VARIATION IN USE OF MANAGED WETLANDS BY WATERFOWL, WADING BIRDS, AND SHOREBIRDS IN OHIO

A Thesis

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By

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ABSTRACT

There is a need to broaden wetland conservation and management to include a greater diversity of wildlife species. Integration of waterfowl and webless wetland bird management under the North American Waterfowl Management Plan (NAWMP) requires an understanding of wetland bird responses to variation in habitat characteristics and management. I compared abundance and composition of 47 species of waterfowl, wading birds, and shorebirds among 47 wetlands in central and northwestern Ohio during March 2001 - June 2002. I used multivariate analyses to describe patterns of wetland bird species abundance and composition associated with wetland size, water level variation, and vegetation characteristics. I compared species composition, species densities, and environmental conditions among coastal and inland landscapes, disturbance levels, cover types, and water management regimes.

Wetland bird communities were structured along water regime and vegetation density gradients in the managed wetlands that I studied. Mean densities (no./visit/ha) of waterfowl (9.84), wading birds (0.72), and shorebirds (3.66) were greatest in unmanaged, open water refuges during autumn. In addition to having the greatest species richness, mean densities of dabbling ducks (5.65) and shorebirds (1.86) were greatest on moist soil wetlands during spring. Waterfowl, wading bird, and shorebird use (use-days/ha) was greatest on wetlands managed with a partial drawdown regime.

The compatibility of moist soil management for waterfowl and other guilds of wetland birds was not apparent during autumn because hunting disturbance affected waterfowl habitat use patterns ($P < 0.10$; Multiple Response Permutation Procedure). The value of moist soil management was more apparent during spring. Slow and partial drawdowns should be conducted on moist soil wetlands during early spring to attract the greatest diversity of wetland birds. However, traditional waterfowl management cannot provide habitat for all wetland birds throughout the year. Compared to waterfowl, shorebirds require shallower, less densely vegetated habitats during autumn and spring. Therefore, a complex of wetlands managed with different water regimes and vegetation structures will provide habitat for the most diverse assemblage of avian species.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The coastal wetlands and inland marshes of Ohio support over 500,000 waterfowl (Bookhout et al. 1989) and other migratory birds. However, wetland loss and degradation is a continuing threat to wetland-dependent wildlife in Ohio. With wetland area having declined approximately 90% from 2,024,000 ha to 196,000 ha over the past 200 years, Ohio ranks second among all U.S. states in percentage of wetland loss (Dahl 1990). Apart from outright loss, degradation of wetlands has had a severe impact on migratory wetland birds. Wetland degradation and hydrological alterations of watersheds can limit habitat availability and may cause decreased use by wetland birds (Reid 1993). Millions of birds that migrate through Ohio and other interior states and provinces of North America depend on wetland habitats to complete life-history events that are prerequisite to successful breeding (Morrison 1984). Indeed, the quality and quantity of migration habitat is a potential limiting factor for survival and breeding productivity of migratory wetland birds.

Several federal, state, and private agencies developed wetland conservation programs in response to the decline of wetland birds and their associated habitats throughout North America. The North American Waterfowl Management Plan (NAWMP) was initiated in 1986 and is one of the largest international wildlife conservation efforts ever attempted (Williams et al. 1999). By protecting, restoring, and enhancing wetlands, NAWMP strives to increase waterfowl populations in Canada, the United States, and Mexico, with 100 million birds in the autumn flight and 62 million birds returning to the breeding grounds. Although the focus of NAWMP is on conservation of waterfowl and their associated habitats, passage of the North American Wetland Conservation Act (NAWCA) in 1989 provided funding to support migratory bird habitat conservation (Williams et al. 1999). As the primary funding source for NAWMP, NAWCA has increased opportunities for wetland ecosystem conservation throughout the 3 countries. Other bird conservation initiatives such as Partners in Flight, the United States Shorebird Conservation Plan, and the North American Waterbird Conservation Plan were developed and recognized to have overlapping conservation interests. As a result, the North American Bird Conservation Initiative (NABCI) arose from the realization of shared interests between these initiatives and serves to broaden and coordinate integrated bird conservation (Andrew 2002).

The NAWMP is implemented locally through joint venture partnerships among state, provincial, private, corporate, and federal conservation organizations. Joint venture partners coordinate landscape-level wetland habitat conservation efforts. Ohio is located in the Upper Mississippi River and Great Lakes Region Joint Venture (UMR & GLR JV). This joint venture was established in 1993 to meet the needs of breeding and migrating waterfowl in the northern region of the Mississippi flyway. The UMR & GLR JV boundaries encompass the Great Lakes marshes and the Ohio, Illinois, upper Mississippi, and lower Missouri river systems (Figure 1.1). This joint venture is located between 2 of the most continentally significant breeding and wintering areas for North American wetland birds: the Prairie Pothole/Parkland regions and the Mississippi Alluvial Valley and Gulf Coast regions (Reid et al. 1989). Migratory wetland birds depend on staging areas in this region to replenish energy stores to continue migration and accumulate nutrient reserves needed on breeding grounds (Ricklefs 1974, Myers 1983). The Lake Erie marsh region was recognized as a critical site where large numbers of shorebirds concentrate during migration. The Lake Erie marshes are 1 of 9 inland sites that have been designated as a regionally significant area by the Western Hemisphere Shorebird Reserve Network (WHSRN) due to its importance as an inland staging site for shorebirds in North America.

The UMR & GLR JV strategic implementation plan focuses on conserving, restoring, and managing wetlands for migratory waterfowl. Specific breeding and mid-migration habitat objectives for waterfowl conservation were established. The breeding habitat objective states that the conservation of 3,690,000 hectares of habitat will be capable of supporting an annual breeding waterfowl population of 1,542,000 by the year 2013. Under the mid-migration habitat objective, conservation of 215,000 hectares of habitat is capable of supporting 25.7 million waterfowl during fall migration by the year 2013. Management activities are assumed to provide additional benefits to nonwaterfowl species. The U. S. Fish and Wildlife Service UMR & GLR JV implementation plan (1998) included an additional objective focused on wetland habitat conservation for nonwaterfowl species. Efforts to protect and/or increase wetland and associated upland wildlife are

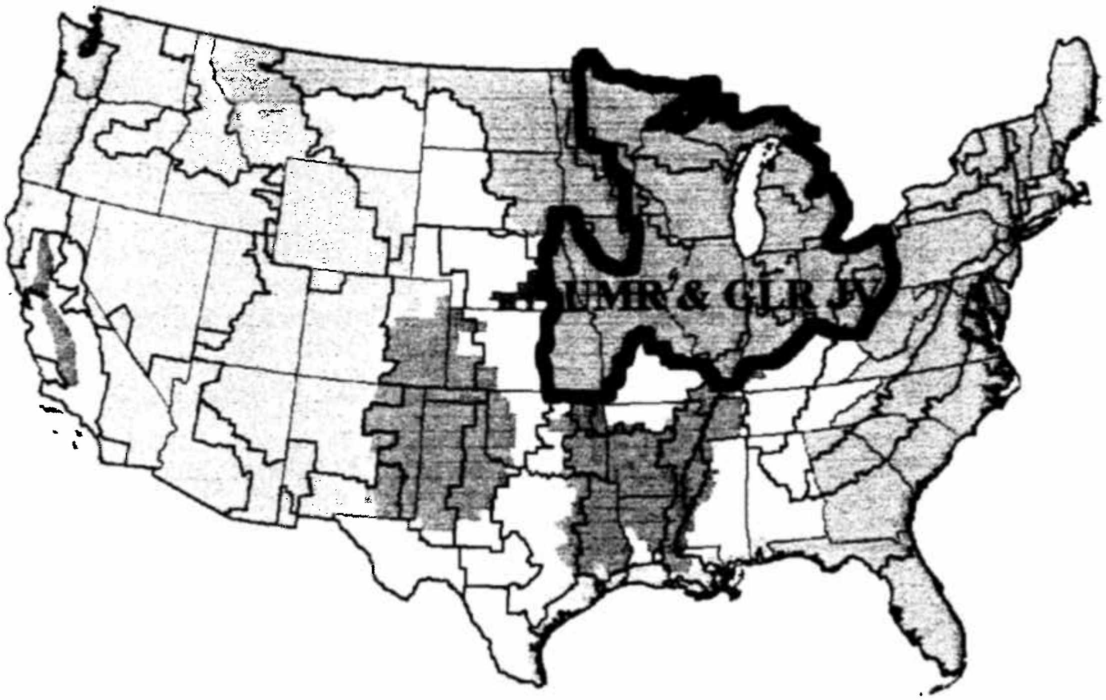

Figure 1.1. Current (2003) map of North American Waterfowl Management Plan joint ventures in the conterminous United States, depicting the boundaries (bold line) of the Upper Mississippi River and Great Lakes Region Joint Venture (UMR & GLR JV).

considered consistent with the waterfowl breeding and mid-migration habitat objectives. Under this objective, benefits of waterfowl conservation are emphasized for declining nonwaterfowl migratory birds.

Although there is substantial spatial and temporal overlap in use of wetlands by waterfowl and other wetland birds during migration (Weller 1999), certain resource values may be diminished or excluded by wetland management to consistently provide waterfowl habitat. For example, traditional waterfowl management emphasizes seed production from annual plants that are interspersed with open water (Haukos and Smith 1993). Conditions needed to produce seeds may conflict with habitat requirements of wetland birds that require different types and amounts of vegetation cover. Spring drawdowns associated with moist-soil management maximize the germination, growth, and seed production of annual plants (Fredrickson 1991). The exposure of saturated soils provides suitable habitat for shorebirds during the growing season, but increased vegetation in autumn may inhibit use by migrant shorebirds (Rundle and Fredrickson 1981, Davis and Smith 1998). With increasing demands on wetland resources and growing interest in preserving biodiversity, wetland managers are now faced with the challenge of managing fewer wetland areas for greater avian diversity (Laubhan and Fredrickson 1993). Hence, there is need to understand relationships between wetland bird and wetland habitats in the UMR & GLR if wetland managers hope to provide benefits to both waterfowl and webless wetland bird species.

NAWMP focuses on monitoring and evaluating habitat conservation efforts and subsequently using this evaluation to improve future conservation efforts. Therefore, a quantitative assessment of wetland management activities to meet waterfowl and other resource requirements of wetland birds is needed to address and refine the assumptions of the UMR & GLR JV conservation plan. There is need for information on the effects of habitat management on wetland bird distribution and abundance. Gaining an understanding of wetland bird distribution on public and private lands is important because this has implications for habitat conservation and population monitoring (Thompson 1977, de Szalay et al. 2001). This project evaluated wetland bird use in Ohio. Understanding how different guilds of wetland birds respond to environmental gradients within managed wetlands in Ohio should also apply to different migratory areas within the UMR & GLR JV. Improved understanding of how migratory shorebird (*Charadriidae*) and wading bird (e.g., *Ardeidae, Gruidae*) guilds respond to water regime, vegetation characteristics, and wetland disturbance will enhance efforts to integrate webless wetland bird and waterfowl management strategies. This research was conducted to gain a better understanding of wetland bird responses to variation in wetland habitat characteristics and management in northern and central Ohio through the following objectives:

1. Determine chronology of use of coastal and inland wetlands by different foraging guilds of waterfowl (*Anseriformes*) and webless wetland birds (*Ciconiiformes, Gruiformes, Charadriiformes*) during autumn and spring migration.
2. Relate seasonal use patterns and behavior of wetland birds to changing habitat conditions (e.g., vegetation cover, water level fluctuations, landscape features, disturbance levels, etc.).

3. Compare relative abundance and species composition of waterfowl and webless wetland birds between managed and unmanaged wetlands associated with coastal and inland site complexes.

4. Compare relative use and species composition of wetland bird foraging guilds on managed wetlands with different water level management strategies (e.g., early vs. late drawdown/re-flooding, fast vs. slow drawdown/re-flooding, partial vs. complete drawdown/re-flooding) during autumn and spring migration.

5. Use information from objectives 1-4 to recommend wetland management strategies to better meet the habitat requirements of wading birds, shorebirds, and waterfowl.

CHAPTER 2

LITERATURE REVIEW

2.1 Interspecific differences in habitat use

Loss and degradation of North America wetlands has focused attention on intensive management of remaining wetlands to provide resources for wetland-dependent wildlife. Managers increasingly incorporate principles of wetland dynamics, community ecology, and species biology into management plans and habitat models (Fredrickson and Reid 1986). Providing habitat for a diverse assemblage of avian species is a common wetland management objective that requires understanding of interspecific variation in habitat use.

Water depth and vegetation structure of a wetland influence the distribution of most wetland bird guilds (e.g., waterfowl, shorebirds, rails, and wading birds) (Fredrickson and Reid 1986). Wading birds generally occupy habitats near dense stands of emergent vegetation, and require seasonal and semipermanent wetlands with a 50:50 interspersion of vegetation cover and water (Stewart and Kantrud 1972, Kantrud and Stewart 1984). Colwell and Taft (2000) found that wading bird diversity was correlated with large, shallow, and topographically variable wetlands. Several wading bird species were found to partition habitat, based on water depth on wintering grounds at a microhabitat scale (DuBowy 1996). Heitmeyer (1986) observed habitat use by wading birds (i.e., *Ardeidae*) during the post-breeding season and found wading birds to be more abundant on natural wetlands. Despite these studies, most of what is known about habitat conservation and management for wading birds comes from studies conducted on breeding grounds (Heitmeyer 1986, DuBowy 1996, Hafner 1997, Kushlan 1997). Thus, there is a need to study habitat use patterns of wading birds during the non-breeding season to determine how wading bird habitat use is affected by autumn and spring migration habitat conditions.

Shorebirds are a highly diverse group of species with respect to body size and shape, habitat use patterns, and foraging behavior (Helmers 1992). They require a wide range of habitats throughout their annual cycle, from sparsely vegetated mudflats to moderately vegetated shallow water. Nearly 40 species of shorebirds migrate through the interior of North America where they generally exploit shallow water habitats with short, sparse vegetation. Over 70% of migrating shorebirds are associated with coastal wetlands, freshwater wetlands, or intertidal mudflats with water depths < 10 cm. However, habitat requirements of migratory shorebirds may vary among different regions (Helmers 1992). Knowledge of shorebird habitat requirements in the UMR & GLR JV is needed to plan management and conservation strategies without having to rely solely on information from other regions (e.g., Northern Great Plains, Playa Lakes Region) (Davis and Smith 1998).

Water depth at foraging sites varies with species morphology. Isola et al. (2000) identified water depth as the most important variable distinguishing interspecific patterns of habitat use by 10 species of wetland birds in California. The range of water depths used by wetland birds increases with body size. Compared to shorebirds, waterfowl use a wider variety of foraging behaviors, allowing them to exploit a greater range of water depths. However, green-winged teal (*Anas crecca*) foraged in water that was shallower than random locations, indicating possible water depth constraints (Isola et al. 2000). Water depth also was the most important variable affecting wetland use by wintering herons and egrets at Rockefeller Refuge in coastal Louisiana during 1987 (DuBowy 1996). Water levels (10-20 cm) managed specifically for wintering waterfowl at Rockefeller Refuge also provided foraging habitat for wintering herons and egrets. Therefore, waterfowl management practices can be manipulated to provide habitat for multiple guilds of wetland birds.

2.2 Landscape effects

Unlike the predictable and abundant food resources found in coastal habitats, resource availability in inland areas is highly variable, both spatially and temporally (Skagen and Knopf 1993). The dynamic climatic cycles of inland areas affects the availability of wetland basins for wetland birds. Migratory wetland birds concentrate at specific staging areas along the Atlantic and Pacific coasts. Inland wetland conditions, influenced largely by precipitation, cause wetland birds that migrate through the UMR & GLR JV to be scattered over larger areas in smaller numbers at numerous sites.

Wetlands in Ohio are highly concentrated near Lake Erie. Wind-driven seiches and long-term precipitation cycles affect short- and long-term lake water levels. These water levels determine dynamics of natural coastal marshes in Ohio. Water level fluctuations in the Lake Erie coastal marshes have important consequences for shorebirds that forage along exposed shorelines. In contrast, wetland conditions on unmanaged inland marshes of Ohio are influenced entirely by precipitation. During dry years, semipermanent and permanent wetlands are important to migrating birds. During wet years, seasonal and temporary wetlands may provide the only unmanaged wetland habitat available to migrating shorebirds (de Szalay et al. 2001).

There is some evidence to indicate that isolated wetlands have fewer species than wetlands that are part of a complex (Weller 1999). A wetland complex is a series of different wetland habitats in close proximity, each having a unique and dynamic hydrologic regime (Fredrickson and Reid 1986). The diversity of habitats provided by wetland complexes is important for birds that utilize a variety of wetland habitats to complete different life-history events. Therefore, wetland distribution within a landscape may be an important variable in habitat selection.

2.3 Reproductive success

Many wetland birds migrate long distances between breeding and wintering grounds to take advantage of seasonally predictable resources and complete important life-history events. Nutrient acquisition is critical for wetland birds during migration. Nutrients are necessary to maintain energy and build body reserves to complete migration and later to defend territories and breed (Reid 1993). Drent and Daan (1980) proposed that the critical factor limiting reproductive success in migratory birds may be body condition at departure from spring staging areas. Heitmeyer (1985) hypothesized that reproductive success of waterfowl is determined by wetland conditions on breeding, wintering, and migration areas. The linkages between these habitat conditions also likely apply to survival and recruitment of webless wetland species, especially herons (*Ardeidae*), cranes (*Gruidae*), and other large-bodied wetland birds (Ankney and MacInnes 1978, Raveling 1979, Alisauskas and Ankney 1985). For example, reproductive success is influenced by water conditions on African wintering grounds for the purple heron (*Ardea purpenis*) and white stork (*Ciconia ciconia*) (den Held 1981, Cave 1983, Dallinga and Schoenmakers 1987). Migration staging areas also are important for small-bodied wetland birds that need to replenish lipid reserves spent during migration and to store lipids for nesting after arrival on the breeding grounds (Alisauskas and Ankney 1985).

2.4 Wetland management

Wetland management strategies are based on manipulating the timing, depth, and duration of flooding which in turn change the direction and rates of plant and animal succession (Weller 1999). Wetland manipulations may influence all components and processes within the system, such as vegetation structure, hydroperiod, water depth, temperature, and oxygen levels. These factors and relative processes determine the distribution and types of food found within a wetland (Weller 1999).

Wetland birds obtain nutrients from a diverse range of foods, including invertebrates, fish, small vertebrates, and plant material (Reid 1993, Weller 1999). Migratory shorebirds consume primarily invertebrates. The presence of invertebrates is largely a function of the wetland hydrologic regime, because many invertebrates are adapted to specific flooding regimes (Helmers 1992). Shorebird access to invertebrates depends largely on the depth of water and density of vegetation, both of which are manipulated by wetland managers. Whereas shorebirds tend to exploit the shallowest end of the wetland spectrum, the morphology of wading birds allows them to forage in deeper waters with a greater density of vegetation. Wading birds consume a variety of fish, invertebrates, small mammals, and insects. Therefore, the timing, extent, and duration of drawdowns and flooding are important in providing habitats and associated foods for wetland birds (Helmers 1992).

To date, habitat management efforts to promote nongame wildlife such as webless wetland birds have been limited when compared to waterfowl. The NAWMP has responded by incorporating nongame resource needs into management strategies. The third objective of the UMR & GLR JV strategic implementation plan focuses on conservation of nonwaterfowl wetland species, with emphasis on declining migratory birds (U.S. Fish and Wildlife Service 1998). Under this plan, habitat management actions of joint venture partners are intended to benefit multiple species of wildlife in addition to waterfowl. Since waterfowl require habitats that range from dry to deepwater habitats, waterfowl management also should meet the needs of other wetland birds. Nevertheless, biodiversity proponents criticize waterfowl management as a narrowly focused effort to manage principally for hunted species such as dabbling ducks. Moist-soil management techniques focus on producing annual plants to increase cover and seed production (Fredrickson 1991). Management that emphasizes one form of food, such as seeds, may compromise the quality of wetland habitat needed by other species or foraging guilds of wetland birds (Reid 1993). Moist-soil management has been found to provide habitat for some nonwaterfowl species (Burgess 1969, Meeks 1969, Andrews 1973, Rundle and Fredrickson 1981), but may not be the best management strategy for shorebirds that prefer sparsely vegetated or open habitats. Also, habitat use patterns of migrant shorebirds may be inconsistent with waterfowl management practices that maximize the availability of deep water areas (Colwell and Oring 1988). Therefore, wetland managers must understand habitat requirements of both waterfowl and webless wetland birds to successfully implement multi-species management.

2.5 Multi-species management

The relationship between water depth and foraging habitat of wetland birds has been the basis for wetland management of wildlife habitat. DuBowy (1996) found water depth to be the most important factor affecting marsh use by herons and egrets during winter. Winter water levels at Rockefeller State Game Refuge, Cameron Parish, Louisiana were maintained at 10-20 cm and seemed to provide optimal conditions for wintering waterfowl, herons, and egrets (DuBowy 1996). However, the suitability of migration wetland habitats for wading birds where water levels are manipulated for waterfowl is largely unstudied.

Moist-soil management involves irrigating or drawing down wetlands in the spring to promote germination, growth, and seed production of annual plants (Fredrickson 1991). Invertebrates concentrate in areas containing water and saturated mud after drawdowns. High levels of invertebrates, sparse vegetation cover, and an interspersion of mudflat and shallow water associated with moist-soil management in the spring may attract migrant shorebirds. However, increased vegetation cover produced by moist-soil management for waterfowl can conflict with shorebird management for autumn migration (Rundle and Fredrickson 1981, Davis and Smith 1998). Helmers (1992) suggested that incorporating management strategies for shorebirds with waterfowl and other wetland birds can be achieved by minor changes in flooding timing, water depth., and duration of drawdowns or re-flooding on wetland complexes. Managers at Ted Shanks Wildlife Management Area in northeastern Missouri attract shorebirds by using a series of differential drawdowns and flooding that still increasied vegetation complexity for waterfowl (Helmers 1992). Moist-soil management of playas provided food resources for species of wetland birds in addition to non-breeding dabbling ducks (Anderson and Smith 2000). Past wetland management efforts for waterfowl also have positively affected rail and shorebird abundance (Burgess 1969). Additionally, moist-soil management for shorebirds and rails in Missouri produced a change in waterfowl species composition but maintained constant waterfowl numbers (Rundle and Fredrickson 1981). Managing wetlands to produce a greater diversity of microhabitats, ranging from open water of varying water depths to mudflat, has been suggested to support greater bird diversity (Reid 1993).

The overlapping niches of waterfowl and other wetland birds implies that management strategies can be devised to accommodate waterfowl and other guilds of wetland birds. Compared to traditional approaches for managing waterfowl, several authors have predicted that the needs of both waterfowl and webless wetland birds can be met by reducing water depth (Helmers 1992, Laubhan and Fredrickson 1993, Reid 1993, Isola et al. 2000). Colwell and Taft (2000) found shallow water depths supported greater diversity and abundance of wetland birds in wetlands managed on wintering grounds. Few other studies have examined the influence of water depth on the number of wetland birds and species composition of communities. There is a need to study the type of management capable of supporting multiple guilds of wetland birds.

CHAPTER 3

METHODS

3.1 Study areas and wetland unit selection

My research compared waterfowl and webless wetland bird distribution and abundance across a spectrum of wetland types at 4 managed site complexes (Figure 3.1). I studied 2 coastal wetland complexes in northwestern Ohio; Winous Point Marsh Conservancy (WPMC) and Pickerel Creek Wildlife Area (PCWA). Located in Ottawa County, WPMC is Ohio's largest private wetland complex, maintaining 1,822 ha of wetlands along western Sandusky Bay. Also located on Sandusky Bay in Sandusky county, PCWA is a 1,143-ha wetland complex managed by the Ohio Division of Wildlife (ODW) for public hunting, trapping, fishing, and wildlife-viewing . North American Wetland Conservation Act funds have been used to conserve and restore wetland habitats at both coastal sites.

Two inland wetland complexes were located in central Ohio; Killdeer Plains (KPWA) and Big Island Wildlife Areas (BIWA). Located in Wyandot county, KPWA is a 3,493-ha wildlife area managed by ODW for public hunting, trapping, fishing, and wildlife-viewing. Located in Marion county south of KPWA, BIWA is a 2,037-ha wildlife area

Figure 3.1. Wetland complex location (asterisk) in Marion, Wyandot, Sandusky, and Ottawa counties of Ohio where research was conducted from August 2001 - June 2002.

managed by ODW for public hunting, trapping, fishing, and wildlife-viewing. North American Wetland Conservation Act funds were used to conserve and restore wetlands at BIWA.

I randomly selected individual wetland units within and near (<1.6 km) each wetland complex based on National Wetlands Inventory (NWI) maps and ground reconnaissance (APPENDIX A). Forty-seven suitable wetland units were selected and defined as basins having distinct water regimes such as saturated or artificially, permanently, semipermanently, temporarily, seasonally, or intermittently flooded (Cowardin et al. 1992). I categorized wetland units as managed or unmanaged. I defined managed wetlands as those having water depths and distributions that were actively manipulated with pumps or siphons through a system of dikes, dams, or levees. I defined unmanaged wetlands as those having an unregulated water regime in which water levels varied only with natural precipitation, evaporation, and transpiration. Wetland units were further classified by their predominant vegetation cover classes including open water, persistent emergent marsh hereafter (deep marsh), and non-persistent emergent marsh hereafter (moist soil). The random sample of wetlands was selected from units stratified by management category and vegetation cover.

3.2 Diurnal counts

I conducted mostly complete coverage diurnal counts of wetland birds 1-2 times per week on each wetland unit during autumn (August-December 2001) and spring (March-June 2002) migrations. Partial coverage counts were obtained on large wetland units where emergent vegetation restricted visibility. Counts on these units were recorded only from consistent survey points where access and visibility were unrestricted. Utilization rates were calculated by dividing cumulative total counts by total wetland area (complete coverage counts) or area surveyed (partial coverage counts).

Surveys were conducted from motorized vehicles or on foot along fixed routes. Survey routes encompassed the perimeter of each wetland unit. Wetland birds were observed during daylight with 8 x 45 binoculars or 15 x 60 spotting scope. Surveys were conducted during 2 time periods each week; morning (sunrise - noon) and afternoon (noon - sunset). Morning and afternoon survey times were randomly alternated to avoid counting birds on individual wetland units at the same time on consecutive days or weeks. All visible birds were counted and identified to species or foraging guild. Guilds were defined according to food and habitat preferences and foraging behavior (APPENDIX B). Counts were separated by vegetation type within wetland units (open water, deep marsh, moist soil) where birds were observed.

Behavior (i.e., feeding, locomotion, loafing, other) also was recorded. Waterfowl and shorebird behaviors were determined with instantaneous flock (>10 birds) scans (Altmann 1974). Behaviors of solitary and secretive wading birds were not recorded.

Shorebird feeding behavior was recorded when heads were facing down and birds were searching, probing, or touching food. Dabbling duck feeding behavior was recorded when heads were submerged in the water and birds were actively searching or touching food. Diving duck feeding behavior was recorded when bodies were completely submerged in the water as a result of diving and when birds were touching food. For all foraging guilds, locomotion was defined as aerial, aquatic, or ground movement in one direction with head in an upright position. Loafing behavior was recorded when bodies were stationary, heads were in an upright position, and in most cases, legs were not visible. Finally, additional types of behavior were recorded as other, such as locomotion which occurred as a result of survey disturbance, preening, and courtship.

3.3 Wetland unit characteristics

Wetland habitat base maps were created from aerial photographs and ground-truthing. Changes in water levels and vegetation distribution were recorded on base maps of each wetland unit throughout autumn and spring migrations. Coverage and interspersion of microhabitats (open water, non-persistent emergent vegetation, persistent emergent vegetation, floating vegetation, submerged vegetation, levee, rocks, dry mud, wet mud) were recorded to compare bird use among habitat types in each wetland unit. Wetland area (ha), wetland perimeter (km), and distance (km) to the nearest wetland were recorded to assess differences in bird use associated with wetland characteristics.

3.4 Wetland management surveys

Study area managers were surveyed in July 2002 to determine how wetlands were managed during autumn 2001 and spring 2002. The timing, extent, and duration of wetland unit drawdowns and re-flooding were recorded during each survey. Additional wetland unit management practices (disking, burning, mowing, planting, chemical application) also were recorded. Each wetland was classified according to hunting or wildlife viewing access (public, private, refuge).

3.5 Data summary and analysis

I used canonical correspondence analysis (CCA) in the computer program PC-ORD (McCune and Mefford 1999), to ordinate species occurrence and abundance along environmental gradients. CCA is a constrained ordination that uses multiple regression to relate species composition to measured environmental variables (McCune and Grace 2002). CCA is a unimodal response model, that tests the statistical significance of linear combinations of environmental variables that are most strongly related to species composition. I chose to use a direct gradient analysis because I was interested only in the wetland bird community structure as it related to the continuous environmental variables [wetland area (ha), wetland perimeter (m), mean percent inundation, percent of wetland inundated during early migration (September 15, autumn; April 15, spring), net change in percent inundation (absolute value of the maximum percent inundation minus the minimum percent inundation), inundation variance, percent cover of vegetation, and the percent cover of mudflat]. Timing of inundation was relative (early vs. late) to wetland bird migration chronology. Associated with the peaks in waterfowl migration chronology, this variable largely distinguished moist soil-managed wetlands from other types of wetland management. Species data were expressed as a density (no./visit/ha) during autumn and spring. I square root-transformed all densities because species data were skewed (many low densities and few high densities). Linear combination (LC) scores were used to compose all biplots to represent the best fit of species community structure to the environmental variables.

A Monte Carlo Permutation Procedure (MCPP) was used to test the null hypothesis that no linear relationship existed between species composition and continuous environmental variable matrices. In other words, MCPP was used to determine whether the species-environment relationships depicted in CCA were different from that which would be observed by chance (McCune and Grace 2002). The significance of the linear combinations of continuous environmental variables defined in CCA were determined by MCPP with 999 permutations.

Nonparametric multi-response permutation procedures (MRPP) were used to compare species composition and environmental conditions among categorically grouped environmental variables (wetland access, landscape, management, wetland cover type). MRPP is analogous to the *t*-test and one-way analysis of variance *F* test in that the purpose of the technique is to detect concentration within *a priori* groups (Zimmerman et al. 1985). However, MRPP does not require data structure that conforms to a normal distribution and homogeneous variances. MRPP was performed separately on the environment and species data matrices to compare species composition and environmental characteristics between pre-determined groupings of individual wetlands (e.g., wetland access, private/public/refuge; landscape, coastal/inland; management, managed/unmanaged; wetland cover type, moist soil/persistent emergent marsh/open water). Wetland access groups were defined according to the type of hunting disturbance during autumn and wildlife-viewing disturbance during spring. For example, a wetland hunted by private landowners was considered a private wetland during autumn. That same wetland was defined as a refuge if it lacked human influence throughout the migration during spring.

I performed a partial CCA with the program CANOCO (ter Braak 1992) to analyze the relative importance and interaction of the continuous and categorical variables in structuring wetland bird communities. Categorical variables were dummy-coded and used as covariables in the partial ordination. The constrained eigenvalues and total inertia obtained from the partial CCA made it possible to calculate the percent variation in species ordination uniquely described by the environment (but not the covariable), uniquely described by the covariable (but not the environment), variation jointly described by both, and the variance that was unexplained.

In addition to the multivariate analyses performed to examine differences in species composition associated with the environment, I used MRPP (BLOSSOM, Cade and Richards 2001) to compare densities among categorical environmental variables within each guild. Instead of examining differences in wetland bird densities pertaining solely to the presence or absence of management, comparisons made among wetlands were further categorized to reflect the timing, extent, and duration of management. September 15, 2001 was the date used to distinguish early and late re-flooding regimes relative to migration chronology and observed wetland management. April 15, 2002 was the date used to distinguish early and late drawdown regimes during spring. Because timing of management directly affects wetland hydroperiods, wetlands that were not managed were categorized as having a natural water regime. A water level management regime that lasted longer than 2 weeks was defined as being slow in duration. The majority of these wetlands had a water level management regime that lasted longer than 14 days. A water level management regime that lasted under 2 weeks was defined as being fast in duration.

The majority of these wetlands had a water level management regime that lasted less than 10 days. The presence of surface water and some exposed substrate defined a partial drawdown or re-flooding regime on managed wetlands. A wetland was determined to be partially flooded when surface water accounted for <80% of the wetland area during autumn. A wetland was considered partially drawn down when exposed substrate accounted for less than 80% of the wetland area during spring. A drawdown regime was defined as complete when more than 80% of the wetland area was exposed substrate. In turn, a re-flooding regime was defined as complete when more than 80% of the wetland area was inundated. Ninety MRPP's were run for each migration (6 guilds, 15 groups). For categories having 3 groups, pairwise comparisons were made by re-running each MRPP constrained by 1 group at a time.

CHAPTER 4

RESULTS

4.1 Relative abundance and species composition

I recorded 142,297 observations of wetland birds during autumn migration (APPENDIX C). The most abundant species observed within each guild included killdeer (*Charadrius vociferus*) (99%), common snipe (*Gallinago gallinago*) (35%), greater and lesser yellowlegs (*Tringa melanoleuca* and *T. flavipes*) (97%), great blue heron (*Ardea herodius*) (76%), mallard (*Anas platyrhynchos*) (56%), and ruddy duck (*Oxyura jamaicensis*) (91%). I recorded 36,402 observations of wetland birds during spring migration (APPENDIX D). The most abundant species observed in each guild were killdeer (71%), dunlin (*Calidris alpina*) (96%), long- and short-billed dowitchers (*Limnodromus scolopaceus* and *L. griseus*) (59%), great blue heron (75%), mallard (29%), and ring-necked duck (*Aythya collaris*) (43%). Dabbling ducks were the most abundant species observed during autumn (Figure 4.1) and spring (Figure 4.2) migration.

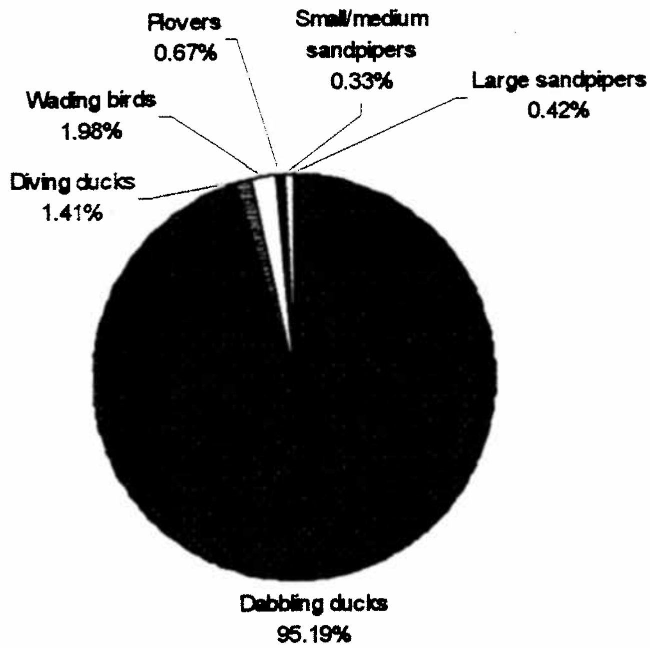

Figure 4.1. Relative abundance (%) of wetland bird foraging guilds observed on wetlands in Ohio during autumn 2001.

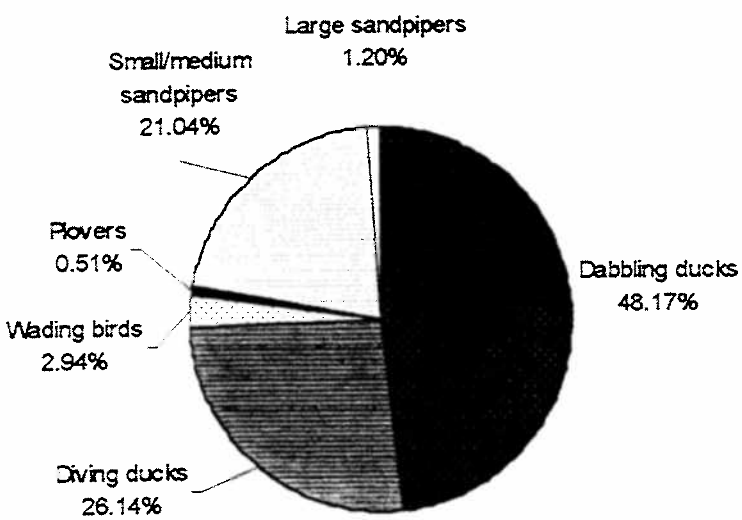

Figure 4.2. Relative abundance (%) of wetland bird foraging guilds observed on wetlands in Ohio during spring 2002.

4.2 Wetland bird activity

Autumn.- Feeding was the most common behavior of dabbling ducks in persistent marshes and moist soil wetlands during autumn (Table 4.1). The majority of dabbling duck behavior observed in open water wetlands was loafing. The majority of diving duck behavior observed in persistent marshes was loafing. All diving duck behavior recorded in moist soil wetlands was feeding. Most diving duck behavior in open water wetlands was locomotion, followed by loafing, and feeding. Feeding was the most common behavior recorded for plovers, small/medium sandpipers, and large sandpipers on persistent marshes and open water wetlands. Shorebird flocks were not large enough to record behavior in moist soil wetlands. The large percent of plover behavior recorded as other on marsh wetlands can be attributed to killdeer disturbance on the levees.

Spring.– The majority of dabbling duck behavior observed on all wetland types was feeding during spring (Table 4.2). The majority of diving duck behavior observed on persistent marshes and moist soil wetlands was feeding. Most diving ducks were loafing in open water wetlands, followed by feeding and locomotion.. Feeding was the most common behavior observed among all shorebird guilds. Contrary to autumn, feeding behavior was recorded for plovers and small/medium sandpipers in moist soil wetlands. Plover flocks were not large enough to record behavior in persistent marshes and open water wetlands. Large sandpiper flocks were not large enough to record behavior in moist soil wetlands.

Guild Behavior	Persistent Marsh	Moist Soil	Open Water
Dabbling ducks			
Feeding	75.5	99.5	23.5
Loafing	29.5	1.0	52.0
Locomotion	9.5		17.5
Other	10.5	0.1	14.3
Diving ducks			
Feeding	76.9	100.0	36.0
Loafing	100.0		36.8
Locomotion	46.2		45.2
Plovers			
Feeding	65.1		98.6
Loafing	3.5		1.4
Locomotion	29.2		
Other	36.0		
Small/medium sandpipers			
Feeding	100.0		77.1
Loafing			22.5
Locomotion			0.4
Large sandpipers			
Feeding	100.0		100.0

Table 4.1. Relative abundance (%) of foraging guild behavior observed on all wetland types at Big Island Wildlife Area, Killdeer Plains Wildlife Area, Pickerel Creek Wildlife Area, and Winous Point Marsh Conservancy during autumn 2001.

Guild Behavior	Persistent Marsh	Moist Soil	Open Water
Dabbling ducks			
Feeding	85.4	84.3	98.2
Loafing	7.6	10.2	0.8
Locomotion	1.4	32.4	1.0
Other	16.5		
Diving ducks			
Feeding	77.0	54.2	46.0
Loafing	25.1	8.4	67.5
Locomotion	5.7	9.2	6.0
Plovers			
Feeding		100.0	
Small/medium sandpipers			
Feeding	97.0	100.0	100.0
Loafing	6.9		
Large sandpipers			
Feeding	100.0		100.0

Table 4.2. Relative abundance (%) of foraging guild behavior observed on all wetland types at Big Island Wildlife Area, Killdeer Plains Wildlife Area, Pickerel Creek Wildlife Area, and Winous Point Marsh Conservancy during spring 2002.

4.3 Migration chronology

Utilization rates were calculated by dividing total observations summed across all surveys by wetland area that was surveyed. Dabbling duck utilization of inland wetlands peaked in late August and early October (Figure 4.3). A noticeable decline in dabbling duck use occurred after the passage of a strong cold front on October 24, 2001. The first peak in dabbling duck use of coastal wetlands occurred during mid-September. Dabbling duck use peaked again between periods of high rainfall in mid-October and the strong cold front in late October. Diving duck use was constant until ruddy ducks (*Oxyura jamaicensis*) passed in mid-October and hooded mergansers (*Lophodytes cucullatus*) moved through inland sites in November and December. Diving duck migration also was affected by strong weather patterns in late October, increasing in mid-October to a peak in early November.

Surveys were begun at least 1 month too late to observe the entire waterfowl migration during spring (Figure 4.4). Spring surveys began during the peak of dabbling and diving duck use of inland wetlands. Dabbling and diving ducks shared similar migration patterns, declining steadily from late March to early June. Diving duck use declined steadily from late March to early June. Although dabbling ducks shared a similar migration chronology with diving ducks on coastal wetlands, resident wood ducks (*Aix sponsa*) and mallards (*Anas platyrhynchos*) caused a slight increase in wetland use during late May and early June.

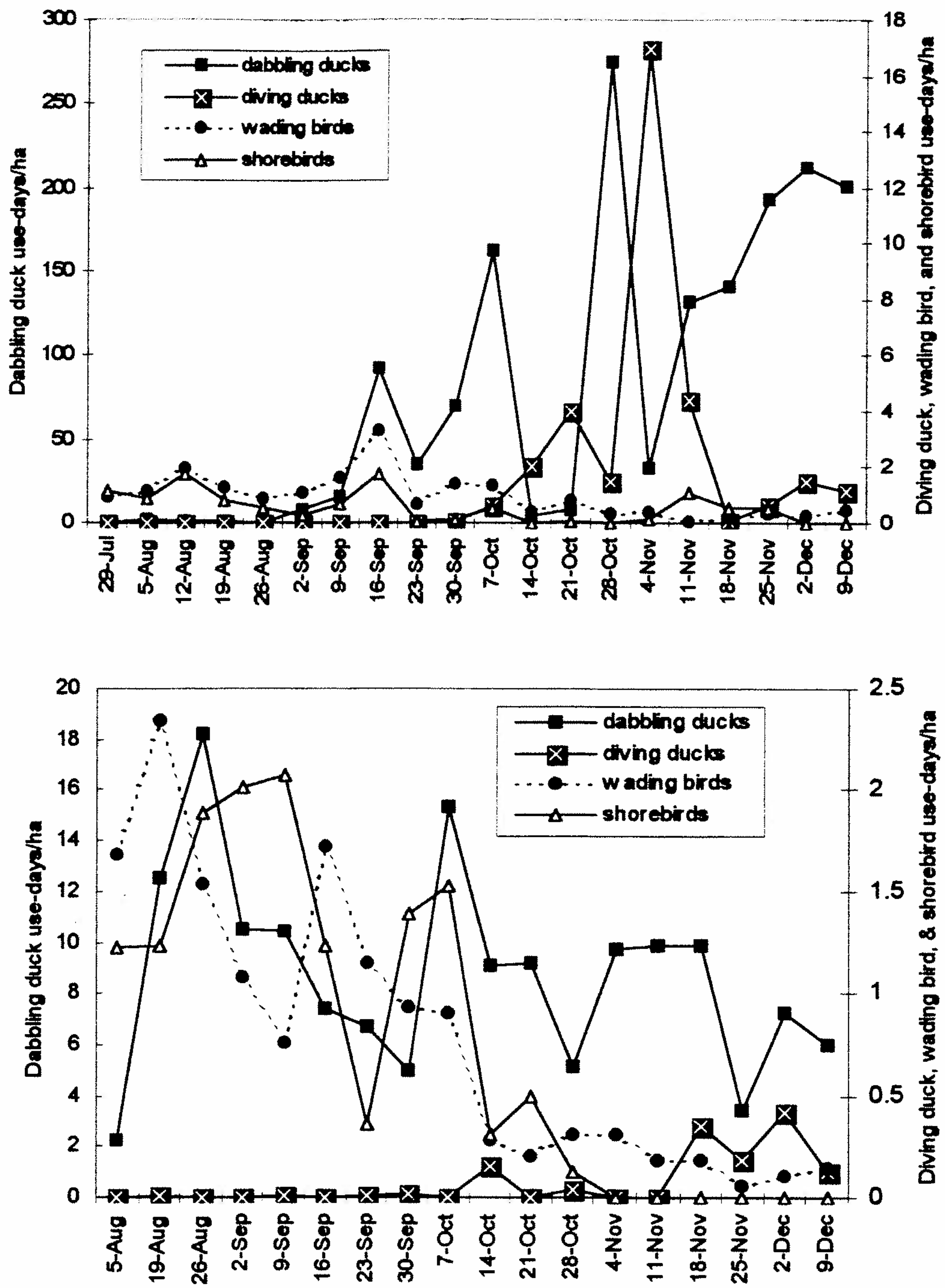

Figure 4.3. Autumn 2001 migration chronology for dabbling ducks, diving ducks, wading birds, and shorebirds on inland (top) and coastal (bottom) wetlands in central and northwestern Ohio expressed as weekly use-days/ha.

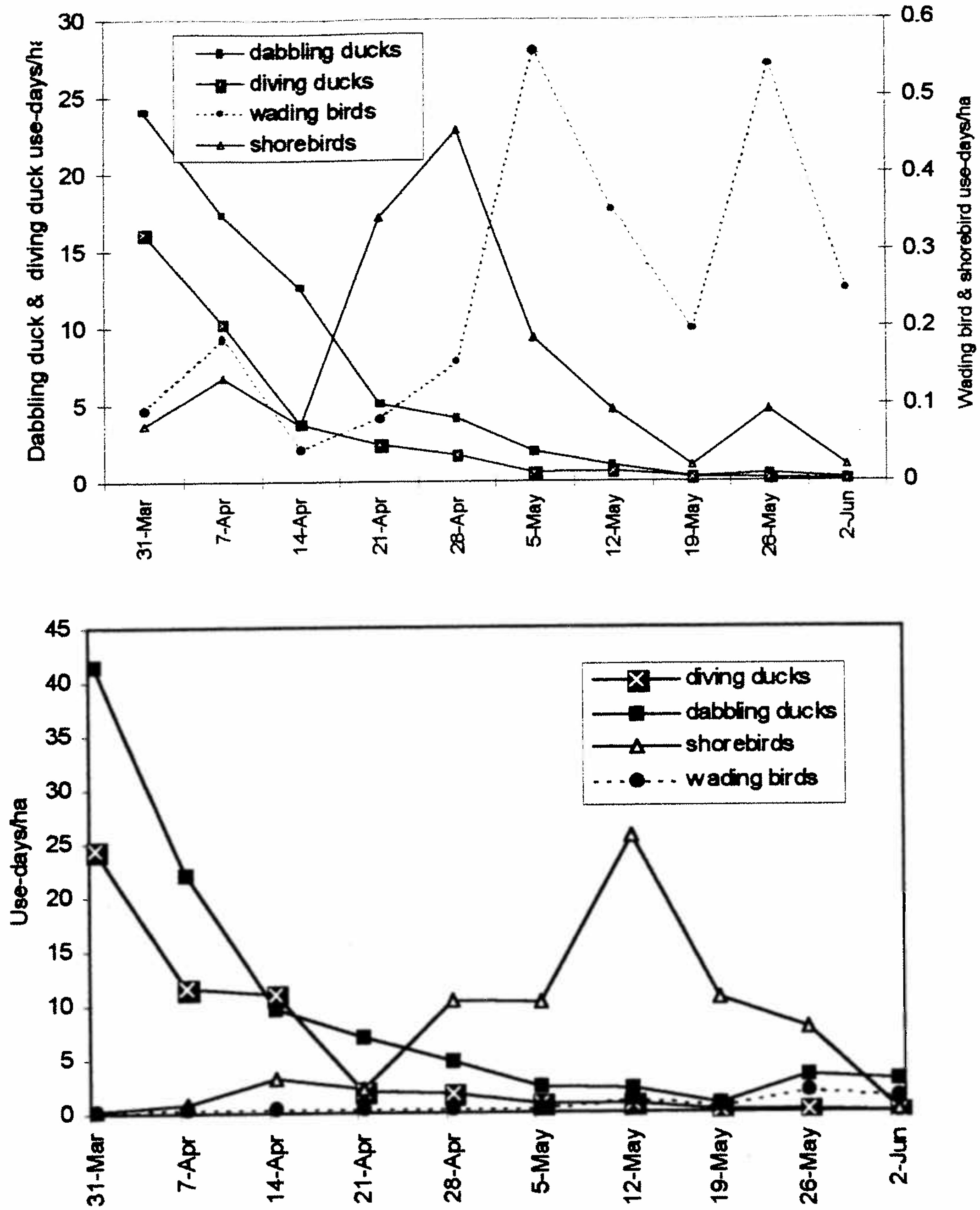

Figure 4.4. Spring 2002 migration chronology for dabbling ducks, diving ducks, wading birds, and shorebirds on inland (top) and coastal (bottom) wetlands in central and northwestern Ohio expressed as weekly use-days/ha.

Shorebird migration peaked twice on inland wetlands during autumn, following the migration pattern of wading birds by approximately 3 weeks (Figure 4.3). Autumn migration on coastal wetlands was characterized by 2 concurrent peaks in shorebird and wading bird use. Dunlins (*Calidris alpina*) were responsible for a small peak in shorebird utilization of coastal wetlands during November. Wading bird and shorebird use peaked 3 times on inland wetlands during spring migration (Figure 4.4). Shorebird utilization of coastal wetlands peaked in mid-May. Wading bird utilization of coastal wetlands peaked twice in early and late May.

4.4 <u>Species ordination along environmental gradients</u>

Canonical correspondence analysis detected a significant relationship between the distribution of species and the continuous environmental variables during autumn and spring (Tables 4.3 and 4.4). The first 2 axes explained most of the variation in the species data and had the highest species-environment correlations. I chose not to interpret axis 3 because it explained the least amount of variance and was not significant ($P > 0.10$; MCPP). Although axis 1 was not significant ($P > 0.10$; MCPP) during spring, I chose to interpret it because it explained the most variance in species data and had a high species-environment correlation.

In order to describe species' response to the environment to control for disturbance, I present the data from CCA constrained by the wetland access variable during both autumn and spring (see 4.5.3 Wetland Access). Environmental variables are represented by arrows radiating from the origin of each CCA biplot (McCune and

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.370	0.214	0.148
Variance in species data			
% of variance explained	10.8	6.3	4.3
cumulative % explained	10.8	17.1	21.4
Species-environment correlation	0.913	0.841	0.799
P (Monte Carlo Permutation Procedure)	0.012	0.085	0.114

Table 4.3. Canonical correspondence analysis (CCA) of wetland bird species in Ohio during autumn 2001. Total variance (inertia) in species data is 3.4253.

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.212	0.164	0.116
Variance in species data			
% of variance explained	8.4	6.5	4.6
cumulative % explained	8.4	15.0	19.6
Species-environment correlation	0.809	0.841	0.767
P (Monte Carlo Permutation Procedure)	0.456	0.097	0.242

Table 4.4. Canonical correspondence analysis (CCA) of wetland bird species in Ohio during spring 2002. Total variance (inertia) in species data is 2.510

Mefford 1999, Kirk and Hobson 2001). The lengths of arrows are directly related to the relative association of each variable with density and frequency of wetland birds at each site. Thus, a long arrow indicates a strong influence of that environmental variable on the species community. The angle of intersection between each environmental variable arrow and ordination axis reflects the degree of correlation of the environmental variable with that axis.

Autumn.— Lengths of arrows representing percent mudflat, net change inundation, area, and perimeter indicated a strong relationship between those continuous environmental variables and the wetland bird community (Figure 4.5). Net change inundation, percent mudflat, inundation variance, early percent inundation, and mean percent inundation were mostly associated with axis 1 (horizontal axis). The arrow representing percent vegetation had a small angle of intersection with axis 2 (vertical axis). The angle of intersection of the arrows representing area and perimeter were approximately 45 degrees, indicating a similar degree of correlation with both axes. Thus, axis 1 represented a water regime gradient from small, shallow wetlands with a greater percent mudflat and net change inundation to large, deep wetlands with little mudflat and a low net change inundation. Axis 2 represented a vegetation density gradient from small wetlands containing a high percentage of vegetation cover to large, non-vegetated wetlands.

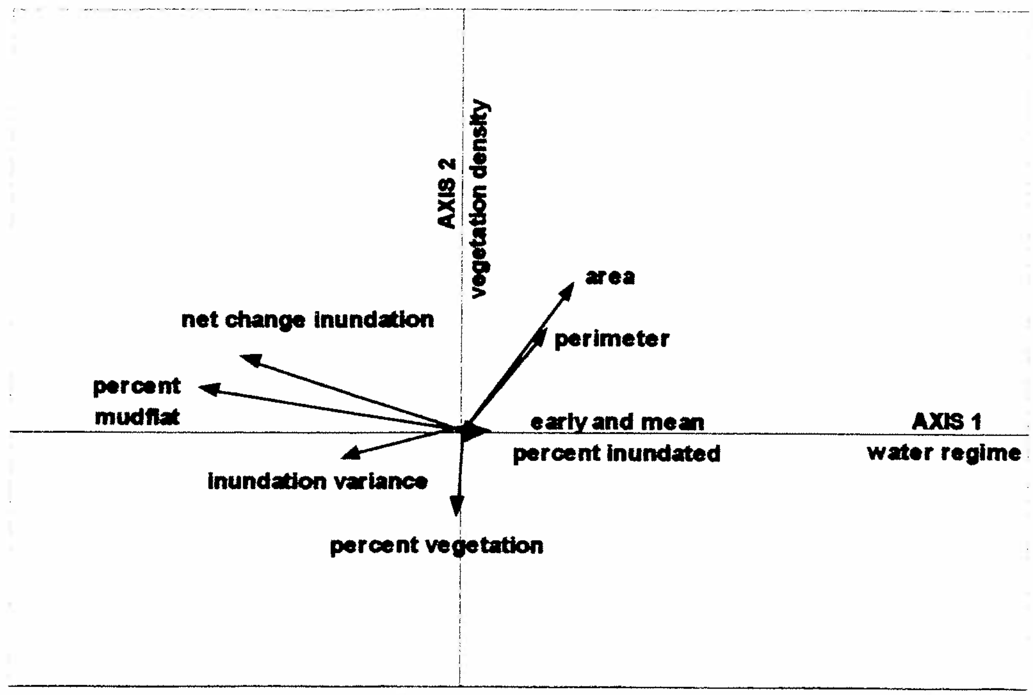

Figure 4.5. Canonical correspondence analysis (CCA) biplot of the continuous environmental variable data collected during autumn 2001 in which arrow lengths and angles of intersect are related to the importance of the environmental variables in the species ordination.

The water regime gradient explained more of the variation in species community structure than did the vegetation density gradient during autumn. Except for common goldeneye (*Bucephala clangula*), species groupings around axis 2 were tighter than along axis 1. The species-environment correlation was also higher for axis 1 than axis 2.

My interpretation of the axes is supported in the species biplot (Figure 4.6). Axes 1 and 2 separated species guilds along wetland water regime and vegetation density gradients (Table 4.5). Polygons representing wading bird and diving duck guilds overlapped with dabbling ducks. Both shorebird guild polygons overlapped with each other but were completely separated from the other guilds.

Spring.—As in autumn, I interpreted axes 1 and 2 as vegetation density and water regime gradients during spring (Figure 4.7). Species-environment correlations were similar among axis 1and axis 2. However, the vegetation density gradient (axis 1) explained more of the variation in the community structure than the water regime gradient (axis 2) during spring. In addition, mean and early percent inundation had a stronger relationship with species community during spring, as indicated by the length of the corresponding arrows.

As in autumn, axes 1 and 2 separated species guilds along vegetation density and water regime gradients (Table 4.6). Species group centroids were grouped tightly along axis 1 (Figure 4.8). Polygons representing dabbling and diving duck guilds encompassed approximately the same region along axis 2. Although wading birds were completely enclosed within the waterfowl polygons, they occupied a position near the more inundated end of the gradient. Polygons that encompassed shorebirds ranged from the middle of

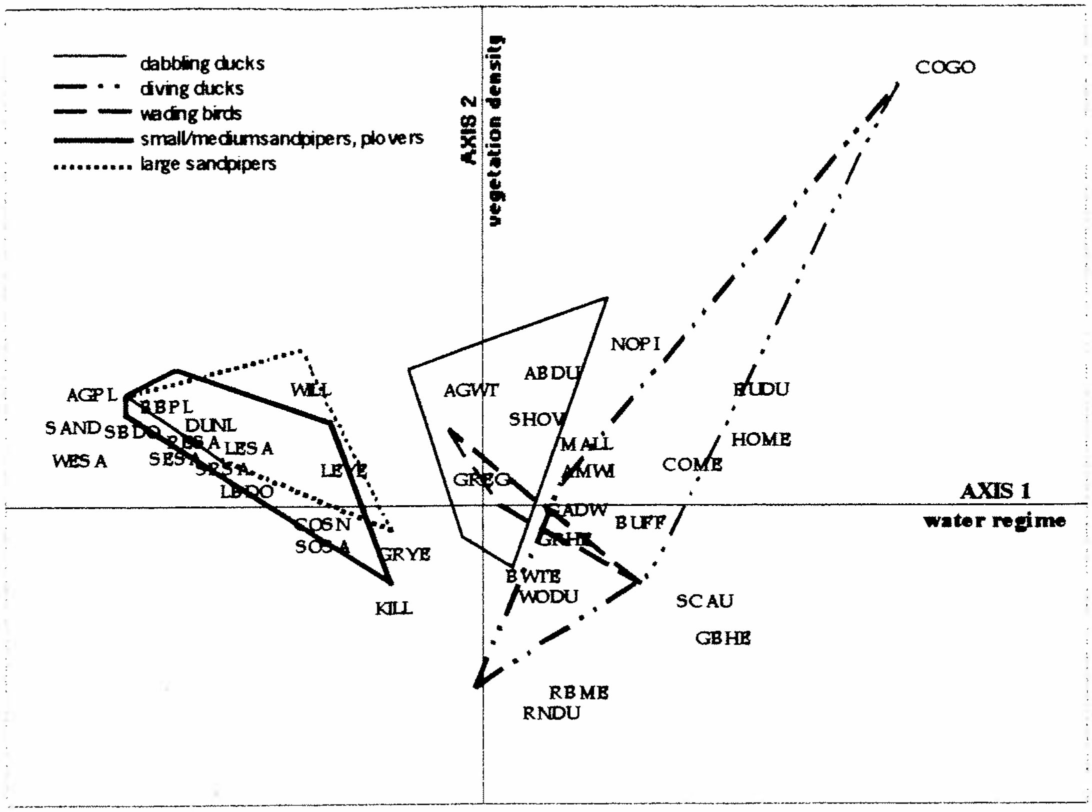

Figure 4.6. Canonical correspondence analysis (CCA) biplot showing the first and second axes and wetland bird species ordination during autumn 2001. Polygons represent the location of dabbling duck, diving duck, wading bird, small/medium sandpiper and plover, and large sandpiper foraging guilds. See APPENDIX B for species codes.

Foraging guild	Water regime gradient	Vegetation density gradient
Dabbling ducks	intermediate depth, intermediate size; intermittently exposed, and artificially, semipermanently, and permanently flooded wetlands	sparsely to moderately vegetated
Diving ducks	large, deep; semipermanently and permanently flooded wetlands	sparsely to densely vegetated
Wading birds	intermediate depth, intermediate size; artificially, semipermanently, and permanently flooded wetlands	moderately vegetated
Small/medium sandpipers & plovers	small, shallow; intermittently exposed wetlands	sparsely to moderately vegetated
Large sandpipers	small, shallow; intermittently exposed and semipermanently flooded wetlands	sparsely to moderately vegetated

Table 4.5. Physical descriptions of the types of Ohio wetlands where foraging guilds were observed according to the ordination of species along the water regime and vegetation density gradients in canonical correspondence analysis (CCA) during autumn (2001).

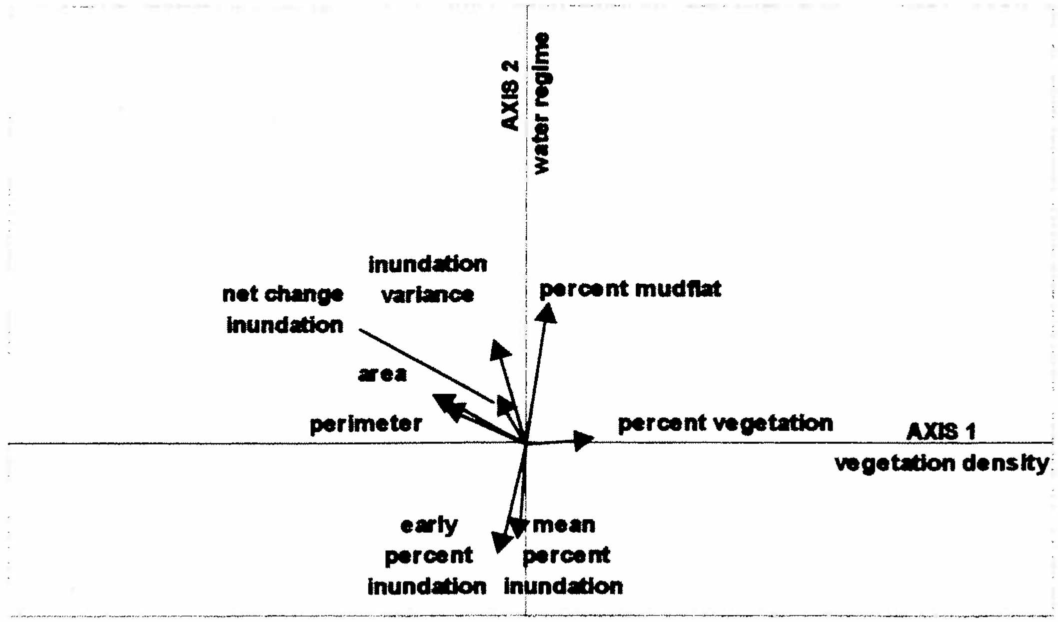

Figure 4.7. Canonical correspondence analysis (CCA) biplot of the continuous environmental variable data collected during spring 2002 in which arrow lengths and angles of intersect are related to the importance of the environmental variables in the species ordination.

Foraging guild	Water regime gradient	Vegetation density gradient
Dabbling ducks	intermediate depth, intermediate size; artificially, semipermanently, and seasonally flooded and intermittently exposed wetlands	moderately vegetated
Diving ducks	intermediate depth, intermediate to large size; artificially, semipermanently, and permanently flooded wetlands	sparsely vegetated
Wading birds	intermediate depth, intermediate size; artificially, semipermanently, and seasonally flooded wetalnds	moderately vegetated
Small/medium sandpipers & plovers	large/small, shallow; artificially, seasonally, and semipermamnently flooded and intermittently exposed wetlands	sparsely to densely vegetated
Large sandpipers	large, shallow; artificially, seasonally, and semipermanently flooded and intermittently exposed wetlands	sparsely to moderately vegetated

Table 4.6. Physical descriptions of the types of Ohio wetlands where foraging guilds were observed according to the ordination of species along the water regime and vegetation density gradients in canonical correspondence analysis (CCA) during spring (2002).

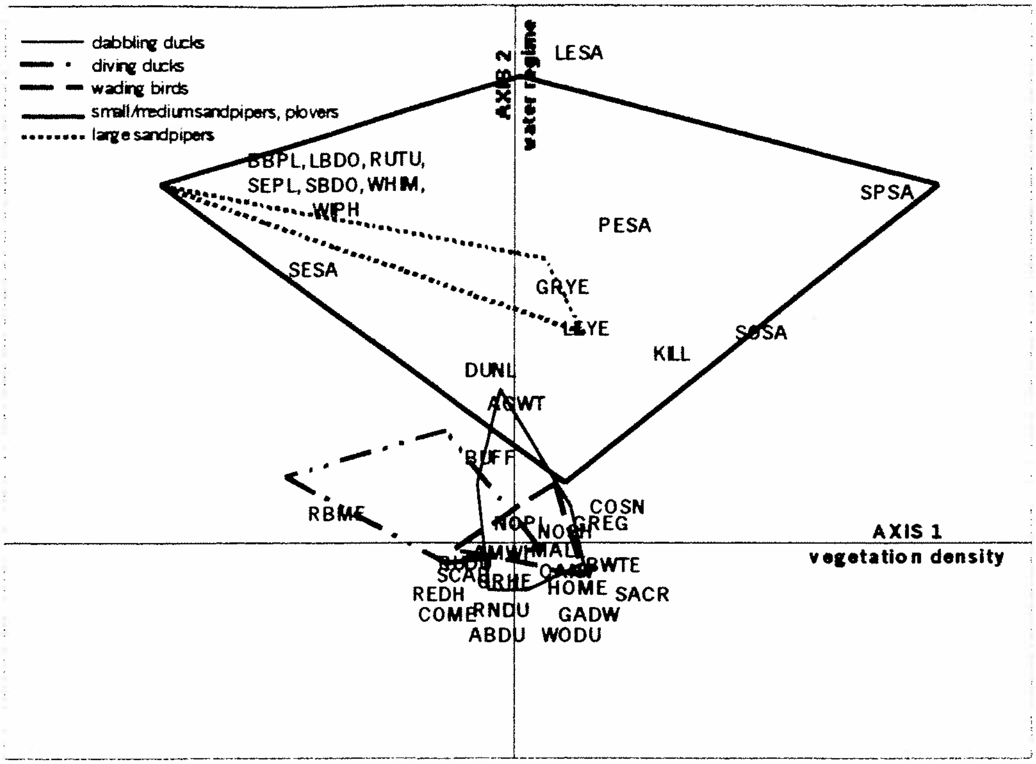

Figure 4.8. Canonical correspondence analysis (CCA) biplot showing the first and second axes and the species ordination during spring 2002. Polygons represent the location of dabbling duck, diving duck, wading bird, small/medium sandpiper and plover, and large sandpiper foraging guilds. See APPENDIX B for species codes.

the waterfowl polygon to the region of the biplot representing wetland conditions having the most mudflat and greatest fluctuations in water levels. Except for large sandpipers, all polygons representing wetland bird guilds overlapped with the polygon representing dabbling ducks. The large sandpiper guild was fully enclosed by the small/medium sandpiper and plover guild polygon.

4.5 Effects of environmental variables

4.5.1 Management regime

There were no differences in species composition or environmental conditions between wetlands categorized as managed or unmanaged during autumn and spring migration (Table 4.7). Management regime as a covariable uniquely explained <5% of the variation in wetland bird community structure during autumn and spring (Figure 4.9). However, the management covariable and the continuous environmental variables together were associated with substantial variation in wetland use patterns of waterfowl, wading birds, and shorebirds.

Wetland bird use was greatest in wetlands managed with a slow flooding regime during autumn (Figure 4.10). Waterfowl and wading bird use were greatest in wetlands managed with late, slow, and complete flooding regimes. Waterfowl use was similar among wetlands with other flooding regimes. The greatest shorebird use was observed in early, slow, and partially flooded units. Shorebird use was similar among wetlands having early and complete flooding regimes.

	n	Group sizes	T[a]	A[b]	P
Access					
Autumn					
Species	3	7,27,11	-2.379	0.026	0.029
Environment	3	7,27,11	-1.383	0.038	0.094
Spring					
Species	3	23,8,14	-3.850	0.029	0.002
Environment	3	23,8,14	-3.436	0.094	0.009
Landscape					
Autumn					
Species	2	24,21	-0.257	0.002	0.296
Environment	2	24,21	0.714	-0.014	0.771
Spring					
Species	2	25,20	-5.342	0.027	<0.001
Environment	2	25,20	0.730	-0.014	0.787
Cover type					
Autumn					
Species	3	28,11,6	-1.610	0.018	0.073
Environment	3	28,11,6	-1.072	0.030	0.132
spring					
Species	3	28,11,6	-5.292	0.040	<0.001
Environment	3	28,11,6	-1.021	0.029	0.139
Management					
Autumn					
Species	2	21,24	0.138	-0.001	0.437
Environment	2	21,24	-0.308	0.006	0.257
Spring					
Species	2	25,20	-1.072	0.006	0.137
Environment	2	25,20	-0.315	0.006	0.255

[a]test statistic

[b]chance-corrected within group agreement

Table 4.7. Multiple response permutation procedure (MRPP) summary statistics for comparisons of wetland bird species composition (species) and environmental characteristics (environment) in Ohio among groups associated with categorical environmental variables (access, landscape, cover type, management) during autumn 2001 and spring 2002.

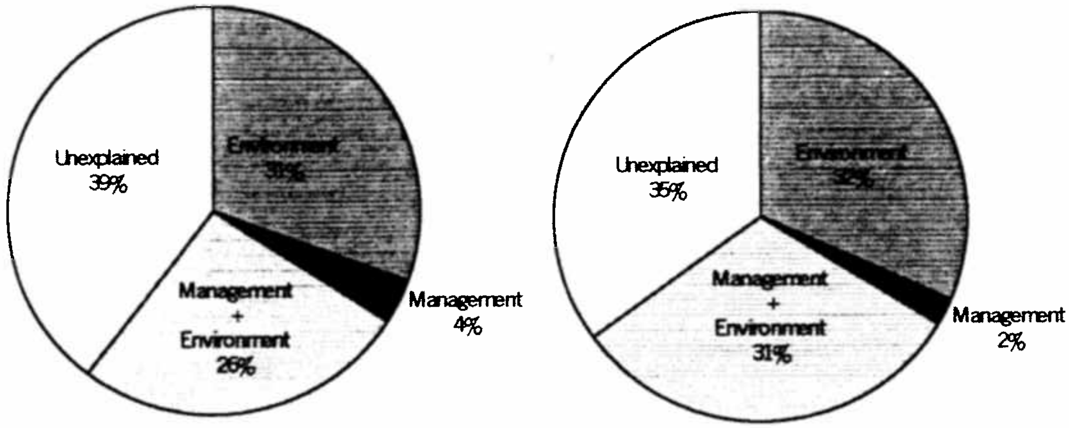

Figure 4.9. Partial canonical correspondence analysis results of the variance (%) in wetland bird species composition in Ohio explained by the environment, wetland management, wetland management and the environment, and an unexplained gradient during autumn 2001 (left) and spring 2002 (right).

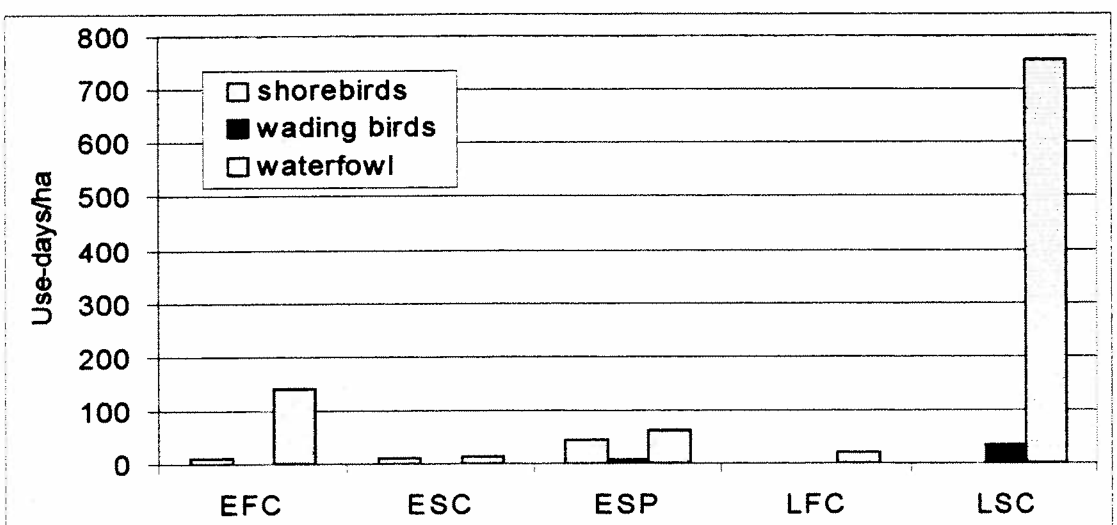

Figure 4.10. Mean cumulative use (use-days/ha) by shorebirds, wading birds, and waterfowl of managed wetlands with different timing (early=E, late=L), duration (fast=F, slow=S), and extent (partial=P, complete=C) of flooding during autumn 2001.

Early, slow, and completely drawn down wetlands accounted for the most area (14.53%) among all managed wetlands and the greatest number of waterfowl observations (80.95%) during spring. However, waterfowl, wading bird, and shorebird use were greatest in wetlands managed with a late, fast, and partial drawdown regime during spring (Figure 4.11). These wetlands accounted for only 3.43% of all surveyed area. Similar waterfowl use occurred on wetlands with partial drawdowns that were early and slow, and complete drawdowns that were late and fast (Figure 4.11). Accounting for the greatest percent of all area surveyed, early, slow, and completely drawn down wetlands and early, fast and partially drawn down wetlands had the greatest proportion of wading bird observations. However, wading bird use was greatest on wetlands with a late drawdown. Wading bird densities were greater on wetlands with a late-spring drawdown ($P < 0.10$), followed by those with a natural regime and early-spring drawdown regime (Table 4.8, Table 4.9, and Figure 4.12). Late, fast, and partially drawn down wetlands accounted for the greatest number of shorebird observations (1.76%) and greatest use among all managed wetlands. Few shorebirds (<0.01%) were observed on wetlands managed with fast, early-spring drawdowns.

4.5.2 Landscape

Partial CCA indicated that landscape type (coastal vs. inland) was associated with substantial variation in habitat use patterns of wetland birds during autumn and spring (Figure 4.13). Indeed, species composition differed between inland and coastal sites during spring (Table 4.7). Five species of shorebirds [dunlin, short-billed dowitcher,

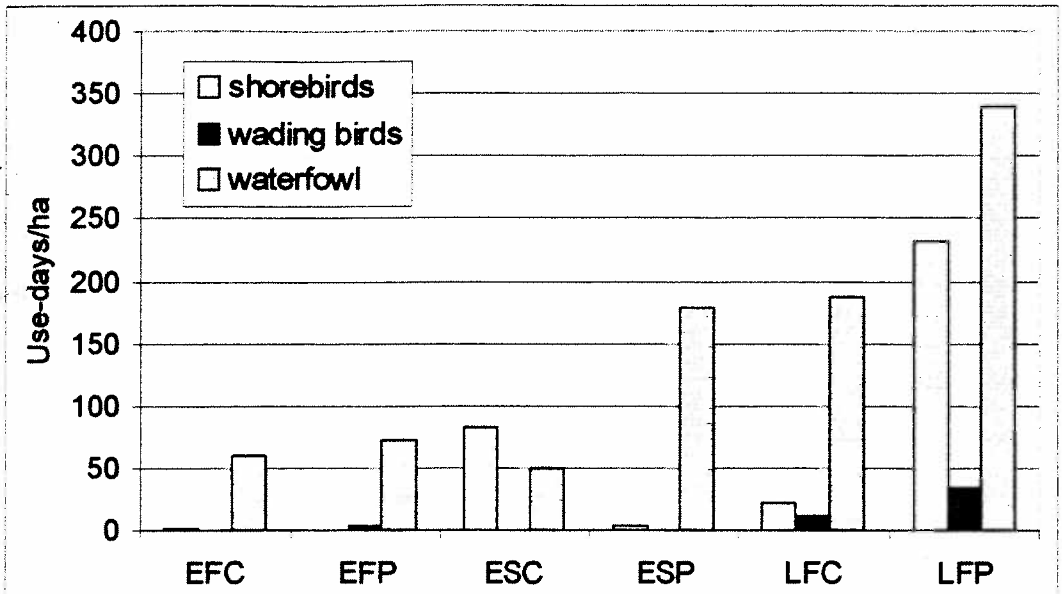

Figure 4.11. Mean cumulative use (use-days/ha) by shorebirds, wading birds, and waterfowl of managed wetlands with different timing (early=E, late=L), duration (fast=F, slow=S), and extent (partial=P, complete=C) of drawdowns during spring 2002.

Table 4.8. Multiple response permutation procedure (MRPP) summary statistics for foraging guild densities (no./visit/ha) in Ohio among categorical environmental variables (landscape, cover type, access, drawdown timing, drawdown extent, drawdown duration) during spring (2002).

		Landscape	Cover type	Access	Drawdown timing	Drawdown extent	Drawdown duration
Dabbling ducks	T[a]	-0.667	-3.301	-4.873	0.913	-0.659	-0.054
	P	0.189	0.011	0.002	0.862	0.226	0.362
	n[b]	19, 25	6, 10, 28	8, 22, 14	23, 11, 5	6, 10	12, 4
Diving ducks	T	0.172	0.154	-1.006	1.129	-0.513	0.025
	P	0.426	0.455	0.142	1.000	0.267	0.413
	n	17, 22	5, 8, 26	8, 17, 14	20, 11, 3	6, 8	10, 4
Wading birds	T	-2.675	1.177	0.365	-4.604	-1.137	-1.433
	P	0.026	0.951	0.559	0.002	0.120	0.089
	n	15, 19	4, 6, 24	8, 13, 13	19, 6, 5	5, 6	8, 3
Plovers	T	0.860	-1.514	-0.620	0.839	0.672	0.901
	P	0.842	0.081	0.219	0.803	0.717	0.845
	n	9, 9	6, 12, 0	4, 8, 6	7, 7, 4	5, 6	7, 4
Small/medium sandpipers	T	-1.451	-0.472	0.639	-0.949	0.741	0.945
	P	0.088	0.242	0.701	0.156	0.757	0.874
	n	6, 11	5, 12, 1	4, 9, 4	6, 6, 4	5, 5	7, 3
Large sandpipers	T	0.171	-4.282	-0.189	0.008	-1.328	1.080
	P	0.483	0.004	0.346	0.426	0.101	0.893
	n	7, 9	4, 12, 0	3, 6, 7	6, 6, 3	4, 5	6, 3

[a] test statistic
[b] group size

	n	T[a]	A[b]	P
Cover type				
dabbling ducks				
moist soil/persistent marsh	10, 28	-1.542	0.021	0.078
moist soil/open water	10, 6	-3.541	0.216	0.009
persistent marsh/open water	28, 6	-2.949	0.031	0.022
plovers				
moist soil/persistent marsh	6, 12	-1.514	0.028	0.081
large sandpipers				
moist soil/persistent marsh	4, 12	-4.282	0.189	0.004
Drawdown timing				
wading birds				
early/late	6, 5	-4.955	0.978	0.002
early/natural	6, 19	-0.154	0.005	0.317
late/natural	5, 19	-4.728	0.184	0.003
Wetland access				
dabbling ducks				
private/public	22, 14	-5.641	0.080	0.001
private/refuge	22, 8	-1.598	0.026	0.074
public/refuge	14, 8	-1.278	0.050	0.101

[a] test statistic
[b] chance-corrected within group agreement

Table 4.9. Multiple response permutation procedure (MRPP) summary statistics for pairwise comparisons of foraging guild densities (no./visit/ha) in Ohio among categorical environmental variables (cover type, drawdown timing, wetland access) with 3 or more groups during spring (2002).

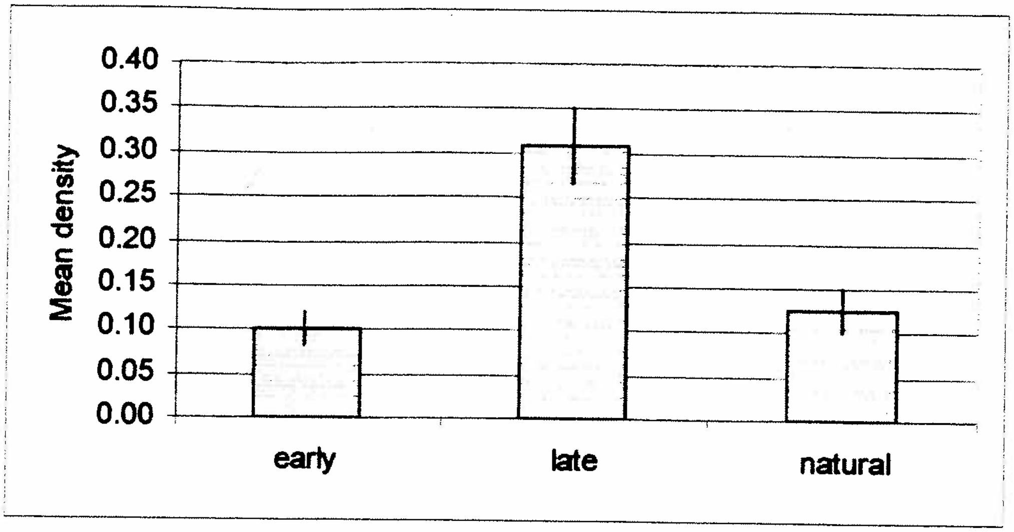

Figure 4.12. Mean densities (no./visit/ha) of wading birds on wetlands with an early, late, or natural drawdown at Killdeer Plains, Big Island, and Pickerel Creek Wildlife Areas and Winous Point Marsh Conservancy in central and northwestern Ohio during spring (2002).

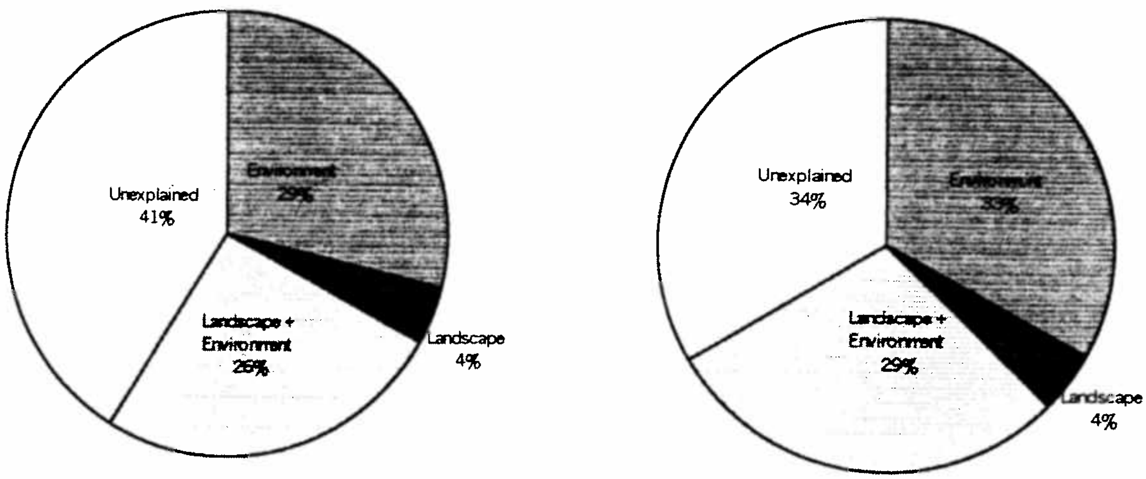

Figure 4.13. Partial canonical correspondence analysis results of the variance (%) in wetland bird species composition in Ohio explained by the environment, landscape, landscape and the environment, and an unexplained gradient during autumn 2001 (left) and spring 2002 (right).

sanderling (*Calidris alba*), black-bellied plover (*Pluvialis squatarola*), American golden plover (*Pluvialis apricaria*)] and 5 species of diving ducks [greater and lesser scaup (*Aythya marila* and *A. affinis*), ring-necked duck (*Aythya collaris*), common merganser (*Mergus merganser*), red-breasted merganser (*Mergus serrator*)] were observed using only coastal wetlands. In addition, common goldeneye was observed using only inland wetlands. Wading bird and small/medium sandpiper densities also were statistically greater on coastal wetlands during spring (Figure 4.14 and Table 4.10). Diving duck and plover densities differed between landscapes during autumn, with greater densities of diving ducks in coastal wetlands and greater densities of plovers in inland wetlands (Figure 4.15 and Table 4.10). Plover densities were greater on inland wetlands due the large number of killdeer observed on levees.

4.5.3 Wetland access

Wetland access was associated with substantial variation in habitat use patterns of wetland birds (Figure 4.16). Species composition and environmental conditions varied among wetlands with different types of hunter access during autumn and wildlife viewing during spring (Table 4.7). Pairwise comparisons indicated differences in species composition on refuge wetlands during autumn (Table 4.11). Few shorebird species were observed using refuges. Compared to public and private wetlands, waterfowl species diversity was greatest on refuges. Dabbling duck densities were different on refuges (Table 4.12) and approximately 10X greater than private wetland densities and 20X greater than public wetland densities (Figure 4.17). Environmental conditions were

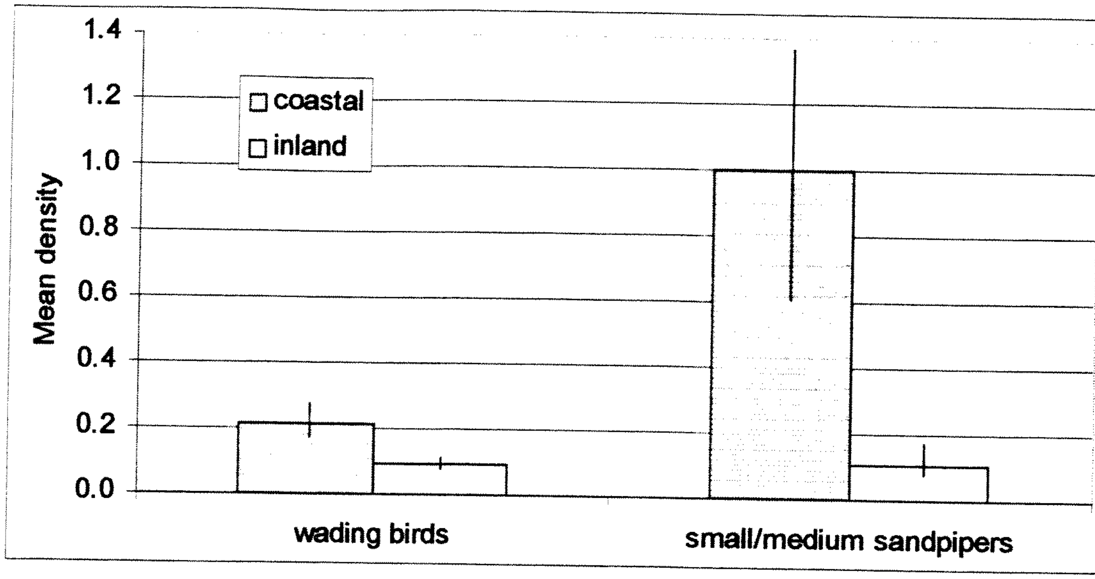

Figure 4.14. Mean densities (no./visit/ha) of wading birds and small/medium sandpipers on coastal wetlands at Pickerel Creek Wildlife Area and Winous Point Marsh Conservancy in northwestern Ohio and inland wetlands at Killdeer Plains and Big Island Wildlife Areas in central Ohio during spring 2002.

		Landscape	Cover type	Access	Flood timing	Flood extent	Flood duration
Dabbling ducks	T[a]	0.700	-1.751	-4.643	7.674	-0.526	-0.115
	P	0.743	0.064	0.003	0.428	0.207	0.357
	n[b]	16, 24	5, 9, 26	6, 27, 7	16, 12, 7	3, 15	6, 13
Diving ducks	T	-1.677	0.233	0.715	-0.224	0.975	0.423
	P	0.056	0.471	0.753	0.317	0.840	0.627
	n	7, 9	0, 4, 12	3, 9, 4	6, 4, 2	2, 4	2, 4
Wading birds	T	0.078	-0.165	0.025	-0.042	0.651	0.911
	P	0.442	0.330	0.400	0.385	0.705	0.919
	n	17, 22	5, 8, 26	5, 25, 9	17, 10, 8	3, 15	7, 11
Plovers	T	-2.174	1.122	-1.120	-1.061	0.100	0.692
	P	0.041	1.000	0.124	0.133	0.434	0.728
	n	11,13	2, 5, 17	3, 15, 6	10, 9, 3	3, 9	3, 9
Small/medium	T	0.785	0.118	-0.713	0.238	-0.627	0.521
	P	0.795	0.387	0.186	0.503	0.218	0.626
	n	10, 12	2, 4, 16	3, 14, 5	10, 5, 5	2, 8	5, 5
Large sandpipers	T	0.099	1.238	1.511	-0.023	-0.133	0.929
	P	0.399	0.917	0.968	0.434	0.383	1.000
	n	7, 9	2, 12, 2	2, 2, 12	6, 6, 2	3, 5	2, 6

[a] test statistic

[b] group size

Table 4.10. Multiple response permutation procedure (MRPP) summary statistics for foraging guild densities (no./visit/ha) in Ohio among categorical environmental variables (landscape, cover type, access, flood timing, flood extent, flood duration) during autumn 2001.

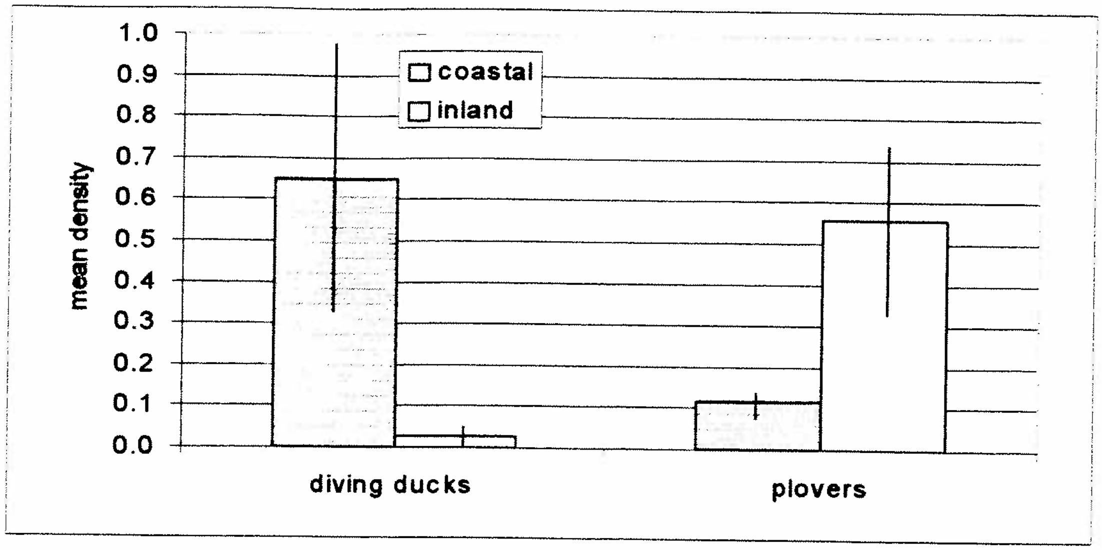

Figure 4.15. Mean densities (no./visit/ha) of diving ducks and plovers on coastal wetlands at Pickerel Creek Wildlife Area and Winous Point Marsh Conservancy in northwestern Ohio and inland wetlands at Killdeer Plains and Big Island Wildlife Areas in central Ohio during autumn (2001).

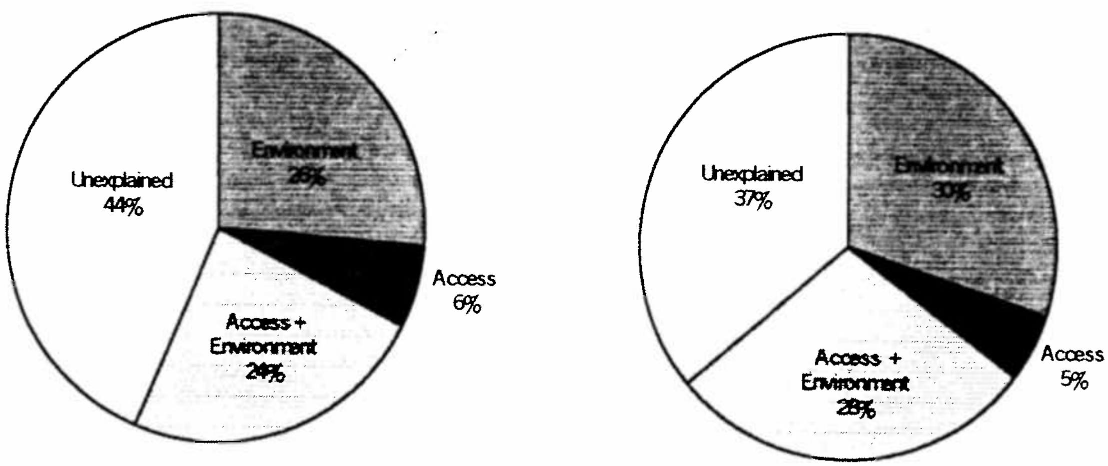

Figure 4.16. Partial canonical correspondence analysis results of the variance (%) in wetland bird species composition in Ohio explained by the environment, wetland access, wetland access and the environment, and an unexplained gradient during autumn 2001 (left) and spring 2002 (right).

	n	T[a]	A[b]	P
Cover type				
Autumn species				
Moist soil/persistent marsh	28, 11	0.555	-0.004	0.650
Moist soil/open water	28, 6	-3.730	0.038	0.008
Persistent marsh/open water	11, 6	-0.039	0.001	0.359
Spring species				
Moist soil/persistent marsh	28, 11	-2.682	0.016	0.018
Moist soil/open water	28, 6	-4.010	0.029	0.003
Persistent marsh/open water	11, 6	-4.569	0.090	0.002
Wetland access				
Autumn species				
Private/public	27, 11	0.998	-0.008	0.918
Private/refuge	27, 7	-2.930	0.034	0.019
Public/refuge	11, 7	-2.393	0.049	0.028
Autumn environment				
Private/public	27, 11	-1.617	0.038	0.072
Private/refuge	27, 7	-0.061	0.002	0.332
Public/refuge	11, 7	-1.724	0.081	0.065
Spring species				
Private/public	23, 14	-5.473	0.034	<0.001
Private/refuge	23, 8	-1.261	0.010	0.109
Public/refuge	14, 8	0.456	-0.006	0.627
Spring environment				
Private/public	23, 14	-4.082	0.089	0.007
Private/refuge	23, 8	-2.346	0.073	0.036
Public/refuge	14, 8	0.006	-0.001	0.368

[a]test statistic

[b]chance-corrected within group agreement

Table 4.11. Multiple response permutation procedure (MRPP) summary statistics for pairwise differences in species composition and environmental characteristics in Ohio among wetland access (private, public, refuge) and cover type (moist soil, persistent marsh, open water) groups during autumn 2001 and spring 2002.

	n	T[a]	A[b]	P
Cover type				
Moist soil/persistent marsh	9, 26	-2.108	0.052	0.004
Moist soil/open water	9, 5	0.583	-0.035	0.658
Persistent marsh/open water	26, 5	-3.174	0.060	0.002
Wetland access				
Private/public	27, 7	-0.726	0.020	0.173
Private/refuge	27, 6	-4.679	0.113	0.004
Public/refuge	7, 6	-2.571	0.171	0.025

[a]test statistic

[b]chance-corrected within group agreement

Table 4.12. Multiple response permutation procedure(MRPP) summary statistics for pairwise comparisons of dabbling duck densities (no./visit/ha) in Ohio among categorical environmental variables (cover type, wetland access) with 3 or more groups during autumn 2001.

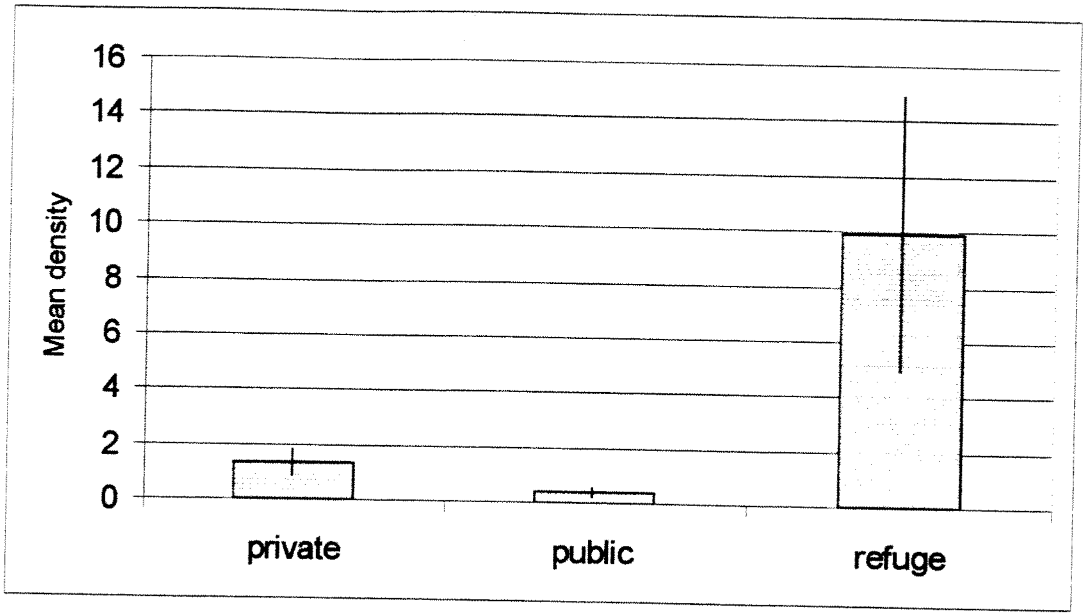

Figure 4.17. Mean densities (no./visit/ha) of dabbling ducks on privately- and publicly hunted wetlands and refuges at Killdeer Plains, Big Island, and Pickerel Creek Wildlife Areas and Winous Point Marsh Conservancy in central and northwestern Ohio during autumn 2001.

different from refuges and private wetlands on public wetlands during autumn (Table 4.7). Compared to refuges and private wetlands, public wetlands were typically large, highly inundated units. In general, public wetlands had the lowest amounts of vegetation cover and less water level fluctuation during autumn.

Species composition was different between private and public wetlands during spring (Table 4.11). Compared to public wetlands, 1 additional wading bird species [sandhill crane (*Grus canadensis*)] and 10 additional shorebird species [long- and short-billed dowitchers, black-bellied plover, sanderling, least sandpiper (*Calidris minutilla*), ruddy turnstone (*Arenaria melanocephala*), semipalmated plover (*Charadrius semipalmatus*), semipalmated sandpiper (*Calidris pusilla*), whimbrel (*Numenius phaeopus*), Wilson's phalarope (*Phalaropus tricolor*)] were observed using private wetlands. The environmental conditions on private wetlands differed significantly from both public and refuge wetlands during spring (Table 4.11). A typical private wetland was small in size and had a high degree of water level fluctuation and more exposed substrate. Dabbling duck densities were greater in private wetlands (Table 4.9), followed by refuges and public wetlands (Figure 4.18).

4.5.4 Cover types

Wetland cover type was associated with substantial variation in wetland use patterns of all foraging guilds (Figure 4.19). Species composition differed among wetland cover types during autumn (Table 4.7). Pairwise comparisons among wetland cover types indicated that species composition differed between moist soil and open water wetlands

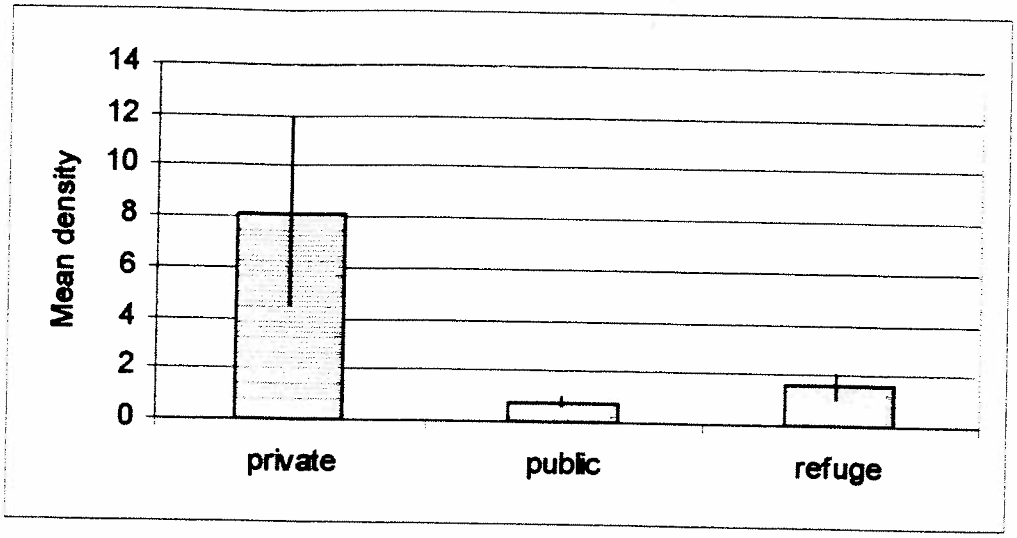

Figure 4.18. Mean densities (no./visit/ha) of dabbling ducks on privately- and publicly accessed wetlands and refuges at Killdeer Plains, Big Island, and Pickerel Creek Wildlife Areas and Winous Point Marsh Conservancy in central and northwestern Ohio during spring 2002.

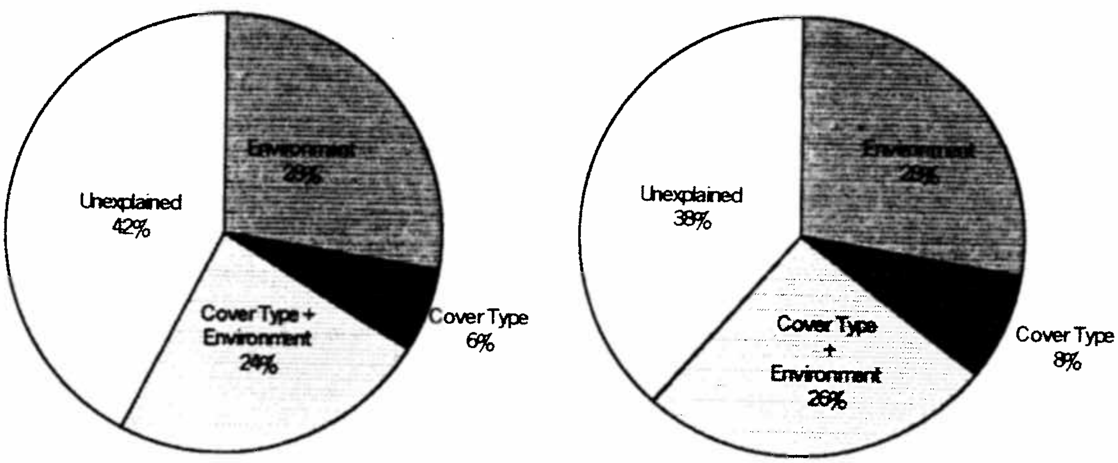

Figure 4.19. Partial canonical correspondence analysis results of the variance (%) in wetland bird species composition in Ohio explained by the environment, vegetation cover type, vegetation cover type and the environment, and an unexplained gradient during autumn 2001 (left) and spring 2002 (right).

(Table 4.11). Compared to moist soil, 2 more species of diving ducks (common goldeneye, common merganser) and 5 more species of shorebirds (black-bellied plover, dunlin, American golden plover, sanderling, and short-billed dowitcher) were observed using open water wetlands. Pairwise comparisons of wetland bird densities using MRPP revealed dabbling duck densities in persistent emergent marsh to be statistically different from those in moist soil and open water (Table 4.10). Dabbling duck densities in autumn were greatest in open water wetlands, followed by moist soil and persistent emergent marsh (Figure 4.20).

Species composition also differed among wetland cover types during spring (Table 4.7). Species composition differed among moist soil, persistent marsh, and open water wetlands (Table 4.11). Several species of wetland birds were observed using only moist soil wetlands (black-bellied plover, whimbrel, Wilson's phalarope, semipalmated plover, ruddy turnstone, sanderling, long- and short-billed dowitchers), only open water wetlands (least sandpiper, red-breasted merganser, spotted sandpiper), and only persistent emergent marshes [sandhill crane, canvasback (*Aythya valisineria*)]. Pairwise comparisons revealed statistical differences in dabbling duck densities among moist soil, persistent emergent marsh, and open water wetlands (Table 4.9). Dabbling duck densities were greatest on moist soil wetlands, followed closely by persistent marsh (Figure 4.21). Contrary to autumn, dabbling duck densities were lowest in open water wetlands. Similar to dabbling duck results, plover and large sandpiper densities were statistically different among moist soil, persistent emergent marsh, and open water wetlands (Table 4.9). Both plover and

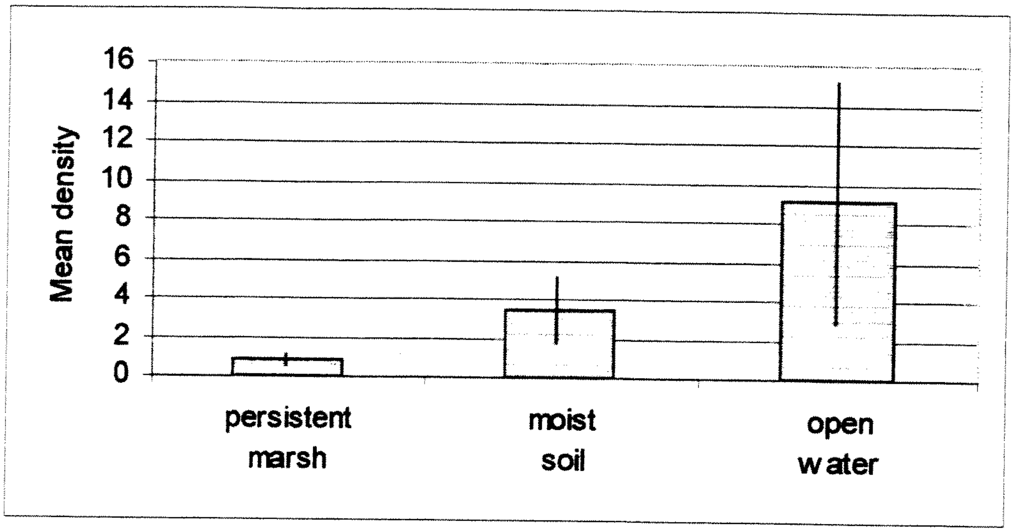

Figure 4.20. Mean densities (no./visit/ha) of dabbling ducks on persistent marsh, moist soil, and open water wetlands at Killdeer Plains, Big Island, and Pickerel Creek Wildlife Areas and Winous Point Marsh Conservancy in central and northwestern Ohio during autumn 2001.

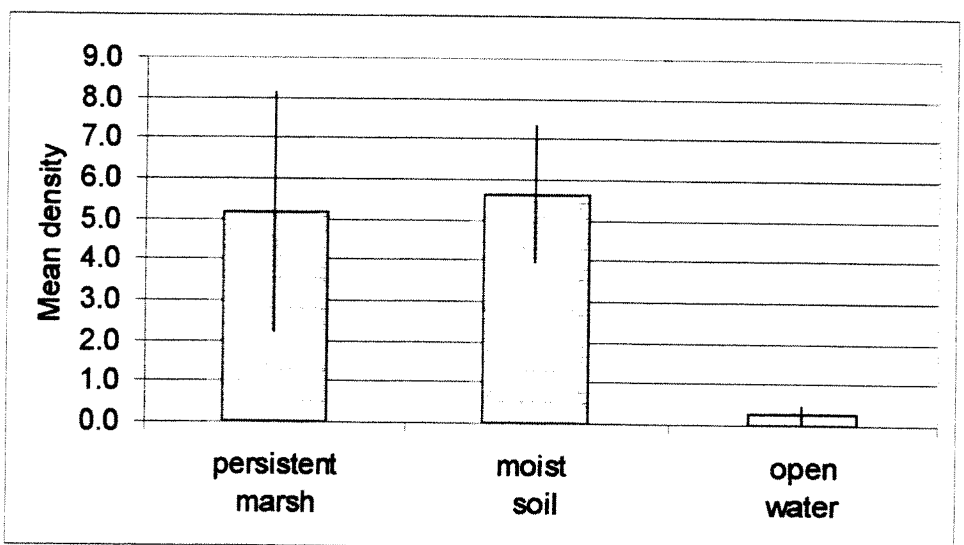

Figure 4.21. Mean densities (no./visit/ha) of dabbling ducks on persistent marsh, moist soil, and open water wetlands at Killdeer Plains, Big Island, and Pickerel Creek Wildlife Areas and Winous Point Marsh Conservancy in central and northwestern Ohio during spring 2002.

large sandpiper densities were greatest in moist soil wetlands, followed by persistent marsh (Figure 4.22). No plovers or large sandpipers were observed using open water wetlands during spring.

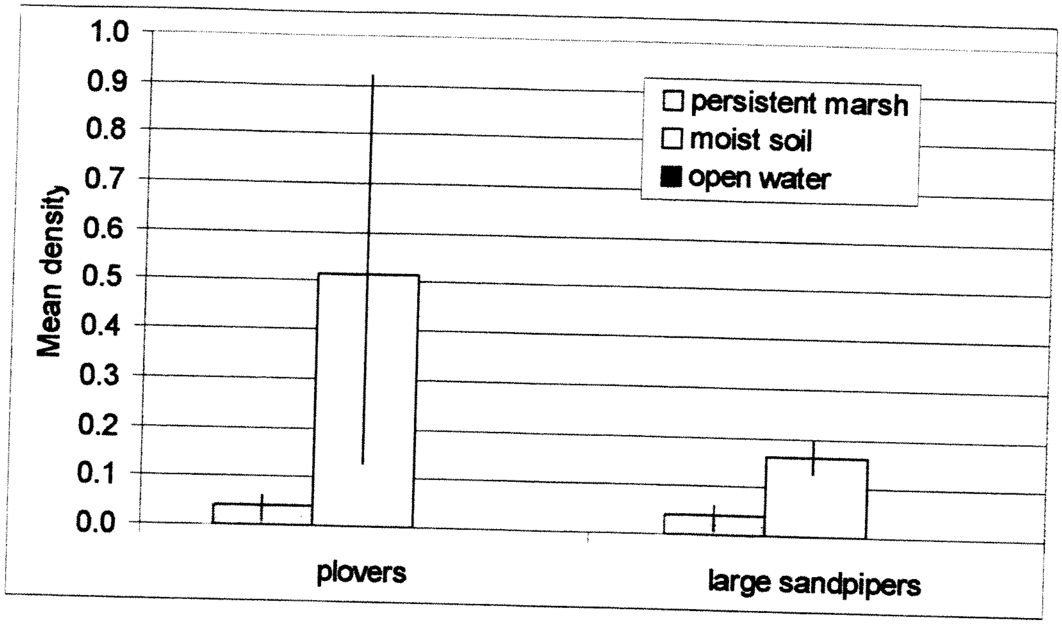

Figure 4.22. Mean densities (no./visit/ha) of plovers and large sandpipers on persistent marsh, moist soil, and open water wetlands at Killdeer Plains, Big Island, and Pickerel Creek Wildlife Areas and Winous Point Marsh Conservancy in central and northwestern Ohio during spring 2002.

CHAPTER 5

DISCUSSION

5.1 Variation in guild responses to wetland habitat conditions

My research was conducted to identify environmental variables that structured the wetland bird community on Ohio wetlands. Not surprisingly, water regime and vegetation density were the dominant gradients explaining wetland species composition. Water regime explained more variation in the wetland bird community structure than did vegetation density during autumn because wetland vegetation density was associated with hunting disturbance. Moist soil wetlands were most densely vegetated and the greatest hunting during autumn. I suspect dabbling ducks and wading birds would have used more moist soil wetlands had there been refuge from hunting disturbance during autumn. However, use of open water and persistent emergent marsh refuges produced more variation in the wetland bird community along the water regime gradient than along the vegetation density gradient.

Non-persistent vegetation died during winter and left open or sparsely vegetated zones in wetlands that provided important foraging habitat for shorebirds and diving ducks during spring. None of the surveyed wetlands contained vegetation cover that was exclusively persistent vegetation. Hence, wetlands of various vegetation densities contained some open water and sparsely vegetated zones. The shallow water regime associated with most managed wetlands during spring attracted a greater diversity of shorebirds than diving ducks. Therefore, a greater species diversity in wetlands with various vegetation densities resulted in more variation in the wetland bird community structure along the vegetation density gradient than the water regime gradient during spring.

Traditional management for waterfowl is compatible with other guilds of wetland birds during spring. As a result of moist soil management, shallow water, sparse vegetation, and concentrated prey attracted the greatest density and diversity of wetland birds compared to all other types of wetland management. However, moist soil management during autumn did not attract the density or diversity of species observed during spring. All guilds were not able to forage in the consistent density and inundation of vegetation cover throughout moist soil wetlands. Therefore, multi-species management during autumn would require managing a complex of different types of wetlands or manipulating moist soil wetlands to contain microhabitats of different water levels and vegetation densities. Whether managing a single wetland or a complex of wetlands, the compatibility of wetland management for waterfowl with other guilds of wetland birds is based on understanding the interspecific differences in wetland use and changing seasonal needs documented in this study.

5.1.1 Wetland disturbance

The polygon representing the distribution of wading birds was centered near the origin of the autumn CCA biplot, where one would expect a guild that generally favors a 50:50 interspersion of vegetation cover and open water (Stewart and Kantrud 1972, 1984). However, wading birds were most abundant in coastal open water wetlands during autumn, 2 of which were refuges. Although disturbance was not a statistically significant factor for differences in wading bird densities among wetlands, closer inspection revealed wading bird use was positively associated with coastal open water wetlands that were not hunted during autumn. The open water wetlands surveyed at inland sites were relatively deep reservoirs not likely to attract wading birds.

Four of the 5 coastal open water units that attracted the largest numbers of plovers and small/medium sandpipers were near-shore areas of Lake Erie embayments. However, wetland access was not a significant factor that distinguished shorebird guild densities among wetlands. The intermittently exposed substrate of embayments provided foraging habitat for shorebirds.

Hunting disturbance influenced use of wetlands by waterfowl during autumn. Waterfowl use was greatest on intermittently exposed embayments near Lake Erie, where hunting was prohibited. Open water units received much lower use by waterfowl in spring, when utilization was more evenly distributed across wetlands of different disturbance categories. In addition to significant differences in species composition in open water refuge wetlands, behavioral data also corroborated the importance of hunting disturbance on wetland utilization patterns during autumn. Whereas the majority of dabbling duck activities were loafing in open water wetlands, feeding accounted for almost all activity in moist soil wetlands. One possible reason for high waterfowl use of private wetlands could be security from wildlife viewing disturbance during spring.

Although wetland access distinguished species composition among wetlands, partial CCA results indicate a very small percent of the variation in species composition to be uniquely attributed to wetland access and other environmental covariables. A substantial proportion of variance in the species ordination may be shared between the environmental covariables and continuous environmental variables. It is also possible that there is an underlying factor associated with the continuous environmental variables and covariables that could be attributed to the shared percent explanation in species ordination. However, the variation in species composition associated with these covariables was confounded with variation represented by the environment. Indeed, wetlands that are hunted during autumn are generally managed to produce habitat that attracts waterfowl. Therefore, wetland access is associated with the resulting environmental conditions. The percent variance jointly described by the covariable and environment is a better indication of the impact wetland access had on the variation in species composition among wetlands. In addition, partial CCA results indicate that environmental conditions explained approximately half of the total variation in wetland species composition. Environmental variables that were not measured in this study may account for some of the unexplained variance in species composition among the wetlands. It is possible that a portion of this unexplained variance can be attributed to migration patterns.

5.1.2 Water level management regime

Species composition did not differ significantly between managed and unmanaged wetlands during autumn and spring. However, it is important to note that these categories were based solely on the presence or absence of active manipulation of water levels and distributions. Each category included wetland units of different sizes and topography having a variety of plant communities and vegetative structures. Of the 24 managed wetlands surveyed, 23 were managed specifically to provide habitat for migratory wetland birds, especially waterfowl.

Wetlands managed with an early, fast, and complete re-flooding regime seemed to provide habitat for early migrating dabbling ducks, such as blue-winged teal (*Anas discors*) and wood ducks (*Aix sponsa*). Although the greatest number of waterfowl observations were recorded on early, slow, and completely flooded wetlands, these wetlands accounted for the most managed wetland area during autumn. Instead, wetland managers are able determine the management regime that attracts the most birds per ha of wetland by examining patterns of wetland use. Although wetlands managed with a late, slow and complete flooding regime accounted for <5% of the area surveyed, the flooding regime provided greater duck use-days/ha than that observed on managed wetlands with other flooding regimes. This regime provided surface water for the longest period during autumn migration. Therefore, dabbling and diving ducks were able to access foraging habitats during the peak of autumn migration.

Waterfowl seemed to be favored by wetlands managed with late spring drawdowns. Similar to autumn, the greatest number of observations were recorded on wetlands managed with an early, slow, and complete drawdown because these wetlands accounted for the most area among all managed wetlands. However, I suspect waterfowl use would have been greater among wetlands associated with early spring drawdowns because I missed the peak waterfowl migration in my surveys. In addition to corresponding with the peak in waterfowl migration, an early, slow, and partial drawdown regime would concentrate food and surface water.

Wading bird use of early, slow, partially-flooded wetlands and late, slow, completely-flooded wetlands corresponded with peaks in autumn migration chronology. It is likely that partial re-flooding was important in providing foraging habitat for wading birds early in the migration, especially on wetlands that remained dry over summer. The slow duration of late re-flooding was likely important for later migrants because it allowed for the longest duration of wading bird foraging habitat. Coincident with migration chronology, wading bird use was greatest on wetlands where fast, partial and complete drawdowns were applied during late spring.

Whereas the greatest peaks in both shorebird and dabbling duck migration chronology occurred in early autumn, shorebird response to the early, fast, and complete flooding regime was slight compared to waterfowl. Shorebirds appeared to favor managed units where autumn flooding was early, partial, and slow. This flooding regime provided access to exposed mudflats in addition to those utilized by early shorebird migrants in the intermittently exposed embayments.

The first and third peak in shorebird migration chronology on inland wetlands differed in timing by approximately 7 weeks. Therefore, maintaining foraging habitat for shorebirds throughout the migration would require a very gradual drawdown or several drawdowns on a complex of wetland units. Indeed, shorebirds responded favorably to an early, slow, and complete drawdown on inland wetlands. Coordinated with the peak in coastal migration chronology, shorebirds responded favorably to late, fast, and partial drawdowns.

5.1.3 Vegetation cover type and landscape

Excluding coastal intermittently exposed wetlands, autumn wading bird use and species diversity was greatest on managed wetlands during autumn. This pattern was similar to that observed in waterfowl. But unlike waterfowl, wading bird use was higher in marsh than in moist soil units in both inland and coastal areas. At the microhabitat level, diving ducks were associated with open water wetland zones among all wetland types. That diving duck use was similar among all wetland types could be attributed to the presence of open water within each type of wetland.

Wading birds made slightly greater use of moist soil units than marsh units during spring. Flooded detritus in moist-soil wetlands provides substrate and nutrients for wading bird prey such as invertebrates, fish, and insects (Helmers 1992) that are concentrated during spring drawdowns. Wading bird and shorebird species richness and use were greatest on moist soil managed wetlands during spring.

Open water wetlands accommodated the largest number of shorebird species during autumn. Except for plovers, open water wetlands also had the highest densities of shorebirds. The resulting high density of plovers on moist soil wetlands was affected by the number of killdeer observed on the levees surrounding moist soil units.

The shorebird community did not appear to be as sensitive to vegetation density as I suspected. Shorebirds were located in approximately the same location along the vegetation density gradient of the CCA biplot as dabbling ducks. However, dabbling duck ordination along the vegetation density axis was affected by the use of coastal open water refuge to avoid hunting disturbance. Therefore, I was unable to determine the compatibility of moist soil management for waterfowl with shorebirds and other guilds because wetland disturbance affected diurnal waterfowl habitat use patterns.

Migrating shorebirds forage primarily in wetlands with water depths <10 cm (Helmers 1992). Fluctuations in coastal marsh water levels are important for shorebirds that forage on exposed shorelines. Coastal wetlands in northcentral Ohio, designated by WHSRN as a regionally significant migration staging area for shorebirds, were more utilized by shorebirds than were inland wetlands in central Ohio. Temporal patterns of shorebird use by vegetation type and water regime seemed to indicate that shorebirds responded negatively to moist soil management for waterfowl during autumn. Overall, shorebird densities were lowest in persistent marsh units and artificially flooded wetlands. However, I observed a pattern of high shorebird abundance wherever dry and wet mudflat zones were present.

In contrast to autumn, shorebird use and species richness were greatest in managed wetlands during spring. Shorebird use also was greatest in both inland and coastal moist soil wetlands during spring. Wetlands managed for moist soil vegetation are typically drawn down in spring to promote germination, growth, and seed production by annual plants. No longer deterred by dense vegetation that disappeared over winter, shorebirds responded positively to conditions created by moist soil management during spring (e.g. invertebrate populations, sparse vegetation cover, and mudflats interspersed with shallow water). From the spring CCA biplot, it seems that the shorebird community was associated with shallow wetlands containing the most mudflat. The expansion of the polygons along axis 1 indicates that shorebirds were able to use wetlands with a wide variety of vegetation densities. This pattern can be attributed to the sparse vegetation conditions in most wetlands during spring.

Managed wetlands can provide consistent habitat for shorebirds, especially when unmanaged wetlands are affected by extreme drought or flooding. This was demonstrated by changes in shorebird use at WPMC between autumn and spring. Total spring shorebird use at WPMC during spring was more than 135X higher than in autumn. Small/medium sandpipers exhibited a 380X increase between autumn and spring at WPMC. Most of this increase was associated with one wetland at WPMC (Horseshoe Marsh), the largest moist soil unit included in this study. There were only 2 instances when Lake Erie water levels were low enough to expose the substrate of embayments during spring. Additionally, drawdowns of managed marshes were not completed after the migration due to the wet spring.

5.2 Compatibility of traditional waterfowl management with the needs of other guilds of wetland birds

The results of this study indicate the potential to improve multi-species management in Ohio. From the standpoint of managing a single wetland unit, a wetland could provide habitat for multiple species of wetland birds during autumn by managing for spatial heterogeneity. Wading bird use of moist soil wetlands could be increased by mowing small openings in the dense vegetation to create a hemi-marsh condition. Interspersion of these open water channels would also attract more diving ducks. Providing habitat for a greater diversity of wetland species would also require managing for shallow wetlands (Colwell and Taft 2000). Shallow moist soil wetlands would likely attract more shorebirds in the open, sparsely vegetated regions.

CHAPTER 6

MANAGEMENT AND FUTURE RESEARCH RECOMMENDATIONS

6.1 Management regime model for a wetland complex

No single wetland provides for the needs of all wetland birds throughout the year because each species has its own diverse habitat requirements. A complex of wetlands managed with different water regimes and vegetation structures will provide habitat for the most diverse assemblage of wetland bird species. I propose a wetland complex management regime model to accommodate the greatest diversity of wetland birds according to the results of this study (Figure 6.1). However, it is important to note that wetland complex management recommendations will vary with the size of individual units and the types and intensities of wetland disturbance. This model is based on a complex of 4 wetlands of equal size and disturbance intensity.

Autumn.--The intention of wetland managers who conducted early, fast, and complete re-flooding regimes during autumn was to attract blue-winged teal and green-winged teal for early teal hunting season. Although waterfowl use was slightly lower on partially re-flooded units, a manager can provide habitat for teal as well as species in other foraging guilds. This is especially important in managing wetlands near refuges. Several

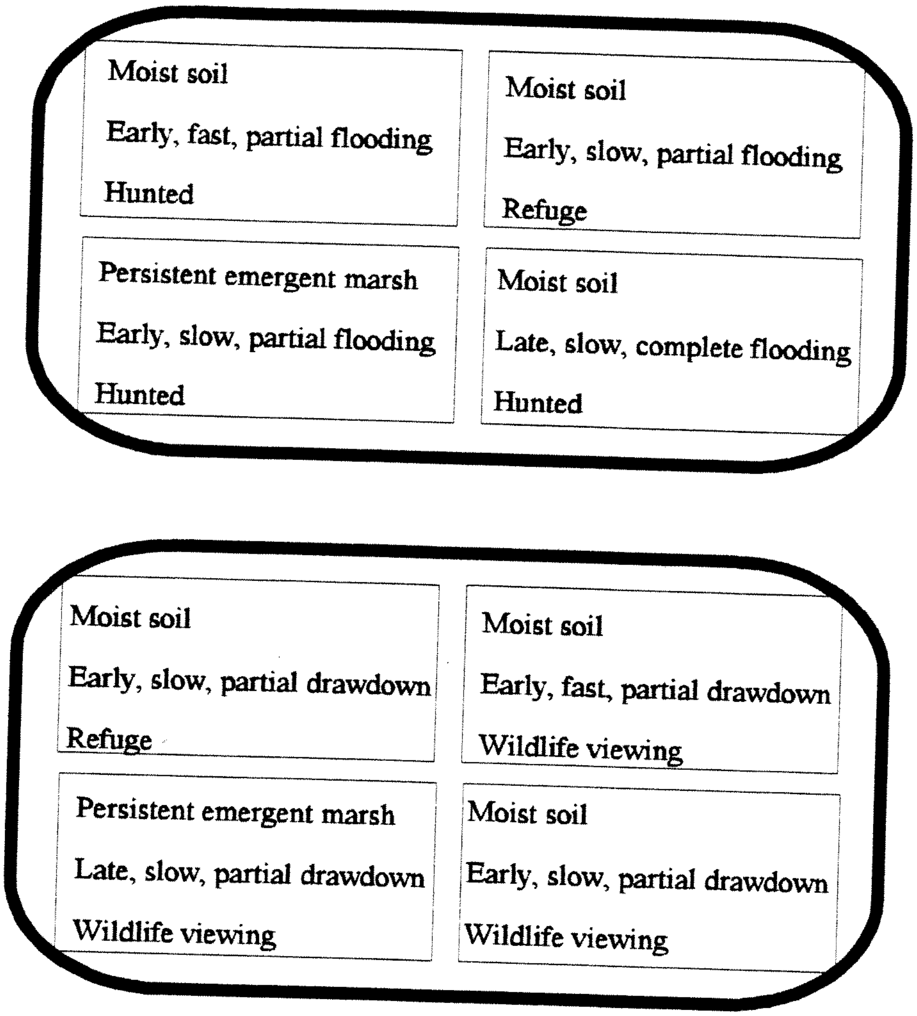

Figure 6.1. Autumn (top) and spring (bottom) wetland complex management model to provide habitat for the greatest diversity of wetland birds, based on foraging guild responses to wetland vegetation structure/type, water regime, and disturbance in Ohio (2001-2002).

days after the start of early teal season, I noticed more waterfowl loafing in open water refuges and less using the wetlands managed specifically to provide teal habitat. Since waterfowl seemed to avoid hunted wetlands during the day, managers might consider partial re-flooding regimes to provide habitat for other foraging guilds during that time. An early, fast, and partial flooding regime on a hunted, moist soil wetland would provide foraging habitat to attract blue-winged and green-winged teal for early teal hunting season as well as for other dabbling duck species throughout the autumn migration. If the manager maintained some open and sparsely vegetated habitat zones, shorebirds, wading birds, and diving ducks could also use the wetland. This would require consideration of wetland topography. A wetland manager should manage for open and sparsely vegetated microhabitat in areas of the highest and lowest elevation. Therefore, the partial flooding regime would create shallower habitat for wading birds and shorebirds and deeper habitat for diving ducks throughout autumn migration.

A closer look at avian use indicates that early, slow, and partial re-flooding regimes attracted the greatest diversity of wetland bird species during autumn. I would recommend this management regime on a persistent emergent marsh and moist soil unit. Provided that the wetland cover resembled hemi-marsh conditions, this regime would provide flooded areas for wading birds, dabbling ducks, and diving ducks throughout autumn migration. Although the peak migration of shorebirds was complete by mid-October, dunlins needed shallow foraging habitat in November. Therefore, the partial flooding regime would provide some shallow areas for shorebirds with an early or late migration chronology. Designating the moist soil unit as a refuge is important to attract multiple species to the wetland complex because it will provide habitat that is secure from hunting disturbance.

Finally, a late, slow, and complete flooding regime should be used to manage at least one moist soil unit. Shorebird and wading bird migrations are completed by mid-October. Therefore, areas of shallow water and exposed substrate can be utilized by migrating wading birds and shorebirds prior to the late flooding regime. By completely flooding a moist soil wetland during late-autumn, wetland managers will provide foraging habitat for the remaining waterfowl migrants during autumn. After spring thaw, these wetlands will likely provide completely flooded habitat coincident with the timing of the peak in dabbling and diving duck migration.

Spring.-- Past studies recommend slow drawdowns (approximately 2 weeks) on moist soil units to prolong use by a greater number and diversity of wetland birds (Fredrickson 1991, Isola et al. 2000). The results of this study indicate greater wetland bird use in units having a fast drawdown. However, it is important to note that the general definitions of fast and slow drawdown timing may have separated wetlands into different categories when the duration differed by only 1 or 2 days. Indeed, only a few wetlands had drawdown durations that lasted <1 week. The duration of most drawdowns lasted between 10 and 14 days. Therefore, I recommend an early, slow, and partial drawdown on 2 of the moist soil units to increase and prolong the availability of shallow water habitats and provide ample time for prey to concentrate throughout the spring migration period. I recommend designating at least one of these units as a refuge for waterfowl security from wildlife viewing disturbance during spring. I recommend an early, fast, and partial drawdown on the other moist soil wetland to provide exposed mudflat for early shorebird migrants while maintaining some inundated habitat for waterfowl and wading birds.

A persistent emergent marsh unit is needed to provide wading foraging habitat during spring. Coincident with wading bird migration chronology, I recommend a late drawdown regime. In addition, this unit was only partially flooded during autumn. Therefore, a manager could concentrate prey and maintain shallow water for foraging by conducting a late, slow, and partial drawdown.

6.2 Recommendations for future research

A key uncertainty of the UMR & GLR JV implementation plan is the importance of security from disturbance when compared to the availability of food energy in developing wetland bird migration habitat objectives (U.S. Fish and Wildlife Service 1998). Wetland management decisions based solely on diurnal surveys can be misleading. Dabbling ducks in particular, used open water refuges for refuge from hunting during the day and moved to moist soil wetlands at night to feed (Steckel 2003). The preference hypothesis proposes that wetland birds prefer to feed nocturnally to avoid disturbance such as that from hunting pressure (McNeil et al. 1992). A wetland manager interested in attracting waterfowl exclusively for hunting would have little interest in nocturnal activity. However, the purpose of this project was to determine the type of habitat conditions and management that could best accommodate the migration needs of multiple guilds of wetland birds. Therefore, future research should involve conducting both diurnal and nocturnal surveys to determine fully the value of wetland management for all foraging guilds (Anderson and Smith 1999).

Wetland topographical variation can make foraging habitats available for different species simultaneously (Williams 1996, Colwell and Taft 2000). This is especially important in the compatibility of traditional waterfowl management with other foraging guilds during autumn. Understanding wetland topography is useful when manipulating the density of moist soil vegetation and the water regime to provide microhabitat for shorebirds, wading birds, and diving ducks. Therefore, I recommend future multi-species conservation studies measure the topographical diversity of a wetland to determine the effect on wetland bird community structure.

The adaptive management approach of NAWMP is important in understanding the connection between habitat actions and wildlife response. I monitored waterfowl and webless wetland bird responses to determine the compatibility of waterfowl management with other guilds of wetland birds in Ohio. I evaluated the assumption that waterfowl conservation efforts would improve habitats for webless wetland birds by comparing the results to previous research findings and interpreting the reasons for any underlying differences. At the very least, this research determined that waterfowl management efforts can be enhanced to achieve multi-species conservation on wetlands in Ohio. However, I purposely conducted research on a large sample of wetland bird species and a diverse sample of Ohio wetlands so that the resulting management recommendations could be applied throughout the UMR & GLR JV. Therefore, the next step is to conduct the previously mentioned additional research recommendations and adjust the evaluation accordingly. The final step in improving the integration of waterfowl and webless wetland bird management is to apply the recommended wetland management actions and adjust or validate the original assumptions used to establish habitat objectives and goals.

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APPENDIX A. Universal Transverse Mercator Coordinates (UTM) of central and northwestern Ohio wetlands on which research was conducted during 2001 - 2002.

Wetland complex or private landowner	UTM Coordinates (Zone 17)	
Winous Point Marsh Conservancy	335422E	4593153N
Winous Point Marsh Conservancy	334833E	4592970N
Winous Point Marsh Conservancy	334791E	4591893N
Winous Point Marsh Conservancy	331948E	4592218N
Winous Point Marsh Conservancy	332090E	4592726N
Winous Point Marsh Conservancy	330261E	4592442N
Winous Point Marsh Conservancy	330342E	4591771N
Killdeer Plains Wildlife Area	307745E	4508371N
Killdeer Plains Wildlife Area	306648E	4508378N
Killdeer Plains Wildlife Area	305917E	4510004N
Killdeer Plains Wildlife Area	300288E	4509007N
Killdeer Plains Wildlife Area	311838E	4508927N
Killdeer Plains Wildlife Area	299069E	4508275N
Killdeer Plains Wildlife Area	302422E	4509698N
Pickerel Creek Wildlife Area	336865E	4585960N
Pickerel Creek Wildlife Area	335503E	4589150N
Pickerel Creek Wildlife Area	335645E	4589292N
Pickerel Creek Wildlife Area	335871E	4589333N
Pickerel Creek Wildlife Area	338186E	4587118N
Pickerel Creek Wildlife Area	338308E	4576082N
Pickerel Creek Wildlife Area	338308E	4585777N
Big Island Wildlife Area	311403E	4495048N
Big Island Wildlife Area	311809E	4495008N
Big Island Wildlife Area	307095E	4493829N
Big Island Wildlife Area	307522E	4493768N
Big Island Wildlife Area	307908E	4493788N
Adams	327618E	4594189N
Arnold	309188E	4511589N
Arnold	309107E	4511650N
Arnold	310306E	4511121N
Beaver	312216E	4493382N
Buehler	326094E	4591446N
Buehler	328106E	4590288N
Dauble	332516E	4586712N
Dauble	332577E	4587037N
Fowler	307359E	4507728N
Kralik	334791E	4586082N
Kralik	334955E	4586204N
Kralik	335077E	4586448N
Metzger	333675E	4586061N
Metzger	333980E	4575797N
Millisor	308131E	4494906N
Moyer	328716E	4591771N
Whorling	315487E	4493260N
Whorling	315670E	4494723N

APPENDIX B. Species [common name, scientific name, and American Ornithological Union (AOU) 4-letter species codes] and associated guilds of wetland birds that were observed in northern and central Ohio during autumn 2001 (August - December) and spring 2002 (March - June) migration.

Guild (family)	Scientific name	AOU Code
Wading birds (*Ardeidae, Gruidae)*		
great blue heron	*Ardea herodias*	GBHE
great egret	*Casmerodius albus*	GREG
black-crowned night heron	*Nycticorax nycticorax*	BCNH
green-backed heron	*Butorides striatus*	GRHE
American bittern	*Botaurus lentiginosus*	AMBI
sandhill crane	*Grus canadensis*	SACR
Diving ducks (*Anatidae)*		
ruddy duck	*Oxyura jamaicensis*	RUDU
canvasback	*Aythya valisineria*	CANV
redhead	*Aythya americana*	REDH
ring-necked duck	*Aythya collaris*	RNDU
greater scaup	*Aythya marila*	SCAU[a]
lesser scaup	*Aythya affinis*	SCAU
common goldeneye	*Bucephala clangula*	COGO
bufflehead	*Bucephala albeola*	BUFF
common merganser	*Mergus merganser*	COME
red-breasted merganser	*Mergus serrator*	RBME
hooded merganser	*Lophodytes cucullatus*	HOME
Dabbling ducks (*Anatidae)*		
mallard	*Anas platyrhynchos*	MALL
American black duck	*Anas rubripes*	ABDU
gadwall	*Anas strepera*	GADW
American wigeon	*Anas americana*	AMWI
American green-winged teal	*Anas crecca*	AGWT
blue-winged teal	*Anas discors*	BWTE
northern pintail	*Anas acuta*	NOPI
northen shoveler	*Anas clypeata*	NOSH
wood duck	*Aix sponsa*	WODU
Plovers (*Charadriidae)*		
semipalmated plover	*Charadrius semipalmatus*	SEPL
American golden plover	*Pluvialis sp.*	AMGP
black-bellied plover	*Pluvialis squatarola*	BBPL
killdeer	*Charadrius vociferus*	KILL

Continued

APPENDIX B Continued

Small/medium sandpipers (*Scolopacidae*)		
Wilson's phalarope	*Phalaropus tricolor*	WIPH
sanderling	*Calidris alba*	SAND
semipalmated sandpiper	*Calidris pusilla*	SESA
western sandpiper	*Calidris mauri*	WESA
least sandpiper	*Calidris minutilla*	LESA
pectoral sandpiper	*Calidris melanotus*	PESA
dunlin	*Calidris alpina*	DUNL
ruddy turnstone	*Arenaria interpres*	RUTU
spotted sandpiper	*Actitis macularia*	SPSA
common snipe	*Gallinago gallinago*	COSN
solitary sandpiper	*Tringa solitaria*	SOSA

[a]species code used to designate greater and lesser scaup due to difficulty in distinguishing differences during diurnal surveys

APPENDIX C. Relative abundance and species composition of wetland birds associated with each foraging guild and Big Island Wildlife Area (BIWA), Killdeer Plains Wildlife Area (KPWA), Pickerel Creek Wildlife Area (PCWA) and Winous Point Marsh Conservancy (WPMC) during autumn 2001.

	BIWA	KPWA	PCWA	WPMC	Species total	% of guild total
Plovers						
killdeer	116	326	484	25	951	99
black-bellied plover			6		6	<1
American golden plover			2		2	<1
Small/medium sandpipers						
dunlin			99		99	21
pectoral sandpiper		61	97		158	34
solitary sandpiper		1	1	3	5	1
spotted sandpiper		2	4	4	10	2
common snipe	15	63	87		165	35
least sandpiper		2	10		12	3
semipalmated sandpiper		12	4	2	18	4
sanderling			1		1	<1
Large Sandpipers						
greater yellowlegs	13	45	98	16	172	29
lesser yellowlegs	4	45	35	2	86	14
yellowlegs[a]	3	288	29	2	322	54
long-billed dowitcher			1		1	<1
short-billed dowitcher			18		18	3
Wading birds						
great blue heron	320	603	424	787	2134	76
great egret	9	126	165	342	642	23
green-backed heron	12	18	1	6	37	1
black-crowned night heron			1	3	4	<1
American bittern				2	2	

Continued

APPENDIX C Continued

Dabbling ducks						
American black duck			13	10003	10016	7
dabblers[b]		220	374	35092	35686	26
gadwall	2	305		1520	1827	1
green-winged teal		597	43	486	1126	<1
blue-winged teal	43	1357	58	797	2255	2
mallard	74	3678	236	72441	76429	56
northern pintail		671		2009	2680	2
northern shoveler		798	26	456	1280	2
American wigeon		522	7	122	651	<1
wood duck	113	2311	37	1042	3503	3
Diving ducks						
bufflehead		3		1	4	<1
common goldeneye		2			2	<1
common merganser				6	6	<1
hooded merganser		53	2	108	163	8
ruddy duck		15	1157	654	1826	91
red-breasted merganser			1		1	<1
Total	724	12124	3521	125931	142297	

[a] name used when greater and lesser yellowlegs were indistinguishable
[b] name used when similar looking dabbling duck species were indistinguishable

APPENDIX D. Relative abundance and species composition of wetland birds associated with each foraging guild and Big Island Wildlife Area (BIWA), Killdeer Plains Wildlife Area (KPWA), Pickerel Creek Wildlife Area (PCWA) and Winous Point Marsh Conservancy (WPMC) during spring 2002.

	BIWA	KPWA	PCWA	WPMC	Species total	% of guild total
Plovers						
killdeer	26	45	40	20	131	71
black-bellied plover				3	3	2
semipalmated plover				51	51	27
Small/medium sandpipers						
dunlin		11	740	6622	7373	96
pectoral sandpiper		2	21	11	34	<1
solitary sandpiper		6	3	4	13	<1
spotted sandpiper		9			9	<1
common snipe			45	85	130	2
least sandpiper			13	4	17	<1
semipalmated sandpiper			1	60	61	1
ruddy turnstone				18	18	<1
sanderling				3	3	<1
Large sandpipers						
greater yellowlegs	1	7	19	22	49	11
lesser yellowlegs	1	10	19	16	46	10
yellowlegs[a]	25	1	1	6	33	8
whimbrel				49	49	11
long-billed dowitcher				253	253	58
short-billed dowitcher				7	7	1
Wading birds						
great blue heron	160	65	187	393	805	75
great egret	7	5	150	100	262	
black-crowned night heron			2		2	<1
sandhill crane			1		1	<1

Continued

APPENDIX D Continued

Dabbling ducks						
American black duck	4	2	111	654	771	4
dabblers[b]				44	44	<1
gadwall		180	315	923	1418	8
American green-winged teal	128	126	180	324	758	4
blue-winged teal	573	733	722	715	2743	16
mallard	252	413	1141	3354	5160	29
northern pintail		10	1	10	21	<1
northern shoveler	187	304	604	1300	2395	14
American wigeon	1291	2048	133	143	3615	20
wood duck	76	119	28	386	609	3
Diving ducks						
bufflehead	18	219	18	202	457	5
canvasback	6		8		14	<1
common merganser			139	157	296	3
hooded merganser	24	276	109	50	459	5
redhead	11	2		72	85	1
ring-necked duck	1205	896	233	1719	4053	43
ruddy duck	27	353	1371	1299	3050	32
scaup[c]	10	393	334	367	1104	12
Total	4032	6235	6689	19446	36402	

[a] name used when greater and lesser yellowlegs were indistinguishable
[b] name used when similar looking dabbling duck species were indistinguishable
[c] name used when greater and lesser scaup were indistinguishable

APPENDIX E. Mean density (no./visit/ha) and standard error associated with each wetland bird guild and the corresponding categorical environmental variable during autumn 2001.

		Access			Landscape		Cover Type			Timing			Extent		Duration	
		Private hunting	Public hunting	Refuge	Coastal	Inland	Persistent marsh	Moist soil	Open water	Early flood	Late flood	Natural flood	Partial flood	Complete flood	Fast flood	Slow flood
Dabbling ducks	mean	1.344	0.393	9.948	2.627	2.229	0.867	3.435	9.052	1.856	0.383	1.799	0.264	1.403	0.699	1.597
	SE	0.443	0.136	4.987	1.394	0.936	0.285	1.637	6.111	0.812	0.277	0.883	0.047	0.614	0.414	0.765
Diving ducks	mean	0.306	0.661	0.223	0.651	0.030	0.241	0.031	0.793	0.637	0.070	0.034	0.115	0.614	0.070	0.637
	SE	0.249	0.622	0.110	0.335	0.009	0.187	0	0.584	0.552	0.068	0.009	0.107	0.558	0.068	0.552
Wading birds	mean	0.135	0.408	0.426	0.312	0.154	0.199	0.091	0.715	0.101	0.143	0.221	0.112	0.122	0.103	0.131
	SE	0.021	0.296	0.212	0.136	0.028	0.047	0.026	0.554	0.019	0.049	0.070	0.034	0.028	0.029	0.035
Plovers	mean	0.217	0.141	1.174	0.116	0.555	0.250	0.577	0.237	0.204	0.009	0.528	0.081	0.180	0.134	0.162
	SE	0.096	0.074	0.727	0.038	0.242	0.097	0.483	0.235	0.082	0.006	0.266	0.036	0.087	0.068	0.087
Small/medium sandpipers	mean	0.057	1.270	0.394	0.592	0.123	0.051	0.299	3.161	0.155	0.002	0.123	0.008	0.096	0.147	0.010
	SE	0.049	1.263	0.204	0.524	0.079	0.042	0.177	3.161	0.135	0.001	0.079	0.000	0.086	0.137	0.006
Large sandpipers	mean	0.143	0.272	0.109	0.112	0.209	0.135	0.166	0.264	0.177	0.014	0.143	0.041	0.193	0.166	0.126
	SE	0.056	0.255	0.109	0.063	0.083	0.054	0.160	0.263	0.010	0.007	0.058	0.031	0.120	0.159	0.098

APPENDIX F. Mean density (no./visit/ha) and standard error associated with each wetland bird guild and the corresponding categorical environmental variable during spring 2002.

		Access			Landscape		Cover Type			Timing			Extent		Duration	
		Private access	Public access	Refuge	Coastal	Inland	Persistent marsh	Moist soil	Open water	Early draw-down	Late draw-down	Natural draw-down	Partial draw-down	Complete draw-down	Fast draw-down	Slow draw-down
Dabbling ducks	mean	8.170	0.762	1.587	6.586	2.022	5.178	5.651	0.265	3.673	4.717	5.979	2.156	5.106	4.656	2.028
	SE	3.724	0.171	0.480	3.317	0.678	2.954	1.676	0.204	1.438	2.514	3.580	0.367	1.889	1.583	0.726
Diving ducks	mean	1.107	1.958	0.537	1.481	1.055	1.289	0.877	1.997	1.005	1.350	1.272	0.477	1.530	1.231	0.698
	SE	0.419	0.634	0.155	0.391	0.474	0.408	0.377	0.815	0.599	0.978	0.434	0.136	0.857	0.698	0.263
Wading birds	mean	0.185	0.155	0.128	0.211	0.095	0.142	0.161	0.225	0.100	0.309	0.126	0.262	0.139	0.234	0.089
	SE	0.035	0.052	0.050	0.040	0.022	0.023	0.058	0.164	0.018	0.043	0.025	0.071	0.025	0.046	0.026
Plovers	mean	0.397	0.054	0.021	0.077	0.321	0.042	0.513	0	0.089	0.097	0.367	0.084	0.098	0.094	0.088
	SE	0.304	0.042	0.006	0.035	0.274	0.021	0.401	0	0.036	0.074	0.356	0.054	0.042	0.045	0.058
Small/medium sandpipers	mean	0.823	0.175	0.887	1.002	0.107	0.403	1.191	0.488	0.749	1.497	0.115	0.974	0.949	0.956	1.264
	SE	0.426	0.106	0.718	0.399	0.080	0.294	0.595	0	0.596	0.664	0.079	0.583	0.692	0.446	1.207
Large sandpipers	mean	0.105	0.039	0.071	0.089	0.045	0.039	0.160	0	0.095	0.048	0.035	0.034	0.117	0.089	0.062
	SE	0.051	0.010	0.022	0.034	0.013	0.006	0.064	0	0.048	0.008	0.012	0.011	0.054	0.048	0.027