ENVIRONMENTAL INFLUENCES ON AVIAN PRESENCE IN ROADSIDE DITCHES IN AN AGRICULTURAL LANDSCAPE

Sara J. Zaleski

A Thesis

Submitted to the Graduate College of Bowling Green
State University in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

August 2015

Committee:

Karen V. Root, Advisor

Shannon Pelini

Andrew Gregory

ABSTRACT

Karen V. Root, Advisor

Roadside ditches are a common element of the agricultural landscape of the Midwest. While roadside ditches are appreciated for their ability to transport excess water they are often overlooked for other purposes. Many animal and plant species can be found in roadside ditches and ditches are known to increase biodiversity in often homogenous agricultural landscapes (Herzon and Helenius 2008). Some avian species which are known to utilize roadside ditches have experienced population declines over the past several decades (Sauer et al. 2014). The focus of our research was to determine which avian species, particularly passerines and wading birds, utilized roadside ditches in an agricultural area and to identify which environmental factors were significantly correlated to avian presence ($P < 0.05$). We conducted avian surveys of roadside ditches and collected data related to ditch size, water depth, vegetation cover and prey species presence. Our findings indicated the presence of passerines, such as red-winged blackbirds and song sparrows, was positively significantly related to ditch depth, amount of open water, vegetation height and density and macroinvertebrate presence. Wading bird presence showed a positive significant relationship with ditch depth and minnow presence and a negative significant relationship with herbaceous cover and maximum vegetation cover. By managing vegetation within roadside ditches, it may be possible to create and maintain breeding and foraging habitat for avian species. However, the management approach must be specific to the type of avian species as passerines are shown to prefer tall, dense vegetation while wading birds prefer sparse vegetation.

This manuscript is dedicated to my family.

ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Karen V. Root, for her knowledge and support with this project, as well as my committee members, Dr. Shannon Pelini and Dr. Andrew Gregory for their helpful assistance. I would like to thank my fellow lab members, Matthew Cross, Bryce Adams, Amanda Martin, Rachel Kappler, Christian Nordal and Amanda Kuntz for their encouragement and assistance. Thank you to William Gyurgyik, for assistance with field work. Finally, I would like to thank the landowners who granted me access to their property and helped to make this research possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figures Page

INTRODUCTION

Roadside drainage ditches are common features of the agriculturally-dominated landscape of the Midwest. Drainage ditches were constructed to carry excess precipitation away from agricultural fields and other areas. The creation of drainage ditches has produced benefits to the agricultural landscape, such as increasing areas for biodiversity by serving as habitat for wildlife and refugia for native plants (Herzon and Helenius 2008). The potential to manage roadside ditches to improve wildlife habitat is often overlooked. The purpose of our study was to determine which avian species were present in roadside ditches and to find environmental variables of the ditches which were related to avian presence.

Many grassland bird species have experienced population declines in recent decades (Askins 2007). These declines can be attributed, in part, to habitat loss and fragmentation. Several grassland bird species are known to utilize roadside ditches as breeding and foraging habitat (Warner 1992, Vierling 1999, Safratowich et al. 2008). Our research objective was to study an often ignored landscape structure, roadside drainage ditches, to determine if characteristics of ditches were significantly related to passerine presence (see Chapter 1). We conducted avian surveys and ditch characteristic surveys to gather data on passerine presence and ditch features.

Large wading birds, such as herons, are also known to use roadside ditches (Grau and Parris 1980), although few studies have been conducted in the Midwest to determine factors of ditches which are related to wading bird presence. Roadside ditches have the potential to serve as foraging habitat for wading birds as larger ditches often contain amphibians, minnows, small mammals and macro-invertebrates on which herons feed (Herzon and Helenius 2008). Roadside ditches may act as a substitute for natural wetlands when prey in natural wetlands is depleted or competition from conspecifics and other species is high. We conducted wading bird surveys and collected ditch characteristic data to find ditch features which were related to wading bird presence (see Chapter 2).

Understanding variables of roadside ditches which are related to passerine and wading bird presence is helpful to determine if roadside ditches can be managed to support avian populations. Managing roadside ditches may improve nesting and foraging habitat for birds. Providing quality habitat could benefit bird species which are known to be in decline. Ditches that provide quality habitat for birds have the potential to serve as patches and corridors which can increase biodiversity and connectedness in a predominately homogenous agricultural landscape.

CHAPTER I. USE OF ROADSIDE DITCHES BY PASSERINE SPECIES

INTRODUCTION

Many avian species populations have been in decline for several decades (Sauer et al. 2014). Much of this decline is related to habitat loss due to expansive agricultural practices and urbanization. Grassland bird populations, in particular, have been decreasing (Askins 2007) likely as a result of agricultural practices which reduce fencerows and field edges and remove conservation lands from easements for the purpose of growing biofuels. Areas which provide food in the form of arthropods, seeds and fruits, as well as vegetation for shelter and nesting locations, are necessary for the survival of many grassland birds. With a considerable reduction in native grassland habitats, passerines may utilize anthropogenic landscape structures to fulfill their habitat needs.

The red-winged blackbird (*Agelaius phoeniceus*) and song sparrow (*Melospiza melodia*) are species of birds associated with grasslands which use edge habitat and are known to nest in marshy areas throughout the Midwest. The red-winged blackbird is one of the most common avian species associated with agricultural land in Ohio. Both red-winged blackbirds and song sparrows are found throughout the United States and are known to use a variety of habitats. The two species feed on invertebrates throughout the summer, especially while raising young. Nests for both species are often built in vegetation near the ground. Red-winged blackbirds are known to nest in reeds and grasses while song sparrows will nest in grasses or on the ground (Terres 1991). Typically, two or more broods are laid during a nesting season for each species.

Red-winged blackbirds and song sparrows represent a guild of grassland birds which are associated with edge habitat and small patches of grasslands. With a decline in field borders due to agricultural practices, these avian edge species are often found in vegetated roadsides including drainage ditches (Warner 1992, Vierling 1999, Safratowich et al. 2008). Although roadsides may contain the habitat components necessary for avian survival, the quality of the habitat may be low. Linear habitats such as roadsides and drainage ditches are known to be corridors for wildlife movement (Herzon and Helenius 2008) including animals, such as snakes and raccoons, which prey upon birds and their eggs. Vierling (1999) found that birds breeding in drainage ditches produced fewer young per nest than birds nesting in other types of habitat. If similar results were found in other areas of breeding bird ranges, it is possible that drainage ditches could serve as sinks in breeding bird populations.

Agricultural drainage ditches are a common landscape element throughout the Midwest. Agricultural ditches and drainage canals have been shown to provide avian species with necessary resources. Ditches provide a food source in the invertebrates found in the damp and wet soils, as well as vegetation for nesting, cover and perching (Rife and Moody 2004, Herzon and Helenius 2008). Ditches provide ecosystem services such as flood control, reducing chemicals and elements that are washed into waterways, erosion control, and supporting pest control populations (Needelman 2007, Herzon and Helenius 2008).

Roadside ditches can range from shallow depressions to engineered trenches which can be over a meter in depth and width with steep sides. Dirt, vegetation, or rocks may line the sides and bottom. Ditches are dynamic structures which change throughout seasons as water levels fluctuate with precipitation and vegetation structure changes during the growing season and by water flow. Flow can be high after a heavy precipitation event or thaw or non-existent during dry weather condition. With such variation in ditch conditions, for conservation purposes it is necessary to have a better understanding of which ditch characteristics are related to avian presence.

Ditches can harbor a large variety of vegetation which is used by various avian species. These species range from obligate wetland species such as *Polygonum sp*., *Potamogeton sp*., and *Leersia sp*. to less water-dependent species such as *Poaceae sp*. and *Lonicera sp*. (Bouldin et al. 2004). Vegetation can be herbaceous or woody. Ditches that are not maintained regularly may contain bushes and trees. An increase in the vegetation structure and composition within a ditch can increase the biodiversity of birds found to utilize such areas (Warner 1992). Vegetation in ditches can provide several ecosystem services. Nesting sites and cover, as well as food sources are services provided by plants in ditches. Vegetation can also help remove excess nutrients and chemicals from field runoff by uptake through their root systems and can help reduce erosion by collecting suspended sediments (Bouldin et al. 2004, Herzon and Helenius 2008).

The ubiquitous presence of roadside drainage ditches throughout the Midwest and their frequent use as habitat by breeding passerines (Warner 1992, Safratowich et al. 2008) makes them an important landscape feature to understand. With the continued decline of avian species which utilize roadside drainage ditches in agricultural landscapes, such as red-winged blackbirds and song sparrows (Sauer et al. 2014), recognizing environmental variables of such ditches as they relate to avian presence is important. The objective of our study was to (1) determine what species of passerines used roadside ditches in the agricultural landscape of northwest Ohio and to (2) find environmental factors of ditches which are significantly related to avian presence.

METHODS

Study Area

Surveys of ditches were conducted in Wood County, Ohio surrounding the city of Bowling Green (Fig. 1.1). Much of the land in Wood County, along with northwest Ohio, is dedicated to agricultural row crop production. The area was once part of a large swamp and contains fertile soils. Due to a lack of elevation change throughout most of the area, drainage ditches were constructed to drain excess rain water. Over 3,000 miles of drainage ditches and open waterways are located within Wood Co. These ditches range from shallow depressions to large, excavated structures over two meters deep. Most ditches are vegetated and may contain grasses, forbs, shrubs and trees. Many ditches are managed by the county and the vegetated sides along roadways are mowed regularly throughout the growing season.

Survey sites were randomly selected using a map of ditch locations using ArcGIS version 10.1 software (ESRI 2014). Each site was a minimum of 400 m apart to avoid detection overlap. Survey transects were 200 m in length and situated between a roadway and an agricultural field.

Avian Surveys

Avian surveys began on 14 May, 2014 and were conducted between 0600-1000 EST when bird activity is generally high. Ditch sites were approached by vehicle from the south or east whenever possible to avoid sun glare during surveys. The vehicle was parked at least 30 m, and preferably 50 m or more, from the survey site to avoid disturbing birds in the area. Upon arrival, there was a three minute pause before approaching the transect to allow any disturbed birds to settle. During this time, the air temperature and wind speed and direction were collected using a Burton ADC Pro weather station. The general weather condition (e.g. sunny, partly cloudy) was also recorded.

Surveys were conducted by walking slowly along the edge of a transect and recording the number of all birds observed. The species of each bird, as well as the sex, if sexually dimorphic, and the apparent activity of each bird was also recorded. A Komelon Meter-man Series 45 distance measuring wheel was used to keep track of the 200 m transect. At the beginning and end of each transect, a marker flag was inserted into the ground and a GPS point and digital picture were taken to ensure that the same area was surveyed for ditch characteristics.

Ditch Characteristic Surveys

After avian surveys were completed each day, we returned to each transect to collect data about the characteristics of the ditch. Ditch data collection began at the same end of the transect from which the avian survey started, typically the south or east end. Five 5 m long plots along the length of each transect were measured out with centers at 33.5, 66.5, 100, 133.5 and 166.5 m. The width of the plots varied depending on the width of the ditch.

In the first, middle and last plots, measurements were taken for ditch width, ditch depth, width at water level, and water depth, as well as the slope of both the road side and field side of the ditch. Ditch width was a measurement from one edge of the ditch to the opposite edge or the opposite side even with the lower edge if the banks were uneven. Ditch depth was measured from the base of the ditch to the measuring tape spanning the top edge of the ditch. Width at water level was determined by measuring from one edge of water to the other edge if water was present in the ditch. The degree of slope on each side was measured using a Brooks-Range slope meter. During subsequent surveys, only the water depth and width at water level were recorded since the other measurements did not vary among visits.

Within each of the five plots, the percent of vegetation cover was visually estimated and recorded along with the percent of herbaceous versus woody vegetation. The percent of open water within the plot was recorded. Dominant vegetation growing along both sides and in the middle of the plot was noted. A Robel pole was used to find the visual obstruction readings (VOR) of the vegetation on each side and in the middle of the plot. This required placing the Robel pole in the center of the section being measured and taking a reading from opposite directions along the length of the ditch, one on each side of the pole. This was repeated in the next two sections of the plot so that six total readings were taken for VOR in each plot.

In the middle and end plots, an Adventure Products 11” dip net was used to sample one scoop of material from the bottom of each plot. Only plots which contained water were sampled. Any macroinvertebrates found in the sample were recorded along with the number or estimates of the number of each type. Organisms were identified at least to Class and to Order whenever possible. Any amphibians and minnows found during the sampling were also recorded. The number of anurans observed along the sides of the ditch or in the water during the data collection survey was recorded. If anurans were observed during the avian surveys, the data was noted.

Statistical Analysis

For statistical analysis, we used average values of variable measurements from the five plots along each ditch transect. Statistical tests were performed using JMP® 11.0. To determine the relationship between environmental variables, we conducted a correlation analysis. Pairs of variables with a value above 0.75 were considered to be highly correlated and only one of those variables was used during modeling. Univariate logistic regression was used on individual variables to determine if each variable was significantly related ($P < 0.05$) to bird presence. Bird presence was used as the response variable while the remaining variables were explanatory variables. Univariate logistic regression was also used to find variables which were significantly correlated with red-winged blackbird presence and song sparrow presence. We performed stepwise logistic regression to find a parsimonious model relating bird presence to environmental variables of the ditch. For modeling, sites were grouped by survey to determine if date had an effect on bird presence. To find a model with the most predictive power, we compared AIC_c values, coefficients of determination, P-values, and performed the Wald test. A principal components analysis using a row-wise estimation method was done to model the variation among our variables. We measured avian diversity in our study by computing species richness for the entire study period, as well as for each survey period. Biodiversity of the habitat was also measured using the Simpson's Index of Diversity (1-D) for each survey period and the entire study period.

RESULTS

Passerines were detected in 31 of the 36 ditches surveyed. Red-winged blackbirds comprised 74% of detections and were recorded as being present in 26 ditches. Six ditches contained red-winged blackbirds during all three surveys. The second most common species detected was song sparrow. Other species detected included common grackle (*Quiscalus quiscula*), chipping sparrow (*Spizella passerina*), American robin (*Turdus migratorius*), field sparrow (*Spizella pusilla*), barn swallow (*Hirundo rustica*), American goldfinch (*Spinus tristis*), and ruby-throated hummingbird (*Archilochus colubris*) (Table 1.1).

The ditches surveyed had a wide range of variable measurements (Table 1.2). Ditch depth varied from 0.52-2.83 m and ditch width had a range of 2.70- 11.73 m. Water width was nonexistent in some ditches while other ditches had a water width up to 4.47 m. Slope of the side of the ditch varied from a gradient of 21º-50º. Vegetation ground cover ranged from 49-97% and the percent of herbaceous versus woody vegetation ranged from 64-100%. Visual obstruction readings ranged from 0-4.8 on the roadside, 0-10.1 on the fieldside, and 0-17.0 in the middle of the ditch. Open water within the ditches varied from 0-93%.

Thirteen types of macroinvertebrates were identified from dip net surveys. Most groups were classified down to Order. The most common species present were members of the Classes Gastropoda (28.4%) and Bivalvia (10.8%) and the Order Isopoda (9.3%). Only one ditch surveyed did not have macroinvertebrates present during at least one survey. Twenty-three ditches had amphibians over the course of the study with the most commonly identified species being the green frog (*Rana clamitans*), northern leopard frog (*Rana pipiens*) and American toad (*Bufo americanus*). Minnows were detected in seven ditches.

Using univariate logistic regression, we found that ditch width, water width and ditch depth were variables significantly correlated with bird presence, however they were also highly correlated to each other. Ditch depth was chosen to represent those variables during modeling. Other variables which were significantly related to bird presence included roadside slope, side VOR, percent open water and macroinvertebrate presence (Fig. 1.2). Ditch depth was positively correlated with bird presence (P = 0.0006, X^2=11.74). Similarly, as roadside slope (P = 0.0055, X^2 = 7.71), side VOR (P = 0.0066, X^2 = 7.39) and percent open water (P = 0.0038, X^2 = 8.38) increased, birds were more likely to be present. Bird presence was positively correlated with the presence of macroinvertebrates (P = 0.0067, X^2 = 7.35). Variables which were not significantly correlated with bird presence included water depth, percent vegetation cover, amphibian presence, presence of a buffer, and crop in adjacent field.

Several other variables were found to be highly correlated with each other; these variables included water depth and water width, side VOR and field side VOR, and total VOR and middle VOR. Of those sets, the water depth, side VOR and total VOR were used for modeling.

Since red-winged blackbirds and song sparrows were the most common bird species detected at 74% and 12% , respectively , we used univariate logistic regression to find variables significantly related to their presence (Table 1.3). For red-winged blackbirds those variables included ditch depth ($P = 0.0008$, $X^2 = 11.22$), ditch width ($P = 0.0013$, $X^2 = 10.33$), water width ($P = 0.0133$, $X^2 = 6.13$), percent herbaceous vegetation ($P = 0.0370$, $X^2 = 4.35$) and side VOR ($P = 0.0012$, $X^2 = 10.43$). Variables significantly related to song sparrow presence were ditch depth ($P = 0.0011$, $X^2 = 10.71$), ditch width ($P = 0.0033$, $X^2 = 8.63$) and percent open water ($P = 0.0119$, $X^2 = 6.32$). For both species, all variables were positively correlated with presence.

When analyzing the data temporally by survey, both ditch width ($P = 0.0076$, $X^2 = 7.14$ and $P = 0.0128$, $X^2 = 6.20$) and ditch depth ($P = 0.0030$, $X^2 = 8.79$ and $P = 0.0332$, $X^2 = 4.34$) remain positive significant variables related to avian presence (Fig 1.3). In the first set of surveys, roadside slope ($P = 0.0248$, $X^2 = 5.04$) and fieldside slope ($P = 0.0491$, $X^2 = 3.87$) are positive significant variables. In the third set of surveys side VOR ($P = 0.0135$, $X^2 = 6.10$), percent open water ($P = 0.0365$, $X^2 = 4.37$), and macroinvertebrate presence ($P = 0.0464$, $X^2 = 3.97$) are positively related to avian presence while percent herbaceous cover ($P = 0.0151$, $X^2 = 5.91$) is negatively related. The second set of surveys did not have variables which were significant. All significant variables followed similar trends across surveys, regardless if they were significant for every survey.

Red-winged blackbirds presence maintained similar results when surveys were temporally separated. Percent herbaceous cover was negatively related for both the first (P = 0.0359, X^2 = 4.40) and the third (P = 0.0281, X^2 = 4.82) survey while side VOR (P = 0.0012, X^2 = 10.50 and P = 0.0107, X^2 = 6.51) and total VOR (P = 0.0266, X^2 = 4.91 and P = 0.0047, X^2 = 8.01) were positively related for the same surveys. In the first set of surveys, ditch width (P = 0.0060, X^2 = 7.56) and ditch depth (P = 0.0075, X^2 = 7.14) were also positively related to red-winged blackbird presence but were not significant in the third set of surveys.

Along with ditch depth, water depth, side VOR and total VOR, the variables used for modeling included roadside slope, fieldside slope, percent herbaceous cover, percent vegetation cover, percent open water, presence of a buffer, crop in adjacent field, amphibian presence and macroinvertebrate presence. The stepwise logistic regression indicated a model using percent open water, total VOR and ditch depth was the most parsimonious (Table 1.4). These variables were all positively correlated with avian presence. For the first set of surveys, the model had an AIC_c of 43.84, an R^2 of 0.2291 and a P-value of 0.0040. The second set of surveys had no significant variables. The third set of surveys had an AIC_c of 43.74, an R^2 of 0.2954 and a P-value of 0.0024. A Wald test indicated ditch depth significantly contributed to the model (P = 0.0113) for the first set of surveys and total VOR significantly contributed to the model (P = 0.0095) for the third set of surveys.

The principal components analysis (Fig. 1.4) showed that principal component 1 explained 35.9% of the variance in variables while principal component 2 explained 18.4% of variance. The eigenvectors for principal component 1with the highest values included water width (0.384), percent open water (0.367) and ditch width (0.340). For principal component 2, the eigenvectors with the highest values were total VOR (0.502), side VOR (0.462) and middle VOR (0.373).

Species richness was 6 for each of the individual survey periods and 10 for the entire study area. Red-winged blackbirds, song sparrows and American robins were detected during each survey period while other species, such as barn swallows, field sparrows and American goldfinches were only present during one survey period. Diversity was calculated as 0.56 for the entire study period and 0.61, 0.50 and 0.57 for the first, second and third survey periods, respectively (Table 1.5).

DISCUSSION

Drainage ditches are dynamic components of the landscape and are numerous throughout northwest Ohio and other Midwestern states. The ditches in our study had a wide range of sizes and other environmental variables. Vegetation ranged from short grasses and forbs to tall grasses, shrubs and trees. Many ditches held water for only a short time while others contained water throughout the study. With such variation, it is likely that environmental variables play a role in whether avian and other species use drainage ditches as habitat for breeding and foraging.

Measurements of the ditches including ditch depth, ditch width and water width were significantly related to avian presence and our results indicate birds are more likely to use larger roadside ditches compared to shallower ditches. Larger ditches have been shown to provide more shelter and food than smaller ditches (Arnold 1983). Red-winged blackbirds and song sparrows show a negative correlation with patch area (Heckert 1994) indicating that they are capable of utilizing narrow, linear areas such as ditches. Our results appear to support the predictions of the theory of island biogeography indicated by a species-area relationship in which birds are more likely to be present in larger ditches (Brown and Dinsmore 1988). A larger ditch is more likely to contain elements necessary for survival. The size of a ditch is designed to accommodate the amount of water that will flow through the ditch during large rain events and is not a characteristic that can be changed readily to benefit wildlife populations. However, certain environmental variables within ditches could be managed to provide more breeding or foraging habitat for avian species.

Diversity results from our study indicated the composition of detected species changed throughout the study period. For example, American goldfinches were only detected during the third survey period. It is possible that goldfinches were present later in the study period because a food source was available in the ditches during that part of the growing season. As vegetation and water levels changed during the summer, the resources available in roadside ditches likely changed as well. The needs of the avian community likely changed over the course of the growing season also, which may have resulted in the diversity seen in the avian community over the course of the study.

Our VOR results indicate passerines prefer to use ditches with tall, dense vegetation compared to ditches with short, sparse vegetation. Taller vegetation provides more cover and nesting locations. The birds are likely using these ditches as breeding and foraging habitat. Heckert (1994) found that red-winged blackbirds presence was not significantly related to vegetation structure although the same was not true for other grassland bird species. Our results however, indicated red-winged blackbird presence had a negative significant relationship to percent herbaceous cover and a positive significant relationship to side VOR indicating that red-winged blackbirds may be using habitat with a particular vegetation structure. Temporal results similarly showed the relationship between red-winged blackbirds and vegetation components. Decreased herbaceous cover and increased VOR could indicate an increase in woody vegetation, which could add heterogeneity to the habitat, a component that many edge species prefer. Many of the red-winged blackbirds exhibited defensive behavior when the researcher approached the area they were using. Several red-winged blackbird nests were also observed during surveys, indicating the red-winged blackbirds were defending nesting territory. The vegetation in the ditch likely provided habitat for arthropods which many passerines are known to feed on, especially during the breeding season (Vickery et al. 2002).

Ditches often serve as patches of grasslands within an agricultural landscape. Passerines which utilize both grasslands and edges are known to use ditches in agricultural areas. This is partially due to the lack of large tracts of grasslands in row crop agriculture settings. Ditches can also serve as corridors that connect patches of vegetation within a landscape. Warner (1994) found that areas well connected to the landscape because of corridors had increased species diversity and nest density. Ditches may serve as pathways for predators (Herzon and Helenius 2008) which can lead to higher predation rates in ditches than in larger tracts of grasslands. If this is the case, ditches can benefit birds by providing breeding and foraging habitat but are likely less productive for avian survival. Although ditches may not serve as sources for avian populations, they still benefit populations by providing habitat, connectivity and refugia (Herzon and Helenius 2008).

The amount of open water in a ditch appears to play a role in avian presence. Our study found that ditches which were utilized by birds had a higher percentage of open water. It is possible that birds could be using these ditches because they are a source of readily available water early in the breeding season. The water could also provide hydration for arthropods within the ditch which could then serve as prey for birds (Herzon and Helenius 2008). Our study did not monitor water quality because the water that often fills ditches enters the ditches as runoff from tiled agricultural fields. This runoff is subject to frequent fluctuations in nutrients and contaminants as farmers apply fertilizers and pesticides to fields. However, future research could examine if there is a link between avian presence and water quality. The majority of macroinvertebrates found in our samples were species tolerant of pollution (e.g. Diptera, Gastropoda, Isopoda) indicating that water quality in the ditches was not high (Barbour et al. 1999).

When we analyzed our data temporally by looking at the three sets of surveys separately, we found that some significant variables remained the same between the first and third survey while others changed. This can also be explained by the different community structure (e.g., change in bird species) over the course of the study. During the second set of surveys, there were no variables which were significantly related to avian presence. This may be a result of resources being available in other areas on the landscape during the second survey period which were more likely to be found in ditches during the first and third survey. Ditch depth and ditch width remained significant, which indicates that the size of the ditch is important to bird presence during the nesting season. In the third survey, variables related to vegetation structure and composition became significant. This may be a result of the growth of vegetation. Early in the season, many plants were still low to the ground or had not leafed out completely. As the season progressed, plants continued to grow and vegetation became denser. Dense vegetation can conceal nests and provide cover which may be more attractive to birds. Similar results were also found in a study by Murray (2014) in Pennsylvania meadows. The presence of species such as red-winged blackbirds was found to be positively correlated with tall vegetation. Red-winged blackbirds were also found to be associated with smaller meadows with irregular borders in the study.

In our first set of surveys, avian presence was higher in ditches with steeper slopes. The ditches in our study tended to have steeper side slopes as the size of the ditch increased. On average, fieldside slope was steeper than roadside slope. Interestingly, when analyzing data from all surveys combined, roadside slope was a significant variable to avian presence, however fieldside slope was not. Steeper slopes may be more important early in the nesting season when vegetation for cover is still low to the ground. The steeper slopes may provide a better view of the surrounding area and more opportunity to identify an approaching predator. Steeper roadside slopes may be a significant factor throughout the season because they offer more protection from perceived threats associated with the roadway.

Some variables which we measured were not significantly related to bird presence. Water depth was one such variable. A study in North Dakota found water depth to be significant to avian presence along roadsides which contained stands of cattails (*Typha spp*.) (Safratowich et al. 2008). Not all of our transects contained cattails and only a few ditches held long stands of cattails which may be a reason we did not see similar results as the other study. Weather and temperature were not significantly related to avian presence, however, we did not survey in adverse weather conditions which may have affected our results. The presence of a buffer and the crop growing in the adjacent field were not significantly related to avian presence. This suggests that the environmental factors of the ditch are more important to avian presence than the immediate surrounding area.

Having avian habitat available that is less than optimal is more beneficial than having no habitat available. Roadside ditches provide breeding and foraging habitat for a number of bird species which use grasslands and edges. Managing these habitats could provide an increase in habitat quality. In a previous study, Warner (1992) found a higher than average survival rate in passerine nests in unmowed roadsides when compared to previous studies of survival in upland and marsh habitats. Currently, many roadside ditches are mowed throughout the growing season. By suspending mowing practices and allowing vegetation to grow throughout the nesting season, vegetation could grow higher and denser which could potentially provide more cover for breeding birds.

To determine the best management practices, more research needs to be conducted. Data regarding the abundance and survival of birds such as red-winged blackbirds and song sparrows could provide a more accurate depiction of how ditches serve as habitat for birds. This could provide insight into whether ditches are a source or sink for avian populations. Data collected from studies conducted later into the summer could provide more information about the fecundity and survival of birds which utilize ditches throughout the breeding season. During our research, many ditches dried up by late June. Continued research into the later part of the summer could help determine if birds change their use of ditches as water levels change. A study encompassing the entire breeding season of most migratory birds, including collecting information on total bird numbers, as well as surveying for nests and nestlings, would be beneficial to understanding the use of ditches by grassland birds. Collecting survey information on mammals and reptiles that use roadside ditches would also give us a better understanding of the predators which may affect bird survival and abundance. A more comprehensive survey of grassland vegetation within and surrounding ditches may also provide information on nesting and foraging habitat for certain bird species.

Many grassland bird populations have been declining (Askins 2007) as a result of habitat loss and fragmentation. By managing lands considered to be marginal, it is possible to increase breeding and foraging habitat for some bird species. Our study provides evidence that birds which utilize small grasslands and edges are often found in medium to large roadside ditches with open water and increased vegetation height and density. By managing ditches to reduce vegetation within the waterways of the ditches and allowing vegetation on the sides of the ditches to grow, the amount of breeding and foraging habitat for some passerines can be increased. With the proper planning and management, roadside ditches can be improved to allow for increased abundance of native species and biodiversity within a landscape.

CHAPTER II. USE OF ROADSIDE DITCHES BY WADING BIRDS

INTRODUCTION

Herons, egrets, and bitterns are wading birds of the family Ardeidae and are sometimes referred to as “the herons”. As carnivores, these birds play a large role in the top-down effects of predator-prey interactions and species composition within their habitats (Estes et al. 2011). These birds utilize wetland-like habitats containing shallow water for foraging areas. With a large decrease in wetlands throughout northwest Ohio, which is now dominated by agricultural crop fields, herons have been observed using roadside ditches, and are the focus of this research.

A large portion of northwest Ohio was once part of a large, inundated area called the Great Black Swamp. As the area was settled by the westward expansion of early settlers in the 19th century, much of the land was drained and ditches were constructed to allow the flow of water out of the area (Wilhelm 1983). The majority of the land was then converted into agricultural land for row crops. This conversion had a major impact on the available wetlands in the area as much of the swamp was eliminated with the construction of the ditches (Wilhelm 1983). Less than two percent of the Great Black Swamp exists today (Ohio Dept. of Natural Resources 2013).

Ditches are important for more than their ability to carry water. Agricultural ditches and drainage canals have been shown to provide wading birds with necessary resources. Ditches provide a food source in the invertebrates found in the damp soils and shallow water, as well as fish and amphibians (Rife and Moody 2004, Herzon and Helenius 2008). Agricultural practices in and around drainage canals such as tilling and ditch clearing have also been shown to attract wading birds (Main and Vavrina 2008), likely because the disturbed soil provides insects for birds to feed on. Ditches in agricultural areas also provide habitat for other organisms such as mammals, amphibians, fish, and macroinvertebrates (Herzon and Helenius 2008).

Ditches provide ecosystem services such as flood control, reducing chemicals and excess nutrients that are washed into waterways by macrophyte uptake, erosion control, and supporting populations of agricultural pest predators (Needelman 2007, Herzon and Helenius 2008). However, ditches can also have a negative effect on the landscape, such as providing a vector for invasive species to propagate (Chester and Robson 2013). Overall, studies to date indicate that agricultural ditches provide a number of benefits to the landscape.

Ten species of Ardeidae have been recorded as breeding birds in Ohio (Table 2.1) (Peterjohn and Rice 1991). All ten species are migrants, however some great blue herons (*Ardea Herodias*) are residents in Ohio throughout the year (Kushlan and Hancock 2005, Peterjohn and Rice 1991). The majority of the species are known to nest in northwest Ohio, while the yellowed-crowned night heron (*Nyctinassa violaceus*) has only had possible cases of breeding in northwest Ohio and the little blue heron (*Egretta caerulea*) and the snowy egret (*Egretta thula*) have only been confirmed to nest on islands in western Lake Erie (Peterjohn and Rice 1991). These ten species have similar life history traits including feeding and breeding characteristics. At the beginning of breeding season in late winter or spring, nests are built with sticks or non-woody vegetation and range from ground-level to several tens of meters high in a tree (Hafner 1997). Some herons, such as the yellow-crowned night heron, black-crowned night heron (*Nycticorax nycticorax*) and great egret (*Ardea alba*) are colonial nesters and will nest in groups, while other species, such as the American bittern (*Botaurus lentiginosus*), least bittern (*Ixobrychus exilis*) and green heron (*Butorides virescens*) prefer to nest solitarily (Butler et al.

2000, Kushlan and Hancock 2005). Clutch size varies by species but is usually in the range of 2-7 eggs and both parents typically care for the young (Kushlan and Hancock 2005).

Adequate food sources must be available within a distance of several kilometers from the nesting site in order for young and parents to survive through the nesting season. In a study by Custer et al. (2004), great blue herons along the Mississippi River flew an average of 5.7 km from the nest to forage with a maximum distance of 43 km, while great egrets foraged an average of 8.2 km from the nest and had a maximum distance of 43 km. Great blue herons nesting along the shores of Lake Erie were found to travel an average of 9 km to a foraging site and typically made two foraging trips per day (Grau and Parris 1980). For altricial birds such as herons, food is often a limiting factor for survival during the nesting season (Hafner 1997).

Within Ohio, the American bittern, snowy egret, and cattle egret (*Ardea ibis*) are considered state endangered while the black-crowned night heron and the least bittern are listed as threatened (Ohio Dept. of Natural Resources 2012). However, none of these species are considered to be federally threatened or endangered.

With 90 percent of wetlands in Ohio now converted to other land uses and approximately 3,000 miles of ditches and other open course waterways present in Wood County (Wood County Engineer 2013), determining how and why wading birds use roadside agricultural ditches could be useful in conserving habitat and resources for these birds so they are not added to a list of endangered wildlife. Ditches are an artificial habitat often used by wading birds for foraging but are a commonly overlooked and little studied resource for birds by humans (Kushlan 2000).

Roadside ditches in this region can range from shallow depressions to engineered trenches which can be over 3 m in depth and 12 m in width with steep sides. Ditches can be lined with dirt, vegetation, or rocks and maintenance of many agricultural area ditches is dependent on the landowner. Water flow varies throughout seasons and can be high after a heavy precipitation event or thaw or non-existent during dry weather condition. With such variation in ditch conditions, for conservation purposes it is necessary to have a better understanding of which ditch characteristics are related to wading bird presence.

Temporary aquatic habitats, such as roadside ditches, are known to support amphibian species. A study in Ohio (Wicknick et al. 2005) found that American toads (*Bufo americanus*) and green frogs (*Rana clamitans*) were most often found in agricultural areas during amphibian presence surveys. In addition to amphibians, aquatic macroinvertebrates are often found in agricultural ditches. Representatives of the groups Ephemeroptera, Crustacea, Mollusca, Annelida, and Diptera have been found in ditches within Wood County, Ohio (Rife and Moody 2004). Mammals such as shrews, voles, and mice also utilize ditch habitat (Kirsch 1997). Amphibians, aquatic macroinvertebrates, and small mammals are all organisms that serve as food sources for herons.

Ditches can harbor a large variety of vegetation. These species range from obligate wetland species such as *Polygonum sp*., *Potamogeton sp*., and *Leersia sp*. to less water-dependent species such as *Poaceae sp*. and *Lonicera sp*. (Bouldin et al. 2004). Vegetation can be herbaceous or woody. Ditches that are not maintained regularly may contain bushes and trees. Vegetation in ditches can provide several ecosystem services. As a primary producer, vegetation is a food source for the many organisms that inhabit ditches and the surrounding landscape. Nesting sites and cover are another service provided by plants in ditches. Vegetation can also help remove excess nutrients and chemicals from field runoff by uptake through their root systems and can help reduce erosion by collecting suspended sediments (Bouldin et al. 2004, Herzon and Helenius 2008). Ditches can also be a haven for plant species that were once common but have become rarer after land was converted for agriculture and other uses (Blomqvist 2006).

With a large diversity of organisms that use roadside agricultural ditches, it is reasonable to believe that trophic-level interactions are an important component of the ditch ecosystem. From autotrophs to multiple levels of consumers, predator-prey interactions affect what species live and survive within ditches. Fluctuating water levels due to snow melts and rainfall can also have a major impact on what species can thrive within ditches. Herons are top-level consumers who will likely have a significant effect on the composition of species found in ditches which they utilize.

With only a fraction of original wetlands remaining in Wood County, the purpose of our research was to identify which species of wading birds utilized roadside drainage ditches. We also wanted to determine which environmental characteristics of the ditches were related to wading bird presence. We predicted that herons would utilize larger ditches with complex vegetation structures. We also predicted that heron presence would be positively correlated to the presence of amphibians and minnows, which would serve as prey for foraging herons.

METHODS

Study Area

Our study was conducted in Wood County, Ohio near the city of Bowling Green (Fig. 2.1). The landscape is mostly comprised of agricultural row crop fields. Due to the lack of elevation change in the area, there are many drainage ditches to drain excess rain water and snowmelt. The ditches which we studied were medium to large in size compared to other ditches in the area and often were connected to smaller ditches which emptied into them. The study area was situated between the north branch of the Portage River and the Maumee River. Ditch sites were located 1.2-7.4 km from the nearest river. The study area lies within 38 km of the southern shore of Lake Erie.

Ditch sites were selected using specified criteria. Each site needed to be a medium to large ditch, approximately 1.5-3 m in depth, which still held water in early August. Sites also needed to be located along a roadway and situated at an intersection to make drive-by surveys possible.

Wading bird surveys

Wading bird surveys were conducted from August through October 2014. Surveys were started at three separate times; sunrise, mid-morning and shortly before sunset. Start times rotated randomly. No more than one survey per ditch was conducted in a day. Surveys were carried out from inside a vehicle. All ditches surveyed were located near the intersection of two roadways. The vehicle was stopped at an intersection so the ditch was clearly visible and the observer studied the ditch long enough to determine if a wading bird was present in or near the area. The location and time of observation was recorded, as well as the species and number of any wading birds seen in the ditch. If a wading bird was seen near the ditch, the sighting was noted.

Ditch Characteristic Surveys

In October, data was collected on characteristic of each ditch. Ditch data collection began at the end of the ditch nearest the intersection. Three 5 m long plots along each transect were used to collect data. The width of the plot varied depending on the width of the ditch. The three plots were estimated to be evenly spaced along the transect, however since ditch sections varied in length from 132-530 m due to visibility during surveys, there was not a set distance between plots. Originally, a ditch that ran under a roadway was considered to be two separate ditches on either side of the culvert and each section was surveyed as an individual ditch. Due to proximity, variable measurements from the individual sections were averaged together for analysis and the two sections were treated as a single ditch transect.

In each plot, measurements were taken for ditch width, ditch depth, width at water level, and water depth, as well as the slope of both the roadside and fieldside of the ditch. Ditch width was a measurement from one edge of the ditch to the opposite edge or the opposite side even with the lower edge if the banks were uneven. Ditch depth was measured from the base of the ditch to the measuring tape spanning the top edge of the ditch. Width at water level was determined by measuring from one edge of water to the other edge if water was present in the ditch. The degree of slope on each side was measured using a Brooks-Range slope meter.

Within each of the plots, the percent of vegetation cover was recorded along with the percent of herbaceous versus woody vegetation. The percent of open water within the plot was recorded. Dominant vegetation growing along both sides and in the middle of the plot was noted. A Robel pole was used to find the visual obstruction reading (VOR) of the vegetation on each side and in the middle of the plot. This required placing the Robel pole in the center of the section being measured and taking a reading from opposite directions along the length of the ditch, one on each side of the pole from a distance of 4 m. This was repeated in the next two sections of the plot so that six total readings were taken for VOR in each plot.

In each plot, an Adventure Products 11” dip net was used to sample one scoop of material from the bottom of each plot. Any macroinvertebrates found in the sample were recorded along with the number or estimates of the number of each type. Organisms were identified at least to Order. Any amphibians and minnows found during the sampling were also recorded. The number of anurans observed along the sides of the ditch or in the water during the data collection survey was recorded.

Statistical Analysis

Averaged values of variable measurements from the three plots along each transect were used for statistical analysis. Statistical tests were performed using JMP® 11.0. To determine the relationship between environmental variables, we conducted a correlation analysis. If variables were found to be highly correlated ($r > 0.75$), only one was chosen for modeling. To determine which variables were highly correlated to heron presence, we performed univariate logistic regression ($P < 0.05$). Heron presence was used as a response variable while the remaining variables were used as explanatory variables. To determine a parsimonious model which related heron presence to environmental factors of the ditches, we used stepwise logistic regression. We compared AIC_c values, coefficients of determination, P-values, and performed the Wald test to find a model with the most predictive power. A principal components analysis using a row-wise estimation method was done to model the variation among our variables.

RESULTS

Great blue herons were the only species of herons detected during surveys. A total of 36 surveys were conducted at eleven sites. Great blue herons were detected in six of the eleven sites. A total of 14 birds were observed. Herons appeared to be foraging within the ditches.

The ditches varied in size, vegetation structure and water levels (Table 2.2). Ditch width ranged from 5-13.1 m and ditch depth ranged from 1.4-3.0 m. Water depth varied from 0.05-0.26 m and width at water level ranged from 0.6-4.2 m. The amount of open water ranged from 84-100%. Two of the ditches dried up temporarily during the surveys but filled with water again after rain fell. The slopes of the sides of the ditches had similar ranges with fieldside slopes ranging from 30-44º and roadside slopes ranging from 34-40º.

The percent of ground covered by vegetation ranged from 53-78% and the percent of herbaceous versus woody vegetation had a range of 83-100%. Side VOR varied widely with roadsides having readings from 0-1.9 and fieldsides having readings of 1.0-7.2. Unlike most fieldsides, many roadsides were mowed, contributing to the lower numbers. Middle VORs were fairly low, ranging from 0-1.7; this was not surprising since most of the ditches we surveyed were open waterways with little vegetation in the middle. Percent of open water within ditches ranged from 84-100%.

All of the ditches surveyed contained aquatic macroinvertebrates. The most common macroinvertebrates found were members of the class Bivalvia which comprised 30.8% of our samples followed by Gastropoda with 14.4% (Table 2.3). Two of the eleven ditches had both amphibians and minnows present while only minnows were detected in four other ditches. Green frogs were the most common species of amphibians detected while minnows were not identified because we did not have IACUC approval to handle vertebrates.

Using logistic regression, four variables were determined to be significantly related to heron presence (Fig. 2.2). Average ditch depth ($P = 0.0344$, $X^2 = 4.47$) and minnow presence ($P = 0.0293$, $X^2 = 4.747$) were positively correlated with heron presence. Percent herbaceous cover

($P = 0.0299$, $X^2 = 4.72$) and maximum percent ground cover ($P = 0.0079$, $X^2 = 7.06$) were negatively correlated with heron presence. Ditch depth, ditch width and water width were highly correlated, therefore only ditch depth was used for modeling.

Three models were developed using stepwise logistic regression (Table 2.4). The first model contained ditch depth and percent open water as variables, which were positively correlated with avian presence ($P = 0.0097$, $AIC_c = 15.318$, $R^2 = 0.611$). In the second model, percent herbaceous cover and percent vegetation cover were negatively correlated to avian presence ($P = 0.113$, $AIC_c = 15.623$, $R^2 = 0.591$). The third model also included ditch depth and percent open water and added presence of minnows, which were all positively correlated to avian presence ($P = 0.0162$, $AIC_c = 19.532$, $X^2 = 0.6790$).

Results from the principal components analysis (Fig. 2.3) indicated principal component 1 explained 25% of the variance among variables while principal component 2 explained 17% of the variance. For principal component 1, the eigenvectors with the highest values included ditch depth (0.440), ditch width (0.432) and heron presence (0.388). The eigenvectors with the highest values for principal component 2 included water depth (0.418), amphibian presence (0.340) and water width (0.322).

DISCUSSION

Drainage ditches are necessary in our study area to drain agricultural fields and other lands. They can have wide variations in their characteristics. The ditches which we surveyed had variation within their features but also shared some similarities. Our survey ditches were medium to large in size compared with other ditches in the area. The roadside slopes of our study ditches were mowed regularly throughout the growing season by county maintenance crews while the fieldside slopes often contained vegetation that was allowed to continue growing. With the exception of two ditches which dried up temporarily, all of our sites contained water throughout the study period (August to October).

Although there are ten species of herons found in Ohio, it is not surprising that we did not detect more species. Yellow-crowned night herons are rare in northwest Ohio while little blue herons and snowy egrets are only known to nest on Lake Erie islands (Peterjohn and Rice 1991). Drainage ditches do not provide preferred habitat for some heron species. Black-crowned night herons are typically found along rivers and the shore of Lake Erie in Ohio (Peterjohn and Rice 1991). Green herons prefer habitat with bushes and trees (Kushlan and Hancock 2005) of which most of our ditches did not contain large amounts. Similarly, American bitterns and least bitterns use habitat with tall, dense vegetation which mostly open water ditches did not provide (Kushlan and Hancock 2005).

Great blue herons showed a preference for larger ditches with a high percentage of open water. In our study area, larger ditches were often more directly linked to streams and rivers than smaller ditches. This link was likely a source for the minnows found in several of our study ditches. These minnows, as well as other aquatic and terrestrial wildlife, are common in the diet of great blue herons (Kushlan and Hancock 2005). The larger ditches in our study were up to three meters deep. If herons forage at the bottom of a large ditch, they are located farther from roadways and other anthropogenic disturbances than shallower ditches. This may offer more protection from potential predators and more room for escape.

Herons also preferred ditches with a mixture of herbaceous and woody vegetation, as well as less ground cover. Woody vegetation ranged from low plants and vines such as poison ivy (*Toxicodendron radicans*) and wild grape (*Vitis spp*.) to shrubs and small and large trees. Herons did not appear to avoid trees and shrubs during our study. Trees provided shade which may have aided in foraging, as well as minimized vegetation growth in the area beneath the tree. In a study by Custer and Galli (2002), great blue herons were found to prefer non-vegetated shorelines as landing sites when foraging. Herons may avoid tall vegetation because it decreases visibility and increases predation risk. Decreased vegetation may also have been a characteristic related to ditch size. Larger ditches often featured roadsides which contained rocks and riprap to prevent erosion along roadways. Large ditches were also more likely to have bare ground along their large, steep slopes due to landslides which decreased the amount of ground cover.

Heron presence was significantly related to the presence of minnows which likely served as an available food source within the ditches. The presence of amphibians was not significantly related to heron presence, contrary to our prediction. Macroinvertebrates were present in every ditch surveyed, however even the presence of large snails and crayfish were not significantly related to heron presence. These species may not be a preferred food source for herons when minnows and other species are available. Minnows and amphibians were detected in six and two ditches, respectively. Since both of these species are typically part of heron diets, it is possible that we did not detect amphibians in ditches in which they were present. Surveys were conducted in late October when water temperatures may have been too cold for most amphibian activity. More intense sampling for prey species may have yielded different results.

Our study area was situated between the North Branch Portage River and Maumee River. Study ditches ranged from 1.2-7.4 km from the nearest river. The southern shore of Lake Erie is within 38 km of our study area. Previous studies on the Upper Mississippi River have shown great blue herons travel between 2.7 and 7.5 km on average to a feeding ground during the nesting season (Custer and Galli 2002, Custer et al. 2004). The maximum distances traveled by great blue herons in the studies were 27 km and 43 km, respectively (Custer and Galli 2002, Custer et al. 2004). If travel distances are similar for great blue herons in northwest Ohio throughout the summer, it is probable that the herons are nesting near the rivers or in secluded woodlots (Peterjohn and Rice 1991) and traveling to ditches to forage. These roadside ditches may serve as important supplemental feeding grounds for herons, particularly later in the season when water and resources in other wetlands are becoming scarce and competition from conspecifics is increasing.

In a previous study we conducted from May-July 2014 in the same area (Chapter 1), we did not find wading birds present in ditches of varying sizes until late July. It is possible that we did not see any wading birds before late July because we were not surveying as intensively. It is also possible that we were surveying ditches which were mostly too small for herons to use. Another explanation for not finding any wading birds is that they do not utilize ditches earlier in the summer if wetlands and other aquatic habitats provide enough prey. Ditches may be a habitat which herons utilize once other foraging habitats begin to dry up and food sources are depleted. Anecdotally, several landowners of the ditches we surveyed told us that they typically see herons in the ditches during late summer.

Ditches are often a poor substitute for intact wetlands. As conduits for agricultural runoff, they may contain high levels of nutrients and pesticides (Needleman et al. 2007) and are a major source of non-point source pollution to our waterways (Buchanan et al. 2013). However, they are common on the landscape and have the ability to provide resources for herons and other wildlife. Ditches which are large enough to contain water throughout most of the summer could be a valuable resource for herons if they were to be maintained to reduce ground cover and herbaceous vegetation. While the ability for ditches to carry water must be maintained, it may be possible to reduce vegetation within sections of ditches by regularly mowing or burning. Clearing ditches mechanically will also reduce vegetation growing within the waterways of ditches and provide more open water. Allowing trees to grow along ditch banks may reduce ground vegetation and attract wading birds to the area. By alternating ditch sections under management from year to year, both open water and vegetated sections of ditches can be present on the landscape to allow for both heron foraging habitat and macrophyte presence, which can increase water quality.

Few studies have been conducted on great blue heron habitat use in Ohio (Edford 1976, Parris 1979, Grau and Parris 1980) and in the Midwest outside of the Mississippi River area (Custer and Galli 2002, Custer et al. 2004, Kirsch et al. 2008). To our knowledge, no research has been published on the use of roadside ditches by herons in the Midwest. Our study contained a relatively small sample size and was conducted during a limited time frame while still yielding some interesting results. Continued research would give us a better understanding of wading bird habitat use in an agricultural landscape. More intensive surveys of a larger number of ditches should be done to determine if similar results are found. Utilizing electronic tools such as cameras traps would allow for more detections throughout both days and seasons. Drainage ditches are anthropogenic landscape features which are typically ignored as manageable avian habitat (Kushlan 2000). By collecting more information about avian use of artificial habitats, we can broaden our understanding of how to manage habitats to benefit both humans and wildlife.

LITERATURE CITED

Arnold, G. W. 1983. The influence of ditch and hedgerow structure, length of hedgerows, and area of woodland and garden on bird numbers on farmland. Journal of Applied Ecology, 731-750.

Askins, R. A., F. Chavez-Ramirez, B. C. Dale, C. A. Haas, J. R. Herkert, F. L. Knopf, and P. D. Vickery. 2007. Conservation of grassland birds in North America: understanding ecological processes in different regions: report of the AOU committee on conservation. Ornithological Monographs, iii-46.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C., USA.

Blomqvist, M. M., W. L. M. Tamis, J. P. Bakker, and E. van der Meijden. 2006. Seed and (micro)site limitation in ditch banks: germination, establishment, and survival under different management regimes. Journal of Nature Conservation, 14:16-33.

Bouldin, J. L., J. L. Farris, M. T. Moore, C. M. Cooper. 2004. Vegetative and structural characteristics of agricultural drainages in the Mississippi Delta landscape. Environmental Pollution, 132:403-411.

Brown, M. and J. J. Dinsmore. 1988. Habitat islands and the equilibrium theory of island biogeography: testing some predictions. Oecologia, 75:426-429.

Buchanan, B. P., K. Falbo, R. L. Schneider, Z. M. Easton, and M. T. Walter. 2013. Hydrological impact of roadside ditches in an agricultural watershed in Central New York: implications for non-point source pollutant transport. Hydrological Processes, 27(17): 2422-2437.

Butler, R. W., J. A. Kushlan, and I. J. Davidson. 2000. Herons in North America, Central America and the West Indies. Pages 151-175 in J. A. Kushlan and H. Hafner, editors. Heron Conservation. Academic Press, San Diego, California, USA.

Chester, E. T. and B. J. Robson. 2013. Anthropogenic refuges for freshwater biodiversity: their ecological characteristics and management. Biological Conservation, 166:64-75.

Custer, C. M., & J. Galli, (2002). Feeding habitat selection by great blue herons and great egrets nesting in east central Minnesota. Waterbirds, 25(1):115-124.

Custer, C. M., S. A. Suarez, and D. A. Olsen. 2004. Feeding habitat characteristics of the great blue heron and great egret nesting along the Upper Mississippi River, 1995-1998. Waterbirds, 27:454-468.

Edford, L. H. 1976. Breeding biology of the great blue heron in southwestern Lake Erie. Unpublished master's thesis, The Ohio State University, Columbus, Ohio, USA.

ESRI. 2014. ArcGIS version 10.1. Earth Systems Research Institute, Redlands, California, USA.

Estes, J. A., J. Terborgh, J. S. Brashares, M. E. Power, J. Berger, W. J. Bond, S. R. Carpenter, T. E. Essington, R. D. Holt, J. B. C. Jackson, R. J. Marquis, L. Oksanen, T. Oksanen, R. T. Paine, E. K. Pikitch, W. J. Ripple, S. A. Sandin, M. Scheffer, T. W. Schoener, J. B.

Shurin, A. R. E. Sinclair, M. E. Soule, R. Virtanen and D. A. Wardle. 2011. Trophic downgrading of planet Earth. Science, 333(6040):301-306.

Grau, G. A., & R. W. Parris. 1980. Great blue herons as environmental indicators: aspects of foraging ecology. The Ohio State University, Columbus, Ohio, USA.

Hafner, H. 1997. Ecology of wading birds. Colonial Waterbirds, 20:115-120.

Herkert, J. R. 1994. The effects of habitat fragmentation on midwestern grassland bird communities. Ecological Applications, 4(3):461-471.

Herzon, I., & J. Helenius, 2008. Agricultural drainage ditches, their biological importance and functioning. Biological Conservation, 141(5):1171-1183.

Kirsch, E. M., B. Ickes, and D. A. Olsen. 2008. Assessing habitat use by the breeding great blue herons (*Ardea herodias*) on the Upper Mississippi River, USA. Waterbirds, 31:252-267.

Kushlan, J. A. 2000. Heron feeding habitat conservation. Pages 219-235 in J. A. Kushlan and H. Hafner, editors. Heron Conservation. Academic Press, San Diego, California, USA.

Kushlan, J. A, and J. A. Hancock. 2005. The herons. Oxford University Press, New York, New York, USA.

Main, M. B. and C. S. Vavrina. 2008. Wading birds and agriculture in southwest Florida. Univeristy of Florida IFAS Extension, pub. WEC143.

Murray, L. D. 2014. Bird-habitat relationships in restored meadows in southeastern Pennsylvania. Ecological Restoration, 32(2):197-203.

Needelman, B. A., P. J. A. Kleinman, J. S. Strock, and A. L. Allen. 2007. Improved management of agricultural drainage ditches for water quality protection: An overview. Journal of Soil and Water Conservation, 62:171-178.

Ohio Department of Natural Resources Division of Wildlife. 2012. Wildlife that are considered to be endangered, threatened, species of concern, special interest, extirpated, or extinct in Ohio. Pub. 5356.

Ohio Department of Natural Resources . 2013. Chapter 7. <http://ohiodnr.com/Portals/13/Atlas_Maps_GIS/coastalatlas2/CH7_habitat.pdf> Accessed 2 April 2014.

Parris, R. W. 1979. Aspects of great blue heron (*Ardea herodias*) foraging ecology in southwestern Lake Erie. Unpublished master's thesis, The Ohio State University, Columbus, Ohio, USA.

Peterjohn, B. G. and D. L. Rice. 1991. The Ohio breeding bird survey. The Ohio Department of Natural Resources. Columbus, Ohio, USA.

Rife, G. S., & D. L. Moody. 2004. Aquatic macroinvertebrate communities from the Portage River watershed headwater streams (Wood County, Ohio). Ohio Journal of Science, 104(2):29-35.

Safratowich, B., G. M. Linz, W. H. Bleier, and H. J. Homan. 2008. Avian use of rural roadsides with cattail (*Typha* spp.). The American Midland Naturalist, 159(1):162-171.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2014. The North American breeding bird survey, results and analysis 1966 - 2013. Version 01.30.2015 USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Terres, J. K. 1991. The Audubon Society encyclopedia of North American birds. Alfred Knopf, Inc., New York, New York, USA.

Vickery, J., N. Carter, and R. J. Fuller. 2002. The potential value of managed cereal field margins as foraging habitats for farmland birds in the UK. Agriculture, Ecosystems & Environment, 89(1):41-52.

Vierling, K. T. 1999. Habitat quality, population density and habitat-specific productivity of red-winged blackbirds (*Agelaius phoeniceus*) in Boulder County, Colorado. The American Midland Naturalist, 142(2):401-409.

Warner, R. E. 1992. Nest ecology of grassland passerines on road rights-of-way in central Illinois. Biological Conservation, 59(1):1-7.

Warner, R. E. 1994. Agricultural land use and grassland habitat in Illinois: future shock for midwestern birds? Conservation Biology, 8(1):147-156.

Wicknick, J. A., C. D. Anthony, and J. S. Reblin. 2005. An amphibian survey of Killbuck Marsh Wildlife Area, Ohio. Ohio Journal of Science, 105:2-7.

Wilhelm, P. 1983. Draining the Great Black Swamp, Henry and Wood Counties, Ohio: A case study in agricultural development. Unpublished master’s thesis, Bowling Green State University, Bowling Green, Ohio.

Wood County Engineer. 2013. Drainage < http://engineer.co.wood.oh.us/Drainage.aspx> Accessed 22 February 2014.

Table 1.1. Species of birds detected during roadside ditch surveys including number of individuals detected, number of ditches in which a species was detected, and percent of total detections per species.

Species	Individual Detections	# of Ditches	% of Total Detections
Red-winged blackbird	148	26	74.37
Song sparrow	25	16	12.56
Common grackle	5	2	2.51
Chipping sparrow	4	3	2.01
American robin	7	5	3.52
Field sparrow	2	2	1.01
Barn swallow	1	1	0.50
American goldfinch	6	3	3.02
Ruby-throated hummingbird	1	1	0.50

Table 1.2. Measurements of roadside ditches. Measurements are averages taken from the first, middle and last plot in each transect.

Location	Ditch Width (m)	Ditch Depth (m)	Water Width (m)	Water Depth (m)	Roadside Slope (º)	Fieldside Slope (º)
1	5.47	1.72	2.02	0.29	36	46
4	3.90	1.05	0.77	0.04	27	32
7	3.65	0.79	0.94	0.09	29	27
8	3.96	1.21	1.67	0.26	41	44
11	4.27	1.12	1.56	0.22	31	45
12	4.85	1.25	1.50	0.20	28	44
15	6.63	1.57	1.63	0.18	39	42
17	3.53	1.09	1.05	0.26	41	41
18	5.10	1.61	1.62	0.23	37	42
21	4.83	1.10	1.32	0.08	23	33
22	4.80	1.42	1.80	0.24	38	40
23	3.91	0.94	1.33	0.08	34	41
24	6.12	1.86	1.88	0.28	41	39
26	6.20	1.70	1.43	0.14	38	44
27	4.90	1.50	1.98	0.31	35	35
29	3.86	0.72	1.24	0.08	31	30
30	3.63	1.00	0.73	0.03	31	32
35	2.74	0.52	0.00	0.00	24	26
36	11.73	2.83	3.93	0.48	32	45
38	6.15	1.89	1.50	0.18	38	42
40	6.23	1.92	1.47	0.17	43	37
48	6.90	1.82	2.59	0.27	42	33
50	4.57	1.49	0.79	0.07	37	41
55	4.80	1.38	1.39	0.19	38	28
56	5.73	1.74	1.54	0.16	40	35
57	6.33	1.47	2.33	0.29	30	32
58	4.47	1.31	1.10	0.07	27	36
59	4.83	1.51	1.34	0.18	36	33
60	9.70	2.40	2.47	0.47	32	36
66	5.57	1.93	1.11	0.17	36	48
67	8.77	2.47	2.70	0.38	31	45
69	4.57	1.38	1.65	0.22	39	36
70	3.10	0.60	0.00	0.00	31	34
71	2.70	0.53	0.00	0.00	21	29
72	4.60	1.47	1.02	0.15	33	50
73	9.17	2.14	2.90	0.30	34	30
Mean±SD	5.34±2.0	1.51±0.8	1.46±0.5	0.19±0.1	34.42±5.6	37.93±6.4

Table 1.3. Logistic regression results relating red-winged blackbird and song sparrow presence to environmental factors. Variables not significant to presence are depicted by *P*-values in parentheses. Chi-square values were obtained using the whole model test except for those indicated by an * which were obtained using the likelihood ration test. A + indicates a positive relationship and a – indicates a negative relationship.

Variable	Red-winged Blackbird			Song Sparrow		
	***P*-value**	**X^2**	**+/-**	***P*-value**	**X^2**	**+/-**
Location	(0.5613)	0.3374	+	(0.2117)	1.5600	+
Date	(0.2281)	1.4523	-	(0.2750)	1.1916	+
Ditch Width[a]	0.0013	10.3300	+	0.0033	8.6343	+
Ditch Depth[a]	0.0008	11.2198	+	0.0011	10.7167	+
Water Width[a,b]	0.0133	6.1316	+	(0.0810)	3.0450	+
Water Depth[b]	(0.1174)	2.4515	+	(0.1302)	2.2899	+
Roadside Slope	(0.2666)	1.2340	+	(0.6098)	0.2605	+
Fieldside Slope	(0.3009)	1.0704	+	(0.3924)	0.7316	+
Herbaceous Cover	0.0370	4.3492	-	(0.1068)	2.6012	-
Vegetative Cover	(0.8159)	0.0542	+	(0.4457)	0.5815	-
Side VOR	0.0012	10.4349	+	(0.3348)	0.9303	+
Middle VOR[c]	(0.6249)	0.2391	+	(0.5275)	0.3991	-
Total VOR[c]	(0.0810)	3.0449	+	(0.9497)	0.0040	-
Open Water	(0.1070)	2.5986	+	0.0119	6.3242	+
Amphibians	(0.6576)	0.196*		(0.3598)	0.839*	
Macroinvertebrates	0.0328	4.833*		(0.3198)	0.990*	
Start Time	(0.8710)	0.0264	-	(0.5892)	0.2916	-
End Time	(0.8764)	0.0242	-	(0.5336)	0.3876	-
Wind	(0.7884)	0.0720	+	(0.8385)	0.0416	+
Temperature	(0.9416)	0.0054	+	(0.4464)	0.5798	+
Weather	(0.7056)	4.625*		(0.3614)	7.682*	
Buffer	(0.8043)	0.061*		(0.9086)	0.013*	
Crop	0.0064	10.105*		(0.9939)	0.012*	

[a,b,c]- indicates variables highly correlated to each other ($r > 0.75$) .

Table 1.4. Model results examining the temporal effects of environmental variables on avian presence in roadside ditches over three survey periods in 2014. The global model and top model for each survey period are shown. Variables included in the model are listed along with Akaike's Information Criterion adjusted for small sample size (AIC_c), degrees of freedom (df), calculated probabilities (*P*-value), coefficients of determination (R^2), and goodness of fit X^2 (GoF X^2) obtained using stepwise logistic regression. Global models were obtained using nominal logistic regression. Survey A ranges from 16 May-12 June, Survey B ranges from 17 June-2 July and Survey C ranges from 9 July-25 July, 2014.

Model	**Variables**	**AIC_c**	**df**	***P*-value**	**R^2**	**GoF X^2**
Survey A	global	190.00	14	0.0269	1.0000	2.659 e^{-8}
	ditch depth + total VOR	43.84	2	0.0040	0.2291	37.091
Survey B	global	76.44	14	0.0484	0.5666	18.209
	-	49.21	0	-	0	-
Survey C	global	54.00	14	<0.0001	1.0000	1.216 e^{-7}
	ditch depth + total VOR + open water	43.75	3	0.0024	0.2954	34.456

Table 1.5. Avian richness and diversity of roadside ditches during study. Included are temporally separated surveys and the entire study period. Diversity was calculated using the Simpson's Index of Diversity (1-D).

	Survey 1	Survey 2	Survey 3	Study
Richness	6	6	6	10
Diversity	0.61	0.50	0.57	0.56

Table 2.1. Species of herons known to breed in Ohio (Peterjohn and Rice 1991).

Common Name	Scientific Name
Great Blue Heron	*Ardea herodias*
Little Blue Heron	*Egretta caerulea*
Green Heron	*Butorides virescens*
Great Egret	*Ardea alba*
Snowy Egret	*Egretta thula*
Cattle Egret	*Ardea ibis*
Yellow-crowned Night Heron	*Nyctinassa violaceus*
Black-crowned Night Heron	*Nycticorax nycticorax*
American Bittern	*Botaurus lentiginosus*
Least Bittern	*Ixobrychus exilis*

Table 2.2. Environmental variables of roadside ditches. Values are averaged from measurements taken from three plots along each ditch transect. The mean ± standard deviation (SD) is included. Amphibians, minnows, macroinvertebrates and herons are listed Y for detected and N for not detected.

Location	Ditch Width (m)	Water Width (m)	Ditch Depth (m)	Water Depth (m)	Roadside Slope (°)	Fieldside Slope (°)
A	5.3	1.1	1.8	0.24	35.7	42.3
B	5.0	0.6	1.4	0.05	34.0	33.0
C	13.1	4.2	3.0	0.26	36.3	34.3
D	6.8	1.9	2.0	0.24	38.3	43.7
E	6.1	1.9	1.9	0.24	36.0	38.7
F	6.2	2.0	1.6	0.15	39.0	38.0
G	10.0	2.7	2.4	0.14	34.7	37.8
H	7.8	1.9	2.3	0.21	40.7	38.8
I	9.2	1.8	2.1	0.15	34.3	30.0
K	8.1	2.1	2.2	0.17	37.2	44.3
L	8.9	2.4	2.3	0.20	35.2	38.0
Mean±SD	7.9±2.4	2.1±0.9	1.9±0.4	0.2±0.1	36.5±2.1	38.1±4.4

Table 2.2. Continued

Location	Vegetation Cover (%)	Herbaceous Veg. (%)	Roadside VOR (cm)	Middle VOR (cm)	Fieldside VOR (cm)	Open Water (%)	Amphibians	Minnows	Macros	Herons
A	58.3	96.0	10.0	0.0	21.7	98.3	N	Y	Y	Y
B	73.3	99.3	0.0	0.0	10.0	100.0	N	N	Y	N
C	66.7	95.3	3.3	0.0	28.3	100.0	N	N	Y	Y
D	76.7	100.0	1.7	0.0	71.7	90.0	N	N	Y	N
E	63.3	95.3	3.3	16.7	21.7	87.5	N	N	Y	N
F	59.2	97.8	18.3	0.0	21.7	91.7	N	N	Y	N
G	63.3	86.7	15.8	0.0	31.7	84.3	N	Y	Y	Y
H	69.2	83.3	8.3	0.0	14.2	92.2	N	Y	Y	Y
I	65.0	86.7	10.0	0.0	45.0	97.7	Y	Y	Y	Y
K	53.3	93.7	6.7	0.0	20.0	94.3	Y	Y	Y	Y
L	77.5	90.8	19.2	0.0	40.8	88.7	N	Y	Y	N
Mean±SD	66.0±7.7	93.2±5.6	8.8±6.7	1.5±5.0	29.7±17.4	93.2±5.3				

Table 2.3. Number of macroinvertebrates in samples from each study sites. Percent of total for each group is included. A total of 2,005 macroinvertebrates was collected.

Site	Bivalvia	Gastropoda	Diptera	Oligochaeta	Hirudinea	Isopoda	Coleoptera	Odonata	Hemiptera	Decapoda	Amphipoda
A		45	4	14	4				1		
B		16	1	2							
C	130			6	1						
D	1	30	23				1		1		1
E	8	5	15			19	1				
F	2	47	1	6	6				1	1	
G	183	75			2	6	3	2	1		
H	87	32	3		3		2	5			
I	32	11		3	2		1				
K	140	23	2	6	11		2	1	2	1	
L	35	5	1	5	3	5	2	1	3	4	
Percent of Total											
	30.82	14.4	2.49	2.09	1.60	1.5	0.60	0.45	0.45	0.30	0.05

Table 2.4. Top models relating environmental variables to heron presence in our study area developed using stepwise logistic regression. Variables included in each model are listed along with Akaike's Information Criterion adjusted for small sample size (AIC_c), degrees of freedom, (df), calculated probabilities (*P*-value), the coefficients of determination (R^2) and the goodness of fit X^2 (GoF X^2).

Variables	AIC_c	df	*P*-value	R^2	GoF X^2
global	-	10	0.1264	1.0000	-
ditch depth + open water	15.318	2	0.0097	0.6114	5.8898
herbaceous vegetation + vegetation cover	15.623	2	0.0113	0.5914	6.1943
ditch depth + open water + minnows	19.532	3	0.0162	0.6790	4.8656

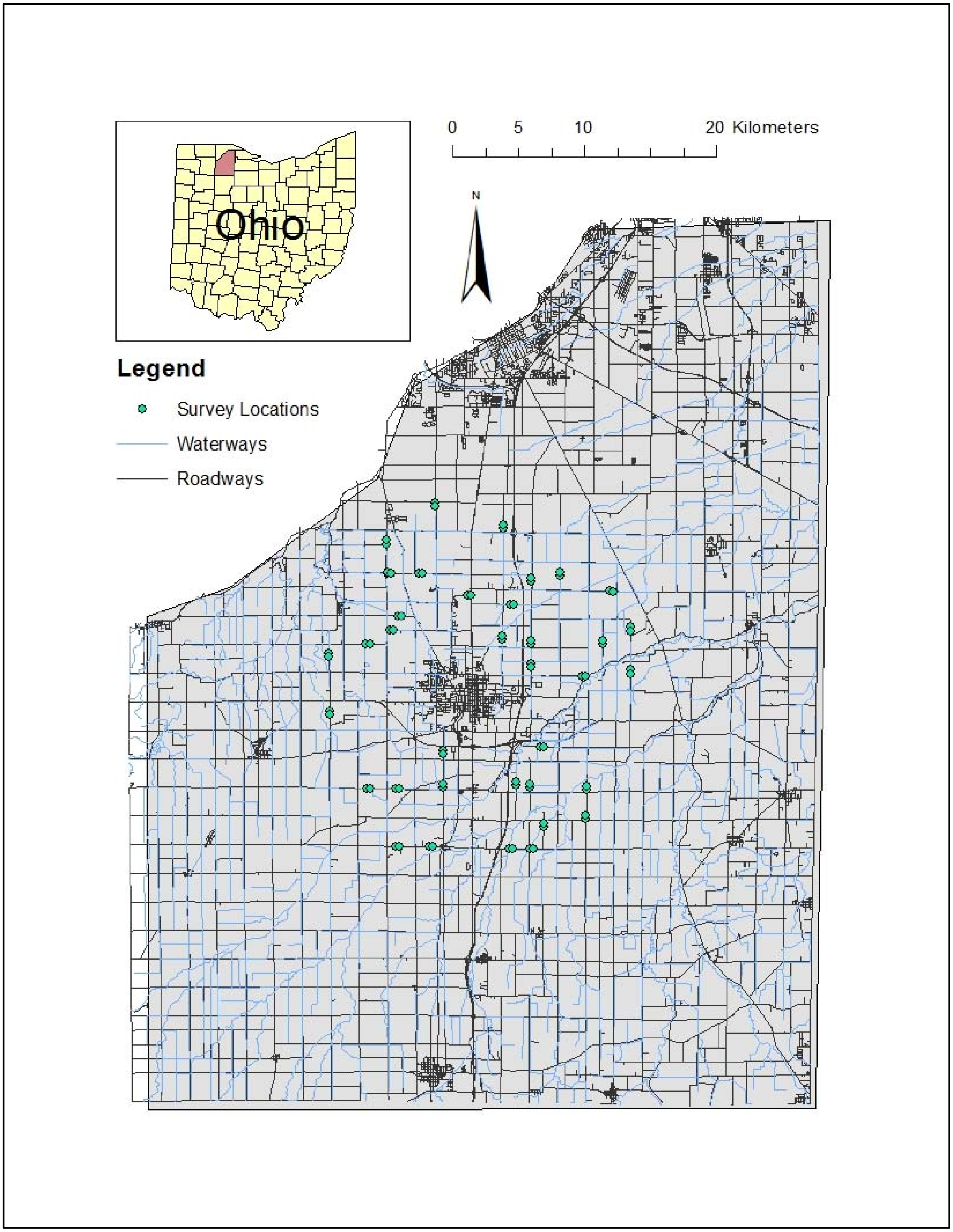

Figure 1.1. Passerine survey transects in Wood County, Ohio. Pairs of dots represent the beginning and end of transects.

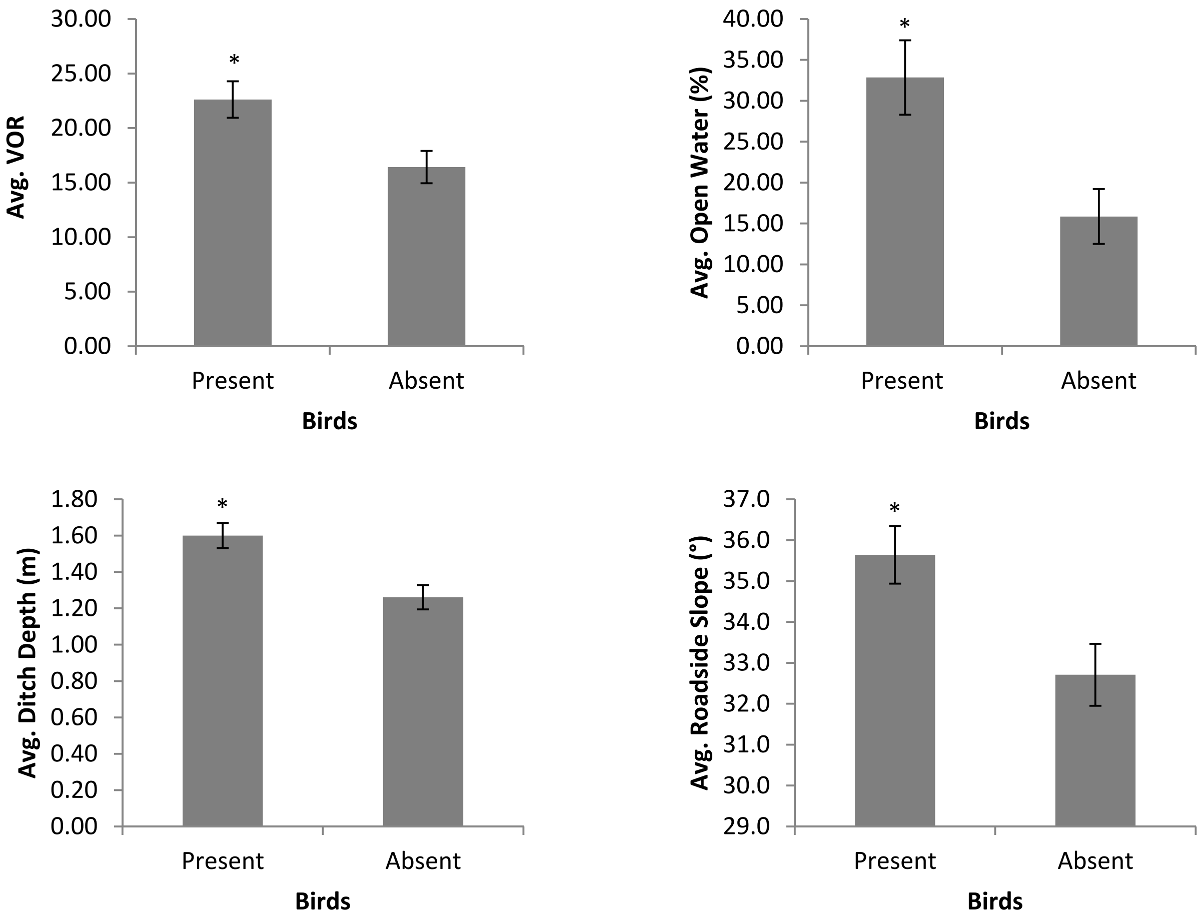

Figure 1.2. Ditch variables positively correlated with avian presence shown with standard error bars. Included are averages for visual obstruction readings (Avg. VOR), percent of open water, ditch depth and degree of roadside slope. An asterisk (*) indicates a significant relationship based on logistic regression (P<0.05)

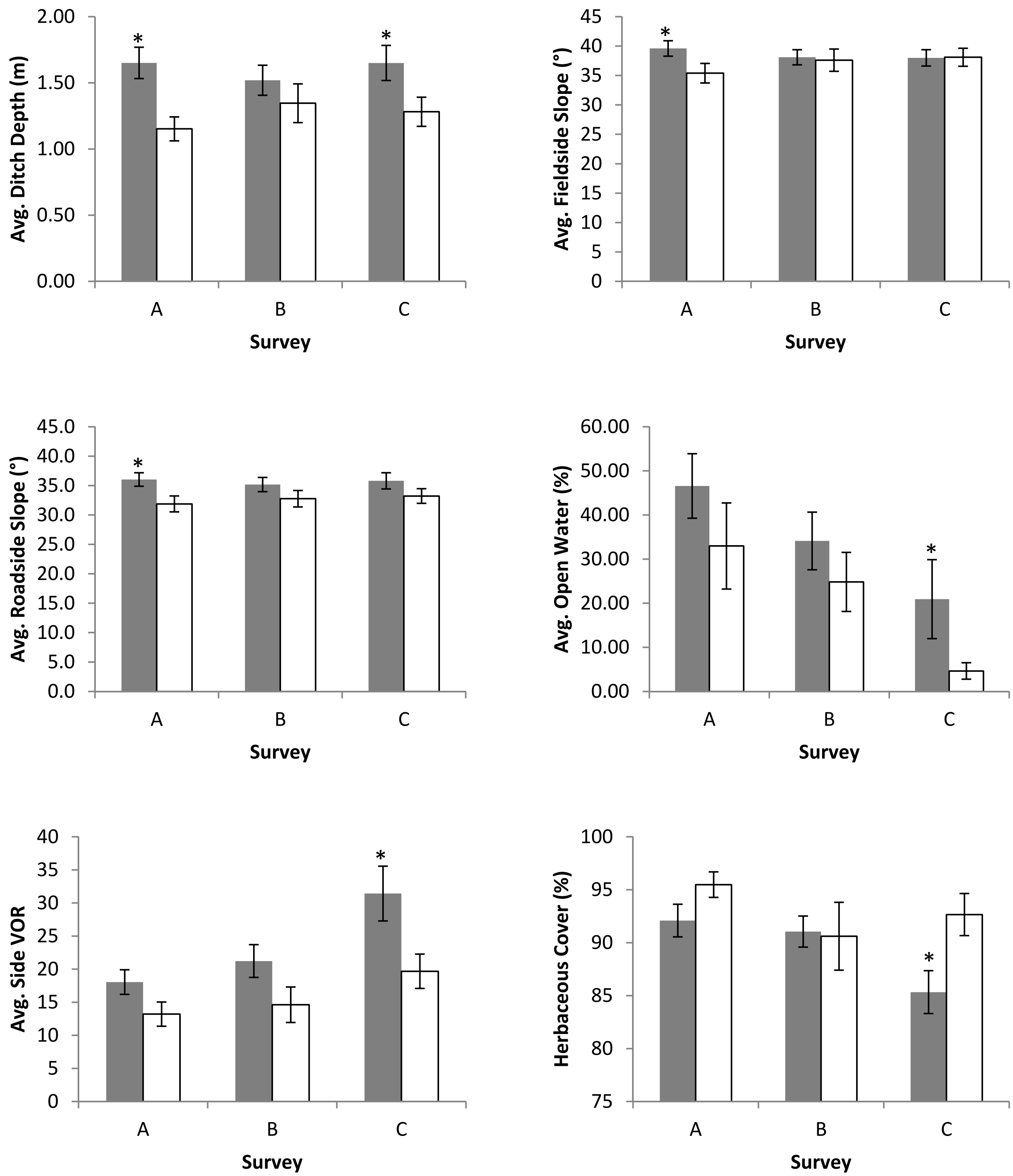

Figure 1.3. Temporal results of variables significant ($P < 0.05$) to avian presence shown with standard error bars. An asterisk (*) above bars indicates the survey in which the variable is significant based on logistic regression. All variables are positively correlated except herbaceous cover which is negatively correlated. Dark bars represent bird presence while white bars represent bird absence. Survey A- 16 May – 12 June, Survey B- 17 June – 2 July, Survey C- 9

July – 25 July, 2014. Included are averages for ditch depth, degree of fieldside slope, degree of roadside slope, percent of open water in ditch, visual obstruction readings along sides of ditch (Side VOR) and percent of herbaceous vegetation cover.

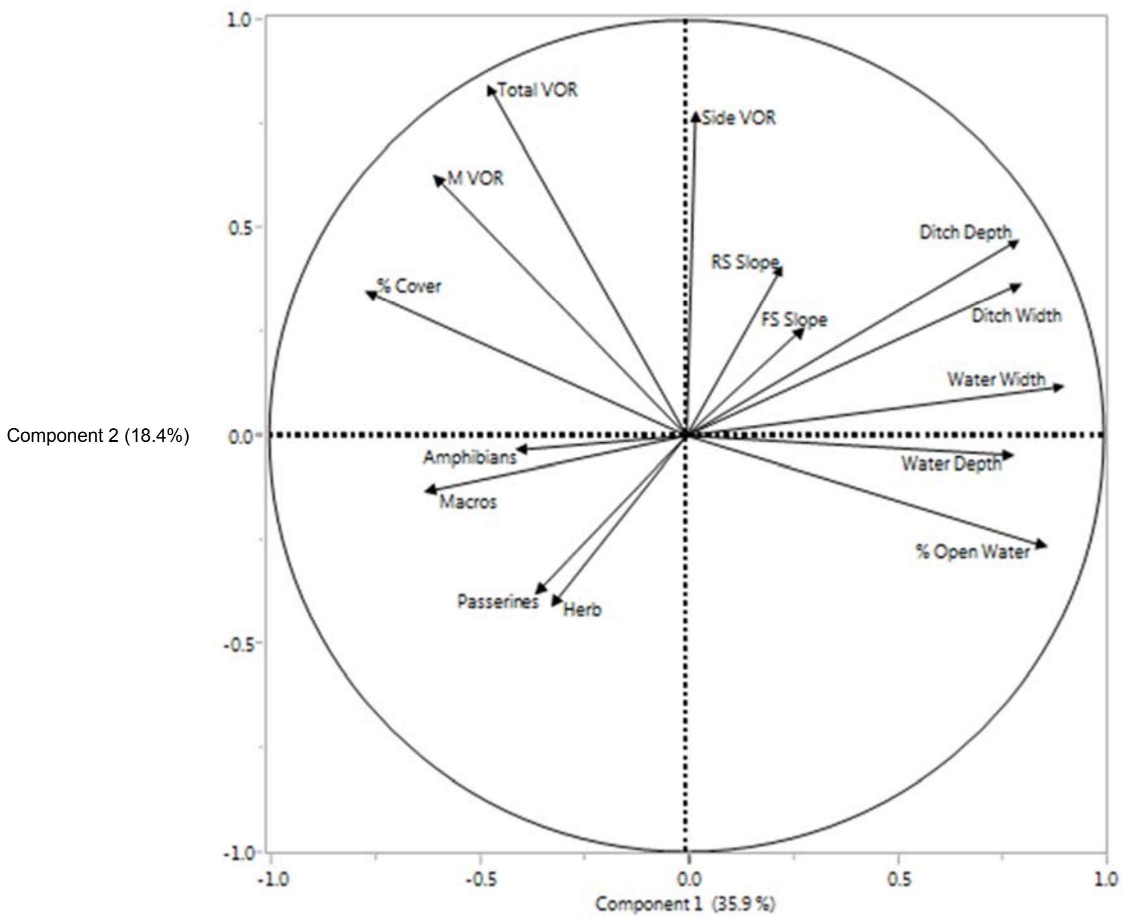

Figure 1.4. Principal components analysis modeling the relationship among passerine study variables. RS indicates roadside variables while FS indicates fieldside variables and M indicates middle variables. Herb is the percent of herbaceous vegetation as opposed woody vegetation.

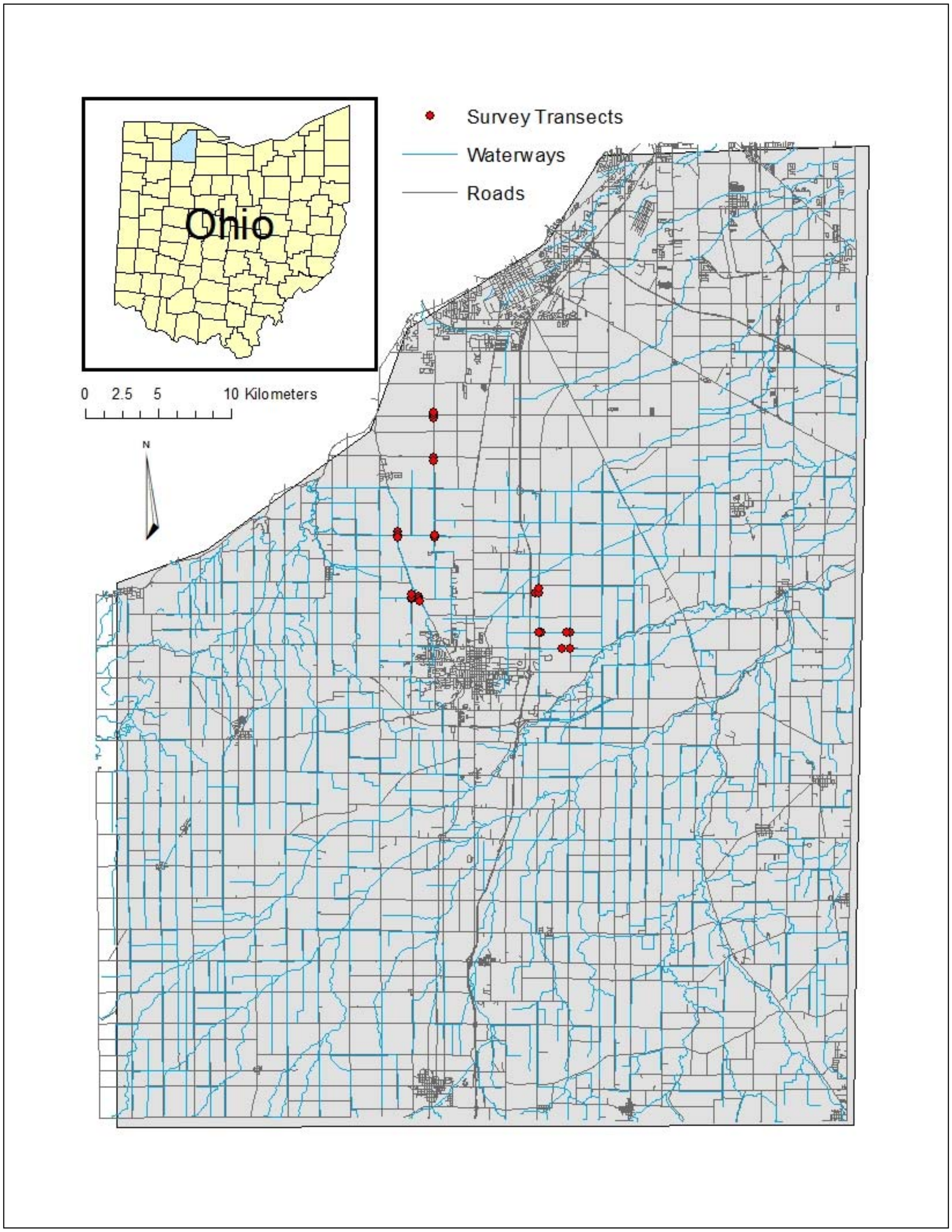

Figure 2.1. Wading bird survey sites in Wood County, Ohio. Pairs of dots indicate the starting and ending point of each transect.

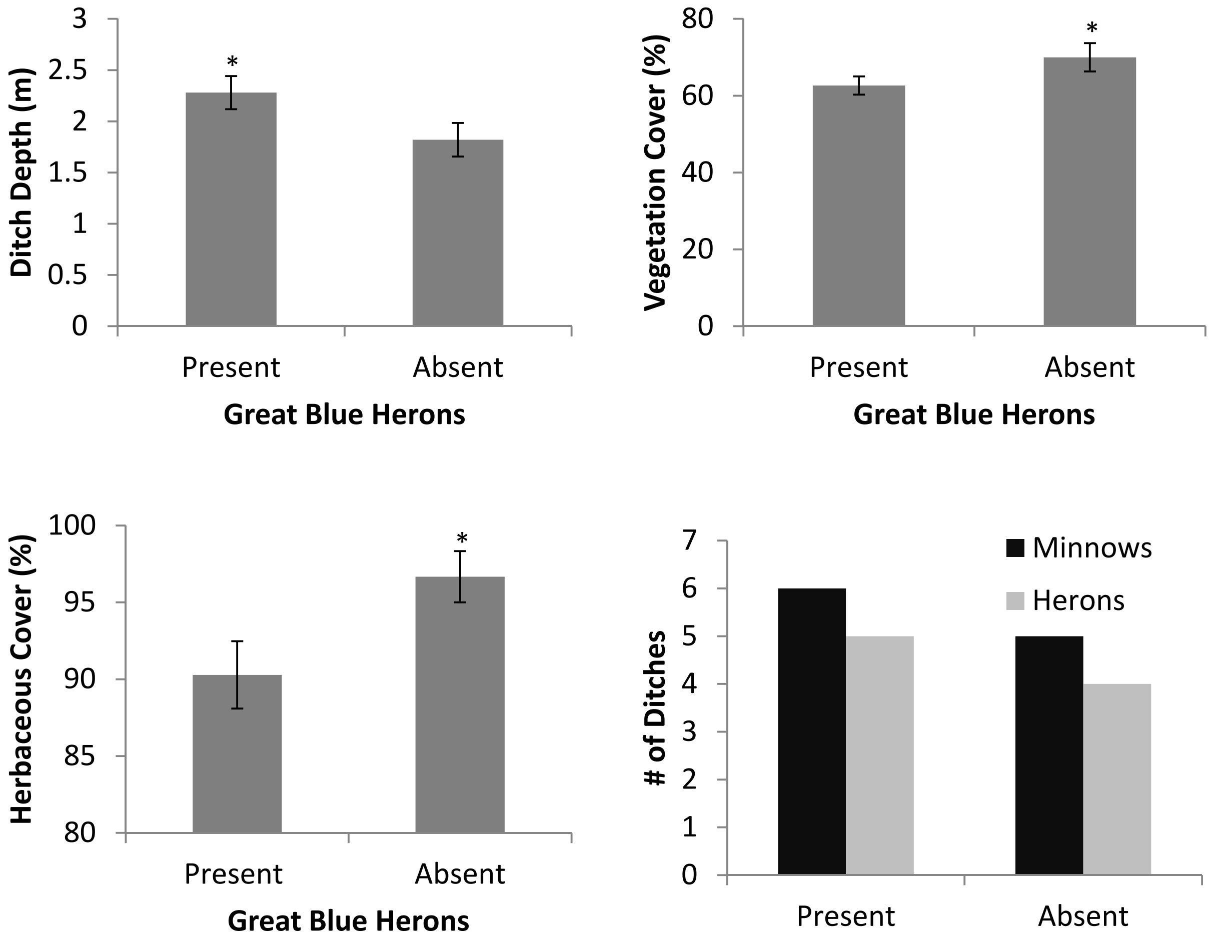

Figure 2.2. Environmental variables significantly related to heron presence (Logistic regression; $P < 0.05$ shown with standard error bars). Included are ditch depth, percent herbaceous vegetation cover, percent overall vegetation cover and minnow presence.

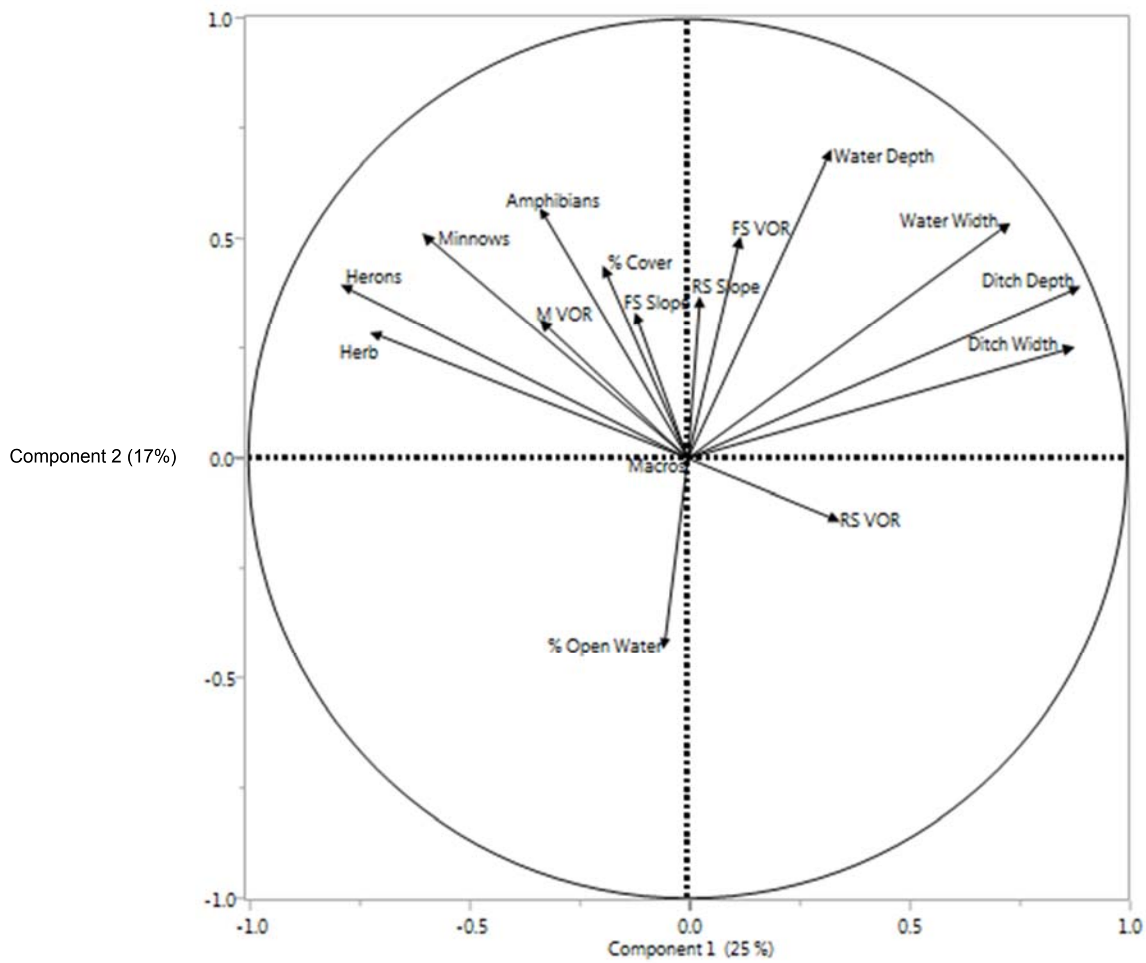

Figure 2.3. Principal components analysis modeling the relationship among wading bird study variables. RS indicates roadside variables while FS indicates fieldside variables and M indicates middle variables. Herb is the percent of herbaceous vegetation as opposed woody vegetation.