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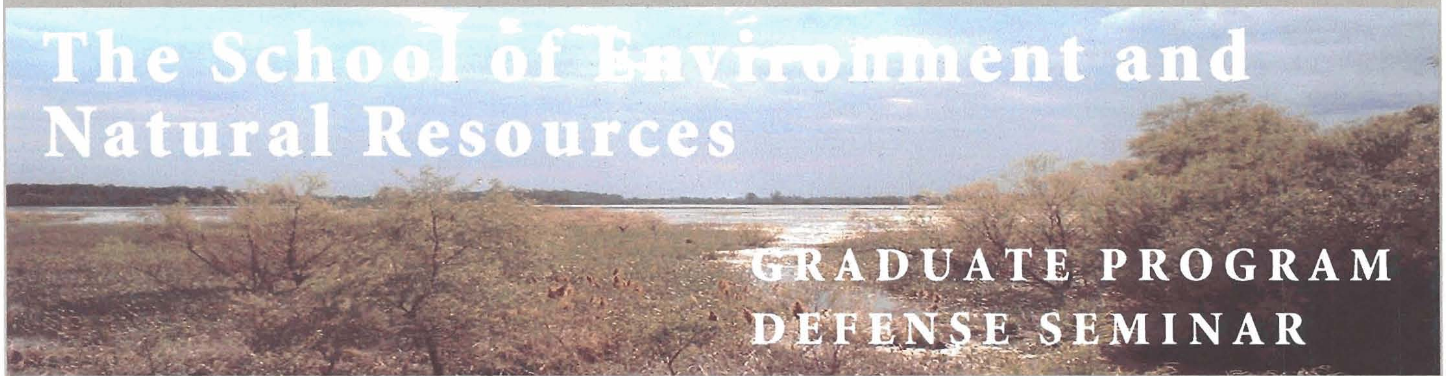

Presenter: Tara E. Baranowski
Date: Thursday, Sept. 6, 2007
Time: 12:00 p.m.
Location: 333C Kottman Hall

Distribution, Abundance and Habitat Associations of Fall- and Spring-migrating Shorebirds in the Southwest Lake Erie Marsh Region

Description:

The southwest Lake Erie marsh region is an historically important waterfowl management area and was recognized recently by the Western Hemisphere Shorebird Reserve Network as a regionally significant stopover site for migrating shorebirds. While it is known that shorebirds utilize this region as a stopover area during autumn and spring migrations, migratory population sizes, utilization rates, and habitat associations are relatively unknown. This research was conducted to: 1) estimate how many shorebirds use the southwest Lake Erie marshes during spring and autumn migrations; 2) determine their distribution among agricultural, managed marsh, and lake-level influenced wetland habitat types within the region; and 3) identify environmental and habitat characteristics that influence local abundance, distribution, and habitat utilization rates. Concurrently, the distribution and habitat utilization rates of waterfowl that were present during shorebird migration periods was determined. Comparing abundance and habitat utilization rates between shorebirds and waterfowl provided insight into habitat conservation practices that could benefit both bird groups.

THE OHIO STATE UNIVERSITY
School of Environment and Natural Resources
College of Food, Agricultural, and Environmental Sciences

DISTRIBUTION, ABUNDANCE AND HABITAT ASSOCIATIONS OF FALL- AND SPRING-MIGRATING SHOREBIRDS AND WATERFOWL IN THE SOUTHWEST LAKE ERIE MARSH REGION

A Thesis

Presented in Partial Fulfillment of the Requirements for

the Degree Master of Science in the

Graduate School of the Ohio State University

By

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2007

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ABSTRACT

The southwest Lake Erie marsh region (SLEMR) has long been known as an important waterfowl staging area and was recently designated as a significant stopover site for shorebirds (Charadriiformes). Waterfowl and shorebirds were counted weekly during spring (March-June) and autumn (July-November) 2002-2003 using a stratified random sample of lake-affected, managed marsh and agricultural plots (0.0625-0.25 km^2). Plots contained various wetland and upland habitat types, but were classified according to their dominant water regime (i.e. lake-level influenced, controlled, precipitation-driven). All habitat types were surveyed within 90 plots (30 plots per stratum) except for spring 2002 when only 60 plots were sampled (20 plots per stratum). Plots were divided evenly among two study sites, one coastal site and one embayment site.

Based upon a 7-day stopover period I estimated a total of 313,451 and 171,852 shorebird use-days in 2002 and 2003 respectively and a total of 250,844 and 299,208 waterfowl days. Managed marsh plots supported the most shorebird use-days followed by lake-affected plots (managed marsh: 318,752, lake-affected: 148,011, agriculture: 18,541 both years combined). Waterfowl use-days were also highest in managed plots followed by lake-influenced plots (managed marsh: 399,080, lake-affected: 138,902, agriculture: 12,070 both years combined). Shorebird population estimates extrapolated by sampling stratum out to the site level ranged from 57,596 (SE $\pm$ 34,703) to 226,760 (SE $\pm$

112,592) while extrapolated waterfowl estimates ranged between 35,342 (SE ± 7,593) to 267,859 (SE ± 60,151).

Total waterbird (shorebird and waterfowl) abundance (birds/km^2) varied ($P \leq 0.026$) among the three wetland sampling strata during all seasons and years. In particular the coastal, lake-affected estuarine wetlands were most significant in terms of shorebird abundance for all shorebird guilds during all seasons except spring 2002. Redundancy analysis of shorebird abundance and environmental variables in the SLEMR also showed that shorebird selection of plots was driven largely by the amount of lake-affected estuarine habitat contained within the plot. Lake-affected estuary plots also attracted the most diverse assemblage of shorebirds for both autumn seasons and suggest the importance of conserving this limited habitat within the region. The repeated importance of estuarine habitat to shorebirds throughout all of the analyses illustrates the association shorebirds have with freshwater estuarine habitat within the SLEMR. Of the habitat types in the region, the estuarine habitat is the least available and yet shorebirds seem to prefer it over the other choices available to them.

The positive response of shorebirds to waterfowl habitat management techniques such as marsh drawdowns was also evident in this study and has been well documented by others. Plots dominated by drawn-down marsh habitat contributed the most diversity to the waterfowl community during both years and both seasons and also contributed the most shorebird diversity for both spring seasons. Early spring drawdowns most benefit shorebirds by supplying shallow water and moist soil habitat at a time when these conditions are rare in the natural wetlands and regional freshwater estuaries. Although current management plans do not target shorebirds per se, they benefit as a byproduct of management for waterfowl habitat.

The Western Hemisphere Shorebird Reserve Network categorizes a site as internationally important if it supports at least 100,000 shorebirds annually or >10% of the biogeographic population for a species. The embayment site alone supported over 100,000 shorebirds and this just during spring 2002 (105,822, SE $\pm$ 52,543). On an annual basis, the most conservative of my migrant shorebird population estimates ranks the SLEMR as a stopover site of international importance for migrating shorebirds. Based upon the results of this study the SLEMR's designation as a site of regional importance to migrating shorebirds should be reevaluated and the designation of international importance should be seriously considered.

Dedicated to my husband and best friend, Patrick, for always believing in me and to my mother, Antoinette, for teaching me to believe in myself.

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FIELDS OF STUDY

Major Field: Natural Resources

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CHAPTER 1

INTRODUCTION

Wetlands of the interior United States are critical habitat for migrating and/or breeding waterfowl as well as for migrating shorebirds that rely upon smaller, inland migration stopover sites for food (Farmer and Parent 1997). The small wetland complexes in the Central and Mississippi Flyways provide crucial foraging habitat for migrating shorebirds and waterfowl. However, small inland wetland complexes are more vulnerable and have experienced greater losses due to drainage and development than their coastal counterparts. Ohio has lost 90% of its wetland habitat, making it second in the nation for wetland loss (Dahl 1990). Most of this loss is attributed to drainage and conversion of wetland habitat to agriculture. This decline in wetland habitat has occurred nationally and is likely responsible for a decline in half of all shorebird species during the last 30 years (Howe et al. 1989, MCCS 2002).

The southwest Lake Erie (SWLE) marsh region is an inland wetland complex that has long been recognized for its importance to waterfowl. Bookhout et al. (1989) estimated that 3 million waterfowl migrate through the Great Lakes region each year. Due to its location between the Mississippi and Atlantic flyways, Lake Erie has historically attracted waterfowl from both flyways. Several rivers and creeks within the SLEMR also provide abundant aquatic vegetation upon which waterfowl feed (Trautman 1981).

The SWLE marsh region historically extended from the Detroit River to Vermillion, Ohio (Figure 1.1), and has experienced substantial wetland loss. In the past, these marshes were protected from Lake Erie by sand bars or barrier beaches. Rising water levels caused the marshes to move inland and this sustained forested swamplands. Consequently, dikes were built to protect cropland from flooding and to inhibit the inland migration of the marshes as lake levels rose.

Bookhout et al. (1989) estimated that the SLEMR once encompassed over 121,000 ha of natural marshland. Today the region's marshes are impounded and coastal beaches and wetlands have been nearly overtaken by shoreline developments or have been eroded by altered lake hydrology and sediment deposition patterns. The 5,300 ha of marsh that remain is held mostly in private trust as waterfowl hunt clubs or in public trust as federal refuge and state wildlife areas (Bookhout et al. 1989).

Indeed only two major wetland marsh complexes remain within the region. One complex, immediately adjacent to the southwestern basin of Lake Erie contains the Ottawa National Wildlife Refuge and Magee Marsh State Wildlife Area. Federal and state lands within this complex are separated from the lake by an extensive dike system and the freshwater Crane Creek Estuary. The second complex is the Winous Point Marsh and is situated around the Muddy Creek and Sandusky Bays. These bays have historically held significant numbers of staging waterfowl (Bookhout et al. 1989). Today this complex of wetlands is predominantly owned and managed by private waterfowl hunting clubs.

In addition to waterfowl, the SLEMR is an important inland stopover site for other wetland bird species in the Mississippi Flyway. Along with Chautauqua National

Wildlife Refuge in central Illinois, the SLEMR is recognized by the Western Hemisphere Shorebird Reserve Network (WHSRN) as one of two regionally significant shorebird stopover sites (supports >20,000 birds annually) in the Midwest. The SLEMR is considered the most significant stopover site between Delaware Bay and Cheyenne Bottoms, Kansas (Shieldcastle 2000).

Olson (2003) previously studied shorebird use of managed wetlands in Ohio and yearly shorebird surveys are performed throughout the region by Black Swamp Bird Observatory volunteers (Shieldcastle 2000). However, little published research is available regarding shorebird habitat utilization in the SLEMR and how this compares to waterfowl use of habitat in the region. Moreover, two gaps in knowledge were identified by the U.S. Shorebird Conservation Plan for the Upper Mississippi Valley/Great Lakes Region, 1) specific shorebird use of wetland and associated upland habitats and 2) the effects of lake-level fluctuations and weather conditions on habitat availability.

My research aimed to fill these gaps and provide information that could be used to improve management for shorebird and waterfowl migration habitat in the SLEMR by answering the following questions:

1. What are the relative contributions of coastal wetlands (lake-influenced), impounded marsh (managed water levels), and agriculture (precipitation-influenced) to meeting habitat needs of migrating shorebirds?

2. How do vegetation composition, habitat structure, and water depth and distribution affect wetland use by migrating shorebirds?

3. How can wetland management be improved in the southwest Lake Erie region to better meet habitat needs of migrating shorebirds?

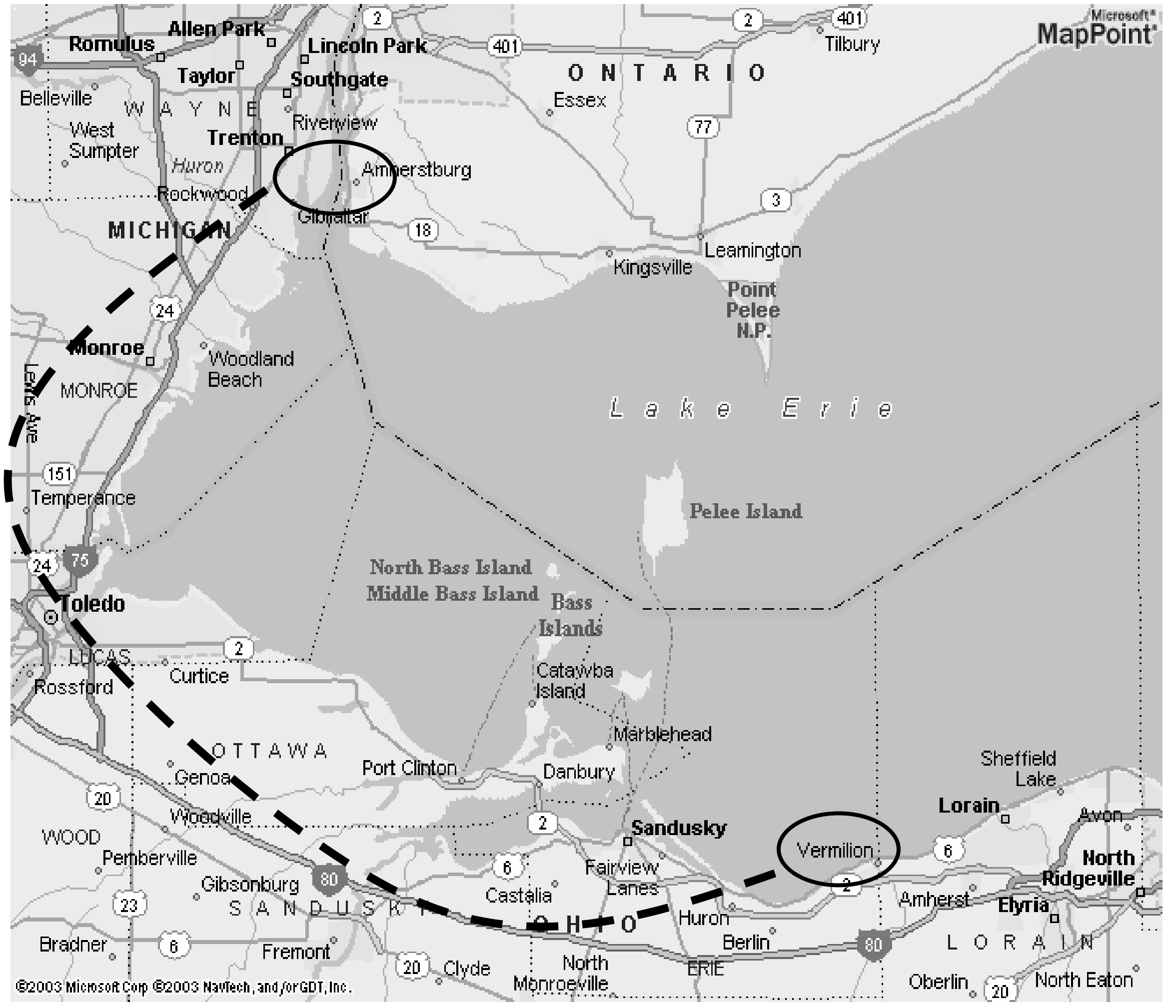

Figure 1.1 Map showing the western basin of Lake Erie. The circles and dotted line show the historic extent of the Lake Erie marshes region, from the Detroit River in Michigan to Vermillion, Ohio.

To answer these questions I estimated how many shorebirds used the southwest Lake Erie marshes during spring and autumn migrations 2002 and 2003, determined their distribution among agriculture, managed marsh, and lake-level influenced wetland habitat types within the region and identified the environmental and habitat characteristics that influenced their local abundance, distribution, and habitat utilization. Simultaneously, I determined the distribution and habitat utilization rates of waterfowl that were present during shorebird migration periods. I compared the abundance and habitat utilization rates between shorebirds and waterfowl in order to provide insight into habitat conservation practices that could benefit both bird groups.

CHAPTER 2

LITERATURE REVIEW

2.1 Shorebird Migration and Stopover Ecology

Nearctic shorebirds must travel annually between their wintering grounds, located from southern North America to South America, and their breeding grounds in the northern Great Plains, or boreal and tundra regions of the northern U.S. and Canada. The annual migration can sometimes exceed 30,000 km (Clark 1995). Such travel is energy demanding and shorebirds must make frequent stops along the way to replenish fat reserves. Consequently, migrating shorebirds seem to follow seasonal changes in availability of food resources (Schneider 1981). Foraging sites, commonly called stopover sites, vary in size and location, but provide the necessary habitat and food resources for shorebirds to complete their migrations. A shorebird arriving at a stopover site may have just completed hours of continuous flight and so must periodically replenish fat reserves in order to complete migration (Myers 1983).

Some researchers believe that stopover sites are not synonymous with staging areas which are areas consistently used by and supporting large numbers of migrating shorebirds. Skagen and Knopf (1994) wrote that interior wetlands within the U.S. are characterized by “dynamic water regimes and unpredictable resources” and may be better classified as stopover sites than staging areas. This is because interior wetlands may be used by migrant shorebirds that employ a “hopping” method of migration which involves making several series of stops between feeding sites enroute to breeding or wintering grounds (Skagen 1994). Conversely a staging area is a regular point of destination for long-distance migrants that may only make a few stops or “jumps” along their migration route (Pfister 1998, Skagen 1994).

The inconsistent and unpredictable nature of small stopover sites suggests that shorebird stopovers will be brief, perhaps lasting only until the local food supply becomes depleted. Shorebird visits to small stopover sites also tend to be opportunistic rather than driven by site-fidelity (Colwell 1988, Post 1976). However, many shorebirds that migrate over land rely on these areas no matter how dynamic the wetland or unpredictable the food resources are (Warnock 1998, Skagen 1994). Indeed, recent research has shown that most shorebirds spend the majority of their life away from coastal areas that have received so much historical attention (Warnock 1998, Colwell 1988).

Small stopover sites and large staging areas are both subject to habitat degradation or loss that can have detrimental effects on shorebird populations (Myers 1983, Dinsmore 1998, Pfister 1998, Skagen 1994). Interior wetlands are small, fragmented, and more easily affected by land use practices than larger, coastal staging areas (Skagen and Knopf 1994). However the important coastal areas are often isolated and if any one staging area is rendered unusable, migrating shorebirds may not easily find alternative foraging sites nearby (Myers 1983). The Western Hemisphere Shorebird Reserve Network (WHSRN) was developed to protect important stopover sites and staging areas, and since 1984 over 21 million acres of shorebird habitat have been recognized for conservation status

(WHSRN website: http://www.whsrn.org/about.html). The Western Hemisphere Shorebird Reserve Network categorizes sites into one of three designations: sites of hemispheric importance, sites of international importance, and sites of regional importance. Hemispheric sites are those that support at least 500,000 shorebirds annually or > 30% of the biogeographic population for a species. International sites support at least 100,000 shorebirds annually, or > 10% of the biogeographic population for a species. Lastly, regional sites support at least 20,000 shorebirds annually, or > 1% of the biogeographic population for a species. WHSRN has designated seven hemispheric sites, 12 international sites and 20 regional sites of importance to shorebirds in the U.S. The Lake Erie Marsh Region, which hosts over 35 species of migrating shorebirds annually, was designated as one of 20 regionally important WHSRN sites on 18 August, 2001.

2.2 The History of Shorebirds in the Lake Erie Marshes

Lands adjacent to the western basin Lake Erie marshes were once known as "the Great Black Swamp" (Reeder and Eisner 1994). For thousands of years these lands were covered by thick swampland, high prairies dotted with giant oaks, and green marshes that covered all or parts of 12 counties from Sandusky, Ohio to Fort Wayne, Indiana and from the Maumee River valley to Findlay, Ohio (Mollenkopf, unpub.account). Only after ca. 1830 did settlers stop avoiding and begin inhabiting the swamp. Soon thereafter, settlers began draining water from the land and by 1900 there was little that remained of the Great Black Swamp. While nearly 90% of the wetlands in this region were drained for agricultural purposes, most of the remaining wetlands were purchased around 1920 by wealthy sportsmen’s groups seeking waterfowl hunting opportunities. The duck hunting clubs were thus formed to protect the Lake Erie marshes from further degradation (Herdendorf 1987). The coastal marshes of southwestern Lake Erie were eventually enclosed by dikes and fitted with water control structures that characterize the impounded marshes that remain today.

Shorebird accounts in Ohio before the late 19th century are sparse, although some historical records prove they were present long before European settlement. A series of archeological digs at Native American sites in the southwest Lake Erie marsh region during the early 20th century produced bones from waterfowl and shorebirds (Mayfield 1972). Mayfield (1972) believed that these bones were evidence of food resources used by indigenous inhabitants of the region during 700-1200 AD.

Early post-European settlement accounts of shorebirds in the region are also scarce, but it is known that both waterfowl and shorebirds were heavily market-hunted and used in the millinery trade in Ohio. By the early 1900's some interest in bird migration prompted early ornithologists to publish accounts of species along the Lake Erie shoreline of Ohio. Jones (1909, 1912) wrote of considerable numbers of sandpipers and other shorebirds observed while visiting the Lake Erie islands. He thought a major migratory flight line existed between the Canadian Point Pelee and the Sandusky Bay area. Jones (1912) also noted spotted sandpipers (*Actitis macularia*) "teetering" along the rocky shores when all other shorebird habitat was underwater. Hicks (1938) reported that unusual amounts of rain and subsequent flooding in the area of Bellevue, Ohio attracted more shorebirds to the muddy fields over the course of a few weeks than the entire state was known to accommodate in one year. Also in the 1930's Lewis Campbell (1931, 1938) published several accounts of shorebird use of the Toledo, Ohio area and other sites along the western basin of Lake Erie. These accounts were meant to document the numbers and movements of shorebirds within extensive mudflats near Bono, Ohio and the existing Little Cedar Point National Wildlife Refuge; habitat that resulted from storm-induced flooding and subsequent failure of drainage canals or dikes.

Today shorebird use of the region is well known and extensive data from surveys describe the dates and location of their occurrence (Black Swamp Bird Observatory unpub. data; Olson 2003). As is true of shorebirds nationwide, the migrants passing through the Lake Erie marshes utilize a variety of habitats to fulfill their dietary requirements.

2.3 Shorebird Use of Coastal, Estuarine, and Riverine Wetlands

The highly dynamic nature of coastal, estuarine, and riverine wetlands makes them very attractive to shorebirds. Shorebirds are attracted to wetlands that supply a moist-soil/water interface along which they feed (Rundle and Frederickson 1981). However, a group of shorebirds can quickly deplete an area of invertebrates if this interface is static. A constantly moving soil/water interface would seemingly provide the best foraging habitat for shorebirds because the fluctuating water regime varies the amount and the location of exposed mudflats where shorebirds feed, preventing any one area from being totally depleted of invertebrate prey. Coastal, estuarine, and riverine wetlands have water regimes that are constantly changing and hence, the moving soil/water interface is renewed both chemically and biologically (Bedford 1992). On the other hand the dynamic water regime that renews the mudflat habitats also creates an unpredictable foraging environment. When weather conditions are favorable, mudflats are briefly (several days to 1 week) exposed for feeding but deeply submerged mudflats are inaccessible to shorebirds at high water levels, or become desiccated if low water levels are sustained for > 1week.

Most of what is written about coastal wetlands and estuaries pertains to marine (saltwater) systems, but the abundance of freshwater coastal wetlands in the Great Lakes region cannot be overlooked. Indeed the classification of some freshwater river inlets as estuaries has been favored by some (see Herdendorf 1980, Odum 1980) because of the short or long-term fluctuation in water levels and the corresponding biological and chemical mixing (Bedford 1992). Estuarine wetlands in the marine sense have been ranked as some of the most productive habitats existing today (Bildstein et al. 1991) and typically support large numbers and species of waterbirds at various times in their life cycles. Shorebird use of estuaries and coastal wetlands as a whole is well understood (Bildstein et al. 1991, Moser 1988, Burger 1984), but the contribution of rivers, freshwater estuaries, and interior coastal wetlands to overall shorebird habitat is relatively unknown (Skagen and Knopf 1994).

Colwell (1993) observed that tides and weather affect habitat availability for shorebirds in a predictable fashion in marine environments. The opposite is true of interior coastal wetlands where habitat availability depends on unpredictable weather patterns such as rain and winds (Bolster 1990, Skagen and Knopf 1994). Colwell (1993) admitted that the dynamics of riverine and river estuary systems and their importance to shorebirds is relatively unknown. Bolster (1990) observed that shorebirds readily used the exposed mudflats and sandbars of the Amazon River when the dry season permitted, but heavy rains during the wet season kept this rich habitat underwater.

The western Lake Erie basin is surrounded by many dynamic coastal wetlands and riverine systems. This basin is very shallow and especially prone to shifting water levels in response to weather (Bedford 1992). River gradients and flow rates are low, creating flat floodplain regions that are in turn highly affected by Lake Erie's changing water levels. The confluences of many of these western basin rivers are analogous to estuarine areas in that fluctuation of water levels and mixing of nutrients and biota tends to be quite high (Bedford 1992). In fact, lake level fluctuations are known to have such an effect on the western basin rivers and confluences that the US Geological Survey placed water quality gauges as far as 30 km upstream to avoid the influence of lake level fluctuations (Bedford 1992).

Human development has threatened or destroyed important shorebird habitat where many of these coastal or riverine wetlands occur (Dinsmore 1998, Senner and Howe 1984). Areas that attract shorebirds are also attractive to humans. Practices such as dredging rivers for navigational purposes and development of coastal areas have eliminated many of these important wetlands.

2.4 Shorebird Use of Impounded Wetlands

Impounded marshes managed for waterfowl are known to also attract shorebirds (Weber and Haig 1996, Rundle and Frederickson 1981, Colwell 1988). Several studies even suggest that shorebirds sometimes prefer impounded managed marshes over natural wetlands (Langely et al. 1998, Boettcher 1997). During periods of high tide or otherwise unfavorable conditions in natural wetlands, impounded wetlands can provide important foraging habitat for shorebirds (Weber and Haig 1996, Burger 1984, Boettcher 1997).

Boettcher's (1997) study of manmade impoundments and intertidal mudflats found that shorebird use of impounded wetlands was far greater than the natural wetlands because shorebirds could locate and capture prey where suitable foraging habitats are confined to smaller areas. Weber (1997) also suggested that impounded wetlands can supplement natural wetland areas as shorebird habitat if managed properly. Impounded wetlands usually contain more organic matter than estuary environments and subsequently may support greater abundance of chironomids, the preferred prey of many shorebirds (Weber and Haig 1996).

Impounded wetlands managed for high prey abundance and at appropriate water levels can attract large numbers of shorebirds. Drawdowns of marsh habitat provide the greatest opportunity for foraging shorebirds within impounded wetlands. Rundle and Frederickson (1981) observed that most shorebirds using impounded wetlands were found within 15 cm of the soil/water interface. Attracting shorebirds to an impounded wetland can be accomplished by creating shallow water (0-5 cm) interspersed with exposed, saturated soil.

Timing of drawdowns is also important. Early spring drawdowns benefit waterfowl by producing the greatest amount of seeds and allowing plants to become established before they become desiccated during the summer dry season (Frederickson 1991). Early spring drawdown (e.g. during April) followed by reflooding during summer stimulates production of invertebrate biomass that can be concentrated and made accessible via drawdown during the fall migration of shorebirds (Rehfisch 1994). Ideally, drawdowns should be performed during both seasons and initiated just before or during the migration period (Hands et al. 1991, Shuford 1998).

The rate of wetland drawdown is also important. Gradual drawdowns have proven more effective for attracting foraging shorebirds (Rundle and Frederickson 1981). Gradual or slow drawdowns last 2 to 3 weeks (Frederickson 1991) and provide a slow-moving soil/water interface across a wetland which lengthens foraging opportunities for shorebirds and prevents depletion of food sources that would occur at a static substrate-water interface. Unlike slow drawdowns, rapid drawdowns last 1 to 3 days and provide only brief opportunity to support shorebirds. Rapid drawdowns also cause substrates to harden more quickly and render burrowing invertebrates inaccessible to foraging waterbirds. In general, slow drawdowns are more effective for promoting plant growth and wildlife use (Frederickson 1991), but the resulting high vegetation cover can limit shorebird use (Rundle and Frederickson 1981).

2.5 Shorebird Use of Agricultural Habitats

Ormerod and Watkinson (2000) estimated that agricultural lands cover about one-third of the earth's surface. Agricultural development can both limit and create opportunities for wildlife conservation. Many species are adversely affected by conversion of native habitats to croplands, but others are able to adapt, exploit, and even benefit from agricultural habitats. Crop fields have been known for some time to attract foraging shorebirds and there is evidence that several species actually prefer this habitat (Colwell and Dodd 1995, Rottenborn 1996). Long and Ralph (2001) divided shorebirds into two groups, *field specialists* who commonly used farmlands and *field opportunists* who only used farmland when preferred habitat was unavailable. Similar to impounded wetlands, shorebirds opportunistically use agricultural lands when conditions are unfavorable in natural wetlands (Colwell 1993, Rottenborn 1996). Likewise, loss of natural foraging sites may be somewhat offset by agricultural land if they are managed to provide conditions suitable for shorebirds (Colwell 1997).

Use of crop and pasture lands by shorebirds depends on weather and land use practices that affect habitat structure and food resources. Water conditions (Colwell and Dodd 1995, Colwell 1993, Shuford 1998), vegetation height (Colwell and Dodd 1995, Rottenborn 1996, Colwell 1993, Fujiyoka et al. 2001), and tillage, cropping, and grazing practices (Tucker 1992, Colwell and Dodd 1995) have been shown to affect shorebird use of agricultural lands.

Expectedly, shorebird use of pasture and crop lands increases when shallow water is present (Colwell and Dodd 1995), demonstrating the importance of local precipitation on use of agricultural lands by shorebirds (Reed et al. 1977). Precipitation and runoff benefits shorebirds by stimulating production of invertebrate food resources, and making food accessible to shorebirds. Similar to effects of flooding in impounded wetlands, heavy precipitation in a short period can dilute prey availability or cause flooding that exceeds the foraging depths of some or all shorebird foraging guilds (Colwell 1993). Colwell and Dodd (1995) found that both seasonal and daily pasture use by shorebirds was correlated with precipitation. Long and Ralph (2001) found that rain was associated with field use by shorebirds in that shorebirds did not use fields until fall rains began.

Presence, type and structure of vegetation all influence the invertebrate community found within croplands and fields. Cropland with little or no vegetation has been found to attract shorebirds (Colwell and Dodd 1994, Rottenborn 1996, Long and Ralph 2001). Colwell found that vegetation height within pastures was strongly correlated with shorebird use and that use increased as vegetation height decreased (Colwell 1993). Fujiyoka et al. (2001) found that sparsely vegetated fallow fields supported more shorebirds than similarly flooded fields with no vegetation. Flooded soybean (*Glycine max*) stubble fields have been shown to be particularly suitable for meeting foraging needs of shorebirds (Twedt et al. 1997).

However, Vickery et al. (2001) reported that invertebrates declined as grass height declined in grasslands. Additionally, cropland monocultures like corn (*Zea mays*), soybean, and wheat (*Triticum* spp) usually have lower invertebrate densities compared to mixed-vegetation pastures or fallow fields (Moreby and Southway, 1999).

Cropland fertilized with manure also tends to increase the invertebrate prey base and hence attracts more shorebirds (Tucker 1992). Paoletti (1999) wrote that earthworm abundance is positively affected by manure application and that earthworms respond better to manure compared to commercial fertilizers. Organic fertilizers (manure) also tend to benefit grassland invertebrates when applied moderately (Vickery et al. 2001). Colwell and Dodd (1995) also found that the presence of cattle on pastures actually increased shorebird use because the manure elevated the availability of prey while also reducing vegetation height. Conversely, other studies have shown that sheep grazing lowers invertebrate densities on pastures (Hutchinson and King, 1980; Vickery et al. 2001) presumably because they out-compete invertebrates for the plant matter.

Herbicide and fertilizer treatments along with intensified management practices within agriculture should also be considered as these actions can decrease the prey base and also cause damaging physical effects to the birds themselves (Freemark 1994; Moreby and Southway, 1999; Vickery et al. 2001). Specialized farming practices, like loss of uncultivated field margin habitats and increased tillage have had negative effects on invertebrate groups in agricultural habitats (Wilson 1999). With intensification of farming, hedgerows and grassy margins have been lost resulting in losses of seed and invertebrate food sources for birds (Wilson 1999).

Farming practices such as tilling and disking may also affect shorebird use. Tucker (1992) found that increased cultivation on farm fields decreased earthworm (*Oligochaeta*) abundance. Conversely, newly disked and flooded lands have been shown to be almost immediately utilized by foraging shorebirds (Rundle and Frederickson 1981) as have plowed fields during migration (Rottenborn 1996). Vickery et al. (2001) reported that increased management intensity (i.e. increased mowing, grazing, and fertilizer application) can lead to decreased invertebrate presence in grasslands.

Rice (*Oryza sativa*) fields have been studied extensively and shown to attract shorebirds under the right conditions (McKay 1980, Barbosa 1997, Shuford 1998, Elphick 1999). McKay (1980) found that rice fields in Colombia, while rarely used by resident species, were preferred habitat for migrant shorebirds. Additionally, Shuford's (1998) study in the central valley of California showed that rice fields supported the greatest proportions of shorebirds among all agricultural lands. The rice-growing region of Louisiana is thought to support the highest number of wintering shorebirds in interior North America (Remsen et al. 1991). Some researchers (Elphick 1999, Fujioka et al. 2001) believe that rice fields may provide surrogate habitat for waterbirds that offset losses of natural wetlands and that water management techniques could increase their overall attractiveness.

Prey abundance and species composition within agricultural lands tend to differ from wetland habitats. Taft and Haig (2005) found that agricultural wetlands in the Willamette Valley, Oregon were dominated by aquatic oligochaetes, earthworms (megadrils) and chironomids. In moist soil environments (natural wetlands, impounded marshes) chironomids are the prevalent prey species (Taft and Haig 2005). However, Taft and Haig (2005) also reported that the nutritional values of Oligochaeta and Chironomidae are comparable. Earthworms are a common diet item for plovers and dunlin have also been observed consuming them (Taft and Haig 2005).

However, the intense management that agricultural land receives in comparison with wetlands creates a more unpredictable and often hostile environment for invertebrates. Plowing, tillage operations, fertilizing and chemical pesticide application can have severe adverse effects on earthworms (Paoletti 1999). In fact, large declines in earthworm abundance have occurred following tillage operations (Paoletti 1999). Earthworms are thought by some to be good indicators of soil fertility and less-intensive practices such as minimum tillage or no-tillage can help maximize earthworm biomass in agricultural soils (Paoletti 1999).

If agricultural lands contain a nutritionally comparable prey base to that found in natural or impounded wetlands, then agricultural lands could contribute substantially to the overall amount of shorebird foraging habitat. But because agricultural practices are so varied and affect invertebrates in different ways, it is important to identify what value, if any, each tillage and cropping practice has for sustaining an invertebrate prey base attractive to foraging shorebirds. Finally, while the importance of some agricultural land to shorebirds has been established (Rottenborn 1996, Taft and Haig, 2005), the overall contribution of agricultural land to migrating shorebird habitat is yet unknown.

CHAPTER 3

STUDY AREA AND METHODS

3.1 Study area

My study area was the southwest Lake Erie marsh region (SLEMR) in Ohio. The SLEMR marsh region is located within the Eastern Tallgrass Prairie Bird Conservation Region (BCR 22) which once contained the tallest and most verdant grasslands of the Great Plains. A broad and dynamic oak (*Quercus* spp.) savanna once stretched between the prairies to the west and the largely beech-maple forest (American beech, *Fagus grandifolia*; maple, *Acers* spp.) to the east (http://www.nabci-us.org/). Urbanization, recreation development, and agricultural expansion are present threats to the upland and wetland habitats within BCR 22 (http://www.nabci-us.org/). Moreover, the SLEMR now consists primarily of agricultural land and has sustained a 50-90% loss of its original wetlands (de Szalay et al. 2003). Average yearly precipitation in the SLEMR is 83 cm, plus an average snowfall of 94 cm. Average wind speed is 18.5 km/hr with gusts ranging from 69-105 km/hr yearly. Yearly temperatures are generally mild averaging 15^{o}C for the high and 4^{o}C as the low.

Average water depths in Lake Erie's western basin are 7.4 m with a maximum depth of 18.9 m. Shallow water makes the basin susceptible to wind-induced seiches. A seiche is the movement and displacement of water within the basin caused by high winds and resulting wave action. The extreme fluctuations in water levels on Lake Erie were studied by Bedford (1992). Seiches strongly influence water levels of unimpounded wetlands in the region. Seiche events are commonly caused by strong (>24 km/h) winds and can empty or flood estuaries, bays, and marshes that surround the basin depending on wind direction. Prevailing northeast winds raise water levels in the western basin, causing water depths to fall in the eastern basin. Conversely, southwesterly winds drive water into the eastern basin while creating shallow water and/or mudflat conditions in near-shore areas of the western basin.

Tributaries in the western basin are particularly susceptible to seiche events due to their physical characteristics. River depths and flow gradients in the region are typically low and easily influenced by Lake Erie water levels. These seiche events promote dynamic vegetation communities and nutrient transport in uncontrolled wetlands (Bedford 1992).

Impounded marsh wetlands in the SLEMR (5,300 ha) comprise 90% of Ohio's remaining wetland area (Bookhout et al.1989). Many of these marshes are managed to provide food for migrating waterfowl, habitat for other wetland species, and to provide recreation opportunities for hunters and wildlife watchers. I define managed wetlands as impounded basins where water levels are controlled or manipulated through use of mechanized pumps or other water-control structures. Managed wetlands in the region are primarily owned and maintained by federal or state wildlife agencies, or private sportsmen's clubs. The United States Fish and Wildlife Service (USFWS) manages the Ottawa and Cedar Point National Wildlife Refuges. Several wildlife areas in the region are owned and managed by the Ohio Department of Natural Resources, Division of

Wildlife, including Magee Marsh (Oak Harbor, OH), Pickerel Creek (Fremont, OH) and Rest Haven (Castalia, OH) among others. Of the 5,300 ha of marshlands that remain in the Lake Erie marsh region, over 2000 ha are owned by private sportsmen's clubs (Bookhout et al. 1989) and are managed to sustain waterfowl populations and to provide hunting opportunities.

The managed marshes within the study area are managed to produce a variety of wetland habitat types, including moist soil, hemi-marsh, and deep marsh. Most consist of robust emergent vegetation, but some are farmed and flooded to produce grain crops for foraging waterfowl. The general goal of marsh management in the region is to attract, hold, and sustain migrating waterfowl populations during autumn and spring.

Unmanaged or natural wetlands in the region are free-flowing creeks, rivers, freshwater estuaries, and coastal shoreline. These wetlands are sparsely vegetated and have highly variable water regimes. The Maumee and Sandusky Rivers are the largest tributaries of Lake Erie within the study area, but the Portage and Touissant Rivers also flow into the lake as do many small creeks. Two large freshwater estuaries (Crane Creek and South Creek) are located at the mouths of two smaller lake tributaries at Ottawa NWR and Winous Point marshes.

Wetlands are present in agricultural fields, but these are mostly shallow basins with temporary water regimes. Temporary standing water is more common in spring when precipitation events are more frequent and lower temperatures delay evaporation, compared to fall. Agricultural land in the region has been extensively tiled and drained, preventing ephemeral basins from holding water long enough to sustain wetland vegetation. Consequently, ephemeral basins are sparsely vegetated with crop stubble in spring or late fall, or are densely vegetated with standing crops during late summer and fall.

3.2 Study sites

The two largest, remaining wetland complexes within Ohio's portion of the SLEMR were selected as study sites for this project. One was named the coastal site because the complex is adjacent to Lake Erie and one was named the embayment site because the complex is adjacent to Sandusky Bay (Figure 3.1). The coastal site was centered on Ottawa National Wildlife Refuge (NWR) and adjacent Magee Marsh Wildlife Area (WA). The embayment site was centered on the Winous Point marshes that surround Muddy Creek Bay and are adjacent to Sandusky Bay.

Figure 3.1 Coastal and embayment wetland complex locations where shorebirds and waterfowl were censused during spring and fall migration 2002 and 2003 within the southwest Lake Erie marsh region.

Coastal Site.—Ottawa NWR (1,895 ha) and Magee Marsh WA (809 ha) are located in Ottawa and Lucas Counties. Together, these federal- and state-owned sites provide 2,704 ha of managed marsh, estuarine, agricultural, and lakeshore habitats that are potentially suitable for migrating shorebirds near the Lake Erie shoreline. Ottawa NWR and Magee Marsh WA share a common dike and are surrounded on three sides by agricultural land use.

I established a 3.2 km radius buffer zone outside the state, and federal property boundaries to sample private-owned agricultural land. The total area of the coastal site, including private-owned croplands adjacent to Ottawa NWR and Magee Marsh WA was 9,550 ha (Figure 3.2). The agricultural landscape is dissected by Lake Erie tributaries including the Toussaint River, Crane Creek, Turtle Creek, and Packer Creek. This site also features sandy beaches, an uncommon habitat on the southwestern Lake Erie shoreline.

Figure 3.2. Shorebirds were censused within a coastal wetland complex that encompassed the Ottawa National Wildlife Refuge and Magee Marsh State Wildlife Area along with a 3.2 km radius of adjacent cropland.

Embayment Site.—The Winous Point marshes are located in Ottawa and Sandusky Counties, Ohio about 26 km southeast of the coastal site. Unlike the coastal site, the embayment site is not located on the Lake Erie shoreline, but it surrounds the mouths of Muddy and South Creeks and the Sandusky River that are tributaries to Muddy Creek Bay, a secondary inland embayment of Lake Erie. The Winous Point marshes are located on Sandusky and Muddy Creek Bays and include 1,821 ha of shallow lake embayments, estuaries, and vegetated wetlands including 809 ha of managed marshes. The embayment site is surrounded by several private sportsmen's clubs and agricultural lands.

The embayment site and its adjacent private land within a 3.2 km beyond the boundary of Winous Point marshes encompassed 11,400 ha (Figure 3.3). The Sandusky, Portage, and Little Portage Rivers along with Muddy Creek are significant tributaries that dissect the predominant agricultural and residential areas within this study site.

Figure 3.3. Shorebirds were censused within an embayment wetland complex that encompassed the Winous Point Marsh Conservancy and Muddy Creek Bay along with a 3.2 km radius of adjacent cropland.

3.3. Survey plot sampling design

Land cover maps of each study site were extracted from United States Geological Survey (USGS) Land Use and Land Cover (LULC) digital data for Ohio (USGS 2000), using ArcView Release 3.2 (Environmental Systems Research Institute, Redlands, CA). The LULC consists of classified land use and land cover data interpreted from satellite imagery for a specific region. Landscapes were classified into 21 various cover classes (i.e. open water, forested, cropland) and were projected to the Universal Transverse Mercator (UTM) system. Files used here were in Composite Theme Grid format and have a resolution of 30 meters.

The boundaries of the coastal and embayment sites were georeferenced into the land use and land cover map using ArcView Release 3.2 (Environmental Systems Research Institute, Redlands, CA) and known latitude and longitude values. A 3.2 km buffer was created from the property boundary layers to include agricultural lands outside the wetland complexes. A 0.25 km^2 square grid-cell layer was overlaid on the LULC layer to create a sampling frame of potential survey plots. Each grid cell was classified into 1 of 3 sampling strata based on proportional areas of agricultural land use types (i.e.. row cropland), vegetated wetlands (i.e. managed marsh), and unvegetated open water (i.e. lakeshore, embayment, or stream channel) contained within the cells. These strata represented land types where the hydrological regimes affecting habitat quality and availability were predominantly driven by: (1) local precipitation and runoff (e.g. agriculture); (2) lake-level fluctuations (e.g. lakeshore, estuaries, rivers); and by human control (e.g. managed marshes).

Each cell was classified into only 1 of the 3 mutually exclusive sampling strata according to three hierarchical *a priori* decision rules. Any grid cell that contained 10% riverine, estuarine, or lacustrine littoral (Cowardin et al. 1979) wetland types was placed in the lake-influenced stratum. Grid cells were placed in the managed marsh stratum if they contained 40% of vegetated wetland habitat. All remaining cells were placed in the agricultural stratum. Because nearly all of the cells that contained unvegetated open water or impounded vegetated wetlands were placed into the first two strata, cells in the agricultural stratum consisted almost entirely of cropland.

I randomly selected 30 plots (10 per sampling stratum) at each site using a web-based randomization tool (Research Randomizer; www.randomizer.org) for the spring 2002 survey. An additional 15 plots were selected (5 per stratum) at each site to increase sample size and to more broadly represent habitat conditions in the region during the latter three surveys. Thus, 60 plots were surveyed throughout my study, while an additional 30 plots also were surveyed during all but the initial spring 2002 survey. Entire plots (0.25 km^2) were surveyed in the agricultural stratum, but only one-quarter of plots (0.06 km^2) were surveyed in the other two strata. There were two reasons the plot size differed between wetland and agricultural strata. First, availability of water was greatly reduced within agricultural plots and I compensated for this by surveying a larger area. Second, habitat conditions within wetland plots (i.e. dense vegetation, deep water, limited observer access) made it very difficult and time consuming to survey plots larger than 0.06 km^2.

Survey plots were inspected in the field to verify their stratum classification from the digital land cover maps. Field observations and or aerial photographs were used to identify vegetation types of lake-affected wetlands and managed marshes because Ohio LULC data did not provide sufficient detail. Table 3.1 summarizes the habitat areas of each stratum and the proportion of the stratum that was surveyed at either study site for all seasons except spring 2002.

Study Site	Total Area	Area per Stratum	Area Surveyed
Coastal	9,550 ha	Agriculture: 5,650 ha	375 ha (0.066%)
		Estuarine: 1,300 ha	93.8 ha (0.072%)
		Managed Marsh: 2,600 ha	93.8 ha (0.036%)
Embayment	11,400 ha	Agriculture: 4,950 ha	375 ha (0.076%)
		Estuarine: 2,250 ha	93.8 ha (0.042%)
		Managed Marsh: 4,200 ha	93.8 ha (0.022%)

Table 3.1. The total available area that could be sampled (ha), the breakdown of that area per stratum and the percentage of each stratum that was sampled at two study sites in the southwest Lake Erie marsh region during spring and autumn migrations 2002 and 2003.

3.4 Diurnal waterbird censuses

Survey plots were visited weekly during spring (April-June) and autumn (July-November) migration periods in 2002 and 2003. Seasonal survey periods coincided phenologically with autumn and spring migration periods of shorebirds in the southwest Lake Erie marsh region (Black Swamp Bird Observatory unpublished survey data 1998-2001). The 2002 surveys were conducted from April 22 through June 7 during spring and July 8 through November 1 during autumn. The 2003 surveys were conducted April 7 through June 6 during spring and July 7 through October 31 during autumn. The census periods were planned to capture the entire shorebird migration but they did not span the entire waterfowl migration period. Waterfowl migration in the southwest Lake Erie marsh region typically occurs between February and late April in spring and between late September and January in autumn. Thus, my censuses captured the latter half of waterfowl migration during spring and the early half of waterfowl migration in autumn.

Diurnal counts of waterfowl and shorebirds were recorded by species in each plot using binoculars or spotting scope from distances that minimized disturbance of birds present on survey plots (Hands et al. 1991). After visually scanning the survey plots, "beat out" counts were conducted by walking through portions of plots where dense vegetation impaired visibility. Birds that were flushed were added to the first visual count. Duration of each plot census (5 min to 2 hrs) varied with number of birds present, observer access, and visibility. Shorebird counts were recorded separately by habitat types present within survey plots. Although many plots contained habitats that characterized more than one sampling stratum, birds were still counted in all habitat types, regardless of the sampling stratum of the survey plot. Surveys also were conducted regardless of weather conditions at the time that plots were visited.

3.5 <u>Habitat Conditions</u>

Habitat characteristics of all survey plots also were recorded weekly, at the same time bird counts were conducted. All habitat types present within a plot were surveyed regardless of plot stratum. Guidelines for classifying wetlands followed Cowardin et al. (1979). Wetland type and dominant plant species were recorded for each habitat type

(Table 3.2), as was the percent cover of vegetation. Wetland cover classes followed the Steward and Kantrud (1971, Figure 3.4) wetland cover classes (1-4) which I later interpreted into average numerical values (Table 3.3). Upland or agricultural classes were assigned cover classes according to the stocking of the crop at the time of survey and were converted into average numerical values prior to data analysis: Standing crop (100% cover), harvested crop (0%), stubble (0%), tilled (0%), and no till (0%).

The percentage of area inundated by water was also recorded for each habitat type within a plot. Percent inundation was estimated by observing the relative proportions of exposed substrate to flooded substrate within each wetland type in the plot. Presence or absence of each water depth class associated with five shorebird foraging guilds was recorded within each wetland habitat type. The guild classes were based primarily upon the morphology and feeding habits of individual species. The shorebird species were assigned to five separate guilds: 1) beach shorebirds, 2) dry mudflat shorebirds, 3) moist mudflat shorebirds, 4) shallow water (0-5 cm) shorebirds and 5) moderate water (5-15 cm) shorebirds (de Szalay, et al. 2003, M.E. Shieldcastle personal communication). Waterfowl species were assigned to the dabbling duck and diving duck classes.

Wetland Type	Dominant Vegetation Classes
Lacustrine	Sandy beach
	Unvegetated open water
	Rocky shore/diked
Estuarine	Unvegetated open water
	Giant reed (*Phragmites australis)*
	Cattail *(Typha* spp.*)*
Riverine	Unvegetated open water
	Giant reed (*Phragmites australis)*
	Cattail (*Typha* spp.*)*
Persistent Emergent Marsh	Giant reed (*Phragmites australis)*
	Cattail (*Typha* spp.*)*
	Grasses *(Poa* spp.*)*
	Rose mallow (*Lavatera trimestris*)
	Japan. Millet (*Echinochola crusgalli)*
Nonpersistent Emergent Marsh	Smartweeds (*Polygonum* spp.)
	Rushes (*Scirpus* spp.)
Floating vascular	Lotus (*Lotus* spp.)
Forested	Oak (*Quercus* spp.)
	Maple (*Acer* spp.*)*
	Poplar (*Populous* spp.)
	Ash (*Fraxinus* spp.)
	Willow (*Salix* spp.)
Shrub Scrub	Poplar (*Populous* spp.)
	Dogwood (*Cornus* spp.)
	Willow (*Salix* spp.)
Channelized	Unvegetated open water
Persistent Herbaceous	Warm season grasses
	Forbs
	Giant reed (*Phragmites australis)*
Crop	Corn (*Zea mays*)
	Soybeans (*Glycine max*)
	Winter wheat (*Triticum* spp.)
	Buckwheat (*Fagopyrum esculentum*)
	Alfalfa (*Medicago sativa*)

Table 3.2. Wetland types and the corresponding dominant vegetation surveyed within 90 wetland plots in the southwest Lake Erie marsh region during spring and autumn 2002-2003 waterbird migrations.

Categorical Cover Class	Percent Vegetation Cover
1	95-100%
2	69.5%
3	20%
4	0-5%

Table 3.3. Wetland vegetation cover classes as they were recorded in the field (categorical) and later interpreted (percent cover) prior to data analysis for 90 plots within the southwest Lake Erie marsh region during autumn and spring migrations 2002-2003.

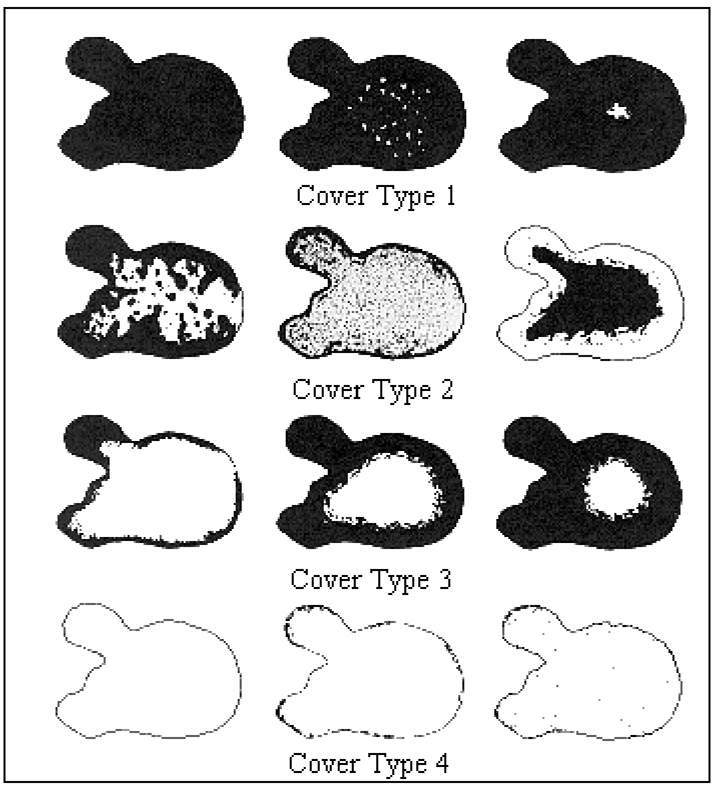

Figure 3.4. Basic cover types of natural ponds and lakes showing common variations in aspect. White areas indicate open water or exposed bare soil; shaded areas indicate emergent vegetation (credit: Stewart and Kantrud, 1971).

3.6 Weather Conditions

Weather conditions were recorded at the beginning of each plot census. Variables recorded were time of day, temperature, wind direction, maximum and minimum wind speed, and precipitation. Wind speed and direction and precipitation were obtained from the closest National Climatic Data Center located approximately ~6 km southwest of the embayment site in Fremont, Ohio (NOAA, 2002-2003).

3.7 Data summary and analysis

3.7.1 Migration chronology

Shorebird and waterfowl use-days were calculated by week for each spring and autumn season. I graphed these weekly totals to compare timing of migration between shorebirds and waterfowl and between years and seasons.

3.7.2 Temporal and spatial variation in waterbird abundance

Shorebird and waterfowl abundance, expressed as cumulative birds per km^2, was compared among strata and between sites, seasons, and years with multivariate analysis of variance (MANOVA) using the Statistical Analysis System (SAS) (Release 8.02). Separate analyses of variance (ANOVA) were also performed to test the effect of site, season, year, and stratum on each waterbird guild.

I analyzed three separate MANOVA models so that balanced comparisons could be made without bias caused by starting surveys after the onset of spring migration in 2002 and fewer plots that were surveyed in spring 2002 (n = 60) compared to thereafter (n = 90) (Table 3.4). Model 1 analyzed differences between year, site, and stratum during autumn 2002 and 2003. Model 2 analyzed differences between season, site, and stratum during spring and autumn 2003. Model 3 analyzed differences between site and stratum during spring 2002.

Season and Year	Main Effects	Interactions
Spring 2002	Site Stratum	Site*Stratum
Autumn 2003 Spring 2003	Season Site Stratum	Site*Season Stratum*Season Site*Stratum Site*Stratum*Season
Autumn 2003	Year Site Stratum	Year*Site Year*Stratum Site*Stratum Year*Site*Stratum

Table 3.4. Descriptions of multivariate analysis of variance (MANOVA) models used to test differences in waterbird abundance between years, seasons, sites, and strata in the southwest Lake Erie marsh region during autumn and spring migration, 2002-2003.

3.7.3 Bird use-days and population estimates

Shorebird and waterfowl use-days were calculated for each plot by summing the numbers of birds (by species and guild) over each seasonal period. The sum (cumulative birds/plot) was multiplied by 7 because each plot was surveyed once in consecutive 7-day periods from the beginning to the end of each season each year (Wilson and Atkinson 1995). Waterbird counts within individual wetland plots were extrapolated out to the entire study site based upon the proportion of the area of each stratum that was surveyed per site and the amount of that stratum present within the study site to obtain estimates of the migrant population (Steel and Torrie 1960).

3.7.4 Shorebird and waterfowl diversity by site and wetland type

Shorebird and waterfowl diversity by wetland type was determined using Shannon Diversity Indices calculated by wetland plot using PC Ord software (McCune and Mefford, 1999). Waterfowl and shorebirds were separated for this analysis in order to compare any differences in diversity observed between wetland types and management practices. Waterfowl and shorebird diversity indexes were then analyzed using SAS statistical software (Release 8.02) to test their correlation. To investigate whether waterfowl and shorebirds were drawn to similar habitat types or management the 15 most diverse plots for waterfowl and for shorebirds were ranked and then compared. Because most wetland management in the region is aimed at providing habitat for a diverse assemblage of waterfowl, I wanted to compare waterfowl and shorebird diversity within habitat types to see if management designed to attract a diverse community of waterfowl might also attract a diverse shorebird community.

3.7.5 Species ordination along environmental gradients

Detrended correspondence analysis (DCA) was conducted using CANOCO version 4.5 (terBraak and Smilauer 2002) to examine lengths of gradients to determine which model was most appropriate for analysis. The DCA showed a linear response of species to environment for all four seasons (gradient length <4 for axes 1 and 2, ter Braak and Smilauer 2002). I therefore used redundancy analysis (RDA) to identify links between bird abundance and environmental characteristics. Redundancy analysis is a direct ordination method designed to analyze the relationship (i.e. correspondence) between species abundance and environmental variables measured within defined sample units (e.g. survey plots) when species are presumed to have linear relationships to environmental gradients.

After examining the DCA results I first eliminated one member of each pair of environmental variables whose simple correlations exceeded $r = 0.7$. I eliminated the variable that explained the least amount of detail (i.e. I kept row crop and deleted general crop when the two were highly correlated). The species data set was cumulative numbers of shorebirds and waterfowl (by species) observed on each plot over an entire year/season. I only included those species with over 25 observations to reduce the effect of rare species on the ordination. Species data were log-transformed before analysis. Environmental variables included vegetation type (e.g. persistent emergent, row crop, persistent herbaceous), mean percent inundation per plot per season, variance in percent inundation per plot per season, distance to lakeshore (from survey plot center), and the percentages of wetland or upland cover contained within a plot (Table 3.5). I also dummy coded my study design covariables that represented the locations and sampling strata from which plots were randomly sampled. These included study site (i.e. Coastal vs. Embayment) and stratum (agriculture vs. lake affected vs. managed marsh).

Variable Name	Description
Upland	% of plot classified as upland habitat
Estuarine	% of plot classified as estuarine habitat
Riverine	% of plot classified as riverine habitat
Lacustrine	% of plot classified as lacustrine habitat
Palustrine	% of plot classified as palustrine habitat
Wetland Vegetation Cover	% of plot covered by wetland vegetation
Persistent Emergent	% of plot covered by persistent emergent vegetation
Nonpersistent Emergent	% of plot covered by nonpersistent emergent veg.
Unvegetated Open Water	% of plot covered by open water
Beach	% of plot covered by sandy beach habitat
Rocky Shore	% of plot covered by rocky interface (e.g. rip-rap)
Crop Cover	% of plot covered by cropland vegetation
Row Crop	% of plot covered by row crops (e.g. corn, soy)
Small Grain Crop	% of plot covered by small grains (e.g. wheat)
Forested/Scrub Shrub	% of plot covered by woody vegetation
Persistent Herbaceous	% of plot covered by persistent herbaceous veg.
Percent Inundation	Arc sin transformed mean % inundation per plot per season
Variation in Percent Inundation	Variance associated with % inundation per plot per season
Distance from coast	Distance (in km) from center of plot to coastline

Table 3.5. List of environmental variables used to evaluate differences in waterfowl and shorebird abundance within 90 wetland plots in the southwest Lake Erie marsh region.

Next, using RDA I performed a partial direct ordination of all species observed on my study plots with the remaining environmental variables. The partial ordinations were conducted with my dummy-coded covariables, which allowed me to analyze the relationships between bird-species abundance and the environmental variables that were measured on a continuous scale after accounting for differences in the bird species-environmental relationship among my categorical covariables. I used variance decomposition to break down the total inertia present in each season/year data set into residual (unexplained) variance, inertia uniquely explained by the continuous environmental variables, inertia uniquely explained by the categorical covariables, and the shared variance among these variable classes.

My initial ordinations revealed that species associated with beach and open water habitats along the shoreline of Lake Erie or Muddy Creek Bay (e.g. ruddy turnstone, sanderling, greater and lesser scaup) were at extremely long ends of the first and/or second ordination axes. Because these species were highly influential in the ordination, most of the other species were crowded near the origin of the resulting biplots. These species did not comprise a large proportion of the waterbird community and they were tightly associated with "beach" sample plots that were likewise relatively unique and rare components of my study areas. Therefore, I made ruddy turnstone, sanderling, greater and lesser scaup passive for subsequent ordinations. When a species is made passive it is included in the analysis, but the effect of the species on the ordination as a whole is minimized.

I used manual forward selection of the uncorrelated ($r < 0.70$) continuous environmental variables in a partial RDA (with site and stratum dummy-coded covariables) to identify the environmental variables with the greatest influence on the species environment relationship observed in each year/season. Variables were retained if their inclusion statistically improved ($P < 0.100$) the fit of the species-environmental relationship. The statistical significance of environmental variables was tested with Monte Carlo permutation tests (499 permutations). The resulting ordination diagrams were used to compare the locations of centroids of species and sample plot scores relative to each other, the selected environmental variables and ordination axes.

CHAPTER 4

RESULTS

4.1 Migration chronology

4.1.1 Spring

Spring censuses began in April and lasted until the first week of June in 2002 and 2003. This period generally spanned most of the spring shorebird migration period, but included only the last few weeks of spring migration by waterfowl. Shorebirds and waterfowl both completed spring migration by early June. Species observed are listed by foraging guild in Appendix B.

Shorebird and waterfowl migrations were already underway when weekly censuses began on 21 April 2002. The late start of surveys missed most of spring migration by pectoral sandpipers (*Calidris melanotos*) and waterfowl (Figure 4.1). Nevertheless, shorebird use-days (bud) did not peak until early May, at 11,879 bud, diminished to 4,676-6,251 bud throughout the remainder of May and declined sharply by early June (728 bud). Weekly waterfowl use-days varied from 1,701 to 2,968 bud through May and declined to 714 bud by early June.

Migration timing varied widely among the waterbird guilds during spring 2002 (Figure 4.2). The moist mudflat shorebird guild peaked during the week of 5 May (11,214 bud), while the shallow water shorebird guild (588 bud), dabbling ducks (3,185 bud) and diving ducks (525 bud) all peaked during the week of 28 April. The beach (196 bud) and dry mudflat (434 bud) shorebird guilds peaked during the last 2 weeks of spring 2002 migration.

Weekly censuses began in the first week of April 2003, before onset of spring shorebird migration. Despite the earlier start compared to spring 2002, waterfowl migration was already well underway (Figure 4.3). I recorded almost 17,654 waterfowl use-days during the week of 7 April. Waterfowl abundance declined to 8,393 bud one week later, then steadily declined through the week of 28 April (4,067 bud), then remained steady at 2,604-2,919 bud through early June. Shorebird abundance peaked (14.665 bud) during the of 14 April in 2003, and fluctuated between 4,697 and 11,690 bud through the week of 19 May before declining to 777 bud by early June.

Unlike 2002 most of the waterbird guilds showed peak abundances during April in 2003 (Figure 4.4). The waterfowl guilds each peaked during the first week of censuses with 12,761 bud for dabbling ducks and 4,893 bud for diving ducks. Weeks 14 April through 28 April captured the peak numbers for the dry mudflat shorebird guild (1,274 bud), moist mudflat shorebird guild (13,741 bud), and shallow water shorebird guild (1,449 bud). Similar to 2002, the beach shorebird guild was last to present peak numbers (19 May, 210 bud).

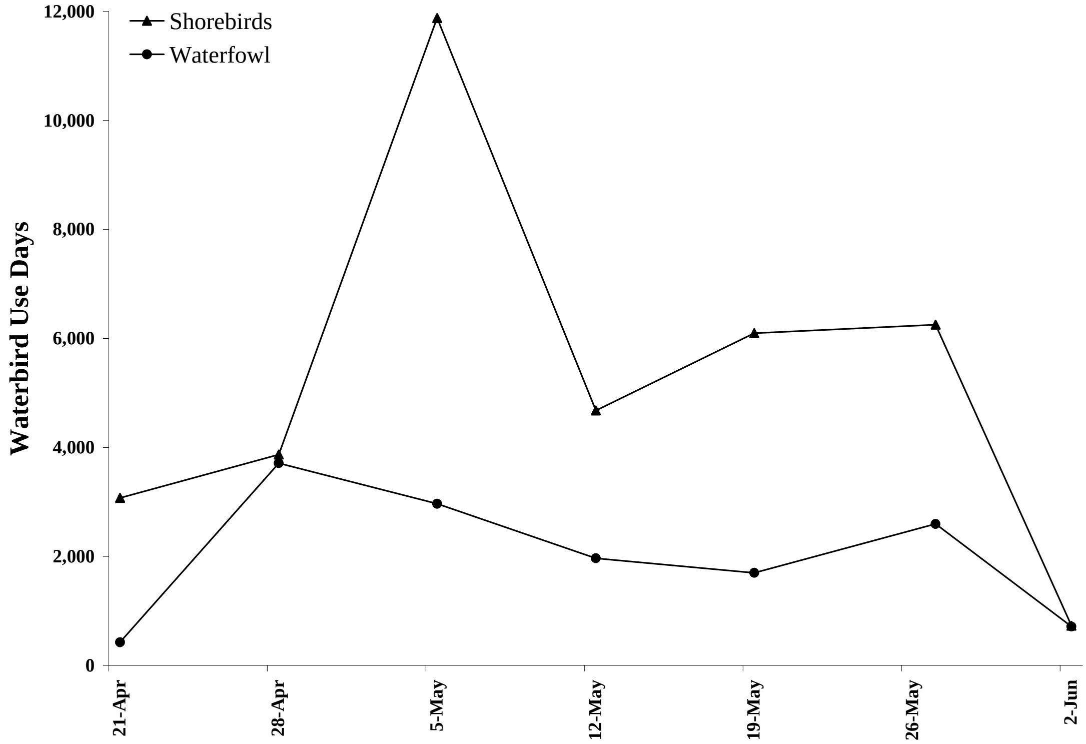

Figure 4.1. Weekly total use-days of shorebirds and waterfowl observed on 60 sample plots during the weeks of 21 April – 2 June, 2002 within the southwest Lake Erie marsh region, Ohio.

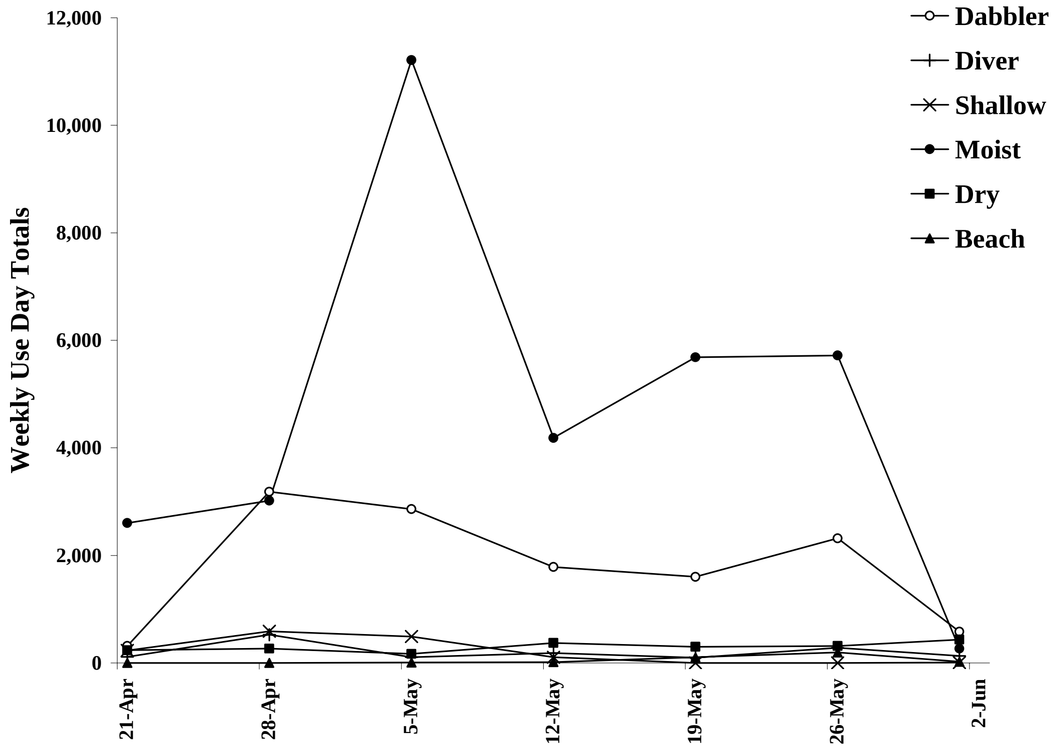

Figure 4.2. Weekly total use-days of shorebirds and waterfowl by guild observed on 90 sample plots during the weeks of 21 April – 2 June, 2002 within the southwest Lake Erie marsh region, Ohio.

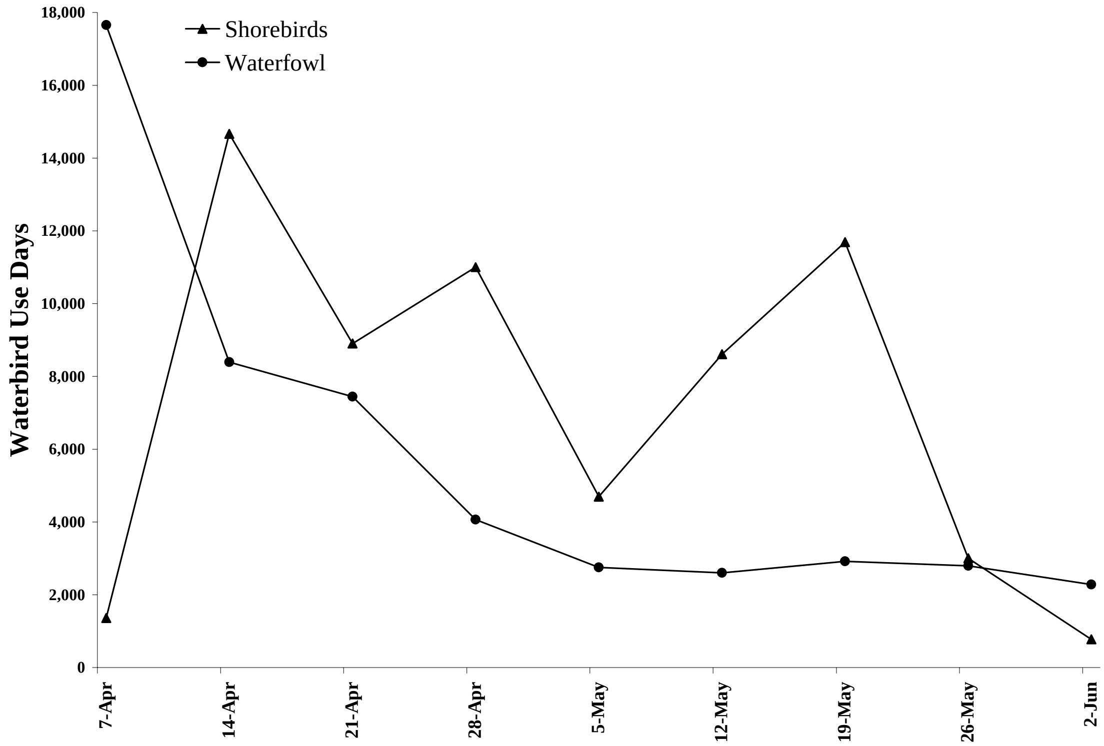

Figure 4.3. Weekly total use-days of shorebirds and waterfowl observed on 90 sample plots during the weeks of 7 April – 2 June, 2003 within the southwest Lake Erie marsh region, Ohio.

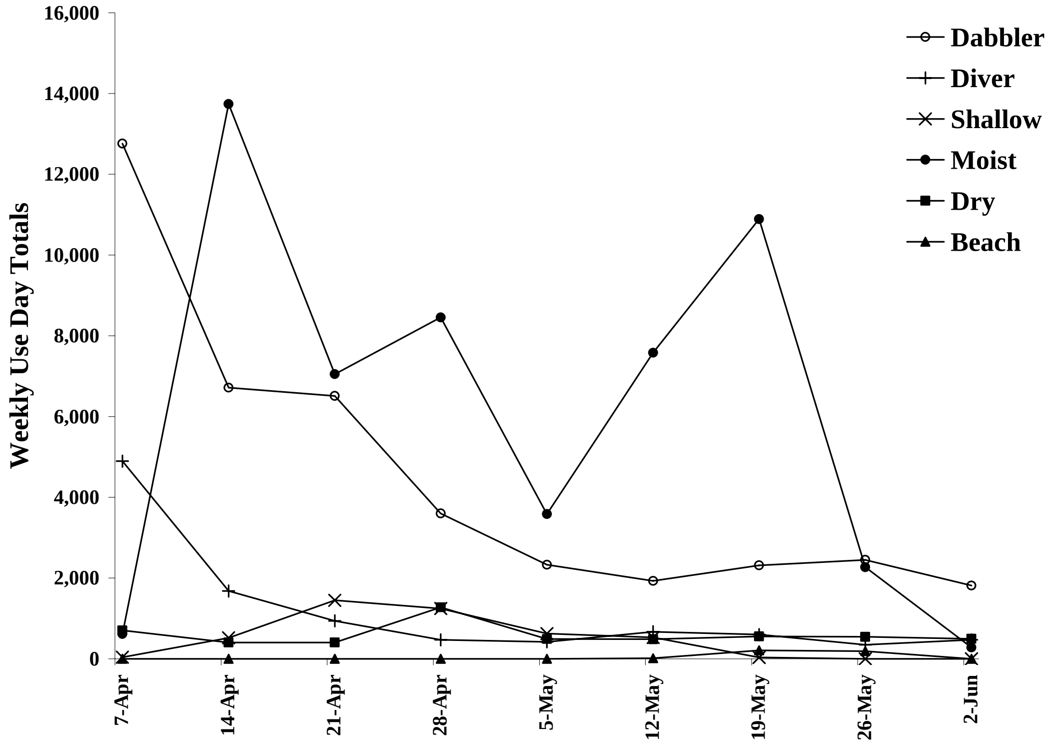

Figure 4.4. Weekly total use-days of shorebirds and waterfowl by guild observed on 90 sample plots during the weeks of 7 April – 2 June, 2003 within the southwest Lake Erie marsh region, Ohio.

4.1.2 Autumn

Autumn censuses began the first week of July and lasted through the end of October in 2002 and 2003. This period spanned most of the autumn shorebird migration period, but included only the beginning of autumn migration by waterfowl.

Shorebird use-days in autumn 2002 first peaked during the week of 11 August (11,004 bud) and then again during the week of 20 October (11,214) with the arrival of dunlin (Figure 4.5). Between these two peaks shorebird numbers spanned from 1,190-7,133 bud. Weekly waterfowl use-days varied from 1,309 to 7,532 bud from 7 July to 22 September before they peaked 25 September (25,284 bud).

All of the shorebird guilds exhibited a peak in numbers during the week of 11 August 2002 (Figure 4.6). The moist mudflat shorebird guild showed comparable and subsequent peaks during the weeks of 15 September (3,871 bud) and weeks 13, 20, and 27 October (4,865, 10,346, and 8,736 bud respectively). Waterfowl use-days were highest for dabbling ducks during the week of 29 September (25,242 bud) and for diving ducks during the week of 13 October (1,176 bud).

Weekly censuses for autumn 2003 again began during the first week of July before onset of autumn shorebird and waterfowl migration (Figure 4.7). However, the 2003 autumn migration did not contain shorebird peaks of comparable magnitude with 2002, although the timing of these peaks was similar. Autumn 2003 contained 3 peaks in shorebird numbers during the weeks of 26 August (3,752 bud), 16 September (4,277 bud) and 14 October (6,517 bud). Similar to autumn 2002 the highest peak in shorebird numbers was observed during October with the onset of dunlin migration.

Migration timing was similar between most of the waterbird guilds during autumn 2003 (Figure 4.8). All waterbird guilds except for beach shorebirds showed highest numbers during the month of October. The beach guild was highest during the week of 26 August (70 bud).

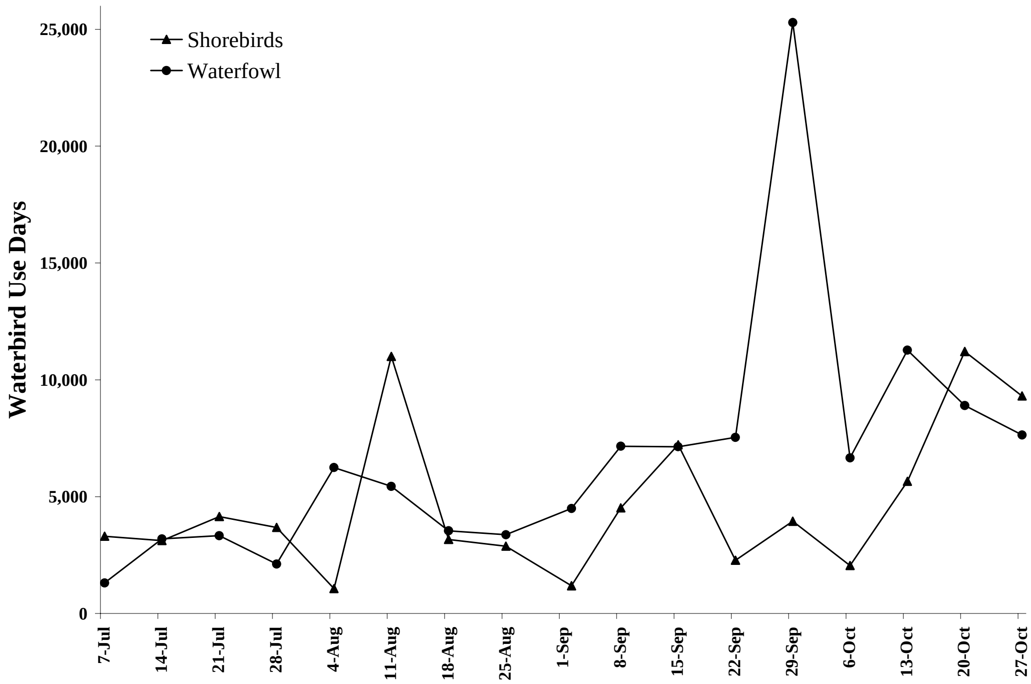

Figure 4.5. Weekly total use-days of shorebirds and waterfowl observed on 90 sample plots during the weeks of 7 July – 27 October, 2002 within the southwest Lake Erie marsh region, Ohio.

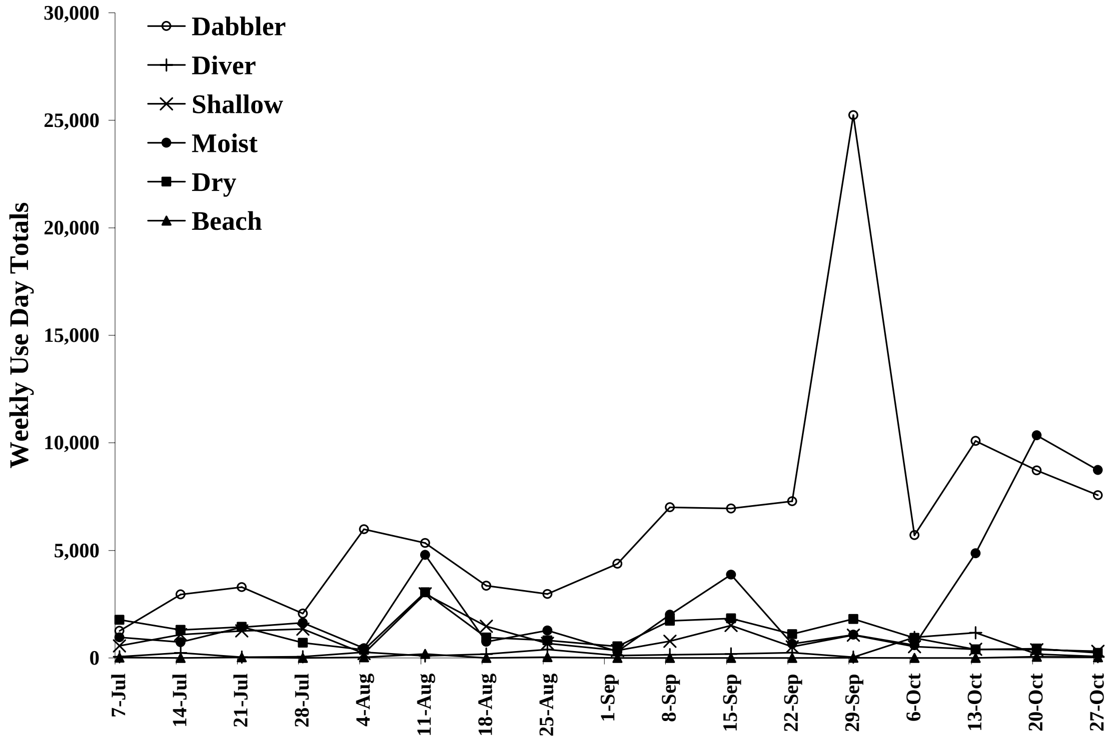

Figure 4.6. Weekly total use-days of shorebirds and waterfowl by guild observed on 90 sample plots during the weeks of 7 July – 27 October, 2002 within the southwest Lake Erie marsh region, Ohio.

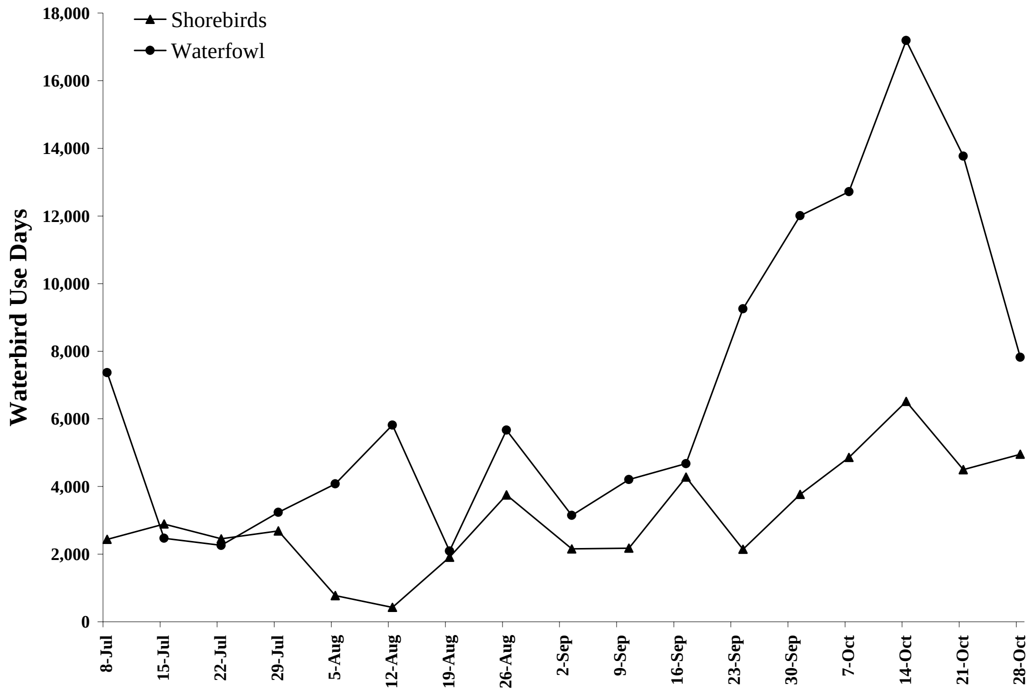

Figure 4.7. Weekly total use-days of shorebirds and waterfowl observed on 90 sample plots during the weeks of 8 July – 28 October, 2003 within the southwest Lake Erie marsh region, Ohio.

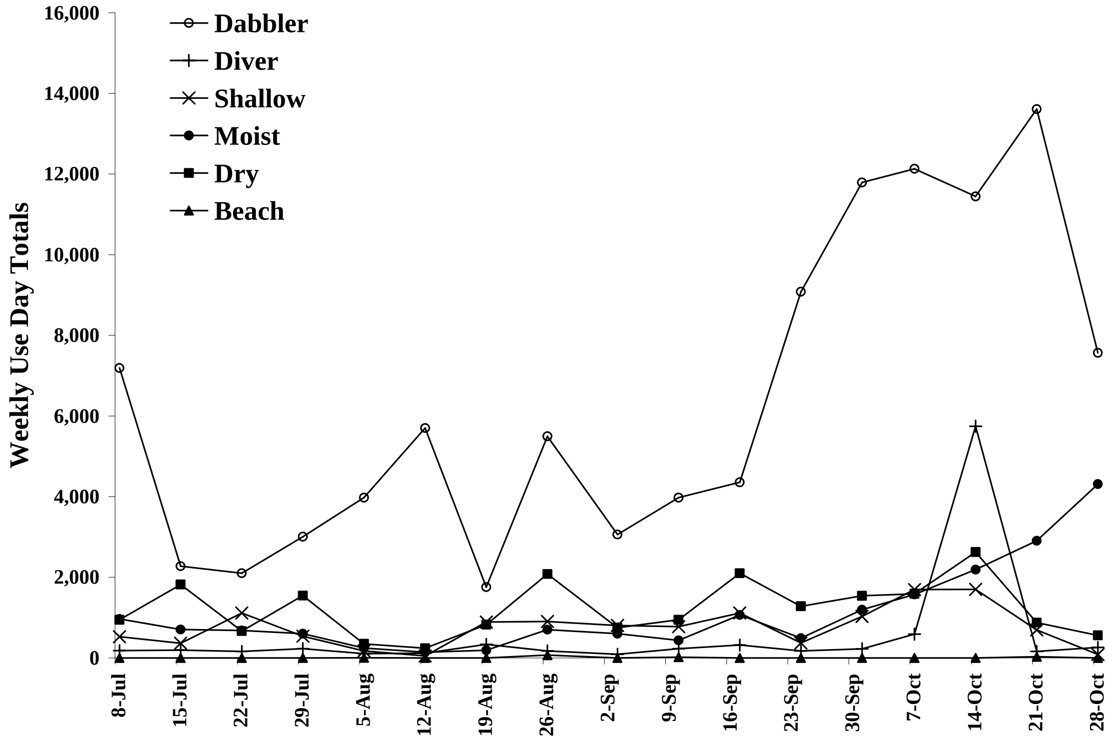

Figure 4.8. Weekly total use-days of shorebirds and waterfowl by guild observed on 90 sample plots during the weeks of 8 July – 28 October, 2003 within the southwest Lake Erie marsh region, Ohio.

4.2 Temporal and Spatial Variation in Waterbird Abundance

Total waterbird (shorebird and waterfowl) abundance (birds/km^2) varied ($P \leq 0.026$) among the three wetland sampling strata during all seasons and years (Table 4.1). Waterbird abundance also differed among sites in all seasons and years, between seasons in 2003, and years during autumn except during spring 2002 ($P \leq 0.093$). Variation in waterbird abundance among wetland sampling strata differed between sites ($P \leq 0.070$) in all seasons and years except spring 2002. Differences in waterbird abundance between sites also varied between seasons in 2003. There were strong effects of year ($P \leq 0.070$)

on waterbird abundance during autumns 2002 and 2003, including interactions with site and stratum.

Model	Source	Pillai trace	df	F	*P*
Spring 02	site	0.2152	1	1.88	0.0937
	stratum	0.4409	2	1.98	0.0271
	site*stratum	0.2549	5	1.02	0.4381
Spring and Autumn, 2003	site	0.1035	1	2.67	0.0121
	stratum	0.3173	2	4.39	<0.0001
	season	0.1644	1	4.55	0.0001
	site*season	0.0783	3	1.97	0.0627
	stratum*season	0.1907	5	2.45	0.0026
	site*stratum	0.1491	5	1.88	0.0281
	site*stratum*seas.	0.1585	11	2.00	0.0170
Autumns, 2002 and 2003	year	0.2627	1	8.24	<0.0001
	site	0.0920	1	2.35	0.0263
	stratum	0.2982	2	4.08	<0.0001
	year*site	0.0814	3	2.05	0.0518
	year*stratum	0.3653	5	5.20	<0.0001
	site*stratum	0.1309	5	1.63	0.0695
	year*site*stratum	0.1900	11	2.44	0.0028

Table 4.1. Results of three multivariate analyses of variance comparing waterbird abundance (birds/km^2) among years, seasons, sites, and strata in the southwest Lake Erie marsh region during autumn and spring migrations, 2002-2003.

4.2.1 Shorebird guild abundance

Beach guild shorebirds were most abundant during 2002 ($P < 0.0001$, $F = 16.59$, $df = 1, 179$) and this was a result of 2002 lake-affected plots receiving the most use compared to all other year-stratum categories ($P = 0.0002$, $F = 8.75$, $df = 2, 179$). Beach guild shorebirds were nearly absent from agricultural plots and about four times more abundant in lake-affected plots than in marsh plots ($P = 0.0002$, $F = 8.73$, $df = 2, 179$, Figure 4.9) with coastal and embayment sites combined. The coastal site supported more beach shorebirds than the embayment site ($P = 0.027$, $F = 4.96$, $df = 1, 179$).

Dry mudflat shorebird abundance was higher in the lake-affected plots during autumn than in any other season-strata category ($P=0.0007$, $F= 7.57$, $df = 1, 179$, Figure 4.10). During 2002 dry mudflat species were most abundant at the coastal site ($P=0.008$, $F= 7.20$, $df = 1, 179$, Figure 4.11).

Moist mudflat shorebird abundance was highest within the lake-affected plots when both seasons ($P=0.0089$, $F = 4.86$, $df = 2, 179$) and years ($P<.0001$, $F = 13.69$, $df = 2, 179$, Figures 4.13 and 4.14) were combined.

Shallow water guild abundance was highest within coastal, lake-affected plots during autumn when spring and autumn migrations were compared ($P=0.0008$, $F = 7.46$, $df = 2, 179$, Figure 4.15). A comparison of both autumn seasons also showed that shallow water guild use was highest within coastal, lake-affected plots ($P=0.001$, $F = 7.18$, $df = 2, 179$, Figure 4.16).

Moderate water guild species abundance was highest in lake-affected plots during autumn 2002 ($P=0.0006$, $F = 7.70$, $df = 2, 179$). Since this guild was rarely observed there were no other significant categories to report.

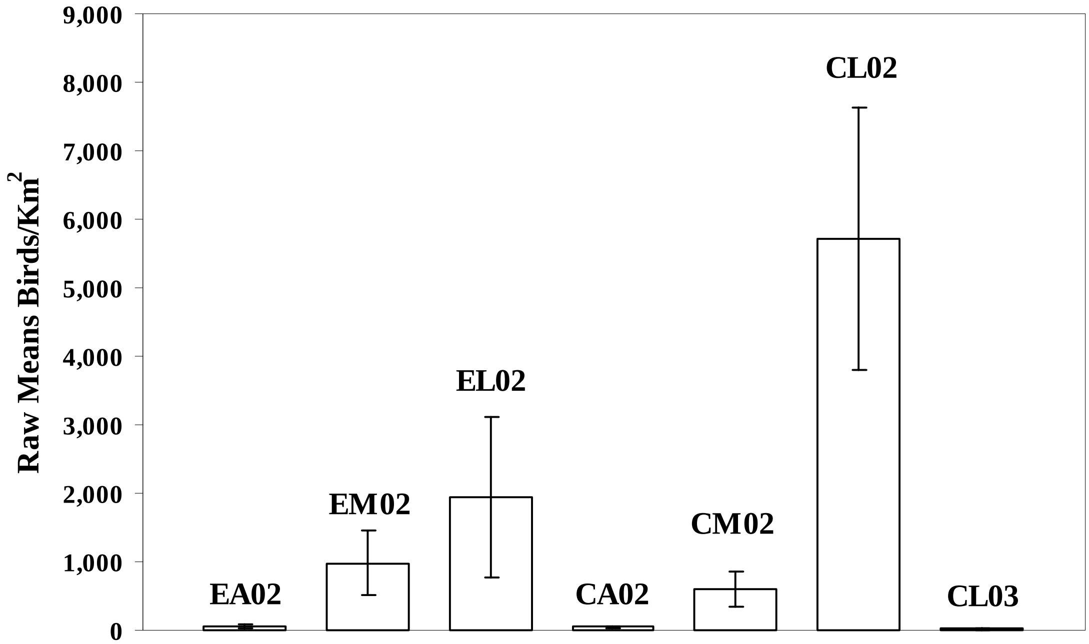

Figure 4.9. Mean (+ 95% C.I.) abundance of beach guild shorebirds by site (coastal vs. embayment) and sampling strata (marsh vs. lake-affected vs. agriculture plots) during autumn migrations 2002-2003. No beach guild shorebirds were observed at the embayment site or within agriculture and managed marsh at the coastal site during 2003. Key to figure is as follows: E=Embayment, C=Coastal, A=Agriculture, M=Managed Marsh and L=Lake-affected.

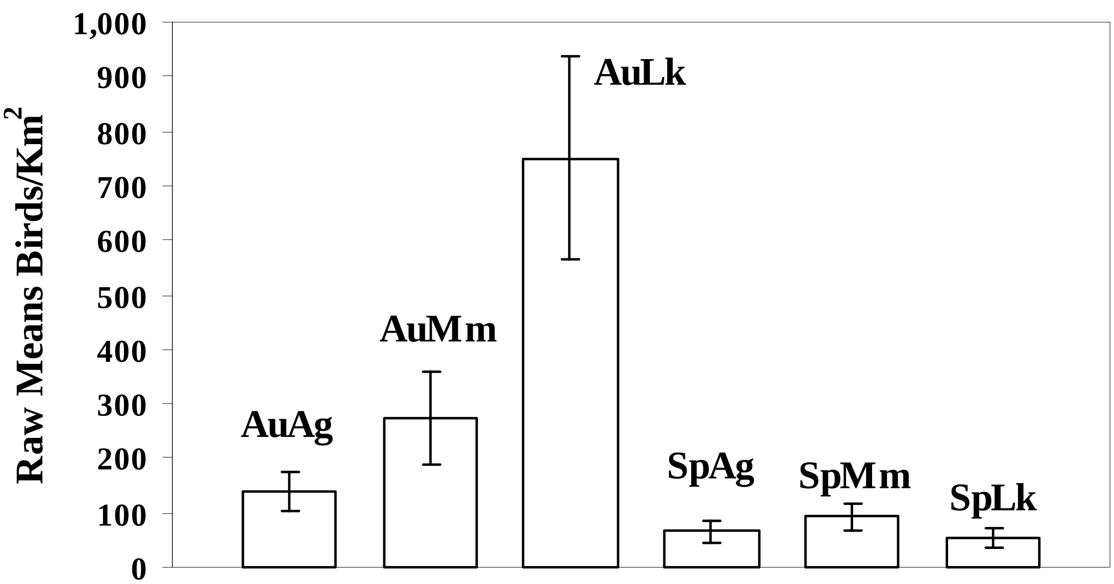

Figure 4.10. Mean (+ 95% C.I.) abundance of dry mudflat guild shorebirds by season (autumn vs. spring) and sampling strata (marsh vs. lake-affected vs. agriculture plots) during 2003.

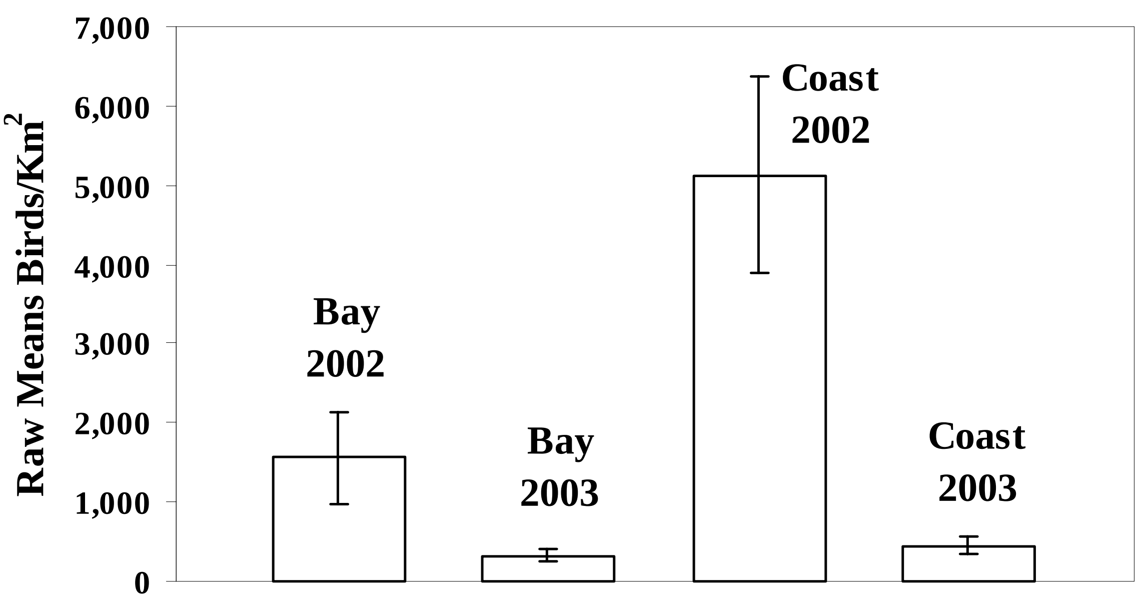

Figure 4.11. Mean (+ 95% C.I.) abundance of dry mudflat guild shorebirds by site (coastal vs. embayment) and year (2002 vs. 2003) during autumn migration.

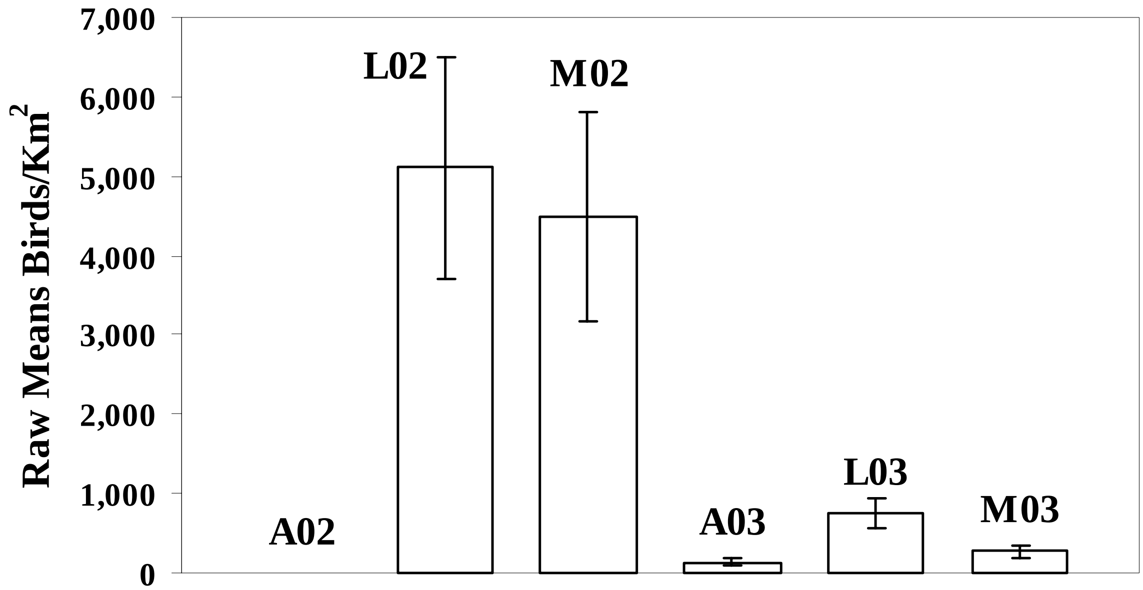

Figure 4.12. Mean (+ 95% C.I.) abundance of dry mudflat guild shorebirds by year (2002 vs. 2003) and stratum (marsh vs. lake-affected vs. agriculture plots) during autumn migration. Key to figure as follows: A=Agriculture, L=Lake-affected, and M=Managed Marsh.

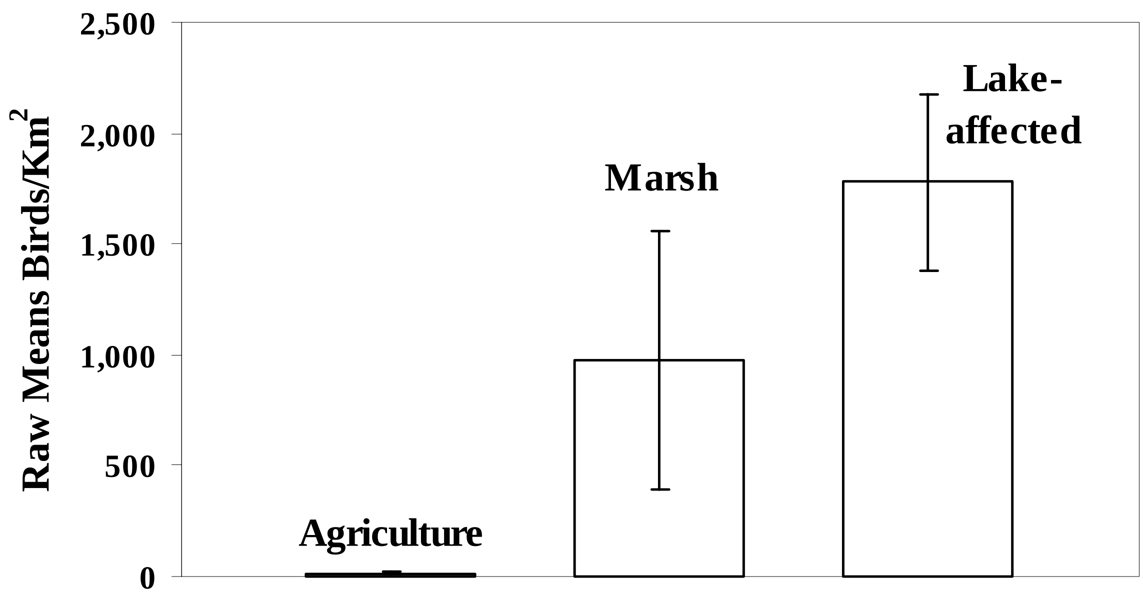

Figure 4.13. Mean (+ 95% C.I.) abundance of moist mudflat guild shorebirds by stratum (marsh vs. lake-affected vs. agriculture plots) during spring and autumn 2003.

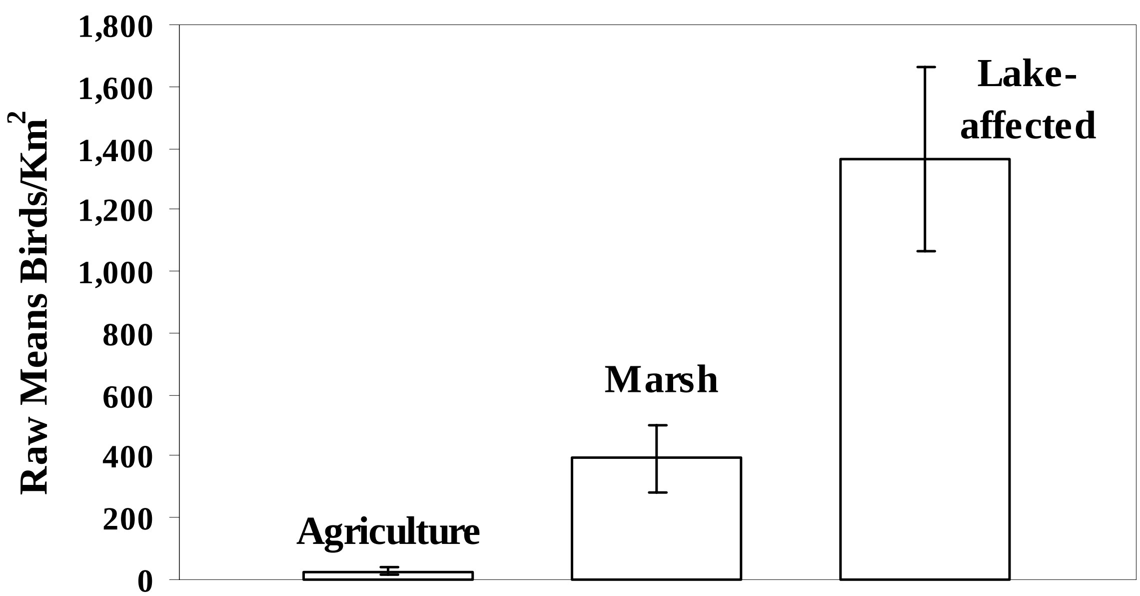

Figure 4.14. Mean (+ 95% C.I.) abundance of moist mudflat guild shorebirds by stratum (marsh vs. lake-affected vs. agriculture plots) during autumn 2002 and 2003.

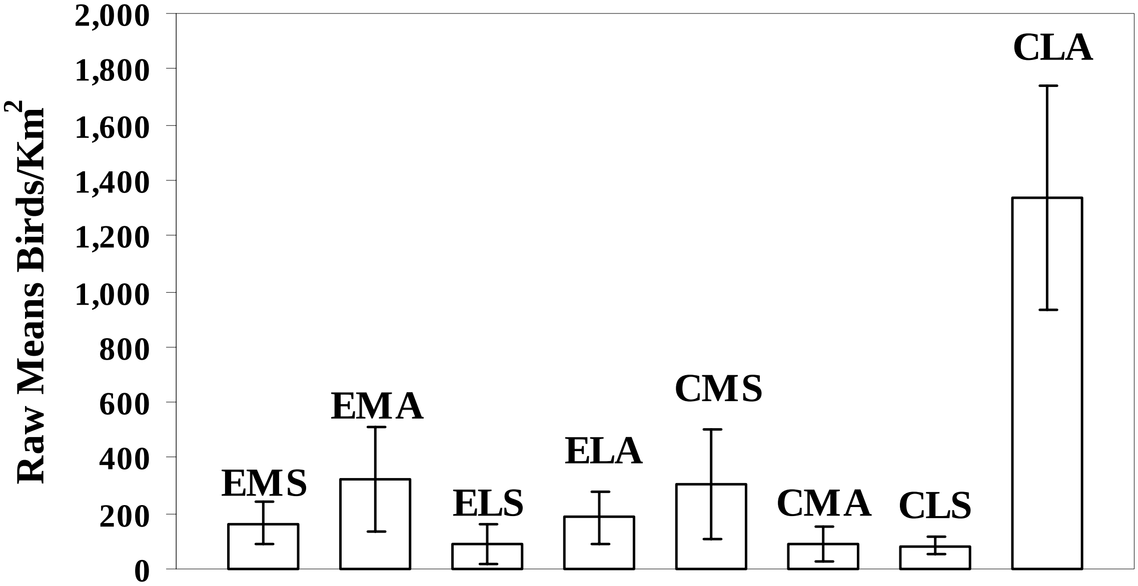

Figure 4.15. Mean (± 95% C.I.) abundance of shallow water guild shorebirds by site (coastal vs. embayment), sampling strata (marsh vs. lake-affected vs. agriculture plots), and season during spring and autumn 2003. No shallow water guild shorebirds were observed within agricultural plots at either site during 2003. Key to figure is as follows: E=Embayment, C=Coastal, M=Managed Marsh, L=Lake-affected, A=Autumn and S=Spring.

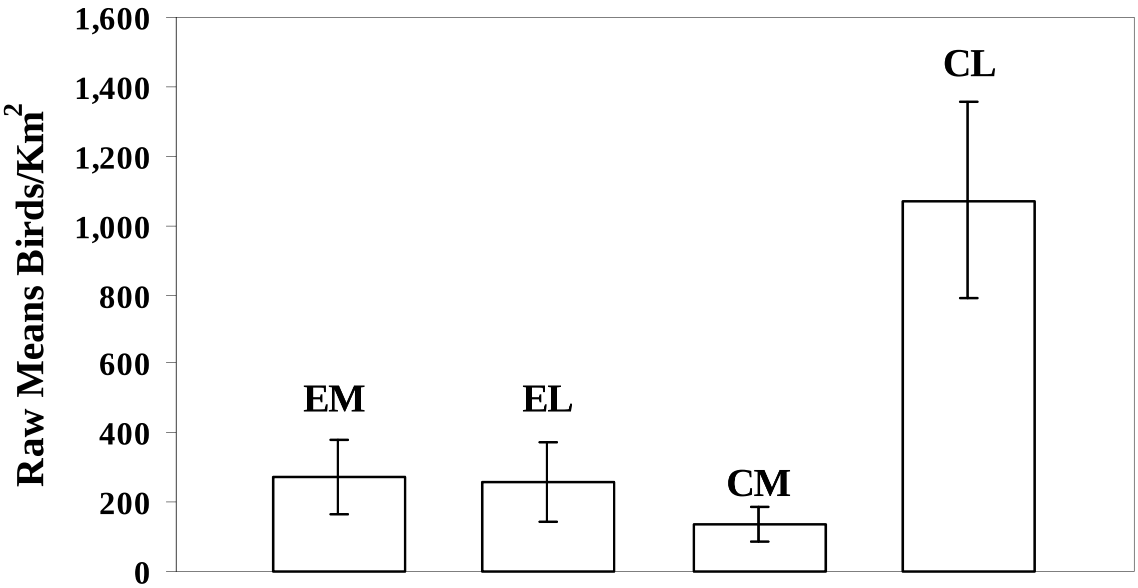

Figure 4.16. Mean (+ 95% C.I.) abundance of shallow water guild shorebirds by site (coastal vs. embayment) and sampling strata (marsh vs. lake-affected plots) during autumn 2002 and 2003. No shallow water guild shorebirds were observed within agricultural plots during autumn 2002 or 2003. Key to figure is as follows: E=Embayment, C=Coastal, M=Managed Marsh and L=Lake-affected.

4.2.2 Waterfowl guild abundance

During spring 2002 dabbler use of marsh plots was highest (P=0.001, F = 7.64, df = 2, 59, Figure 4.17) as it was also in 2003 (P<.0001, F = 11.62, df = 2, 179, Figure 4.18). The coastal, lake-affected plots had the highest dabbling duck abundance when autumn seasons were compared (P=0.046, F= 3.12, df = 2, 179, Figure 4.19). Dabbling duck abundance was highest during 2003 at the coastal site in autumn (P=0.0364, F = 4.45, df = 1, 179, Figure 4.20).

Diver abundance was affected by year (P=0.047, F = 4.01, df = 1, 179), site (P=0.004, F= 8.65, df = 1, 179), and stratum (P=0.029, F= 3.60, df = 2, 179) during autumn migration. Almost three times as many divers were observed during autumn 2002 than in autumn 2003 and almost seven times more divers were observed at the coastal site than at the embayment site. Slightly more diving ducks were observed in marsh plots compared to lake-effected plots.

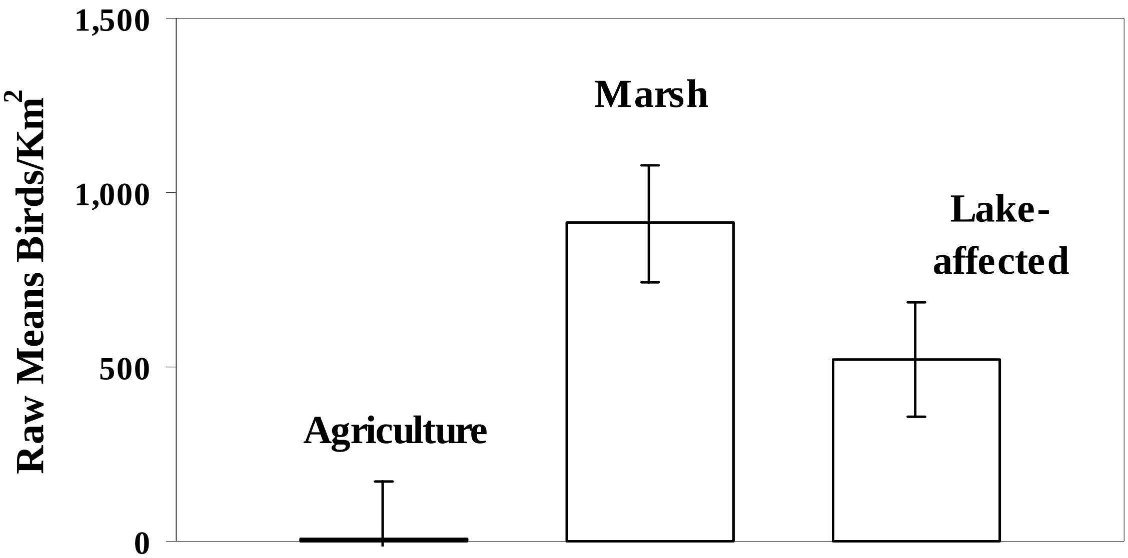

Figure 4.17. Mean (± 95% C.I.) abundance of dabbling ducks by stratum (marsh vs. lake-affected vs. agriculture plots) during spring 2002.

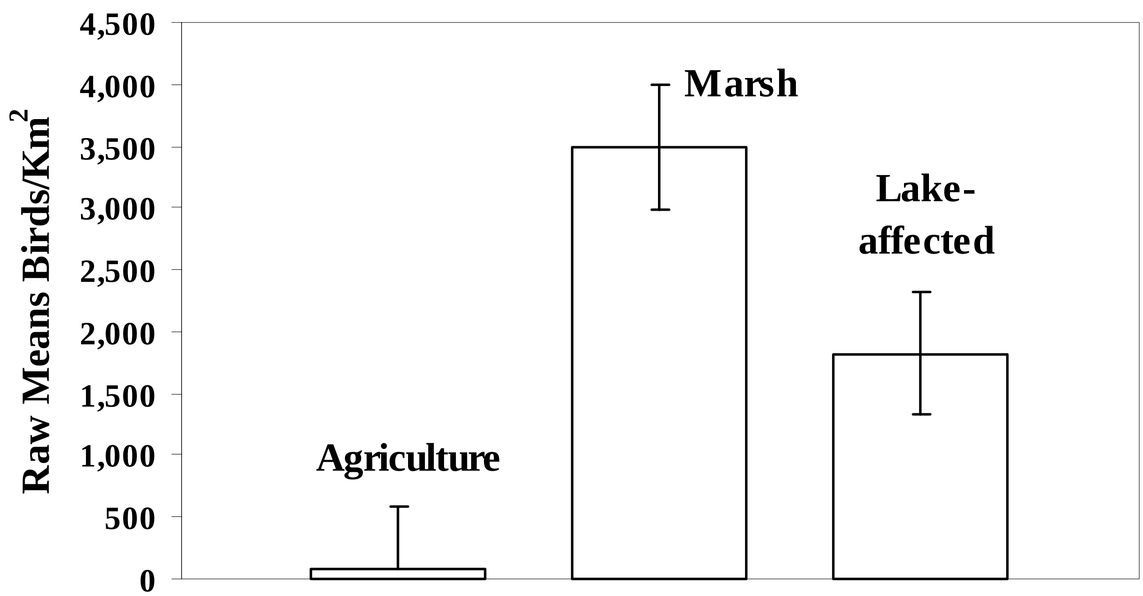

Figure 4.18. Mean (+ 95% C.I.) abundance of dabbling ducks by stratum (marsh vs. lake-affected vs. agriculture plots) during 2003.

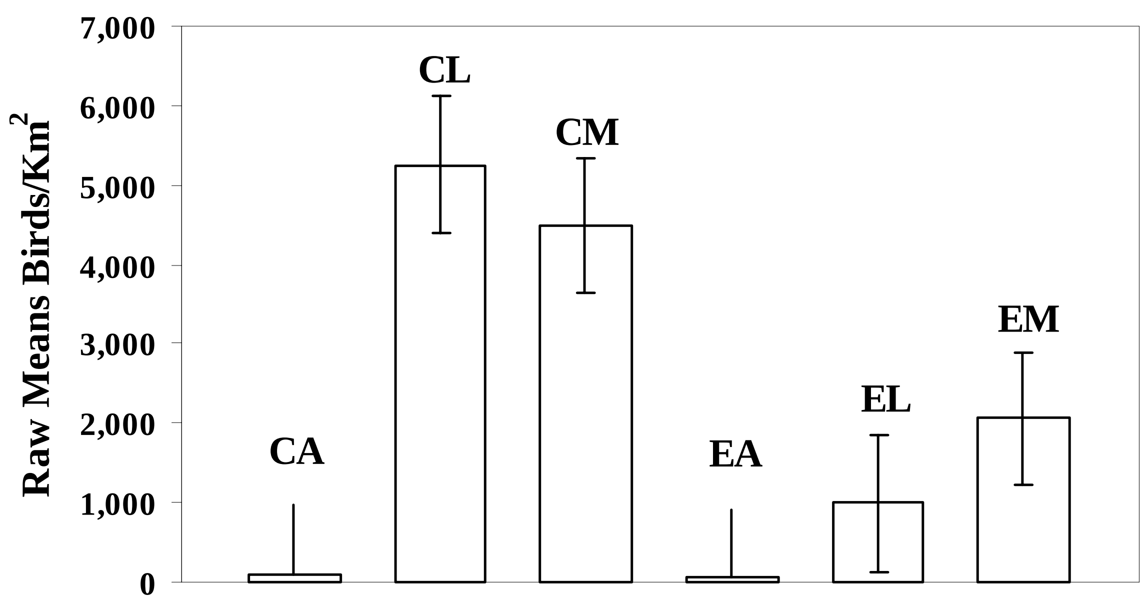

Figure 4.19. Mean (+ 95% C.I.) abundance of dabbling ducks by site (coastal vs. embayment) and stratum (marsh vs. lake-affected vs. agriculture plots) during autumn 2002 and 2003.

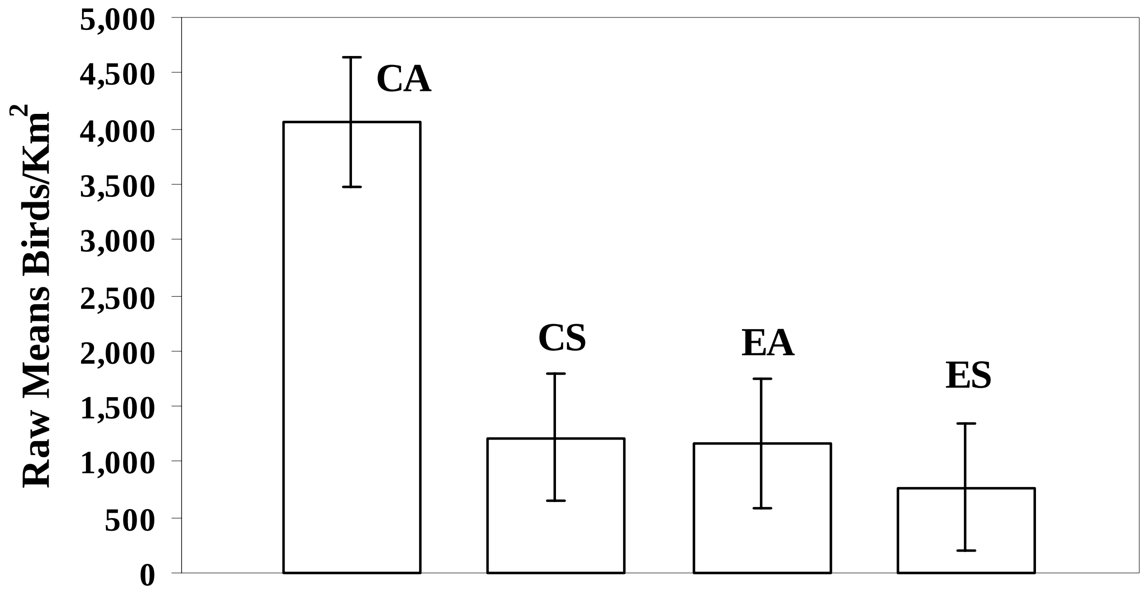

Figure 4.20. Mean (± 95% C.I.) abundance of dabbling ducks by site (coastal vs. embayment) and season (autumn vs. spring) during 2003.

4.3 Bird use-days and population estimates

4.3.1 Shorebirds

Shorebird numbers were highest at the coastal site during autumn 2002 and spring 2003, but highest at the embayment site for spring 2002 and autumn 2003 (Figures 4.21 and 4.22). The Crane Creek Estuary supported a preponderance of shorebird numbers at the coastal site during all seasons and years when extensive mudflat habitat was available in the estuary. Availability of mudflat habitat was limited by high water levels in Crane Creek Estuary during spring 2002. Similar estuarine mudflat habitat had very limited availability at the embayment site, but the South Creek Estuary was exposed during autumn 2003 and contributed most to the numbers of shorebirds observed there.

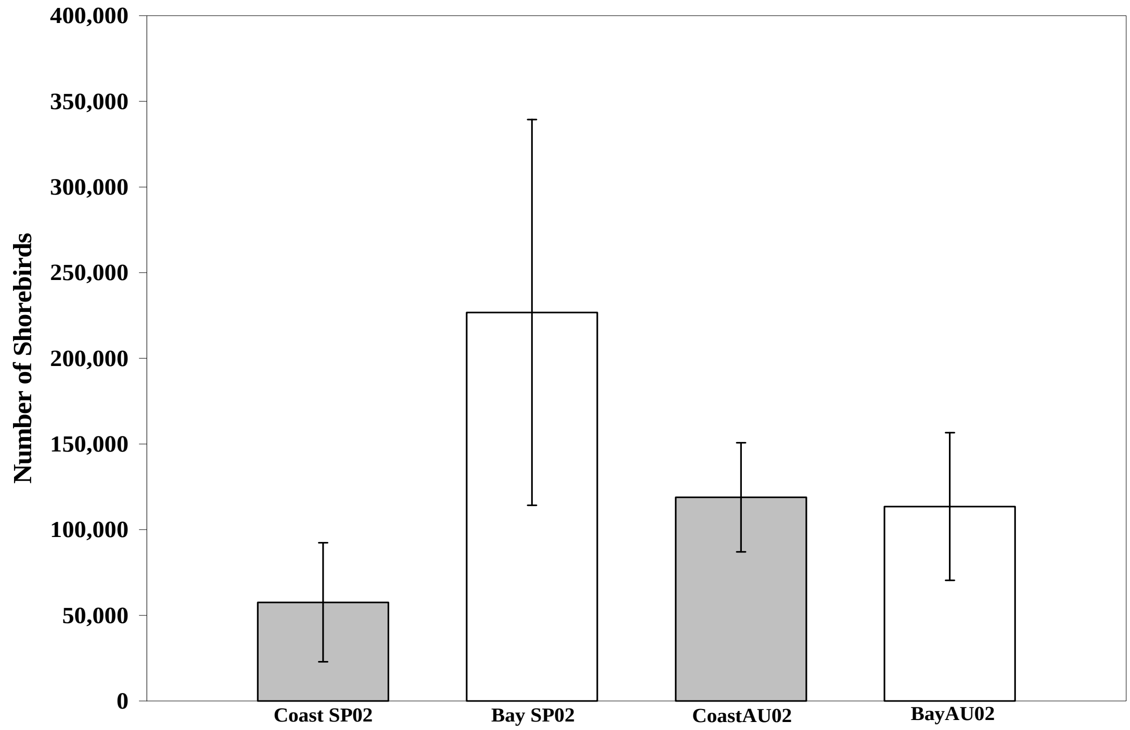

Figure 4.21. Shorebird numbers observed during spring and autumn 2002 on 60-90 survey plots on or near Ottawa National Wildlife Refuge (coastal) and Winous Point Marsh Conservancy (embayment) study sites in the southwest Lake Erie marsh region. Shorebird count numbers have been extrapolated out to the landscape scale based upon amount of strata sampled and actual amount of each stratum available at the site. These migrant population estimates assume a 7-day stopover duration.

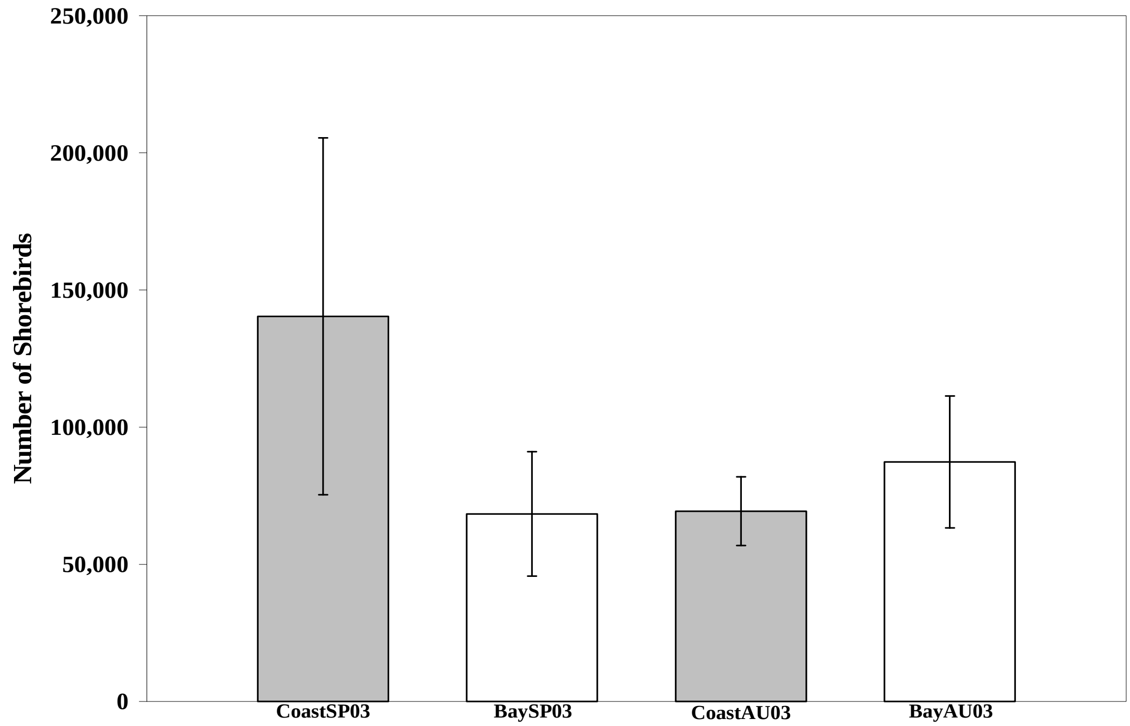

Figure 4.22. Shorebird numbers observed during spring and autumn 2003 on 90 survey plots on or near Ottawa National Wildlife Refuge (coastal) and Winous Point Marsh Conservancy (embayment) study sites in the southwest Lake Erie marsh region. Shorebird count numbers have been extrapolated out to the landscape scale based upon amount of strata sampled and actual amount of each stratum available at the site. These migrant population estimates assume a 7-day stopover duration.

Marsh wetland habitat at the embayment site attracted the most shorebirds during spring 2002 and remained most important for all seasons except spring 2003 when shorebird use was highest within lake-affected wetlands (Figure 4.23). At the coastal site, shorebirds relied on managed marshes during spring in both years, but shifted use to lake-affected wetlands during autumn (Figure 4.24). Use of agricultural plots was lower than use of wetland plots throughout all seasons studied.

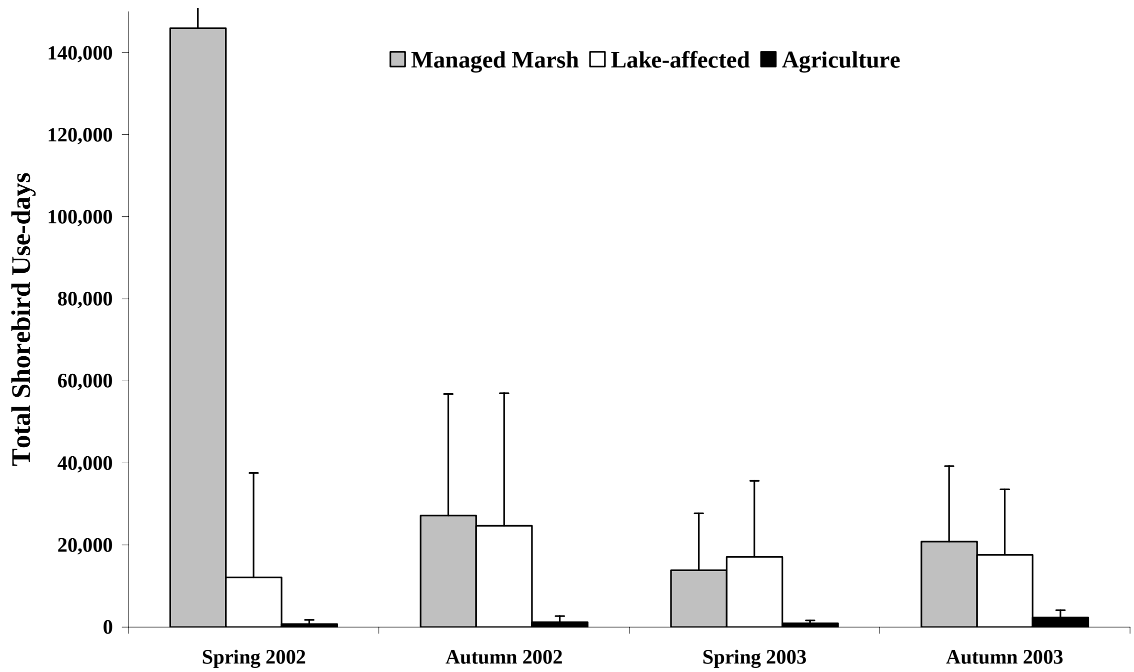

Figure 4.23. Shorebird use-days observed during spring and autumn 2002 and 2003 on 60-90 survey plots on or near Winous Point Marsh Conservancy (embayment) study site in the southwest Lake Erie marsh region. Use-days represent a 7-day stopover duration.

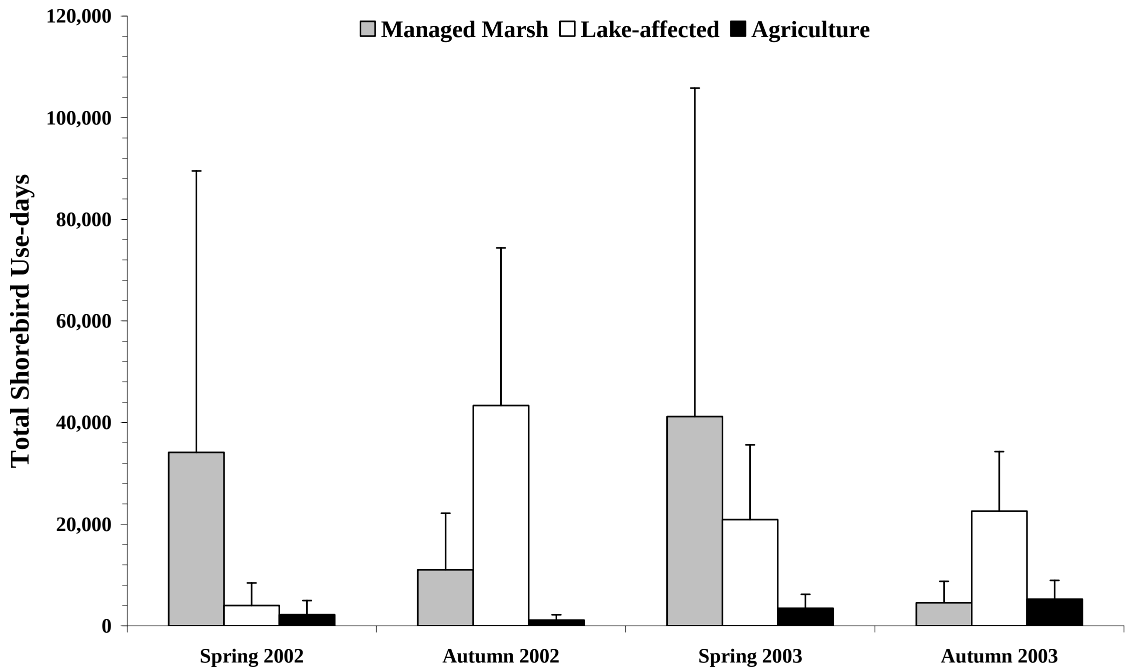

Figure 4.24. Shorebird use-days observed during spring and autumn 2002 and 2003 on 60-90 survey plots on or near Ottawa National Wildlife Refuge (coastal) study site in the southwest Lake Erie marsh region. 2003. Use-days represent a 7-day stopover duration.

4.3.2 Waterfowl

Total waterfowl numbers were highest at the coastal site during both 2002 and 2003 (Figures 4.25 and 4.26). High waterfowl numbers at the coastal site were due to large flocks of scaup observed in plots that included the Lake Erie shoreline. Managed marsh wetlands were used the most by waterfowl for all seasons surveyed and at both sites (Figures 4.27 and 4.28). However, seasonal variation in wetland use was observed at the coastal site where waterfowl use of lake-affected wetlands increased in autumn of both years.

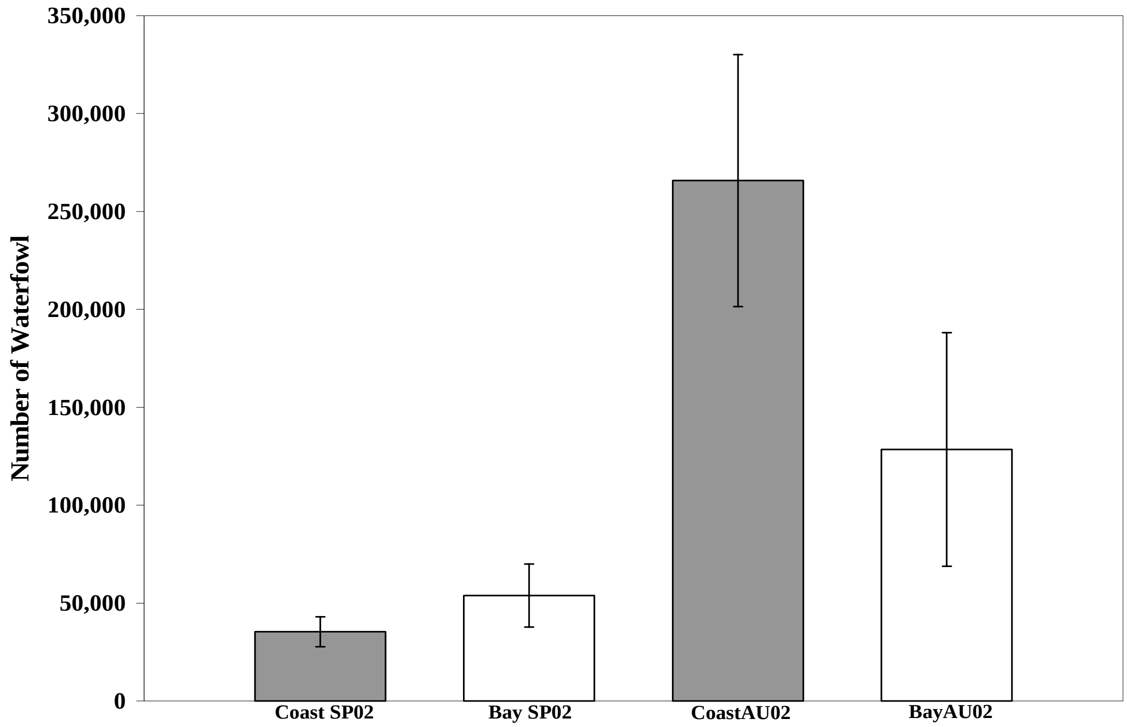

Figure 4.25. Waterfowl numbers observed during spring and autumn 2002 on 60-90 survey plots on or near Ottawa National Wildlife Refuge (coastal) and Winous Point Marsh Conservancy (embayment) study sites in the southwest Lake Erie marsh region. Waterfowl count numbers have been extrapolated out to the landscape scale based upon amount of strata sampled and actual amount of each stratum available at the site. These numbers assume a 7-day stopover duration.

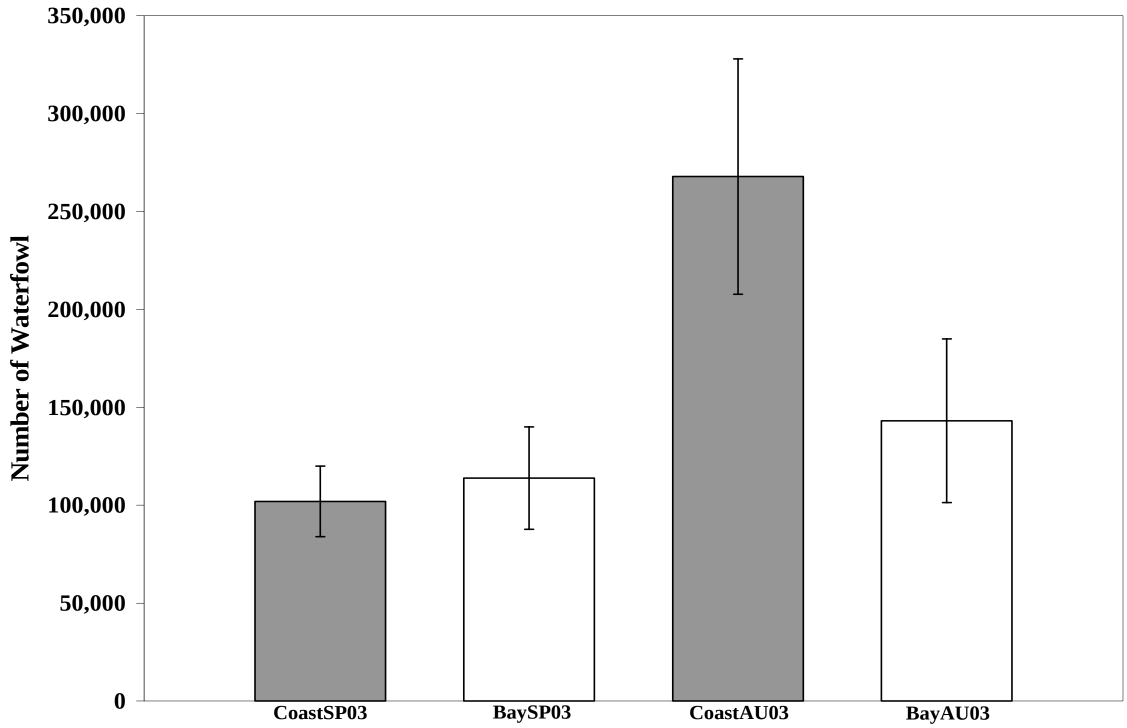

Figure 4.26. Waterfowl numbers observed during spring and autumn 2003 on 90 survey plots on or near Ottawa National Wildlife Refuge (coastal) and Winous Point Marsh Conservancy (embayment) study sites in the southwest Lake Erie marsh region. Waterfowl count numbers have been extrapolated out to the landscape scale based upon amount of strata sampled and actual amount of each stratum available at the site. These numbers assume a 7-day stopover duration.

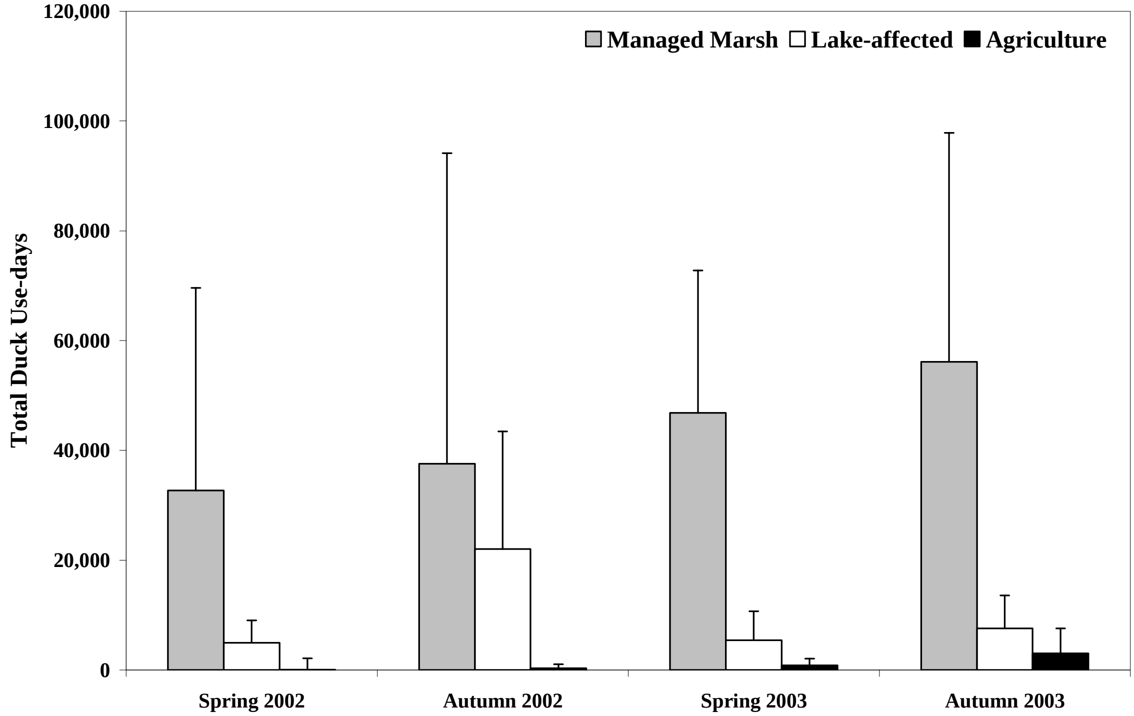

Figure 4.27. Waterfowl use-days observed during spring and autumn 2002 and 2003 on 60-90 survey plots on or near Winous Point Marsh Conservancy (embayment) study site in the southwest Lake Erie marsh region.

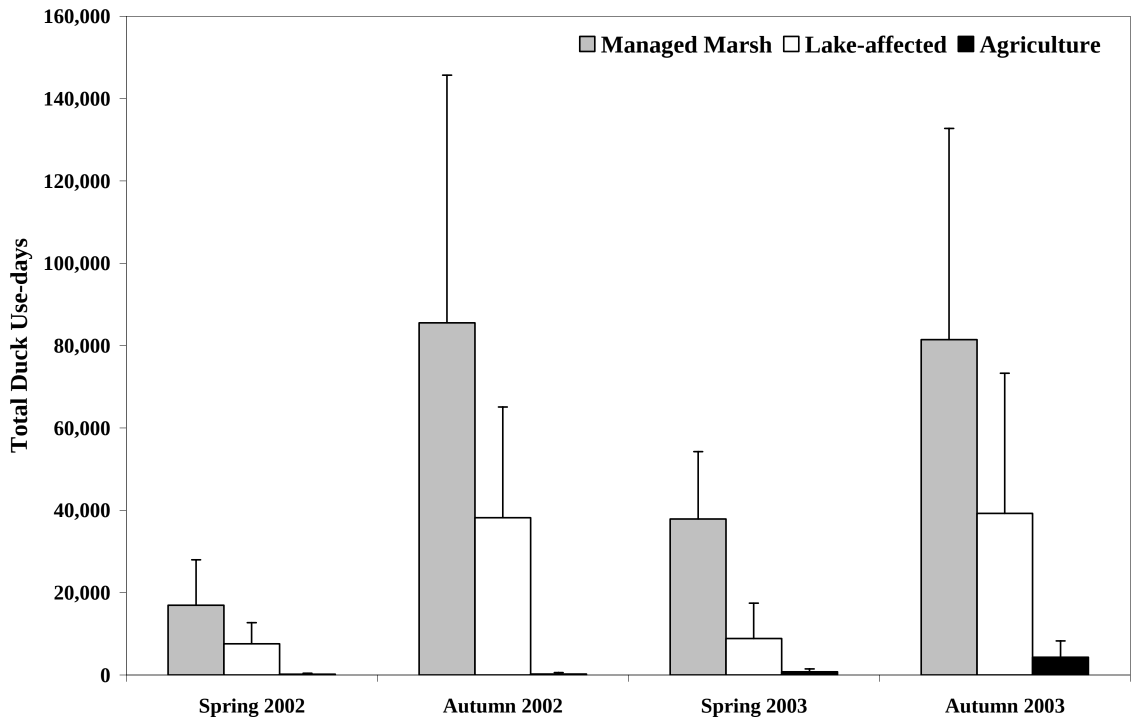

Figure 4.28. Waterfowl use-days observed during spring and autumn 2002 and 2003 on 60-90 survey plots on or near Ottawa National Wildlife Refuge (coastal) study site in the southwest Lake Erie marsh region.

4.4 Bird Community Composition and Diversity

The waterbird community I studied consisted mostly of dabbling duck and moist mudflat shorebird guilds (Figures 4.29 and 4.30). In general, moist mudflat shorebirds dominated the waterbird community during spring and dabblers dominated during autumn. The late start of surveys in spring 2002 and the early termination of surveys for both autumn seasons likely caused pectoral sandpipers and dunlin (both moist mudflat guild species) to be underrepresented in my data.

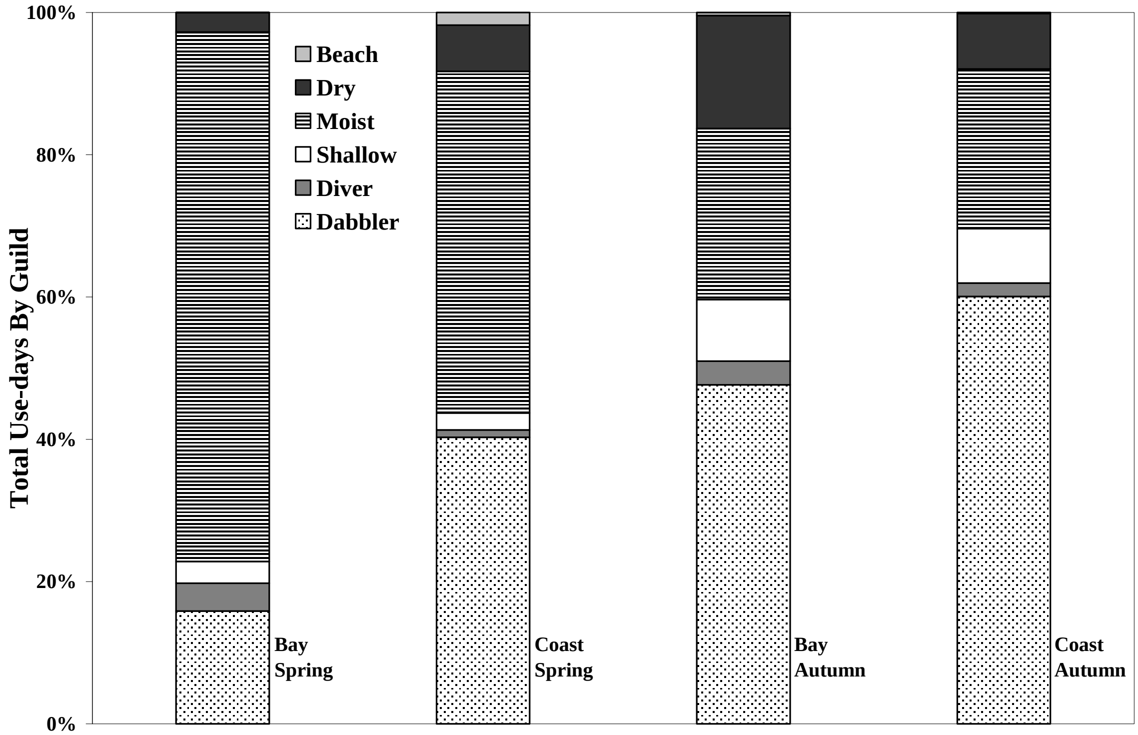

Figure 4.29. Percent composition of bird use-days by waterbird guild observed during spring and autumn 2002 on and near Ottawa NWR (coastal) and Winous Point Marsh Conservancy (bay) study sites in the southwest Lake Erie marsh region.

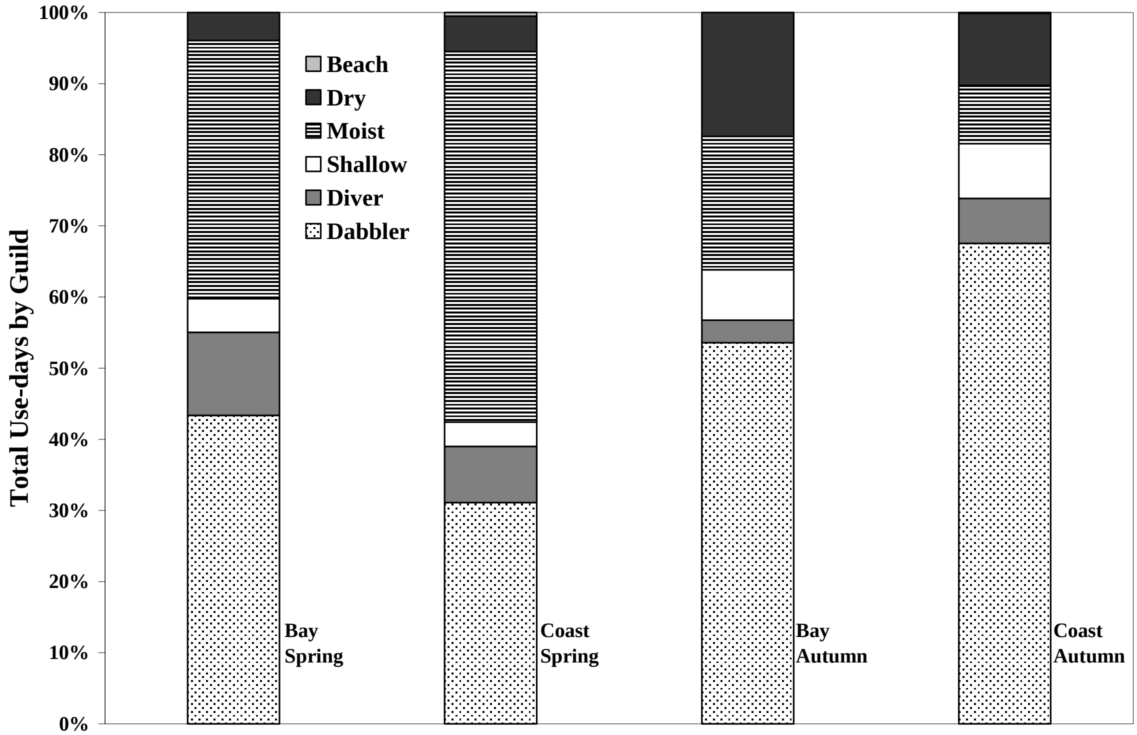

Figure 4.30. Percent composition of bird use-days by waterbird guild observed during spring and autumn 2003 on and near Ottawa NWR (coastal) and Winous Point Marsh Conservancy (bay) study sites in the southwest Lake Erie marsh region.

Shorebird diversity was highest within coastal lake-affected wetlands, followed in order by coastal marshes, embayment lake-affected wetlands, and embayment marshes during 2002. Waterfowl diversity was highest within the coastal marsh wetlands and then second highest within the embayment marsh wetlands during 2002 (Figure 4.31). Shorebird and waterfowl diversity was lowest overall within agricultural plots. Diversity scores for each survey plot are listed by year in Appendices C and D.

Shorebird diversity was again highest within the coastal lake-affected wetlands, but was second highest within embayment marsh wetlands during 2003 (Figure 4.32). Similar to 2002, waterfowl diversity was highest in the coastal marsh wetlands and second highest in embayment marsh wetlands during 2003. Agricultural plots consistently had the lowest diversity of shorebirds and waterfowl during 2003.

Ranking of the most diverse plots for shorebirds and for waterfowl showed that 60% of these plots were used by both avian groups in 2002. In 2003 the percentage of high diversity plots common to both waterfowl and shorebirds was 57%. Waterfowl diversity and shorebird diversity were highly correlated (Pearson $r = 0.699$, $P < 0.0001$).

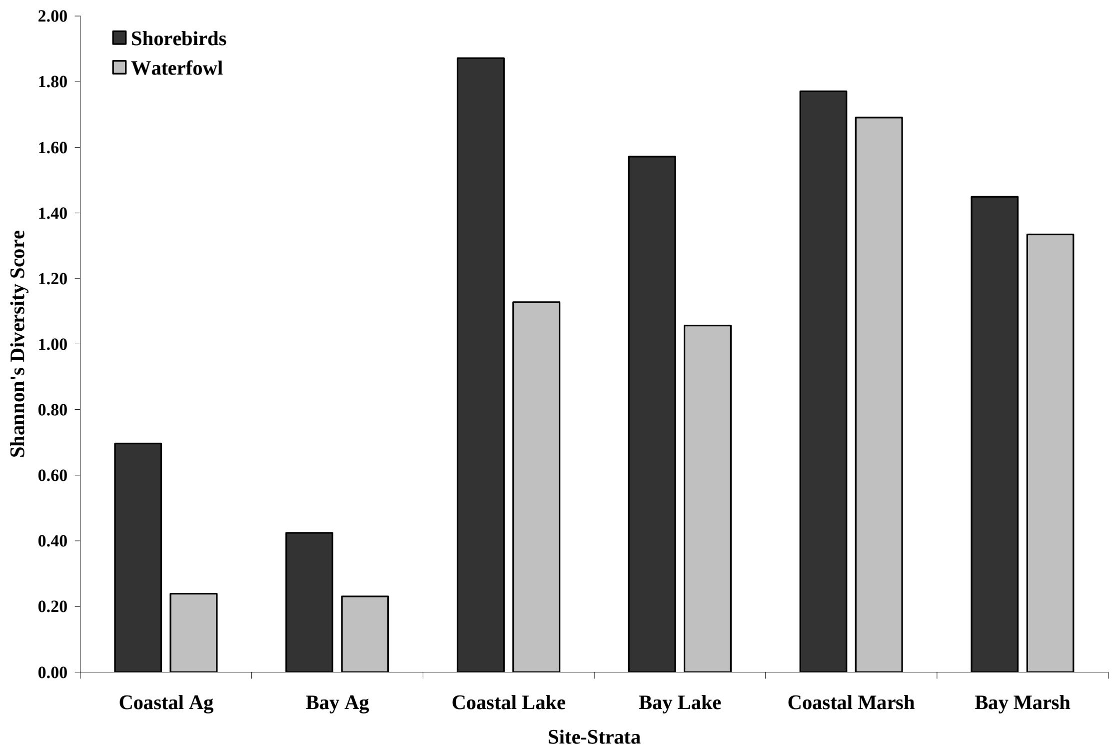

Figure 4.31. Mean Shannon's Diversity index for shorebirds and waterfowl by site (coastal vs. embayment) and wetland strata (Agriculture vs. Marsh vs. Lake-affected) for 2002 spring and autumn seasons combined in the southwest Lake Erie marsh region.

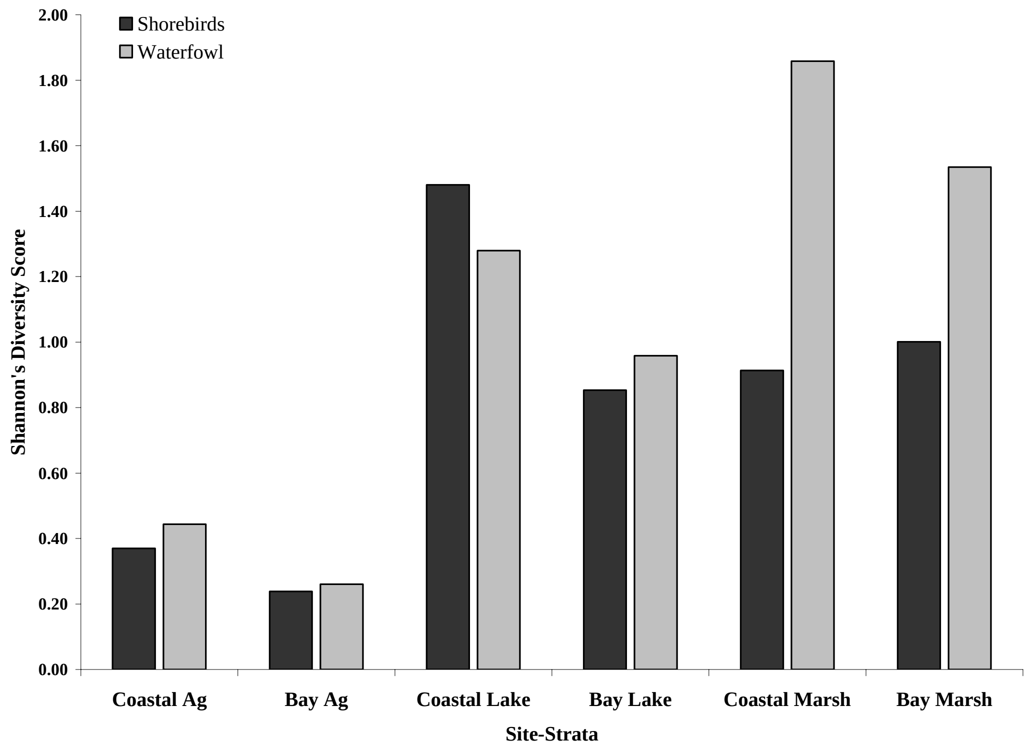

Figure 4.32. Mean Shannon's Diversity index for shorebirds and waterfowl by site (coastal vs. embayment) and wetland strata (Agriculture vs. Marsh vs. Lake-affected) for 2003 spring and autumn seasons combined in the southwest Lake Erie marsh region.

4.5 Variance decomposition and species ordination along environmental gradients

I used Detrended Correspondence Analysis (DCA) to examine the lengths of the gradients and thereby select the appropriate model for further analysis. The DCA conducted by each season and year showed a linear response of species to environment for every season (Table 4.2) and so I used redundancy analysis (RDA) to identify relationships between habitat variables and waterbird abundance during each season (ter Braak and Smilauer 2002).

Season-Year	Axis 1	Axis 2	Axis 3	Axis 4
Spring 2002	3.207	2.266	3.568	2.519
Autumn 2002	2.584	2.436	3.097	2.809
Spring 2003	2.679	2.595	2.816	3.455
Autumn 2003	3.080	3.106	2.392	2.262

Table 4.2. Results of Detrended Correspondence Analysis identifying the relationship (lengths of gradient) between habitat variables and waterbird use of 60-90 plots in the southwest Lake Erie marsh region during autumn and spring migrations, 2002-2003.

4.5.1 Spring 2002

Variance decomposition during spring 2002 showed that the combined analysis of strata with the rest of the environmental variables explained most (64%) of the variance surrounding the distribution of shorebirds and waterfowl among the different plot types (Figure 4.33). When the environmental variables were analyzed apart from the effect of site and strata they accounted for 41% of the total variance in waterbird abundance between plot types, whereas site and strata accounted for only 1% and 3% respectively.

Redundancy analysis (RDA) identified nine environmental variables that contributed significantly ($P<0.10$) to waterbird abundance in the 60 plots surveyed (Figure 4.34). The nine environmental variables representing plot habitat characteristics were 1) percent of plot covered by forest/shrub, 2) percent of plot characterized by estuarine habitat, 3) percent of plot characterized by persistent emergent wetland vegetation, 4) percent of plot characterized by nonpersistent emergent wetland vegetation, 5) percent of plot inundated, 6) mean variability in inundation per plot, 7) percent of plot characterized by palustrine habitat, 8) percent of plot that was unvegetated or open water, and 9) percent of plot that was characterized as riverine habitat. There were no obvious effects of environmental variables upon the sample plots, but there was considerable overlap among plots regardless of their site or stratum affiliation (Figure 4.35).

The first two axes of the RDA accounted for 34.5 % of the total variation in species abundance among plots. Of this, 54.8% is attributable to the environmental variables included in the analysis (Table 4.3). Axis 1 represented the association of species within an upland to wetland gradient with the majority of waterfowl and shorebirds occurring on the positive, or wetland, end of the gradient. Axis 2 represented a gradient moving from highly variable water conditions (negative end) to more stable water levels (positive end) and most species were centrally located along this gradient. There was considerable overlap in habitat use between waterfowl and shorebirds centered around the nonpersistent emergent vegetation and palustrine wetland variables.

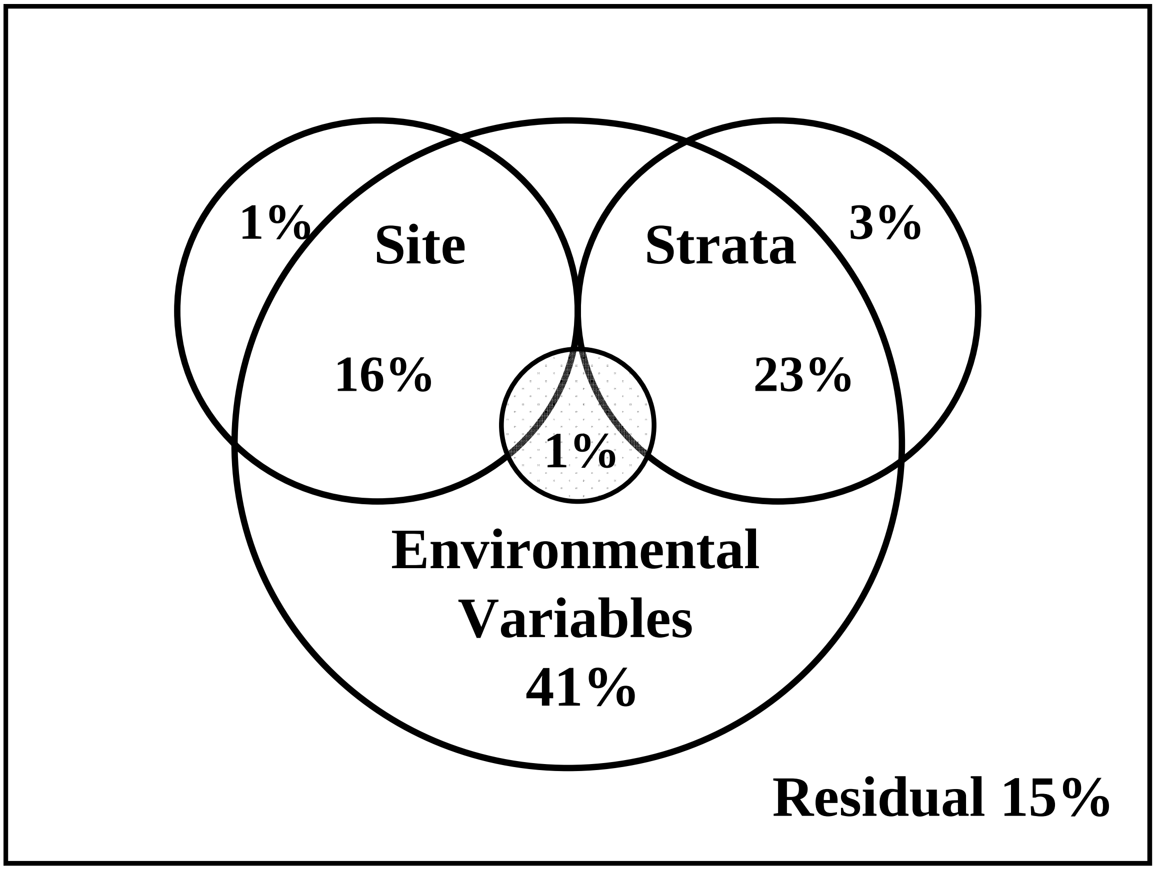

Figure 4.33 Venn diagram showing the proportion of the total variance in waterbird abundance within plots explained by the measured environmental variables during spring migration 2002 in the southwest Lake Erie marsh region.

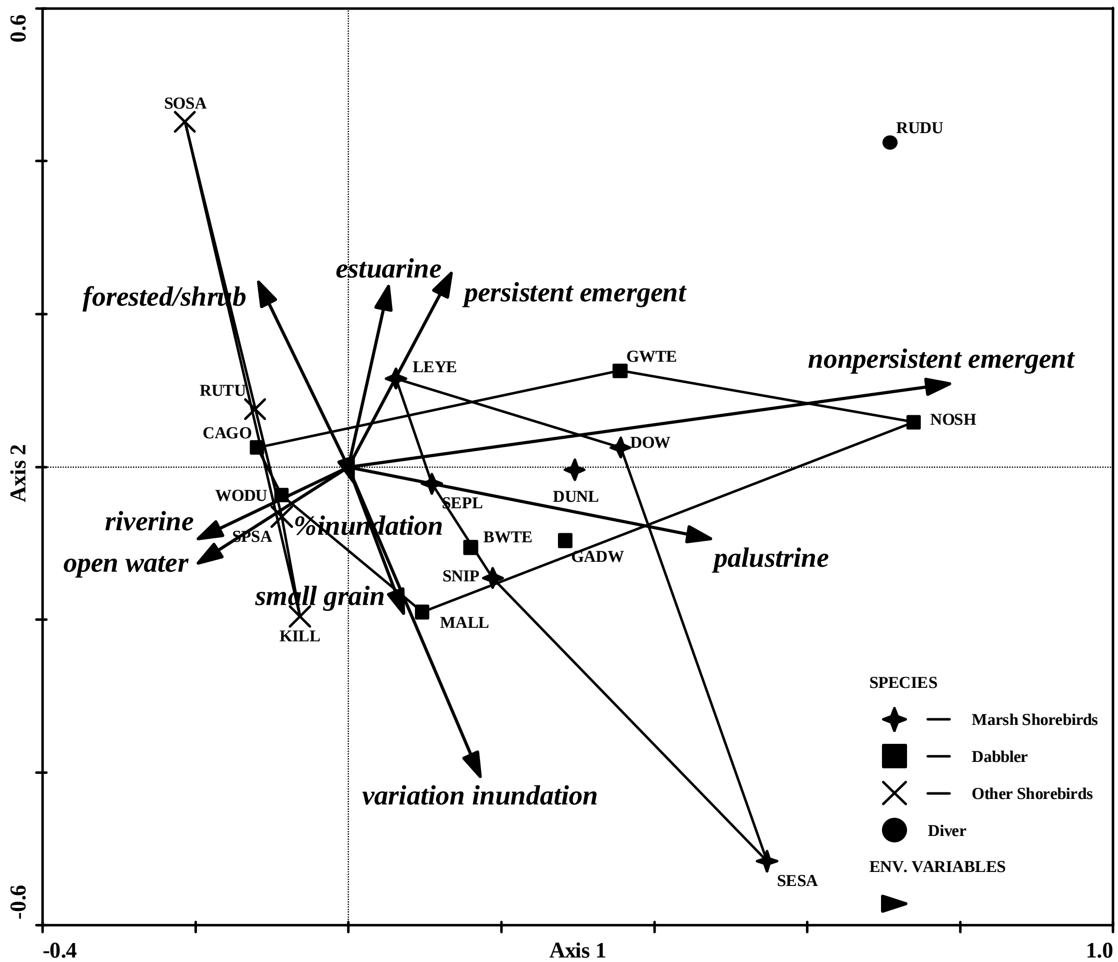

Figure 4.34. Redundancy Analysis (RDA) biplot of the species data and explanatory environmental variables collected during spring 2002 in which arrow lengths and angles of intersect are related to the importance of the environmental variables in the species ordination. Species codes are listed with full species' names in Appendix E.

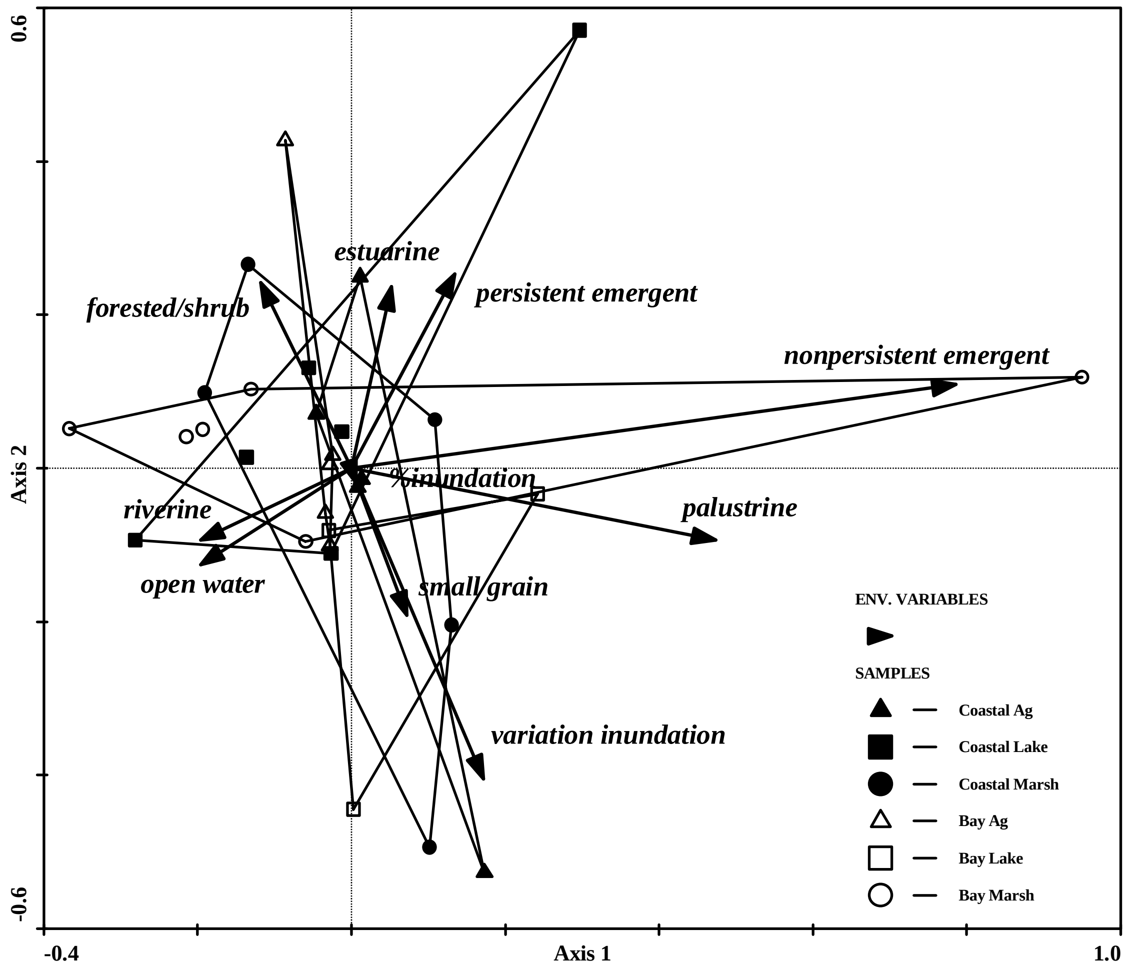

Figure 4.35. Redundancy Analysis (RDA) biplot of the sample plots and explanatory environmental variables collected during spring 2002 in which arrow lengths and angles of intersect are related to the importance of the environmental variables in the species ordination.

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalue	0.210	0.087	0.074	0.051
Species-environment correlation:	0.925	0.939	0.945	0.843
Cumulative percentage variance:				
of species data:	24.4	34.5	43.0	49.0
of species-environmental relation:	38.7	54.8	68.3	77.7
Sum of all eigenvalues: 0.863				
Sum of all canonical eigenvalues: 0.544				

Table 4.3. Summary results of Redundancy Analysis identifying the relationship between habitat variables and waterbird use of 60 plots in the southwest Lake Erie marsh region during spring migration 2002. Total variance = 1.000.

4.5.2 Autumn 2002

Variance decomposition during autumn 2002 showed that the combined analysis of strata with the rest of the environmental variables explained most (42%) of the variance surrounding the distribution of shorebirds and waterfowl among the different plot types (Figure 4.36). When the environmental variables were analyzed apart from the effect of site and strata they accounted for 32% of the total variance in waterbird abundance between plot types, whereas site and strata accounted for only 2% and 3% respectively.

Redundancy analysis identified five environmental variables that contributed significantly ($P<0.10$) to waterbird abundance in the 90 plots surveyed (Figure 4.37). These five variables were 1) percent of plot inundated, 2) percent wetland cover within plot, 3) percent of plot characterized by estuarine habitat, 4) percent of plot characterized by persistent emergent wetland vegetation, and 5) percent of plot that was characterized as riverine habitat. Figure 4.38 illustrates the placement of sample plots along the axes where lake-affected plots were distributed along axis 2 and managed marsh plots were distributed along axis 1. Agricultural plots were clustered around the center of the biplot.

The first two axes of the RDA accounted for 21.9 % of the total variation in species abundance among plots. Of this, 80.4% is attributable to the environmental variables included in the analysis (Table 4.4). Axis 1 represented an inland to coastal habitat gradient with the majority of species associated with the coastal end of the gradient. Axis 2 was a gradient traveling from estuarine wetlands (variable or shallow water) on the negative end to wetlands with increasing percent inundation on the positive end. Unlike spring 2002, shorebirds and waterfowl showed greater separation along these environmental gradients in autumn 2002. Shorebirds displayed more of an association with estuarine habitats while waterfowl associated more closely with increasing inundation, persistent emergent vegetation and percent wetland cover.

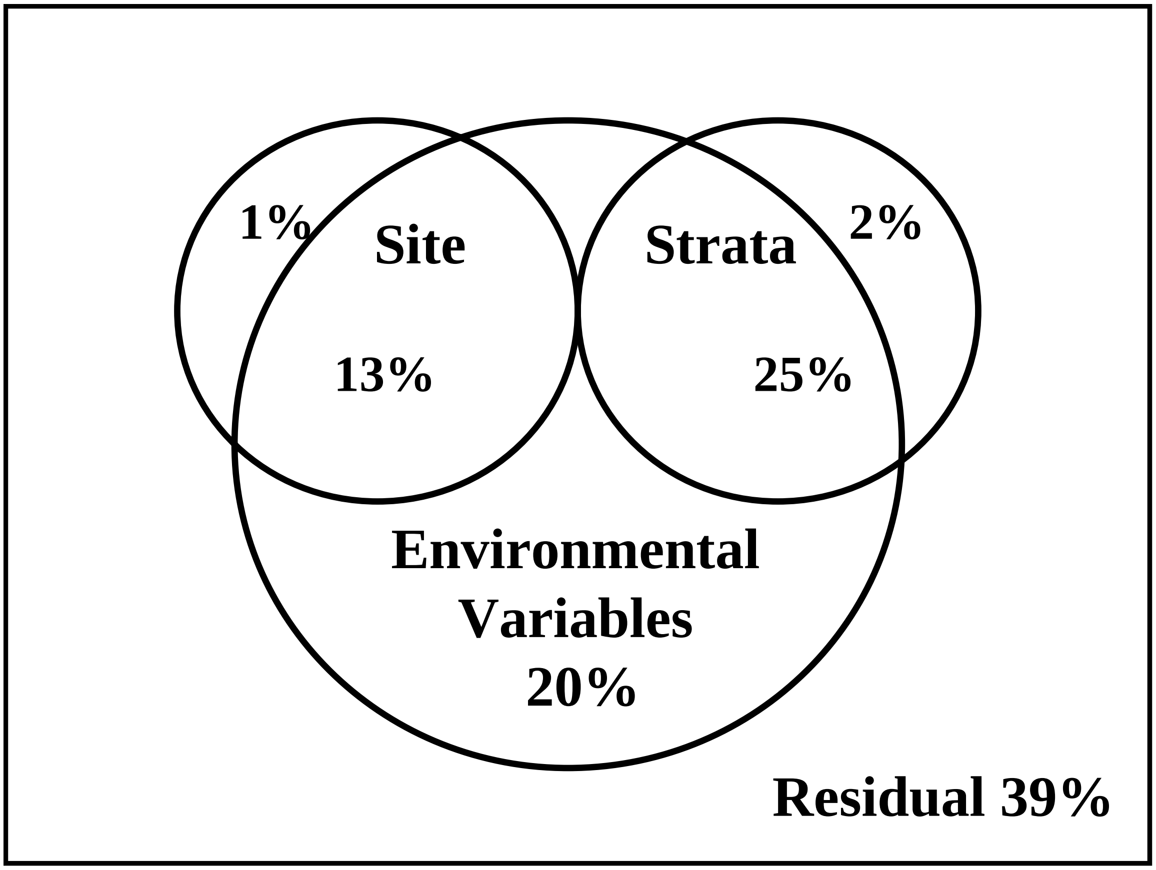

Figure 4.36 Venn diagram showing the proportion of the total variance in waterbird abundance within plots explained by the measured environmental variables during autumn migration 2002 in the southwest Lake Erie marsh region.

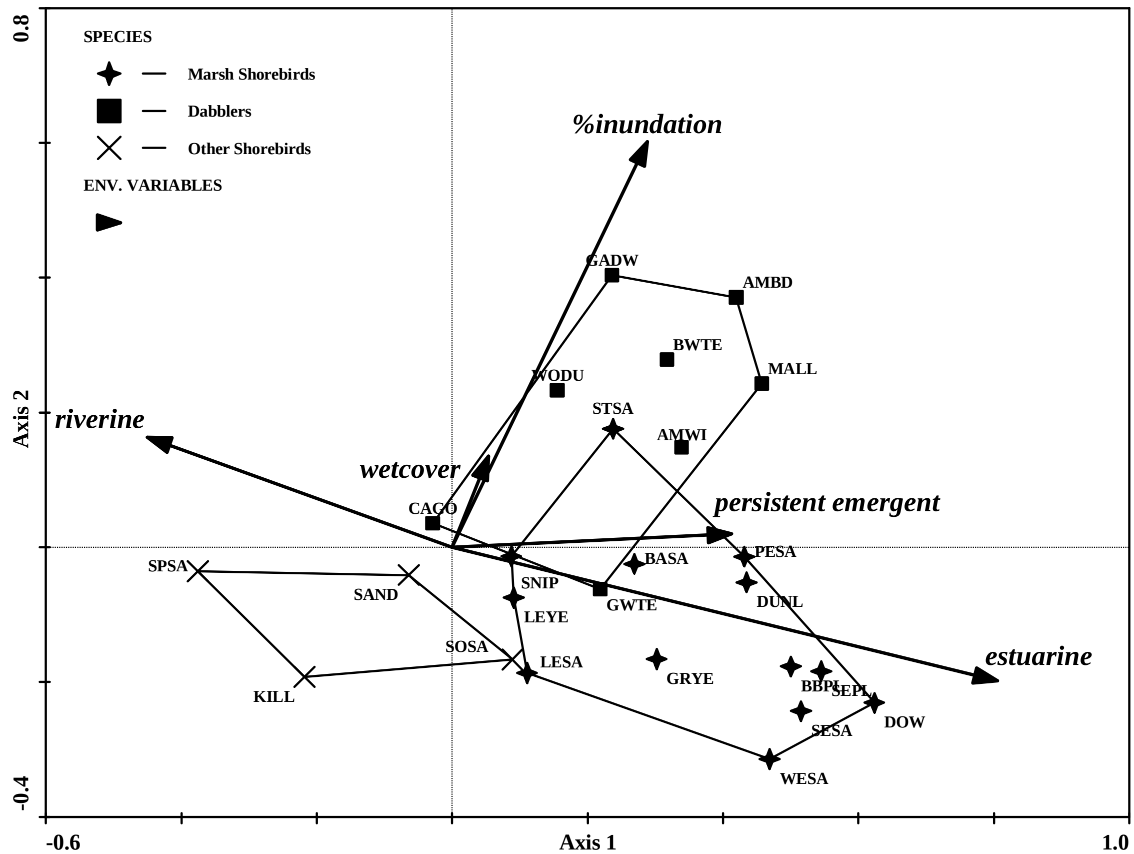

Figure 4.37. Redundancy Analysis (RDA) biplot of the species data and explanatory environmental variables collected during autumn 2002 in which arrow lengths and angles of intersect are related to the importance of the environmental variables in the species ordination. Diving ducks were not included due to few observations. Species codes are listed with full species' names in Appendix E.

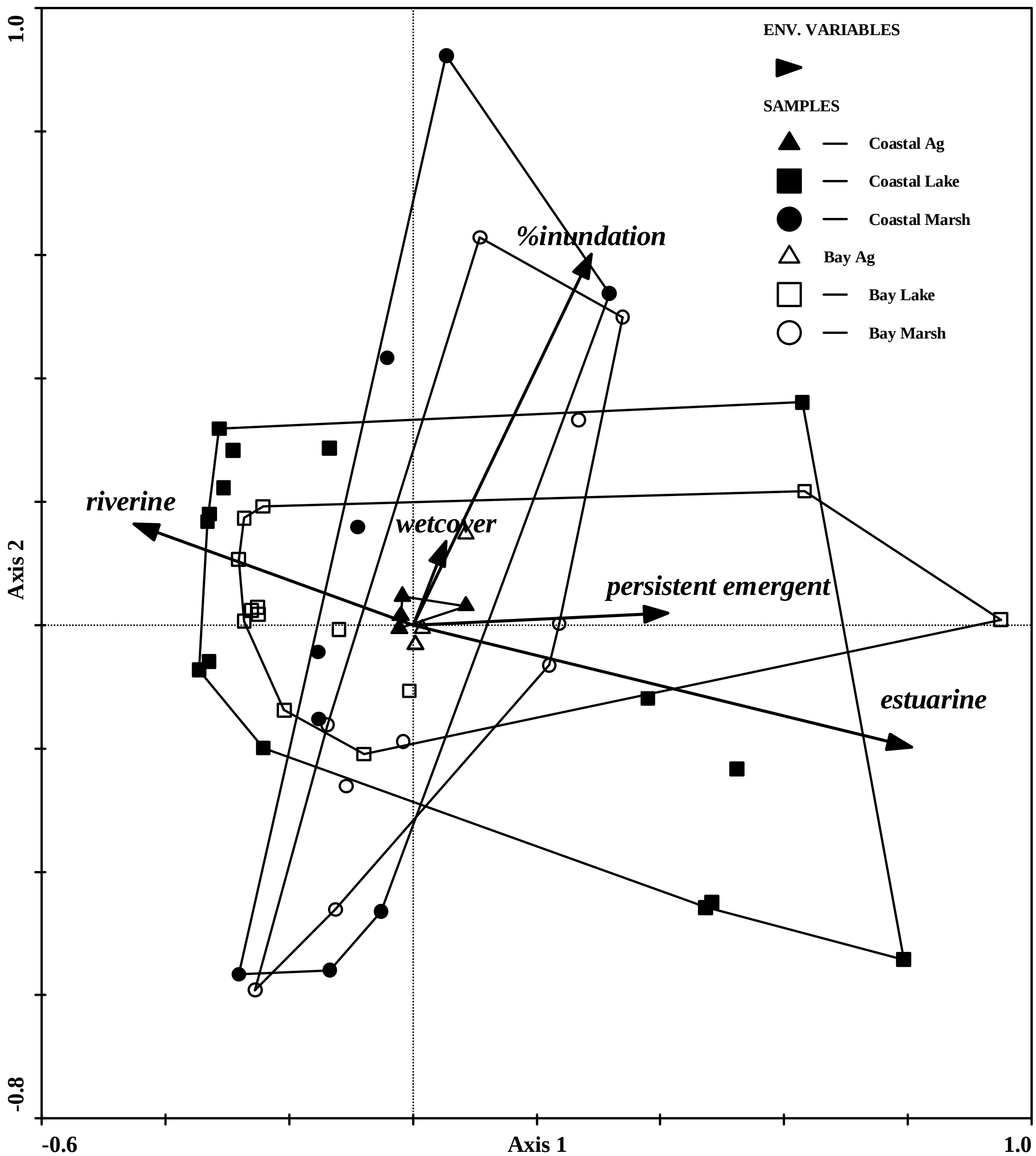

Figure 4.38. Redundancy Analysis (RDA) biplot of the sample plots and explanatory environmental variables collected during autumn 2002 in which arrow lengths and angles of intersect are related to the importance of the environmental variables in the species ordination.

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalue:	0.135	0.045	0.024	0.012
Species-environment correlation:	0.821	0.651	0.686	0.625
Cumulative percentage variance:				
of species data:	16.4	21.9	24.8	26.3
of species-environmental relation:	60.2	80.4	91.1	96.6
Sum of all eigenvalues: 0.822				
Sum of all canonical eigenvalues: 0.224				

Table 4.4. Summary results of Redundancy Analysis identifying the relationship between habitat variables and waterbird use of 90 plots in the southwest Lake Erie marsh region during autumn migration 2002. Total variance = 1.000.

4.5.3 Spring 2003

The results of variance decomposition showed that environmental variables explained more variation in waterbird abundance when the covariables site (27%) and strata (44%) were also considered (Figure 4.39). Alone the environmental variables accounted for 21% of the total variation in waterbird abundance among plot types. Site and strata alone were not important in explaining the variance in bird use of plots.

Redundancy analysis identified six environmental variables that contributed significantly ($P<0.10$) to waterbird abundance in the 90 plots surveyed. These variables were percent of plot covered by persistent herbaceous vegetation, percent of plot characterized by estuarine habitat, percent of plot characterized by nonpersistent emergent wetland vegetation, percent of plot inundated, distance from plot to the coast, and percent of wetland cover within the plot (Figure 4.40). The biplot of environmental variables and sample plots showed a strong association of lake-affected plots with Axis 1 and managed marsh plots with Axis 2 (Figure 4.41). Agricultural plots were again situated around the center of the biplot.

The first two axes of the RDA accounted for only 8.8 % of the total variation in species abundance among plots. Of this, 52.2% is attributable to the environmental variables included in the analysis (Table 4.5). Axis 1 represented a gradient that increased in wetland vegetation cover as it increased in value from negative to positive and there was a greater association of waterfowl with the positive end of this gradient. Axis 2 represented a gradient where positive values corresponded with increasing estuarine habitat and negative values corresponded with wetlands increasing in distance from the coast. As in autumn 2002, spring 2003 showed a strong shorebird association with estuarine habitat and strong waterfowl attraction to wetland vegetative cover.

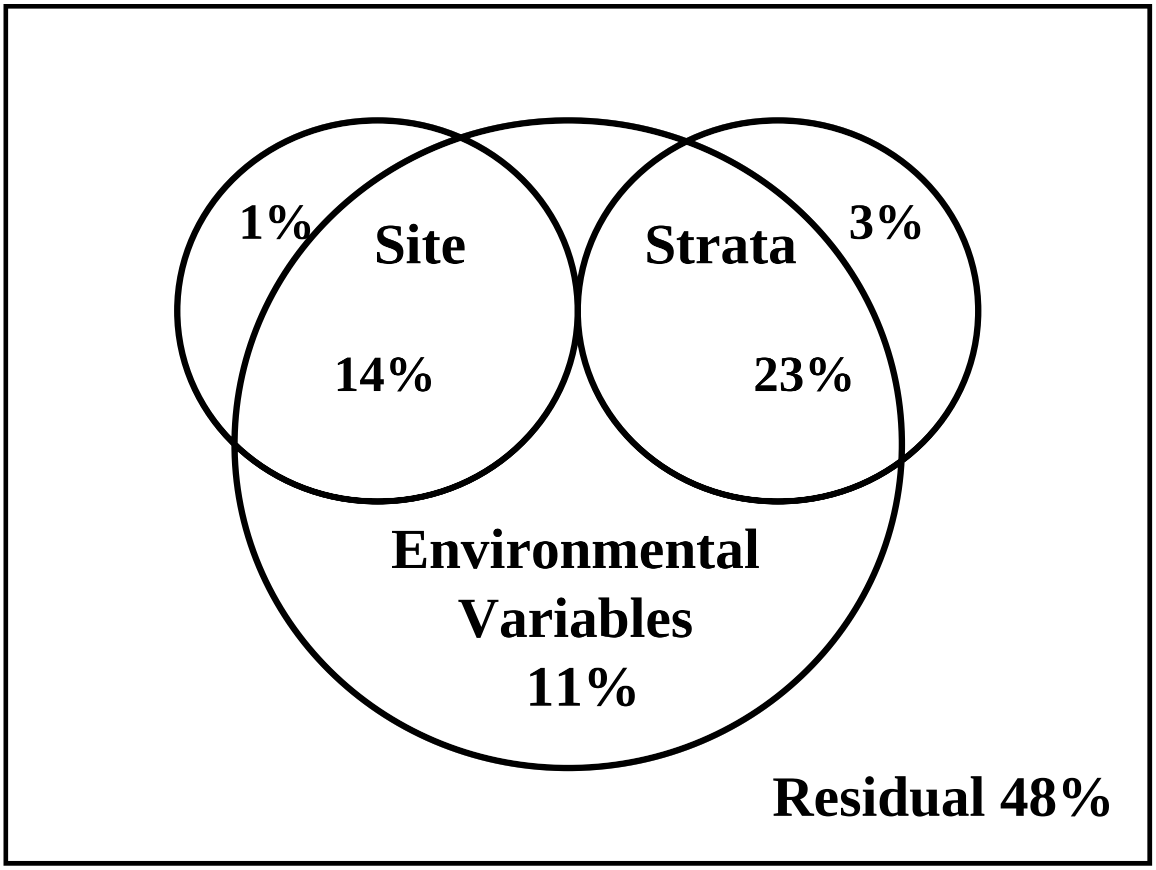

Figure 4.39 Venn diagram showing the proportion of the total variance in waterbird abundance within plots explained by the measured environmental variables during spring migration 2003 in the southwest Lake Erie marsh region.

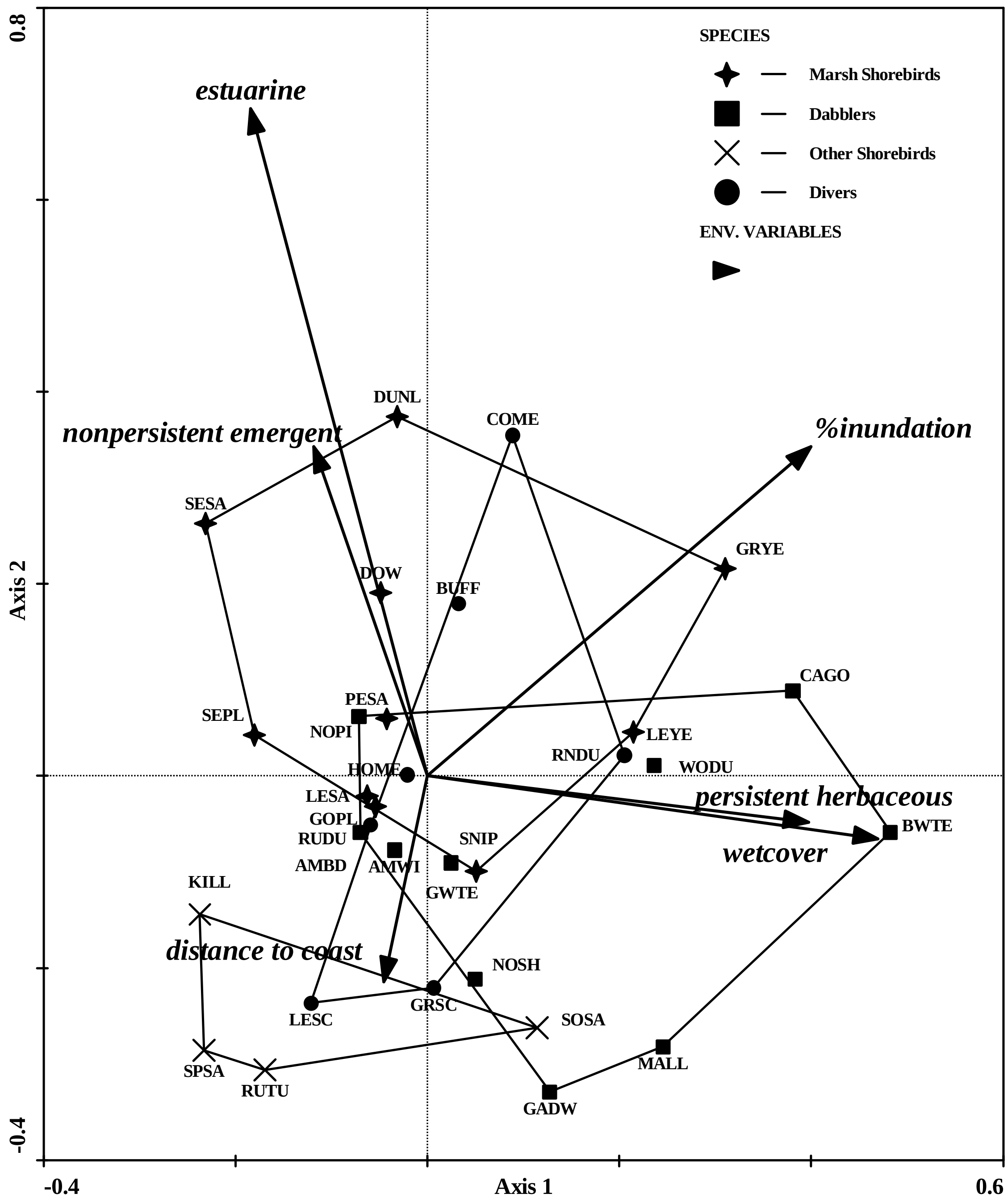

Figure 4.40. Redundancy Analysis (RDA) biplot of the species data and explanatory environmental variables collected during spring 2003 in which arrow lengths and angles of intersect are related to the importance of the environmental variables in the species ordination. Species codes are listed with full species' names in Appendix E.

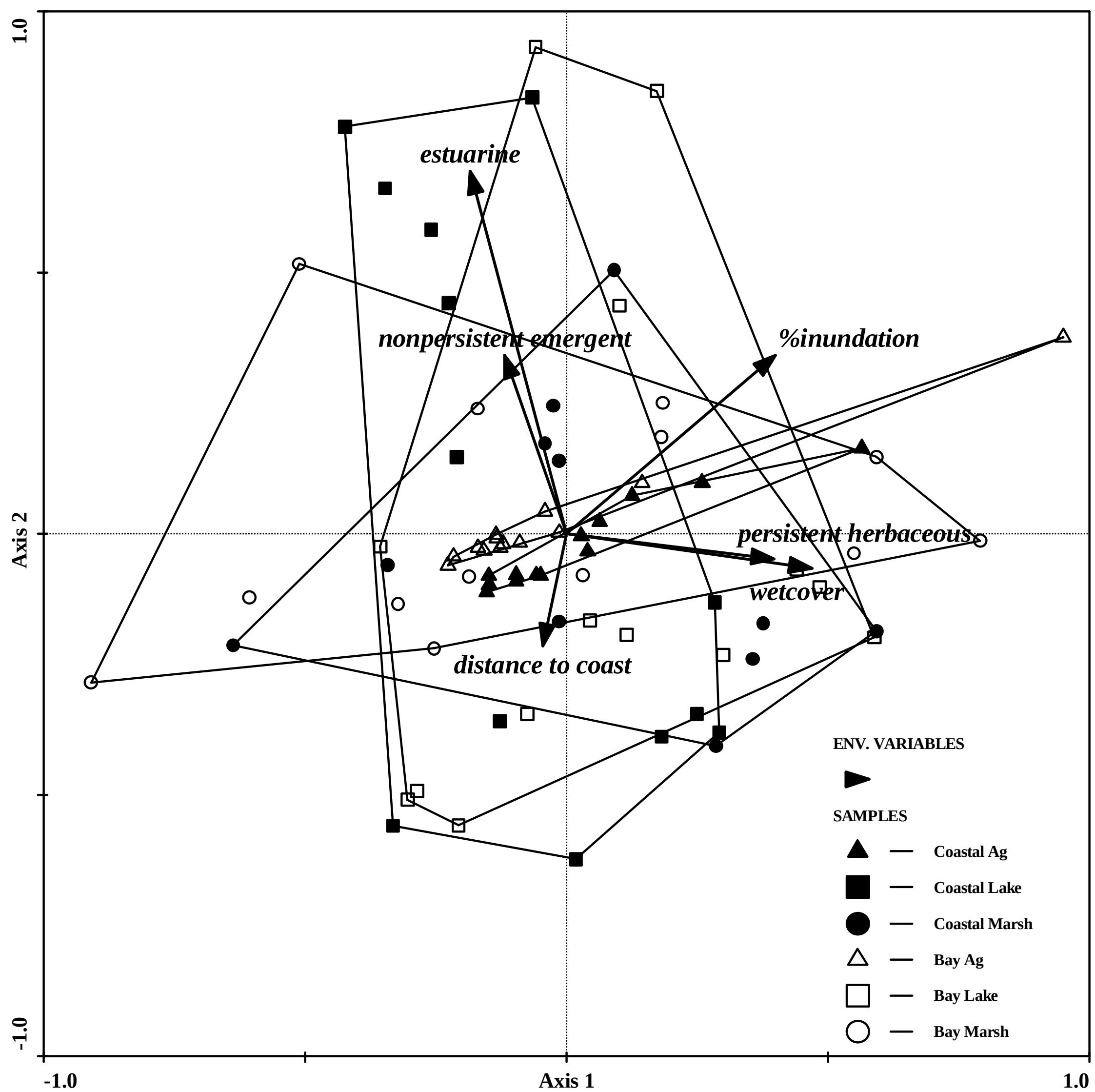

Figure 4.41. Redundancy Analysis (RDA) biplot of the sample plots and explanatory environmental variables collected during spring 2003 in which arrow lengths and angles of intersect are related to the importance of the environmental variables in the species ordination.

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalue:	0.039	0.035	0.033	0.015
Species-environment correlation:	0.739	0.803	0.628	0.546
Cumulative percentage variance:				
of species data:	4.6	8.8	12.7	14.5
of species-environmental relation:	27.6	52.2	75.2	86.1
Sum of all eigenvalues: 0.844				
Sum of all canonical eigenvalues: 0.142				

Table 4.5. Summary results of Redundancy Analysis identifying the relationship between habitat variables and waterbird use of 90 plots in the southwest Lake Erie marsh region during spring migration 2003. Total variance = 1.000.

4.5.4 Autumn 2003

The environmental variables accounted for 44% of the variation in waterbird abundance among plots when the variables analyzed also included strata (Figure 4.42). As in the other seasons analyzed the covariables site and strata when analyzed alone contributed little to the overall variance in waterbird use among plots.

Redundancy analysis identified five environmental variables that contributed significantly ($P<0.10$) to waterbird abundance in the 90 plots surveyed (Figure 4.43). The five influencing environmental characteristics were 1) percent of plot characterized by lacustrine wetland habitat, 2) percent of plot characterized by estuarine habitat, 3) percent of plot characterized by nonpersistent emergent wetland vegetation, 4) percent of plot characterized by persistent emergent wetland vegetation, and 5) mean variability in inundation per plot. Figure 4.44 illustrates the relationship between the environmental variables and the sample plots. As was true for all other seasons, the agricultural plots were located at the center of the biplot. The majority of lake-affected and marsh plots were clustered bottom left and associated closely with non-persistent emergent wetland vegetation. Additionally there was a clear association of several coastal, lake-affected plots with the estuarine habitat variable.

The first two axes of the RDA accounted for only 13.9 % of the total variation in species abundance among plots. Of this, 68.2% is attributable to the environmental variables included in the analysis (Table 4.6). Axis 1 was a stable water to variable water gradient where plots with stable water levels were associated with the negative end and plots with variable water conditions were along the positive end. Waterfowl were associated more closely with stable water conditions than shorebirds which were closely associated with variable water conditions. Axis 2 represented a gradient traveling from nonpersistent emergent wetlands on the negative end to lacustrine wetlands on the positive end. Persistent emergent wetlands were close to the center along this gradient and were encompassed on all sides by the waterfowl species. As was true of all seasons except spring 2002, the majority of shorebird species showed a strong association with the estuarine wetlands.

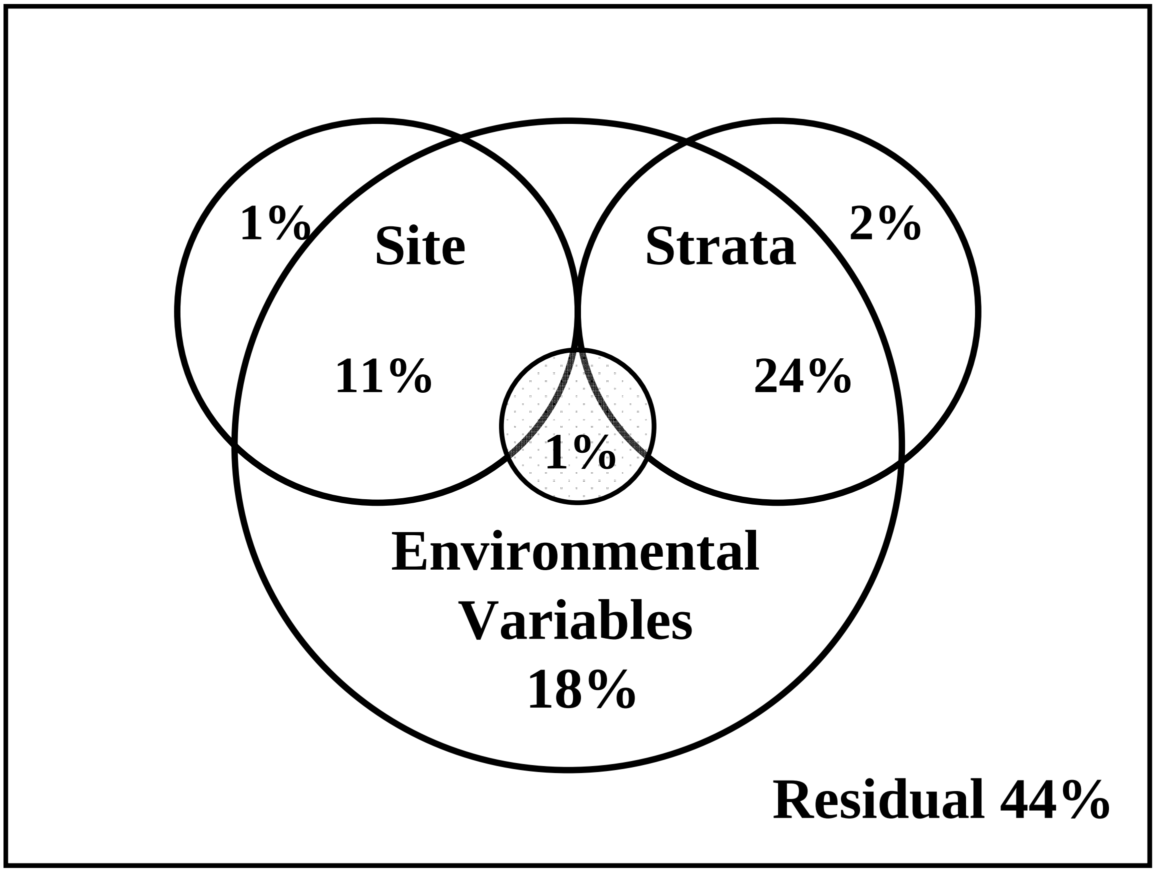

Figure 4.42 Venn diagram showing the proportion of the total variance in waterbird abundance within plots explained by the measured environmental variables during autumn migration 2003 in the southwest Lake Erie marsh region.

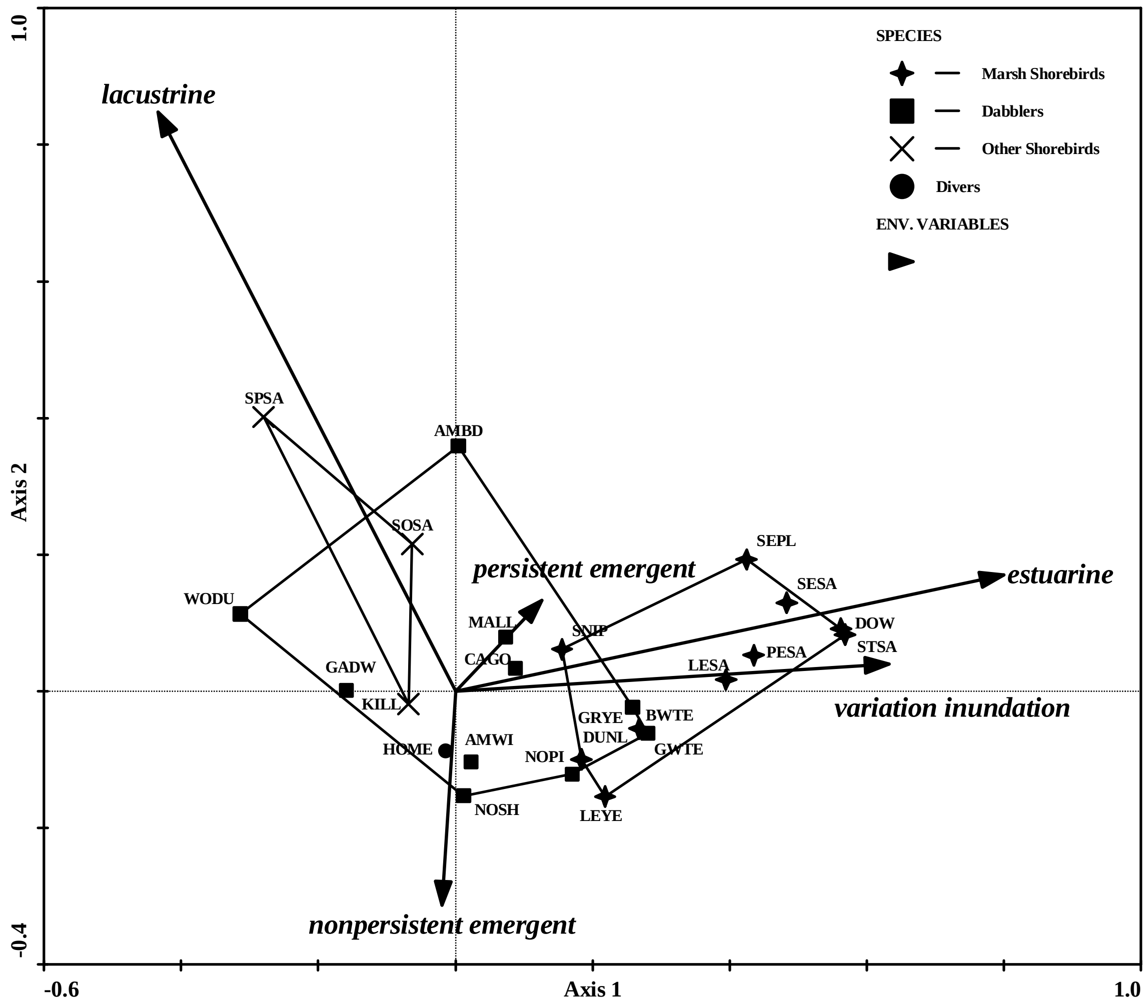

Figure 4.43. Redundancy Analysis (RDA) biplot of the species data and explanatory environmental variables collected during autumn 2003 in which arrow lengths and angles of intersect are related to the importance of the environmental variables in the species ordination. Species codes are listed with full species' names in Appendix E.

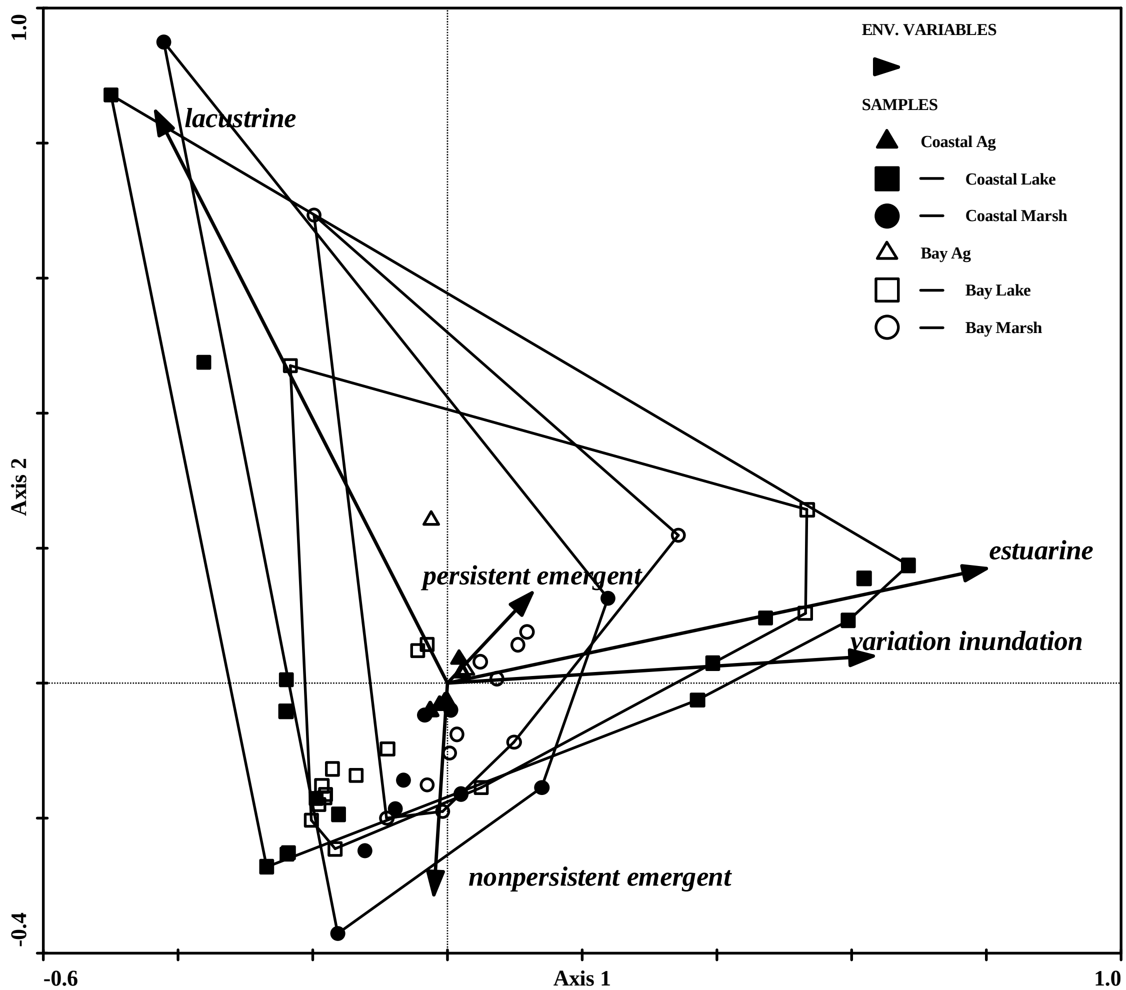

Figure 4.44. Redundancy Analysis (RDA) biplot of the sample plots and explanatory environmental variables collected during autumn 2003 in which arrow lengths and angles of intersect are related to the importance of the environmental variables in the species ordination.

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalue:	0.086	0.025	0.023	0.018
Species-environment correlation:	0.793	0.662	0.586	0.575
Cumulative percentage variance:				
of species data:	10.8	13.9	16.8	19.1
of species-environmental relation:	53.0	68.2	82.3	93.6
Sum of all eigenvalues:	0.800			
Sum of all canonical eigenvalues:	0.163			

Table 4.6. Summary results of Redundancy Analysis identifying the relationship between habitat variables and waterbird use of 90 plots in the southwest Lake Erie marsh region during autumn migration 2003. Total variance = 1.000.

CHAPTER 5

DISCUSSION

5.1 Shorebird abundance and distribution in relation to habitat

The purpose of my research was to identify the abundance and distribution of migrating shorebirds in the southwest Lake Erie marsh region in relation to the habitat types present. Through this research I determined that plots within the managed marsh stratum supported the greatest number of shorebird and waterfowl use-days when sites, seasons, and years were combined. However, shorebird use of the different strata showed a strong seasonal component when sites were separated. At the coastal site shorebirds tended to use managed marsh during spring but moved to lake-affected plots during autumn. At the embayment site, shorebird use was consistent within managed marsh for all seasons except spring 2003 when lake-affected plots received more use.

The seasonal difference in habitat use at the coastal site was likely attributable to both manmade and natural changes in water regimes within the available habitat. During spring at the coastal site, waterfowl management techniques included the use of early (initiated in mid-March to mid-April) drawdowns within the managed marsh habitats. These drawdowns, intended to produce lush vegetation for autumn waterfowl, normally lasted into May and provided suitable water levels and ample foraging habitat at the onset of and throughout spring shorebird migration. Lake-affected wetlands in contrast, were normally deeply inundated during the spring due to high lake levels and increased precipitation which limited the availability to migrating shorebirds. During fall however the conditions reversed; lake-affected wetlands became available due to natural evaporation and managed marshes were reflooded or maintained at depths more suitable for waterfowl.

At the embayment site managed marshes were available to shorebirds despite the season largely due to manmade water level manipulations during both spring and autumn. Similar to the coastal site, early drawdowns were conducted at the onset of shorebird migration during a time when natural wetlands were unavailable due to high water levels. However, managers at the embayment site also conducted autumn drawdowns within managed marshes to provide foraging habitat for teal species. These autumn drawdowns usually produced water levels of 1” to 8” and were suitable for shorebirds as well.

The only season in which managed marshes did not receive the most shorebird use at the embayment site was spring 2003. The habitat conditions present during spring 2003 were largely a result of drought conditions during summer and autumn 2002. The large, freshwater estuary known as South Creek was exposed during most of spring 2003 because of the draught-caused lower water levels within the lake and bays. The South Creek estuary is a tributary to the Muddy Creek Bay, a federally- protected no hunting zone. South Creek is exposed and flooded according to shifting lake-levels and provides foraging opportunity for all shorebird guilds. Shorebird use of South Creek and other exposed, natural wetlands caused the discrepancy in habitat use at the embayment site during spring 2003.

Despite managed marsh receiving the highest number of shorebird use-days, a comparison of shorebird abundance among the different strata showed lake-affected wetlands to be consistently significant for all shorebird guilds. In particular the coastal, lake-affected wetlands were most significant in terms of shorebird abundance for the beach, dry mudflat, shallow water, and moderate water shorebird guilds. The Crane Creek Estuary, centrally located at the coastal site, was the driving force behind this phenomenon. This freshwater estuary is an example of how historic wetlands in the region probably functioned. The rise and fall of estuary levels in relation to Lake Erie seiche events provides renewed resources to shorebirds in the form of extensive mudflats. When the region experiences several days of prevailing southwesterly winds Lake Erie water levels shift within the lake-basin. Water is blown to the east end of the lake and shallow water and mudflat conditions then dominate the shallow western basin of Lake Erie and its tributaries.

The Crane Creek Estuary is mostly unvegetated and has a shallowly sloping basin making it highly susceptible to the lake-level seiches. In high water periods macroinvertebrates can reproduce and recharge their populations. In low water periods substrates are exposed and allow shorebirds opportunity to build crucial lipid reserves for migration. The dynamic nature of the estuary's water regime permits the system to provide extended shorebird use without overexploitation.

The coastal, lake-affected plots also were important in terms of waterfowl abundance. During autumn dabbling duck abundance was greatest within the coastal, lake-affected plots and was likely a result of the Crane Creek Estuary as well. The estuary is known to provide habitat for large groups of staging or migrating waterfowl and because it is protected from hunting the waterfowl can easily seek refuge and rest there. Diving duck abundance differed between sites with the coastal site receiving more use. Diving ducks commonly form large rafts (several hundred to 1,000) on Lake Erie and this resulted in the higher diver abundance at the coastal site.

Agricultural plots received the least use by both shorebirds and waterfowl. However the results of shorebird and waterfowl use of agricultural plots may have been underestimated due to the lumping of entirely dry agricultural plots with agricultural plots containing some wet areas. Further analysis among agricultural plots could actually show that shorebird use was substantial within plots that contained moist soil-standing water conditions. Notwithstanding, agricultural plots cannot be expected to attract as many shorebirds or waterfowl as wetland plots because they typically do not provide stable wetland conditions. Throughout the course of this study agricultural plots, as would be expected, exhibited the lowest mean percent inundation and contained the least amount of wetland cover when compared to the managed marsh and lake-affected wetland plots at both sites (Tables 5.1 and 5.2).

Stratum	Season	Mean % inundation	Mean % wetland vegetation cover
Agriculture	Spring 02	11 (SE ± 5)	20 (SE ± 18)
Lake-affected		45 (SE ± 21)	37 (SE ± 18)
Marsh		40 (SE ± 13)	43 (SE ± 13)
Agriculture	Spring 03	7 (SE ± 2)	1 (SE ± 1)
Lake-affected		69 (SE ± 7)	12 (SE ± 2)
Marsh		60 (SE ± 8)	33 (SE ± 6)
Agriculture	Autumn 02	0	13 (SE ± 11)
Lake-affected		55 (SE ±8)	33 (SE ± 7)
Marsh		51 (SE ± 12)	57 (SE ± 6)
Agriculture	Autumn 03	2 (SE ±2)	9 (SE ± 7)
Lake-affected		59 (SE ± 7)	31 (SE ± 7)
Marsh		52 (SE ± 7)	51 (SE ± 6)

Table 5.1. Mean percent inundation and wetland vegetation cover for all sampling strata within the embayment site. Sampling strata were surveyed for shorebirds and waterfowl during spring and autumn migrations 2002 and 2003 within the southwest Lake Erie marsh region.

Stratum	Season	Mean % inundation	Mean % wetland vegetation cover
Agriculture	Spring 02	6 (SE ± 4)	0
Lake-affected		75 (SE ± 9)	24 (SE ± 11)
Marsh		33 (SE ± 13)	55 (SE ± 16)
Agriculture	Spring 03	9 (SE ± 3)	1 (SE ± 1)
Lake-affected		59 (SE ± 5)	11 (SE ± 4)
Marsh		57 (SE ± 6)	42 (SE ± 8)
Agriculture	Autumn 02	4 (SE + 3)	1 (SE ±1)
Lake-affected		48 (SE ± 8)	12 (SE ± 5)
Marsh		42 (SE ± 13)	65 (SE ± 11)
Agriculture	Autumn 03	5 (SE ± 3)	1 (SE ± 1)
Lake-affected		58 (SE ± 6)	12 (SE ± 5)
Marsh		50 (SE ± 11)	66 (SE ± 9)

Table 5.2. Mean percent inundation and wetland vegetation cover for all sampling strata within the coastal site. Sampling strata were surveyed for shorebirds and waterfowl during spring and autumn migrations 2002 and 2003 within the southwest Lake Erie marsh region.

5.2 Environmental factors affecting plot selection by waterbirds

Redundancy analysis (RDA) of shorebird abundance and environmental variables in the SLEMR showed consistently that shorebird selection of plots was driven largely by the amount of estuarine habitat contained within the plot. The repeated importance of estuarine habitat to shorebirds throughout all of the analyses illustrates the strong association that shorebirds have with the freshwater estuarine habitat within the SLEMR. Of the habitat types in the region, the estuarine habitat is most limiting and yet shorebirds seem to prefer it over the other choices available to them.

Shorebird habitat selection was also driven somewhat by the variability of inundation within a plot. Shorebirds preferred those plots with higher mean variation in water depths during both seasons. These results fit well with shorebirds' preference toward the highly variable estuarine habitats. Lastly shorebird habitat use was influenced by the percent of nonpersistent emergent wetland vegetation within a plot. However, this association was only present during the spring migration seasons and is likely a result of shorebird selection of early drawn-down marshes. In the spring nonpersistent emergent vegetation within managed marshes has been mostly if not completely decomposed during the previous autumn and winter seasons. This decomposition process lessens the vegetation density in the unit while promoting macroinvertebrate growth and both of these factors increase the attractiveness of the wetland to shorebirds.

Waterfowl selection was consistently affected by the amount of persistent or nonpersistent emergent vegetation within a plot, the percent of the plot that was inundated and the percent total wetland cover. As is predictable, these results support the association of waterfowl with habitat managed specifically *for* waterfowl in the SLEMR.

For all seasons the environmental variables explained only 21-49% of the variation in bird abundance among plots suggesting the influence of other unknown variables on waterbird selection of habitat. There seemed to be a strong covariable effect when stratum (27-44%) was combined with the other environmental variables bringing the total explained variation up to 48-93%. This is not surprising when we consider the effect that stratum had on both use-days and abundances for both shorebirds and waterfowl.

Weather

Although my analysis did not include the effect of weather conditions upon shorebird use of or availability of habitat, anecdotal evidence suggests that shorebird habitat use in the southwest Lake Erie marsh region is affected by significant weather events including high winds, lake-level seiches, and precipitation. During the course of my study I observed shorebirds seeking refuge from high winds within managed marsh units. This change in foraging behavior in response to wind activity has been observed elsewhere (Oring and Davis 1966, Robertson and Dennison, 1979, Dugan et al. 1981). Significant wind events also caused lake-level seiches which temporarily increased the availability of mudflats within natural wetlands.

Natural fluctuation in Lake Erie water levels may be partly responsible for seasonal differences in shorebird use of wetland types. Apart from seiche events there are noticeable fluxes in Lake Erie’s water levels. During spring the natural wetlands are usually inundated due to higher lake levels but retreating lake levels in autumn may expose these same wetlands for shorebird use (Figure 5.1).

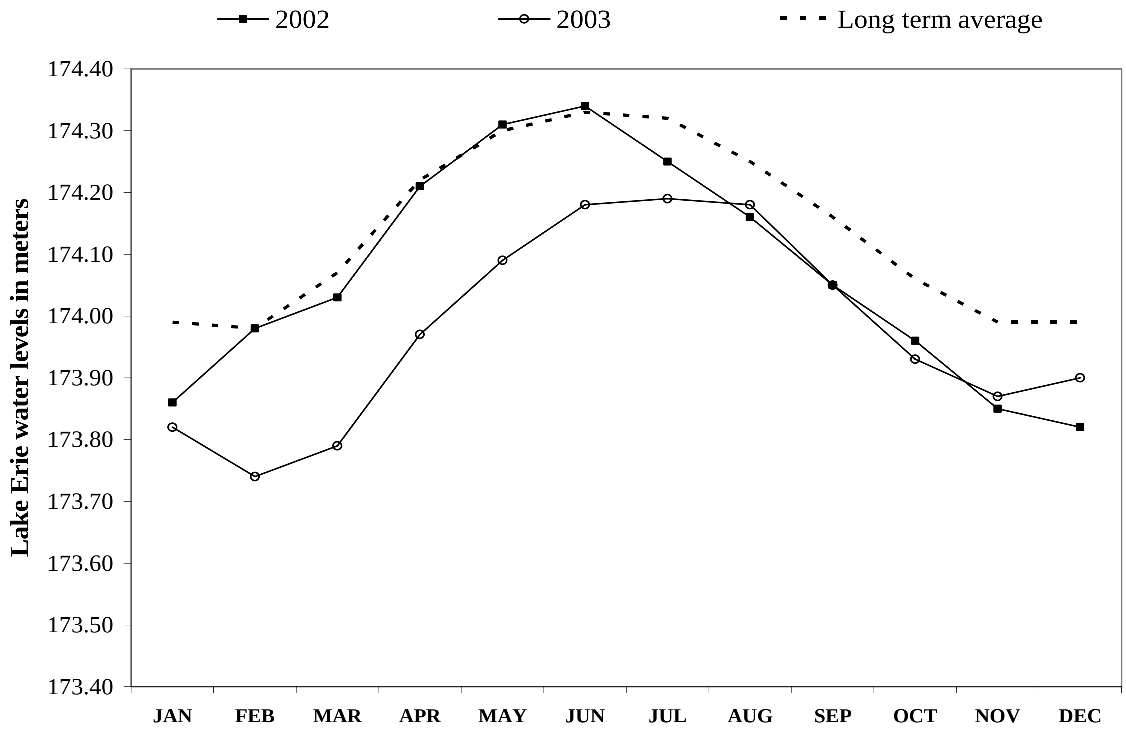

Figure 5.1. Mean Lake Erie water levels (in meters) by month for 2002 and 2003. United States Army Corps of Engineers historical data.

Precipitation also seemed to affect shorebird habitat use. Spring 2002 was characterized by increased precipitation which increased moist soil and shallow water habitats within agriculture, but also increased water levels within natural wetlands and managed marshes. During January to May, 2002 the total amount of precipitation exceeded the normal probabilities for the region (National Climatic Data Center/NESDIS/NOAA, 2002). Although 2002 was below the normal range for precipitation overall in the region, nearly 40% of the actual precipitation occurred from March through May.

In the southwest Lake Erie marsh region the nature of drainage with agricultural lands (tiling) promotes rapid drainage of farm fields into ditches which eventually drain into natural waterways such as rivers and creeks. As evidenced by my personal observations of precipitation events, a significant amount of rain is not required to raise natural water levels in the area creeks and rivers due to the extensive network of agricultural and residential drainage. However, during these periods of low foraging habitat availability in natural wetlands, shorebirds in the southwest Lake Erie marsh region did not switch over to using agricultural land as has been observed in other studies (Long and Ralph 2001, Colwell 1993, Rottenborn 1996). It is unclear why most shorebirds did not take advantage of the moist soil habitat provided by agricultural land.

5.3 Shorebird and waterfowl diversity among habitats

The correlation between high diversity plots for shorebirds and waterfowl suggests that the two avian groups can and are utilizing similar habitat. Between 57-60% of plots with the highest diversity of bird species were most diverse for both shorebirds and waterfowl. Several studies have shown positive response by shorebirds to habitat managed for waterfowl (Rundle and Frederickson 1981, Twedt et al. 1998). This research illustrates the importance of waterfowl management in providing critical habitat to other wildlife groups. The SLEMR has a rich historical background in waterfowl management and it is likely that this management has also lead to the region's importance to migrating shorebirds.

Plots dominated by drawn down marsh habitat contributed the most diversity to the waterfowl community during both years and both seasons. They also contributed the most shorebird diversity for both spring seasons. Early spring drawdowns most benefit shorebirds by supplying shallow water and moist soil habitat at a time when these conditions are rare in the natural wetlands and regional freshwater estuaries. Waterfowl also positively respond to moist soil management as it provides protein-rich invertebrates prior to the nesting season (Bookhout et al. 1989).

Lake-affected estuary plots attracted the most diverse assemblage of shorebirds for both fall seasons and suggest the importance of conserving this limited habitat within the region. Two freshwater estuaries consistently attracted large numbers of shorebirds and waterfowl during this study. The Crane Creek estuary (coastal site) and South Creek estuary (embayment site) are both federally protected areas with limited access and are closed to waterfowl hunting.

5.4 Shorebird prevalence within an important waterfowl migration and management area

Table 5.3 shows again the breakdown of extrapolated shorebird and waterfowl count numbers by site and season. While 2 years of observations may be inadequate for forming comparisons between shorebird and waterfowl use of the SLEMR, my data clearly show that shorebird presence in the region is nearly as significant as waterfowl presence. That being said, the integration of shorebird management with waterfowl management may, in fact, already occur. Practices commonly used in traditional waterfowl management (i.e. mowing of vegetation, water level manipulation) are currently providing important habitat for migrating shorebirds while still meeting waterfowl production/retention objectives.

Site	Season	Shorebird Population	Waterfowl Population
Coastal	Spring ’02	57,596 (SE ± 34,703)	35,342 (SE ± 7,593)
	Autumn ’02	118,892 (SE ± 31,813)	265,782 (SE ± 64,384)
	Spring ’03	140,410 (SE ± 65,035)	101,904 (SE ± 18,051)
	Autumn ’03	69,369 (SE ± 12,519)	267,859 (SE ± 60,151)
Embayment	Spring ’02	226,760 (SE ± 112,592)	53,850 (SE ± 16,109)
	Autumn ’02	113,477 (SE ± 43,124)	128,450 (SE ± 59,671)
	Spring ’03	68,381 (SE ± 22,682)	113,827 (SE ± 26,168)
	Autumn ’03	87,291 (SE ± 24,018)	143,107 (SE ± 41,829)

Table 5.3. Extrapolated shorebird and waterfowl populations by study site (coastal vs. embayment) and season (spring vs. autumn) during 2002 and 2003 within the southwest Lake Erie marsh region.

5.5 Summary: Revisiting the WHSRN designation of the SLEMR

As stated in the introduction, the southwest Lake Erie marsh region (SLEMR) has been designated as a regionally important stopover site by the Western Hemisphere Shorebird Reserve Network (WHSRN). A regionally important site is one that hosts at least 20,000 shorebirds annually or supports at least 1% of a species biogeographic population. Through my study I have shown that the SLEMR hosts a great deal more than 20,000 shorebirds on an annual basis. During spring 2002 the extrapolated population estimate for shorebirds for both the coastal and embayment sites was 284, 356. Since this survey was initiated after the commencement of spring migration in 2002 it is reasonable to assume that my count was incomplete and that shorebird numbers in the region could have been higher. The remaining seasons surveyed, autumn 2002, spring 2003, and autumn 2003 resulted in even higher population estimates for shorebirds (see figures 4.21 and 4.22).

The shorebird population estimates for the 2 sites were based upon a 7-day stopover period. Shorebird stopover durations have been known to last anywhere from 1 day to 14 days (Senner and Howe 1984) and the 7-day period was selected as a middle-of-the road estimate. Assuming a 5, 10, and 15 day stopover duration also results in population estimates that exceed the 20,000 bird criterion for a WHSRN regional site (Figures 5.2-5.4).

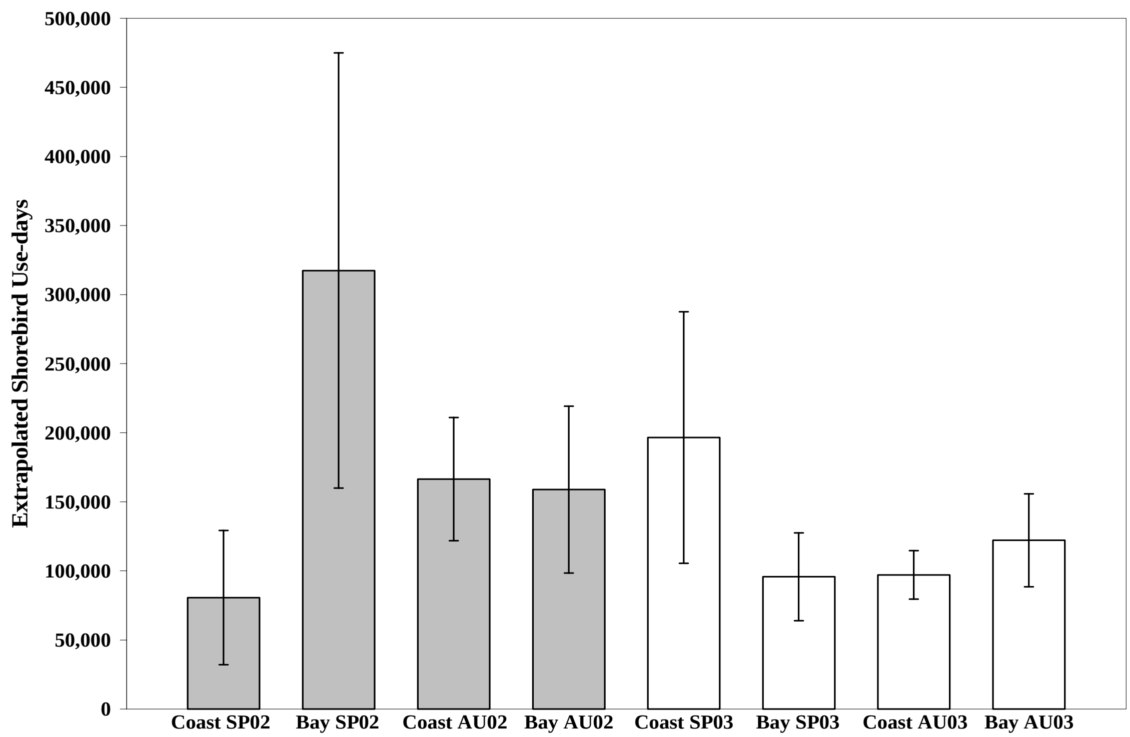

Figure 5.2 Shorebird population estimates by season (spring vs. autumn) and year (2002 vs. 2003) assuming a 5- day stopover at the coastal and embayment sites of the southwest Lake Erie marsh region.

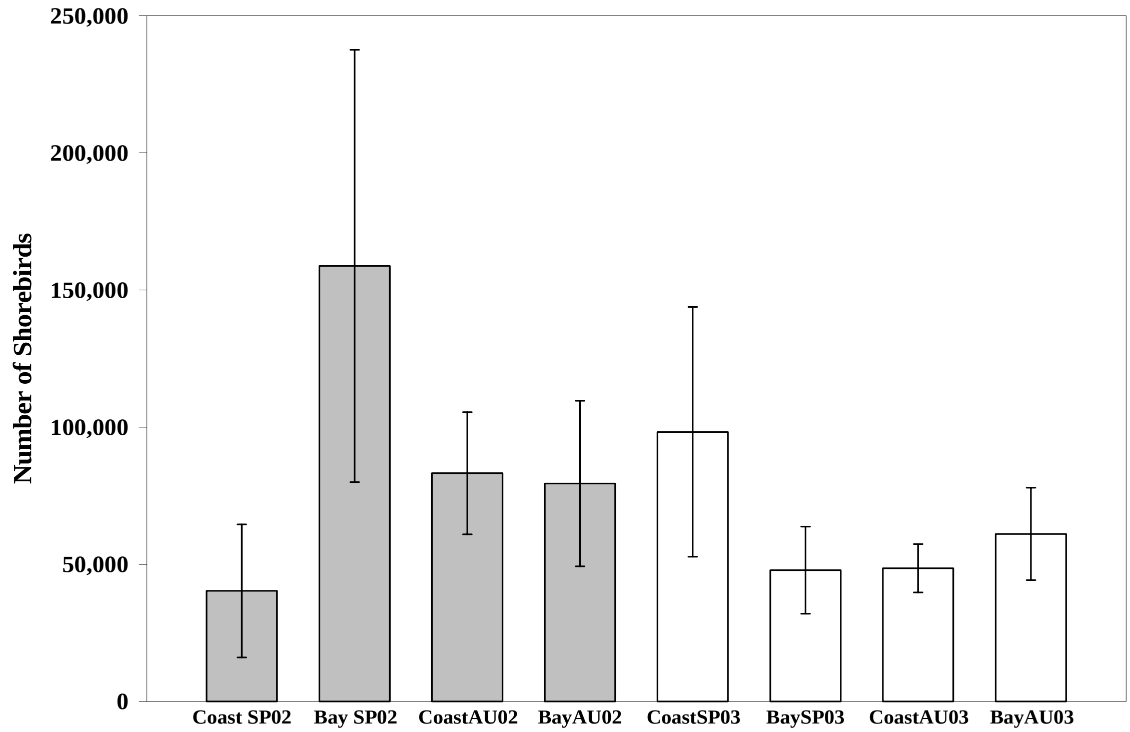

Figure 5.3 Shorebird population estimates by season (spring vs. autumn) and year (2002 vs. 2003) assuming a 10- day stopover at the coastal and embayment sites of the southwest Lake Erie marsh region.

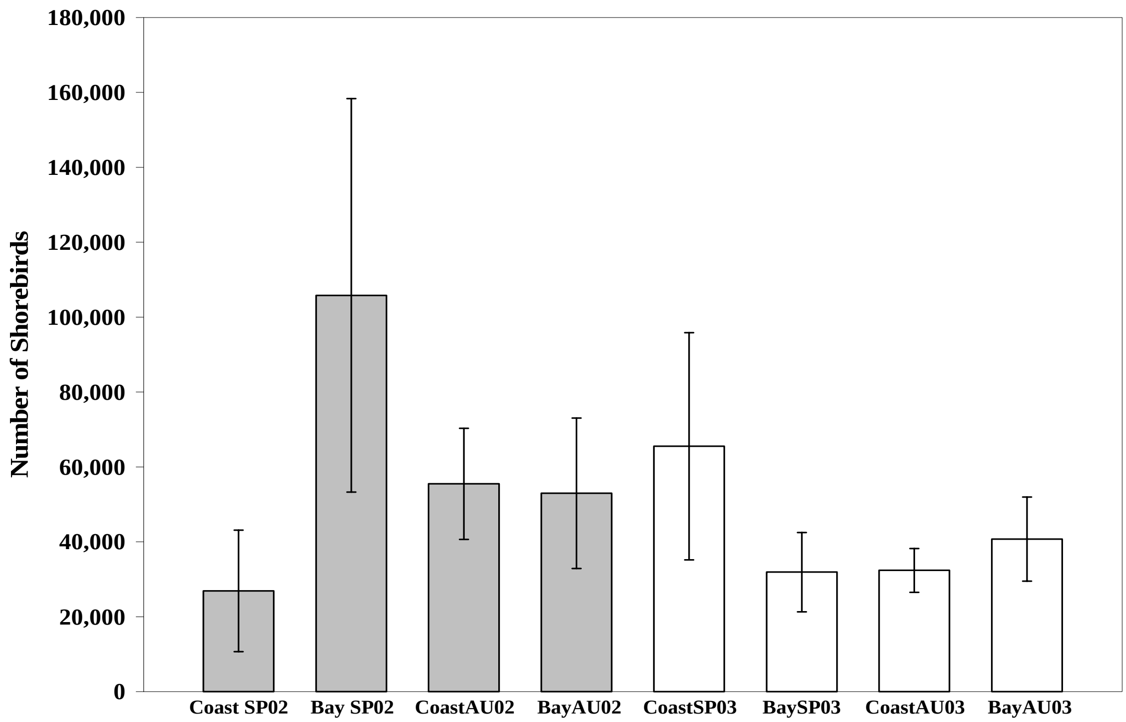

Figure 5.4 Shorebird population estimates by season (spring vs. autumn) and year (2002 vs. 2003) assuming a 15-day stopover at the coastal and embayment sites of the southwest Lake Erie marsh region.

Given even the most conservative estimates based upon a 15-day stopover, the number of shorebirds in the SLEMR is enough to justify an international importance status. The WHSRN categorizes a site as internationally important if it supports at least 100,000 shorebirds annually or >10% of the biogeographic population for a species. The embayment site alone supported over 100,000 shorebirds and this just during spring 2002 (105,822, SE ± 52,543). On an annual basis, the most conservative of my estimates ranks the SLEMR as a stopover site of international importance for migrating shorebirds.

CHAPTER 6

RECOMMENDATIONS AND FUTURE RESEARCH NEEDS

6.1 Land acquisition and conservation priorities in the southwest Lake Erie marsh region

Land acquisition in the Lake Erie marsh region to promote shorebird/waterbird conservation should focus on natural wetlands and impounded marshland. Natural wetlands (i.e. estuaries, rivers, and coastal beaches) should be conserved because they support much more use by the avian community than is expected from their relative abundance within the landscape. Natural wetlands and beaches are uncommon in the region due to coastal and agricultural development. Unfortunately, efforts to reclaim coastal properties are often more expensive than public agencies can afford. Funding for conservation in the region needs to be a joint effort among all interested parties.

Impounded marshland should also be procured and managed to provide for a diverse array of wildlife groups. This research has proven the importance of managed wetlands to meeting the needs of two very different avian groups.

6.2 Management to increase the value of the southwest Lake Erie marsh region for migrating shorebirds

Spring drawdowns

According to my data shorebirds are more prevalent in the SLEMR during spring migration than during autumn migration. Particularly, shorebird numbers peak once in early April and then again during May with numbers dropping off dramatically closer to June (Figures 4.1 and 4.3). Natural wetlands within the SLEMR during spring tend to have deep water conditions making them unavailable for migrating shorebirds. Because of this the importance of managed marshes to provide shorebird foraging habitat is elevated during the spring migration timeframe of late March through the beginning of June. Managers wishing to provide adequate foraging opportunity for migrating shorebirds during spring could initiate drawdowns in late March or early April and continue the drawdown gradually into May. Waterfowl migrating through the area or establishing local nesting territories would also benefit from a significant invertebrate prey source.

Autumn drawdowns

Drawdowns of managed marsh units during autumn shorebird migration (August – November) are less common than spring drawdowns. However, the August reflooding of units that were drawn down during spring can be beneficial to shorebirds at the onset of autumn migration. My data show that shorebird migration in the region first peaks during August and then secondly during early September (Figures 4.5 and 4.7). These early autumn migrants could use these units for foraging if the reflooding process is gradual and if vegetation within the unit is not too dense. Additionally, some marsh managers within the SLEMR do perform early autumnal drawdowns with the objectives of attracting and sustaining large numbers of blue-winged (*Anas discors*) and green-winged (*A. carolinensis*) teal during the early waterfowl hunting season (first two weeks of September). These particular drawdowns were observed to attract many shorebirds during the course of this study and may serve to supplement important migration habitat if drying, natural wetlands suffer depleted prey conditions due to prolonged exposure.

The last peak during autumn shorebird migration, as shown by my data, occurred during mid to late October. This peak was likely a result of large flocks of dunlin (*Calidris alpina*) which arrived much later than other species within the region. As observed during this study and others (Taft and Haig 2005) dunlins will use various habitat types to meet foraging requirements. I observed dunlin (moist-soil guild species) feeding in the moist-soil and shallow water of agricultural fields and marshes, and on extensive estuarine mudflats. Drawdowns of managed marshes during late October specifically aimed at providing habitat for late-arriving dunlin may be an option for managers interested specifically in shorebird management. Additionally these drawdowns may be beneficial during years where high water levels render natural wetlands unavailable. Under normal conditions, October drawdowns may be unnecessary due to the opportunistic foraging nature of dunlin and their ability to utilize various wetland types.

6.3 Items for future research

Agriculture

During some seasons, agriculture provided considerable amounts of moist-soil and shallow water habitat, but was still used relatively infrequently by shorebirds. It is difficult without proper research to predict why shorebird use of agriculture was low even under favorable water and vegetative conditions. A study by Kahler (2004) investigated differences in macroinvertebrate abundance between managed marshes and freshwater estuaries within the SLEMR, but did not evaluate the agricultural habitat component.

Further evaluation of the various agricultural practices in the region such as crop selection, fertilizer or herbicide application and tillage, rotation, and harvest practices and their effects on the invertebrate prey base may be useful. Identifying the agricultural invertebrate communities within the region and comparing these to invertebrate communities found in natural and managed wetlands may be useful in explaining the differences in shorebird use between habitat strata.

Weather- related factors (seiche, precipitation)

Wind, seiche events and precipitation likely affect shorebird habitat availability and selection within the SLEMR. Strong winds and the resulting seiche events are common and displace water within natural wetlands depending upon wind direction (Bedford 1992). Seiches occur when strong winds shift water levels within Lake Erie's relatively shallow basin. Southwesterly winds push water from the western basin of Lake Erie eastward causing a deepening of water levels in the eastern basin (Buffalo, NY). Conversely, northeasterly winds push eastern basin water westward deepening water levels in the western basin (Toledo, OH). It is not known however, how these seiche events effect habitat selection by or habitat availability for migrating shorebirds. A useful comparison could be made between the duration and resulting water depth change of seiche events and the corresponding shorebird use of habitat within the seiche timeframe.

Precipitation within the region also has a marked effect upon water levels in both managed and unmanaged wetlands. Due to extensive drainage systems within agricultural lands, precipitation events, even when small, result in elevated water levels in the area creeks and rivers. Additionally, draw down efforts within managed units are sometimes thwarted by unusually high rainfall within a season (P. Baranowski, Ohio Division of Wildlife, personal communication). The effects of precipitation and wind-induced seiche events on local habitat availability to shorebirds merit additional research.

6.4 Conclusions

Migrant shorebird use of the SLEMR is highly influenced by the estuarine habitat found there. Shorebird use of wetland habitat was consistently associated with plots belonging to the lake-affected stratum or the amount of estuarine habitat found within plots. However, the use of managed marsh wetlands by shorebirds in the SLEMR cannot be over-looked. Shorebirds had a tendency to rely upon managed marsh wetlands during spring migration when high water levels within natural or estuarine wetlands inhibited their use. Impounded marshes drawn-down as part of a moist-soil management regime provided optimal water levels and sparse vegetation conditions for spring migrants. These same units when reflooded in August provided suitable water depths for autumn migrants where vegetation was not too dense. Nevertheless, the change by shorebirds from use of managed marshes during spring to lake-affected wetlands during autumn suggests that perhaps most managed marsh habitat was unavailable due to the high density of marsh vegetation. Further, these results suggest that perhaps there should be greater emphasis on managed marshes providing spring foraging habitat because shorebirds readily and maybe preferably use natural wetlands to fulfill their dietary needs during autumn migration. Natural wetlands are not thusly available during spring and so supplemental habitat may be necessary in the form of spring draw-downs.

Except for one large flock of golden plover (*Pluvialis dominica*) observed in a tilled soybean field on May 1st, 2003, overall use of agricultural land was low for shorebirds. Shorebird use-days associated with the agricultural stratum accounted for less than 4% of the total bud for the region. Shorebirds used agricultural land infrequently but we cannot infer its relative unimportance to migrating shorebirds in the SLEMR based upon this research alone. A comprehensive study of shorebird use of SLEMR agricultural lands is needed to assess why shorebirds do not use seemingly good habitat conditions provided by cropland.

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APPENDIX A

TOTAL NUMBER OF EACH SHOREBIRD AND WATERFOWL SPECIES THAT WAS OBSERVED DURING SPRING AND FALL MIGRATIONS OF 2002 AND 2003 IN THE SOUTHWEST LAKE ERIE MARSH REGION.

Species	Total Number Observed All Seasons Combined
American avocet *Recurvirostra Americana*	4
Marbled godwit *Limosa fedoa*	1
Wilson's phalarope *Phalaropus tricolor*	19
Whimbrel *Numenius phaeopus*	1
Greater yellowlegs *Tringa melanoleuca*	480
Dowitcher *Limnodromus spp*	1,696
Lesser yellowlegs *Tringa flavipes*	2,572
Stilt sandpiper *Calidris himantopus*	124
Willet *Catoptrophorus semipalmatus*	1
Red knot *Calidris canutus*	1
Least sandpiper *Calidris minutilla*	553
Semi-palmated sandpiper *Calidris pusilla*	2,253
Solitary sandpiper *Tringa solitaria*	184
Spotted sandpiper *Actitis macularia*	513
Western sandpiper *Calidris mauri*	48
American woodcock *Scolopax minor*	6
Common snipe *Gallinago gallinago*	977
Dunlin *Calidris alpine*	13,993
Pectoral sandpiper *Calidris melanotos*	2,587
Semi-palmated plover *Charadrius semipalmatus*	400
Killdeer *Charadrius vociferous*	6,535
Baird's sandpiper *Calidris bairdii*	64
Buff-breasted sandpiper *Tryngites subruficollis*	2
Upland sandpiper *Bartramia longicauda*	9
Black-bellied plover *Pluvialis squatarola*	46
Golden plover *Pluvialis dominica*	142
Sanderling *Calidris alba*	73
Ruddy turnstone *Arenaria interpres*	110
Mallard *Anas platyrynchos*	12,670
Wood duck *Aix sponsa*	3,565
American black duck *Anas rubripes*	630
Northern pintail *Anas acuta*	653
American widgeon *Anas americana*	311
Gadwall *Anas strepera*	1,780
Green-wing teal *Anas carolinensis*	2,370
Blue-wing teal *Anas discors*	2,701
Canada goose *Branta canadensis*	7,181
American coot *Fulica americana*	5,285
Northern shoveler *Anas clypeata*	295
Trumpeter swan *Cygnus buccinator*	143
Redhead duck *Aythya americana*	7
Ruddy duck *Oxyura jamaicensis*	166
Common merganser *Mergus merganser*	159
Hooded merganser *Lophodytes cucullatus*	78
Bufflehead *Bucephala albeola*	112
Ring-necked duck *Aythya collaris*	281
Lesser scaup *Aythya affinis*	68
Greater scaup *Aythya marila*	350

APPENDIX B

LIST OF SHOREBIRD AND WATERFOWL GUILDS AND THEIR ASSOCIATED SPECIES THAT WERE OBSERVED DURING SPRING AND FALL MIGRATIONS OF 2002 AND 2003 IN THE SOUTHWEST LAKE ERIE MARSH REGION.

Guild Name	Associated Species
Moderate Water	American avocet *Recurvirostra Americana*
	Marbled godwit *Limosa fedoa*
	Wilson's phalarope *Phalaropus tricolor*
	Whimbrel *Numenius phaeopus*
Shallow Water	Greater yellowlegs *Tringa melanoleuca*
	Long-billed dowitcher *Limnodromus scolopaceus*
	Short-billed dowitcher *Limnodromus griseus*
	Lesser yellowlegs *Tringa flavipes*
	Stilt sandpiper *Calidris himantopus*
	Willet *Catoptrophorus semipalmatus*
Moist Mud Flats	Red knot *Calidris canutus*
	Least sandpiper *Calidris minutilla*
	Semi-palmated sandpiper *Calidris pusilla*
	Solitary sandpiper *Tringa solitaria*
	Spotted sandpiper *Actitis macularia*
	Western sandpiper *Calidris mauri*
	American woodcock *Scolopax minor*
	Common snipe *Gallinago gallinago*
	Dunlin *Calidris alpine*
	Pectoral sandpiper *Calidris melanotos*
	Semi-palmated plover *Charadrius semipalmatus*
Dry Mud Flats	Killdeer *Charadrius vociferous*
	Baird's sandpiper *Calidris bairdii*
	Buff-breasted sandpiper *Tryngites subruficollis*
	Upland sandpiper *Bartramia longicauda*
	Black-bellied plover *Pluvialis squatarola*
	Golden plover *Pluvialis dominica*
Beach	Sanderling *Calidris alba*
	Ruddy turnstone *Arenaria interpres*
Dabblers	Mallard *Anas platyrynchos*
	Wood duck *Aix sponsa*
	American black duck *Anas rubripes*
	Northern pintail *Anas acuta*
	American widgeon *Anas americana*
	Gadwall *Anas strepera*
	Green-wing teal *Anas carolinensis*
	Blue-wing teal *Anas discors*
	Canada goose *Branta canadensis*
	American coot *Fulica americana*
	Northern shoveler *Anas clypeata*
	Trumpeter swan *Cygnus buccinator*
Divers	Redhead duck *Aythya americana*
	Ruddy duck *Oxyura jamaicensis*
	Common merganser *Mergus merganser*
	Hooded merganser *Lophodytes cucullatus*

APPENDIX B Continued

Divers	Bufflehead *Bucephala albeola*
	Ring-necked duck *Aythya collaris*
	Lesser scaup *Aythya affinis*
	Greater scaup *Aythya marila*

APPENDIX C

SPECIES RICHNESS (S) AND SHANNON'S DIVERSITY INDEX (H) SCORES FOR EACH OF THE PLOTS SURVEYED DURING SPRING AND AUTUMN MIGRATIONS 2002 WITHIN THE SOUTHWEST LAKE ERIE MARSH REGION. PLOT NAMES INCLUDE THE SITE AND STRATA IDENTIFICATION: O=OTTAWA (COASTAL), W=WINOUS (EMBAYMENT), A=AGRICULTURE, E=ESTUARINE (LAKE-AFFECTED), AND M=MARSH.

Plot Name	Shorebirds		Waterfowl	
	S	H	S	H
OA10	1	0.000		
OA13	7	1.506	2	0.5495
OA14	1	0.000	1	0
OA15	2	0.667		
OA16	5	1.129		
OA17	5	1.388	1	0
OA18	2	0.432		
OA19	1	0.000		
OA2	3	0.772	2	0.645
OA3	1	0.000		
OA4	4	1.153		
OA5	3	0.978		
OA6	4	0.660		
OA7	3	0.907	1	0
OA8	3	0.861		
OE12	12	2.239	6.5	1.6215
OE13	15	2.487	7	1.656
OE16	12	2.333	5.5	1.602
OE1	9	1.947	10	2.131
OE20	14	2.444	3.5	0.827
OE21	11	2.225	2	0.688
OE22	4	1.053	1	0
OE23	8	1.872	2	0.685
OE24	10	2.178	2	0.693
OE25	7	1.726	4	1.204
OE26	4	1.239		
OE3	16	2.588	4	1.321
OE5	6	1.669	4	1.3175
OE7	3	0.998		
OE9	3	1.076	3	0.923
OM10	10	2.224	4	1.3125
OM11	9	1.886		
OM14	11	2.348		
OM1	5	1.514	5	1.58
OM22	12	2.339	6	1.648
OM23	4	1.218		
OM24	6	1.718		
OM25	1	0.000	10	2.121
OM3	12	2.298	10	2.069
OM6	6	1.504	3	1.0135
OM7	11	2.248	9	2.062
OM8	8	1.961	7	1.914
OM9	7	1.760	5	1.495
WA11	2	0.488		
WA12	1	0.000	1	0
WA13	2	0.515		
WA14	2	0.628		
WA15	1	0.000		
WA16	1	0.000		
WA17	2	0.484		
WA2	1	0.000	2	0.693

WA3	3	1.052		
WA4	1	0.000		
WA6	5	1.360	1	0
WA7	3	0.781		
WA8	1	0.000		
WA9	2	0.637		
WE10	8	1.713	1	0
WE11	3	0.940	2	0.527
WE12	15	2.387	5	1.41
WE13	10	2.099	3	1.015
WE14	2	0.671	3	1.04
WE15	3	1.039		
WE1	10	2.114	6	1.459
WE2	14	2.410	5	1.517
WE3	6	1.421	4	1.313
WE4	6	1.648	4	1.271
WE5	2	0.672		
WE6	7	1.850		
WE7	7	1.603		
WE8	7	1.633	3	1.016
WE9	4	1.373		
WM10	11	2.136	2	0.658
WM11	15	2.368	6	1.72
WM12	13	2.332	5	1.484
WM13	1	0.000		
WM14	11	2.269	5	1.572
WM15	9	2.024	10	2.217
WM1	13	2.424	8	2.076
WM2	1	0.000		
WM3	4	1.335	2	0.656
WM4	5	1.502	2	0.652
WM5	7	1.703	6.5	1.7935
WM6	9	2.107	3.5	1.2215
WM7	1	0.000		
WM8	2	0.546	8	1.963
WM9	3	0.996	1	0

APPENDIX D

SPECIES RICHNESS (S) AND SHANNON'S DIVERSITY INDEX (H) SCORES FOR EACH OF THE PLOTS SURVEYED DURING SPRING AND AUTUMN MIGRATIONS 2003 WITHIN THE SOUTHWEST LAKE ERIE MARSH REGION. PLOT NAMES INCLUDE THE SITE AND STRATA IDENTIFICATION: O=OTTAWA (COASTAL), W=WINOUS (EMBAYMENT), A=AGRICULTURE, E=ESTUARINE (LAKE-AFFECTED), AND M=MARSH.

Plot Name	Shorebirds		Waterfowl	
	S	H	S	H
OA10	1	0.000	3	0.968
OA13	4	1.194	1.5	0.3385
OA14	1	0.000	1	0
OA15	2	0.667	2	0.687
OA16	3	0.728	1.5	0.3435
OA17	3	0.791	1	0
OA18	1.5	0.299	1.5	0.321
OA19	1	0.000	2	0.681
OA2	1	0.000	3	0.91
OA3	1	0.000	1	0
OA4	2	0.618		
OA5	2	0.667		
OA6	1.5	0.257		
OA7	1.5	0.327	2	0.632
OA8	1	0.000		
OE1	5.5	1.369	2.5	0.6415
OE12	7.5	1.855	4.5	1.344
OE13	9	2.050	8.5	1.993
OE16	9	2.163	7.5	1.9495
OE20	6	1.626	4	1.153
OE21	8	1.915	4.5	1.1995
OE22	2.5	0.792	2	0.67
OE23	6.5	1.788	8	1.9865
OE24	6.5	1.778	6.5	1.657
OE25	4	1.246	8	1.943
OE26	3.5	1.196	3	0.935
OE3	8	1.831	3.5	1.234
OE5	4.5	1.379	4.5	1.206
OE7	2	0.539		
OE9	2	0.683	1	0
OM1	2	0.692	6	1.76
OM10	6	1.479	3	1.09
OM11	3	1.035	3	1.0815
OM14	10	2.228	8	1.9815
OM22	3.5	0.876	6	1.5315
OM23	2.5	0.864	11.5	2.3505
OM24	5	1.534	6.5	1.7985
OM3	7.5	1.732	8.5	2.108
OM6	1.5	0.313	7	1.857
OM7	1.5	0.214	7	1.848
OM8	1	0.000	13	2.431
OM9	1	0.000	12	2.462
WA11	1	0.000		
WA12	1	0.000	1	0
WA13	1.5	0.340	1	0
WA14	1.5	0.346		
WA15	1	0.000		
WA16	1	0.000	1	0
WA17	1.5	0.328		
WA2	1	0.000		

APPENDIX D Continued

WA3	3	1.032	3	1.041
WA4	1	0.000		
WA6	3	0.761		
WA7	2	0.536		
WA8	1	0.000		
WA9	1	0.000		
WE1	2.5	0.868	2.5	0.8725
WE10	4	1.300	2	0.684
WE11	1	0.000	3	1.0695
WE12	7.5	1.541	3	1.072
WE13	5	1.035	2	0.5995
WE14	1	0.000	4	1.33
WE15	1.5	0.285	2	0.684
WE2	7	1.864	7.5	1.8535
WE3	1	0.000	1.5	0.306
WE4	2	0.583	3.5	1.2195
WE5	1.5	0.347	2.5	0.8565
WE6	4.5	1.355	2	0.5445
WE7	2.5	0.798	4	1.309
WE8	5	1.388	3	1.0835
WE9	3	1.017	2.5	0.8895
WM1	6	1.180	2.5	0.683
WM10	3	0.782	3.5	0.8845
WM11	8.5	2.009	11.5	2.3595
WM12	8.5	1.960	8	1.9915
WM13	1	0.000	10	2.24
WM14	7	1.836	5.5	1.644
WM15	9	2.037	8	1.904
WM2	1	0.000	2	0.688
WM3	1.5	0.347	5	1.463
WM4	3	0.921	2	0.5285
WM5	4	1.266	7	1.8025
WM6	6	1.744	5	1.5195
WM7	1	0.000		
WM8	2	0.592	8	2.033
WM9	1.5	0.347	7	1.7445

APPENDIX E

SHOREBIRD AND WATERFOWL SPECIES AND THEIR ABBREVIATED CODES THAT WERE OBSERVED DURING SPRING AND FALL MIGRATIONS OF 2002 AND 2003 IN THE SOUTHWEST LAKE ERIE MARSH REGION.

Species Name	Code
American avocet *Recurvirostra Americana*	AMAV
Marbled godwit *Limosa fedoa*	MAGO
Wilson's phalarope *Phalaropus tricolor*	WIPH
Whimbrel *Numenius phaeopus*	WHIM
Greater yellowlegs *Tringa melanoleuca*	GRYE
Long-billed dowitcher *Limnodromus scolopaceus*	LBDO
Short-billed dowitcher *Limnodromus griseus*	SBDO
Lesser yellowlegs *Tringa flavipes*	LEYE
Stilt sandpiper *Calidris himantopus*	STSA
Willet *Catoptrophorus semipalmatus*	WILL
Red knot *Calidris canutus*	REKN
Least sandpiper *Calidris minutilla*	LESA
Semi-palmated sandpiper *Calidris pusilla*	SESA
Solitary sandpiper *Tringa solitaria*	SOSA
Spotted sandpiper *Actitis macularia*	SPSA
Western sandpiper *Calidris mauri*	WESA
American woodcock *Scolopax minor*	WOOD
Common snipe *Gallinago gallinago*	SNIP
Dunlin *Calidris alpine*	DUNL
Pectoral sandpiper *Calidris melanotos*	PESA
Semi-palmated plover *Charadrius semipalmatus*	SEPL
Killdeer *Charadrius vociferous*	KILL
Baird's sandpiper *Calidris bairdii*	BASA
Buff-breasted sandpiper *Tryngites subruficollis*	BBSA
Upland sandpiper *Bartramia longicauda*	UPSA
Black-bellied plover *Pluvialis squatarola*	BBPL
Golden plover *Pluvialis dominica*	GOPL
Sanderling *Calidris alba*	SAND
Ruddy turnstone *Arenaria interpres*	RUTU
Mallard *Anas platyrynchos*	MALL
Wood duck *Aix sponsa*	WODU
American black duck *Anas rubripes*	AMBD
Northern pintail *Anas acuta*	NOPI
American widgeon *Anas americana*	AMWI
Gadwall *Anas strepera*	GADW
Green-wing teal *Anas carolinensis*	AGTE
Blue-wing teal *Anas discors*	BWTE
Canada goose *Branta canadensis*	CAGO
American coot *Fulica americana*	COOT
Northern shoveler *Anas clypeata*	NSHO
Trumpeter swan *Cygnus buccinator*	TRUM
Redhead duck *Aythya americana*	RHDU
Ruddy duck *Oxyura jamaicensis*	RUDU
Common merganser *Mergus merganser*	COME
Hooded merganser *Lophodytes cucullatus*	HOME
Bufflehead *Bucephala albeola*	BUFF
Ring-necked duck *Aythya collaris*	RNDU
Lesser scaup *Aythya affinis*	LESC
Greater scaup *Aythya marila*	GRSC