	USFWS
2	Agriculture	Unmanaged	Drainage Ditch	Private
3	Agriculture	Unmanaged	Drainage Ditch	Private
4	Idle Grassland	Unmanaged	Patoka River	Private
5	Agriculture	Passive	Patoka River	USFWS
6	Agriculture	Passive	Patoka River	USFWS
7	Woodlot	Passive	Patoka River	USFWS
8	Agriculture	Unmanaged	Drainage Ditch	Private
9	Agriculture	Unmanaged	Drainage Ditch	Private
10	Agriculture	Unmanaged	Drainage Ditch	Private
11	Idle Grassland	Passive	Patoka River	USFWS
12	Agriculture	Unmanaged	Patoka River	Private
13	Agriculture	Unmanaged	Patoka River	Private
14	Agriculture	Unmanaged	Drainage Ditch	Private
15	Idle Grassland	Unmanaged	Drainage Ditch	Private
16	Agriculture	Unmanaged	Drainage Ditch	Private
17	Agriculture	Unmanaged	Drainage Ditch	Private
18	Agriculture	Unmanaged	Drainage Ditch	Private
19	Agriculture	Unmanaged	Drainage Ditch	Private
20	Agriculture	Unmanaged	Drainage Ditch	Private
21	Agriculture	Passive	Patoka River	USFWS

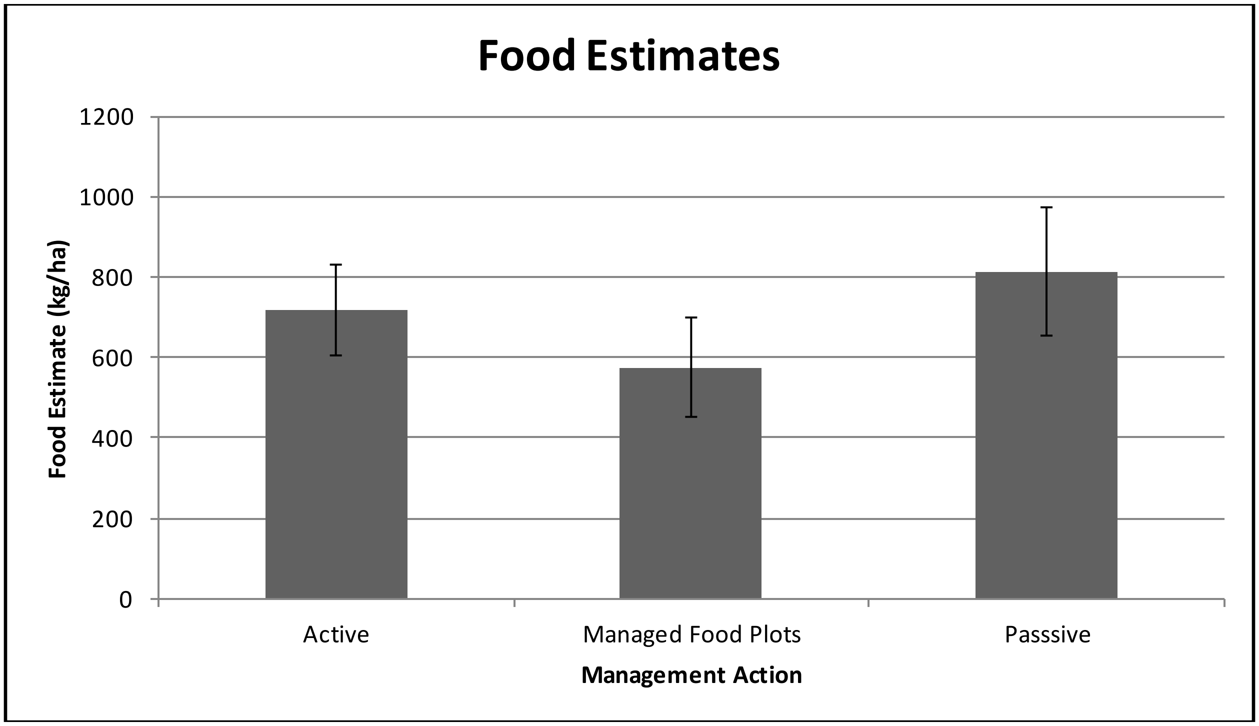

Figure 1.1. Estimates of food availabilities to spring migrating waterfowl by management action on Patoka National Wildlife Refuge, Indiana. Error bars indicate standard error.

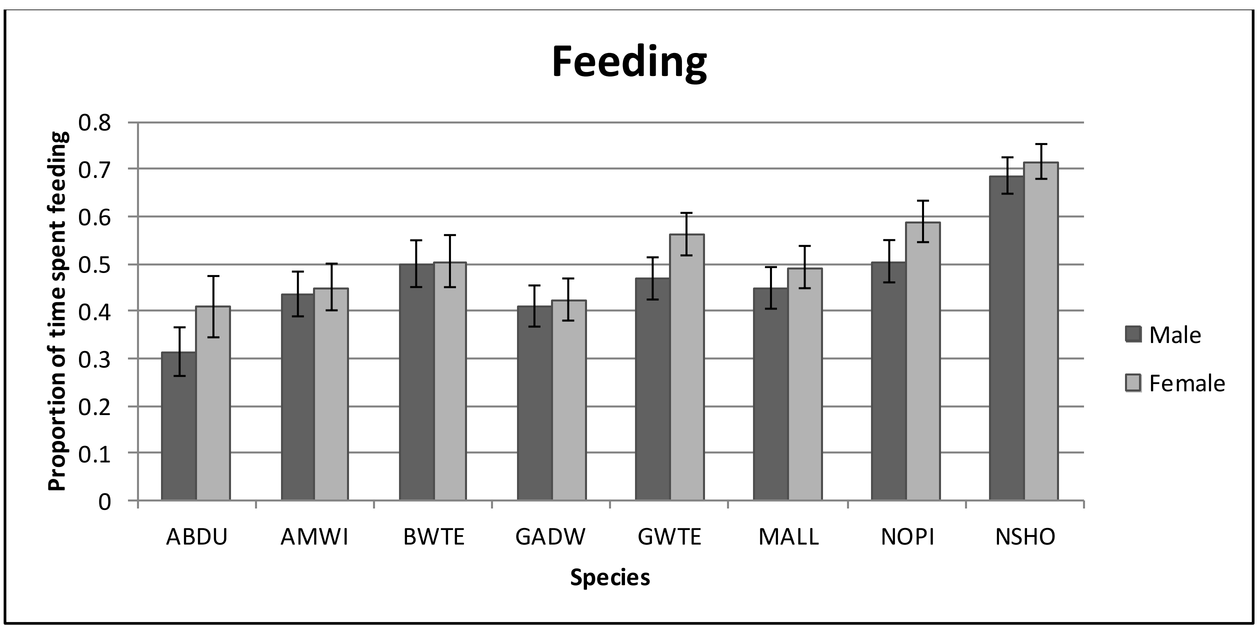

Figure 1.2. Estimates of proportions of time spent feeding, broken down by sex, by species of dabbling ducks on Patoka River National Wildlife Refuge and Management Area, Indiana. Error bars indicate standard error.

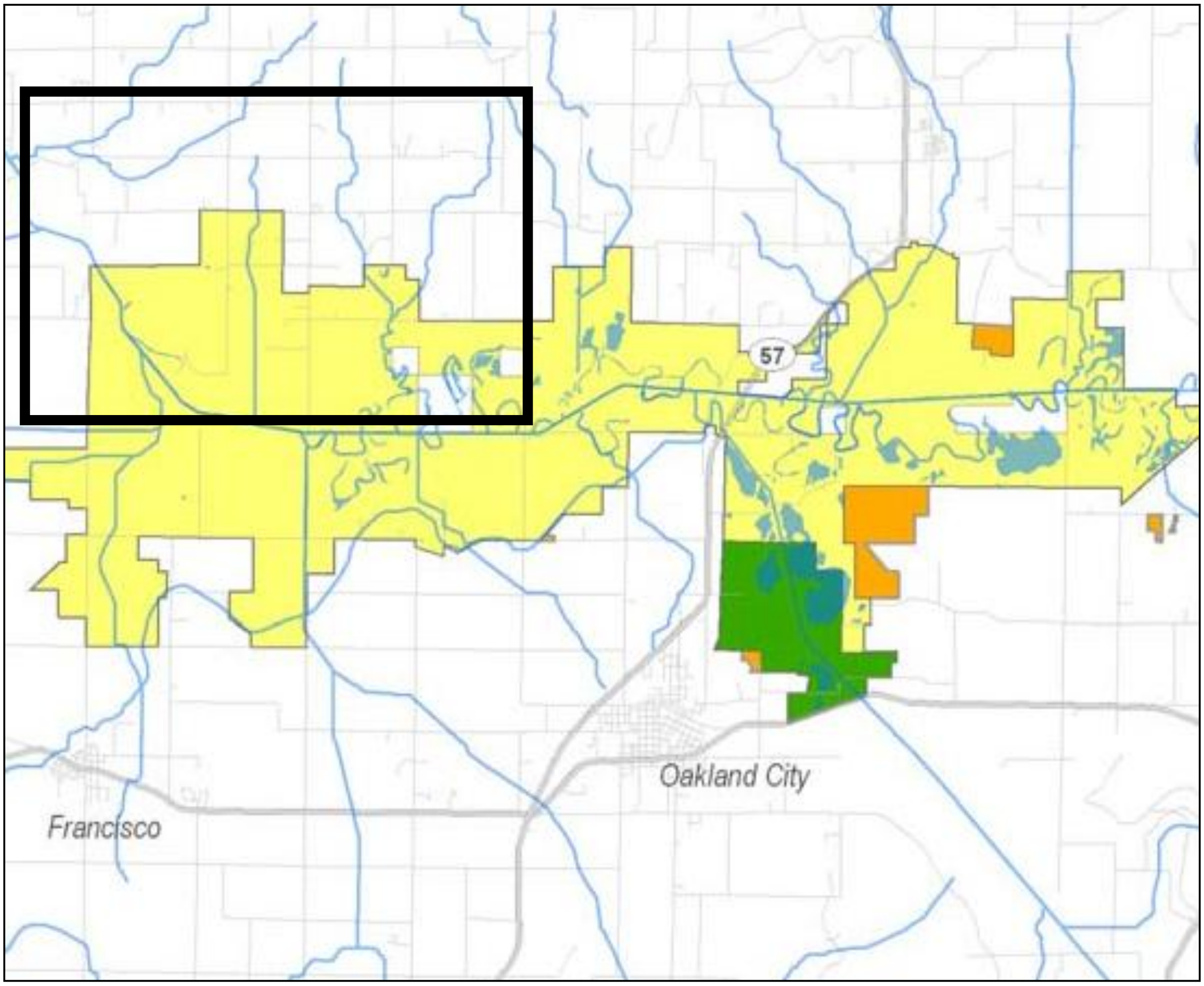

Figure 2.1. Areas inside the bold rectangle were targeted for potential wetland basins prior to rain events in southwestern Indiana, 2013.

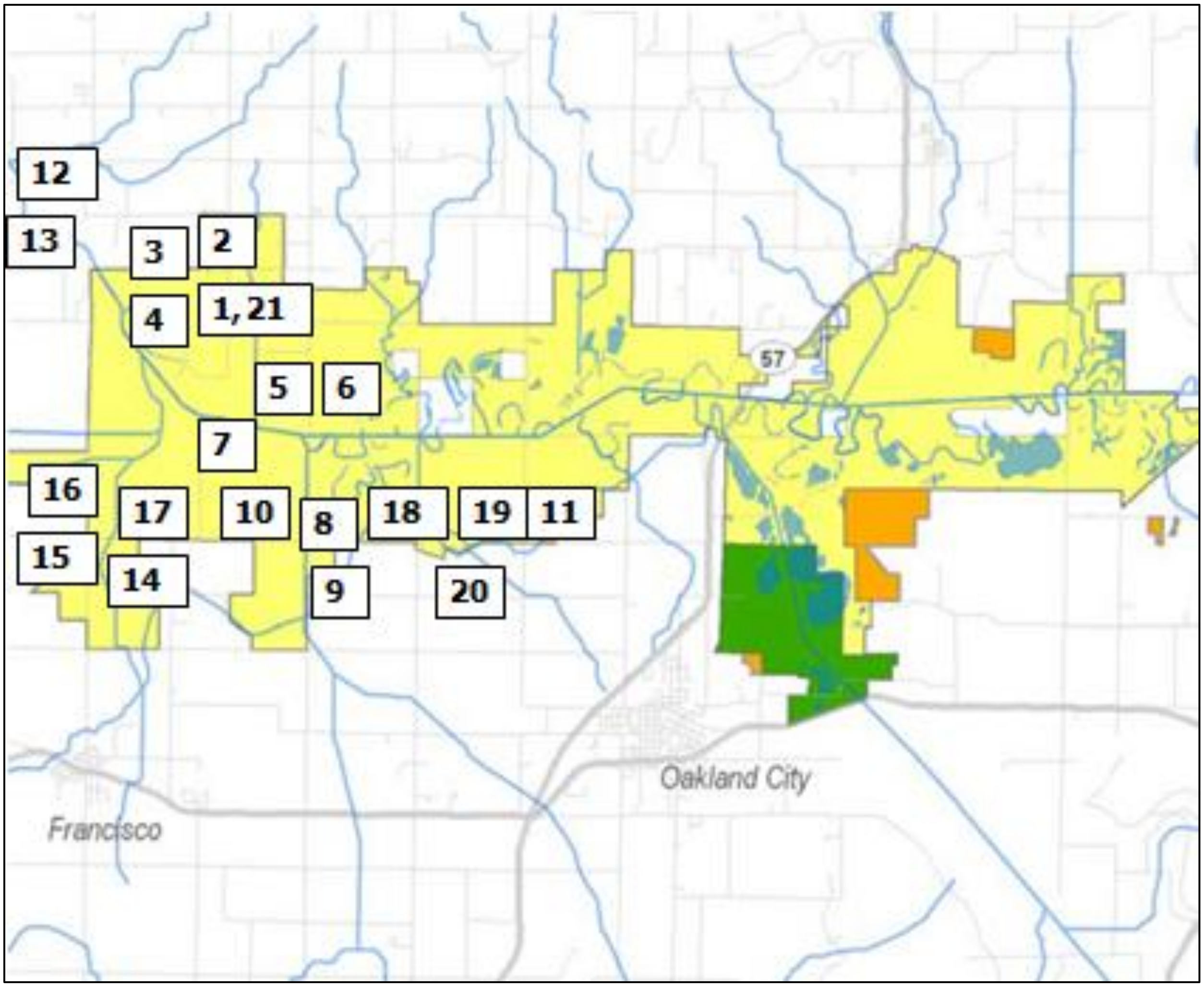

Figure 2.2 Locations of wetlands studied in southwestern Indiana, 2013.

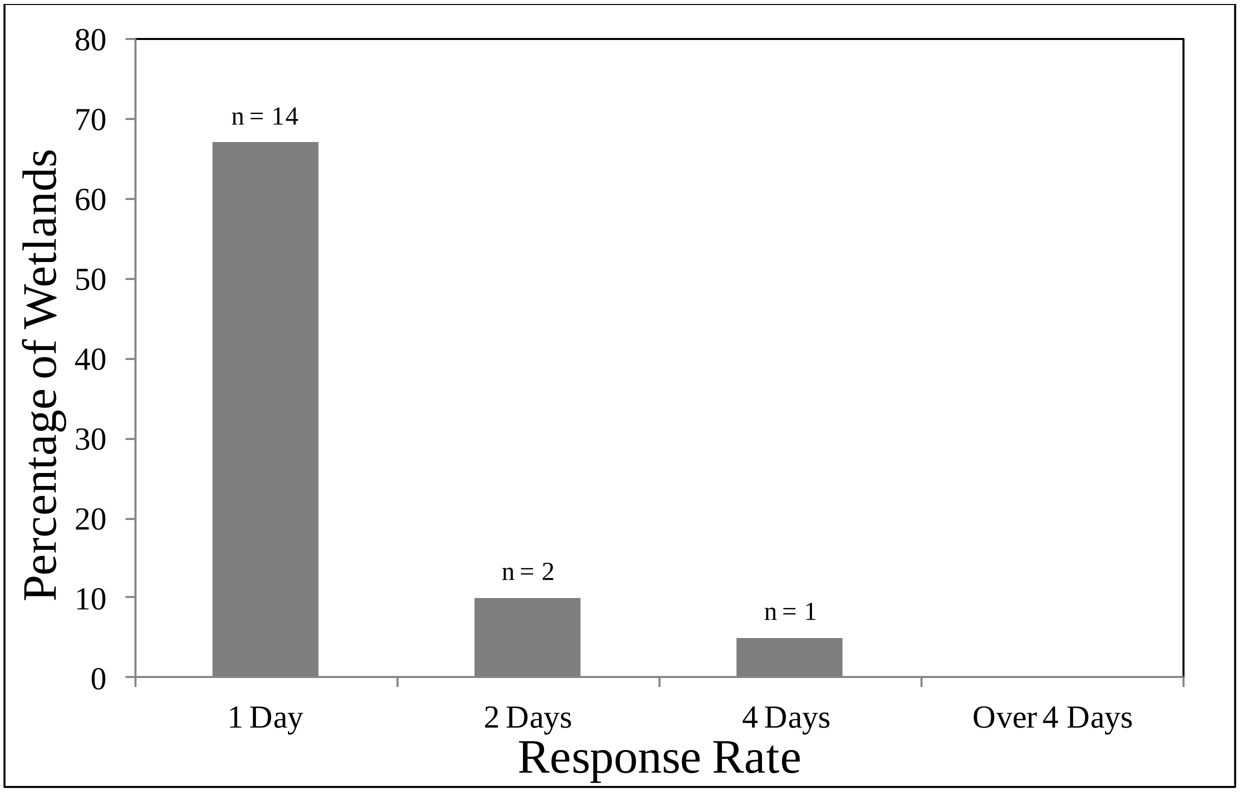

Figure 2.3. Response rate of waterfowl to inundation in southwestern Indiana, 2013.

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Major Professor: Michael Eichholz