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Shorebird migration in western Kentucky: phenology, habitat use, and possible effects of prey availability

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SHOREBIRD MIGRATION IN WESTERN KENTUCKY: PHENOLOGY, HABITAT USE, AND POSSIBLE EFFECTS OF PREY AVAILABILITY

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SHOREBIRD MIGRATION IN WESTERN KENTUCKY: PHENOLOGY, HABITAT USE, AND POSSIBLE EFFECTS OF PREY AVAILABILITY

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DEDICATION

This thesis is dedicated to my parents
Nicholas and Ann-Marie Ranalli
For all their support and encouragement.

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ABSTRACT

Staging areas along the coasts provide reliable food resources and shorebirds may use the same stopover locations every year. However, shorebirds use sites opportunistically in the interior of North America due to the transient nature of many habitats. Little is known, however, about the use of wetlands by migrating shorebirds in Kentucky. During 2004 and 2005, I examined the phenology of migration and habitat use of shorebirds using stopover habitats in Kentucky, and also examined possible relationships between prey availability and habitat selection by migrating shorebirds. To mitigate wetland loss, the Kentucky Department of Fish and Wildlife Resources (KDFWR) constructed four moist-soil units on Ballard, Sloughs, and Peabody Wildlife Management Areas (WMA) in western Kentucky. From March to October, I surveyed shorebirds at each moist soil unit as well as other natural and man-made wetlands at each WMA. Species abundance and foraging habitats were recorded a minimum of once per 10-day period. I also measured microhabitat variables (i.e., detritus depth and cover) and sampled macroinvertebrate populations throughout migration.

Twenty-five species and 12,307 individual shorebirds were observed at the three wildlife management areas during my study, with Killdeer (*Charadrius vociferous*; N = 4134), Pectoral Sandpipers (*Calidris melanotos*; N= 2912), Least Sandpipers (*Calidris minutilla*; N = 1138), Greater Yellowlegs (*Tringa melanoleuca*; N = 942), and Lesser Yellowlegs (*Tringa flavipes*; N = 911) being most abundant. I recorded more individuals and species at Ballard WMA (the western-most site) than at Sloughs and Peabody WMAs. Wet mud was the most commonly used foraging microhabitat by shorebirds (2832 of 11936 observations, or 23.7%), and the presence of shallow water best

discriminated between sites where shorebirds were observed foraging and randomly selected, apparently unused sites. Although used by shorebirds in my study, such habitat was not always available during migration at the units designed for use by shorebirds. Because both natural and managed wetlands provide stopover sites for shorebirds during spring and fall migration in Kentucky and, given that populations of many species are declining, it is important that wetlands be preserved and better managed and that additional habitat be created.

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I. INTRODUCTION

Migrating shorebirds use stopover sites to renew and store energy to continue migration (Myers et al. 1987). Staging areas in coastal regions provide reliable food resources and shorebirds may use the same stopover locations every year (Myers 1983). However, stopover sites are often used opportunistically in interior North America due to the transient nature of many habitats (Skagen and Knopf 1994). In addition, wet and dry cycles make it difficult for shorebirds to predict the location and availability of food resources and the duration of suitable conditions in inland areas (de Szalay et al. 2000, Skagen et al. 2005).

Most studies of shorebird migration in the United States have focused on major stopover locations, such as Cheyenne Bottoms, Kansas (e.g., Helmers 1991) or Delaware Bay (e.g., Tsipoura and Burger 1999). However, smaller, less frequently visited sites could prove essential for shorebirds in the future because of unpredictable hydrologic patterns (Skagen and Knopf 1993). Furthermore, shorebirds may increasingly use inland sites rather than coastal areas due to human disturbance (Lafferty 2001) and the effects of climate change (Barleen and Exo 2007).

During fall migration, sites throughout the Mississippi Alluvial Valley (MAV) support roughly 500,000 shorebirds representing an estimated 30 species (Loesch et al. 2000). Historically, habitat for migrating shorebirds in the MAV included extensive mudbars, sandbars, drying oxbows, and sloughs. With the construction of levees and other changes in hydrology, the natural function of such systems has been altered (MAVGCP Working Group 2000), lessening the value of the MAV to many wildlife species (Murray et al. 2009) and changing the abundance and dispersion of refueling sites for shorebirds (Twedt et al. 1998). Because up to 90% of the original wetlands in the MAV have been lost (Dahl and Johnson 1991), flooded agricultural fields, aquaculture ponds, and managed impoundments currently provide most shorebird habitat in the region (MAVGCP Working Group 2000). In Kentucky, natural wetlands are small and dispersed (235 of 241 wetland forest patches in Kentucky are categorized as small; Brown et al. 1999, Twedt and Loesch 1999) and their suitability for shorebirds has not been studied. Therefore, information regarding the suitability of both managed and natural wetlands for shorebirds in Kentucky is needed to better understand basic shorebird needs.

Historically, wetland management in the MAV has focused on waterfowl, with less emphasis on the narrower habitat preferences of shorebirds (Elliott and McKnight 2000). Those preferences include shallow water (<20 cm) and mudflat habitat with sparse (< 25% cover), short vegetation (Helmers 1991, 1992, Potter et al. 2007). Additionally, shorebirds require appropriate densities of invertebrates to maintain and increase body mass (a 45-g bird requires 6 g/day to maintain and 8 g/day to increase its mass; Loesch et al. 2000), as well as minimal disturbance when foraging and roosting (Lafferty 2001).

Differences in life-history traits and morphology among different species of shorebirds require the availability of a variety of habitats. Such sites should be diverse in space and time and should also contain a variety of microhabitats that provide foraging habitat for different species (MAVGCP Working Group 2000). For example, in the Mississippi Valley, Killdeer (*Charadrius vociferous*) forage in dry mud, whereas Least

Sandpipers (*Calidris minutilla*) forage primarily in wet mud and Greater Yellowlegs (*Tringa melanoleuca*) in shallow water (Potter et al. 2007).

The most important management issue for migrating shorebirds in the MAV is to ensure the proper mix of water depth and vegetative structure at the appropriate times (MAVGCP Working Group 2000). The key to providing suitable habitat is to understand both the habitat use of each species and the timing of their migration through Kentucky. Therefore, my objectives were to (1) determine the timing of migration and habitat preferences of shorebirds that use stopover habitats in Kentucky, and (2) examine possible relationships between prey availability and habitat selection by migrating shorebirds.

II. METHODS

Study areas

To help mitigate wetland loss for shorebirds, four moist-soil units were established by the Kentucky Department of Fish and Wildlife Resources (KDFWR) for use by migrating shorebirds (shorebird units), including one on the Ballard-Boatwright Wildlife Management Area (WMA; hereafter referred to as Ballard WMA), two on the Peabody WMA, and one on the Sloughs WMA. The use of these sites by migrating shorebirds had not been examined prior to this study. Sloughs WMA is a 4,449-ha area of alternating ridges and sloughs with agricultural fields interspersed. The shorebird unit, a 6.5-ha moist-soil unit completed in 2002, is located on the Sauerheber Unit in Henderson County. Ballard WMA encompasses 6,640 ha of agriculture fields, cypress swamps, oxbow lakes, and upland forest. The shorebird unit, located on the Swan Lake Unit in Ballard County, is an 8-ha impoundment completed in the fall of 2003. Peabody WMA is a 19,016-ha area of reclaimed emergent wetlands and mine lands. The Homestead shorebird unit in Ohio County is a 1-ha impoundment composed of five subunits and completed in the summer of 2004. Additionally, another shorebird unit, about 1 ha in area, was created on the Sinclair tract in Muhlenburg County and built at the base of a hill to collect rainwater. I also conducted surveys at additional locations on and adjacent to the three WMAs (Table 1[1]).

[1] All Tables are located in Appendix A and all Figures are located in Appendix B.

Shorebird surveys

I conducted shorebird (suborder Charadrii) surveys during the spring (11 March to 20 June) and fall (11 July to 31 October) migration in 2004 and 2005. Surveys were conducted at three wildlife management areas (Ballard WMA, Peabody WMA, and Sloughs WMA).

Methods used for shorebird surveys were taken from the Program for Regional and International Shorebird Monitoring (PRISM; wss.wr.usgs.gov/data/PRISMOverview_01.doc) and the International Shorebird Survey (ISS; http://shorebirdworld.org). Surveys were conducted at least once per 10-day period. Because most shorebirds migrate at night and move to roost sites by late afternoon (Skagen et al. 2003), all surveys began during the period from 0700-0900 h. To eliminate possible time-of-day effects, the order in which WMAs were surveyed varied among survey periods. Factors that could introduce unnecessary variability in count data were determined before the study began and avoided during the study (i.e., not conducting surveys when wind exceeded 25 kph or when raining).

Bird identification guides (Sibley 2000, Peterson 2002) were used to aid in identification of shorebirds. However, even individuals with experience in identifying shorebirds sometimes have trouble identifying some species (Skagen et al. 2003). As a result, shorebirds were sometimes combined into size categories (e.g., small shorebirds categorized as ‘peeps’) or taxonomic categories (e.g., yellowlegs or dowitchers). In addition, because vocalizations are species-specific (Skagen et al. 2003), vocalizations were used when possible to identify species.

When large numbers of shorebirds were present and counting individuals was difficult, estimation techniques were used. As suggested by Skagen et al. (2003), the estimation techniques used included counting a small number of birds (e.g., 10 birds) to gain a sense of what 10 birds "look like," then using this approach to determine what groups of 50, 100 and 1000 birds "look like."

A potential bias associated with shorebird surveys is measurement bias, e.g., the height of vegetation can change during the survey period, and taller plants could limit visibility (Skagen et al. 2003). I attempted to reduce the likelihood of such bias by surveying from three or four locations around each area being surveyed. Another potential bias, selection bias, occurs when some part of the study area cannot be surveyed due to limited access or time constraints (Skagen et al. 2003). I initially attempted to reduce this bias by delineating areas into Types 1, 2, and 3 sites based on habitat type and extent of shorebird use, with Types 1, 2, and 3 containing >75% shorebird days, <20% shorebird days and <5% shorebird days, respectively (a shorebird day defined as "one shorebird spending 24 hours within the study area during the study period;" Skagen et al. 2003). However, this approach did not work because unpredictable hydrology altered shorebird use of my study sites. I attempted to alleviate this bias by visiting every site once during each survey period. I then revisited a minimum of one randomly selected location toward the end of each survey period (ensuring that four days separated the surveys at any one location).

During surveys, I recorded the species and numbers of shorebirds present and the habitat types where birds were foraging. Habitat categories included dry sand, wet sand, sand-water film (shallow water interspersed with sand), dry mud, wet mud, mud-water film (shallow water interspersed with mud), open water < 5 cm deep, open water 5-15 cm deep, open water > 15 cm deep, and emergent wetland vegetation (Skagen et al. 2003). I estimated water depth using the relative leg length and body size of different species of shorebirds.

Microhabitat sampling

I sampled invertebrates during both the spring and fall of 2004 and 2005 at all study sites (N = 3). Sampling took place at 2-3 week intervals at each location. At each of the three WMA sites, 24 sampling stations were established during each migration period, including 12 open stations and 12 exclosure stations (96 sampling stations per migration period). Methods for sampling invertebrates followed those described by Sherfy (1999). Sampling locations were established after delineating use by shorebirds on maps of each study site, placing a 10-m x 10-m grid over each of the used areas and, using a random number table, selecting grids to be sampled. After selecting the grids, two 1.5-m x 1.5-m sampling stations were randomly established per grid, one open station and one exclosure. Open stations were marked at the corners with small wooden stakes and were open for shorebird foraging, and the exclosure consisted of four wooden stakes at the corners that were covered with wire mesh (2.5-cm mesh holes) on the top and sides to exclude shorebirds. The wooden corner stakes had holes drilled in the top; wire looped through the holes and fastened to the chicken wire to hold the station in the substrate. New locations for invertebrate sampling were selected during each migration period to minimize possible effects of previous sampling on invertebrate abundance.

During spring migration 2004 (after the results of three shorebird survey periods), I initially placed eight invertebrate sampling stations in locations where >75% shorebird observations occurred, two stations where <20% shorebird observations occurred, and two where <5% shorebird observations occurred. However, fluctuating water levels caused the stations to dry out, become inundated, or become overgrown with vegetation. Additionally, several stations in public-use areas on each WMA were stolen. Therefore, during the next three migration periods, stations (N = 72) were placed so that some would likely occur in shorebird habitat. To supplement stations that could not be sampled at the WMAs (due to unpredictable hydrology), 20 additional samples were taken where shorebirds were observed foraging and at random locations.

Before collecting invertebrate samples, I visually estimated the amount of herbaceous plant cover, submerged aquatic vegetation cover, and detritus cover (all estimated using 10% increments). Water depth (± 1 cm) and detritus depth (± 1 cm) were measured with a meter stick. A 20-cm deep x 10-cm diameter benthic sample was also collected using a core sampler. The sample was retrieved by twisting the core sampler into the substrate, and using my hand to cover the bottom of the sampler. On the day of collection, samples were washed over a 550-µm sieve. The substrate that remained in the sieve was poured into a pan and invertebrates removed and placed in 500-ml plastic jars containing 95% ethanol.

In the lab, invertebrates were identified to the lowest taxonomic category possible (usually order or family) using Merritt and Cummins (1996) and Thorpe and Covich (2001). To determine biomass, samples were placed on Petri dishes for 24 hours at 60°

C. Samples were then placed in a dessicator for at least two hours before dry mass was determined. Dry mass was determined (± 0.01 mg) using a Mettler balance.

Statistical analysis

Variation in and relationships between shorebird numbers and diversity and prey availability during spring and fall migrations were examined using correlation analysis. Variation in prey biomass over time (years and sampling periods), among sampling areas (locations where the birds were seen foraging and random locations), and between sample types (open vs. closed) were examined using analysis of variance and repeated measures analysis of variance. Variation in prey biomass among habitat types (e.g., dry mud, wet mud, and open water) was examined using correlation analysis. Additionally, the effects of vegetation, detritus cover, and water depth on biomass values were analyzed using stepwise discriminate analysis. All analyses were conducted using the Statistical Analysis System (SAS 1999).

III. RESULTS

Shorebird surveys – seasonal and yearly variations

During 2004 and 2005, I observed 25 species and 12,307 individual shorebirds at the three wildlife management areas (Table 2). Overall, more species and individual shorebirds were observed during fall migration than during spring migration, and during 2005 than 2004 (Figures 1, 2, 3, and 4). The seven most frequently observed species were Killdeer (*Charadrius vociferous*; N = 4134, 33.6%), Pectoral Sandpipers (*Calidris melanotos*; N = 2912, 23.7%), Least Sandpipers (*Calidris minutilla*; N = 1138, 9.2%), Greater Yellowlegs (*Tringa melanoleuca*; N = 942, 7.7%), Lesser Yellowlegs (*Tringa flavipes*; N = 911, 7.4%), Semipalmated Plovers (*Charadrius semipalmatus*; N = 596, 4.8%), and Dunlins (*Calidris alpina*; N = 586, 4.8%; Table 2).

During 2005, fewer Killdeer were observed (N = 1673) than during 2004 (N = 2461). However, for several species, I observed greater numbers in 2005 than 2004 (Table 2), including Greater Yellowlegs (N = 748 vs. 194), Semipalmated Plovers (N = 528 vs.68), and Least Sandpipers (N = 736 vs. 402). Wilson's Snipes, Short-billed Dowitchers, Long-billed Dowitchers, and Dunlins were also more abundant in 2005 than 2004 (Table 2).

During spring migration, the most commonly observed shorebirds (Table 2) were Pectoral Sandpipers (N = 1052, or 23.4% of shorebirds observed during spring migration), Greater Yellowlegs (N = 852, or 18.9%), Lesser Yellowlegs (N = 665, or 14.8%), Semipalmated Plovers (N = 512, or 11.4%), and Dunlins (N = 377, or 8.4%). During fall migration, the most commonly observed species (Table 2) were Killdeer (N =

3906, or 49.9% of all birds during fall migration), Pectoral Sandpipers (N = 1860, or 23.8%), Least Sandpipers (N = 799, or 10.2%), Lesser Yellowlegs (N = 246, or 3.1%), and Semipalmated Sandpipers (*Calidris pusilla*; N = 241, or 3.1%).

Shorebird surveys – site differences

Some variation was found in numbers of the most common species of shorebirds observed at the three wildlife management areas (Table 2). At Ballard WMA, shorebirds observed most often included Killdeer (N = 3145), Pectoral Sandpipers (N = 1753), Least Sandpipers (N = 469), Lesser Yellowlegs (N = 466), and Greater Yellowlegs (N = 305). At Peabody WMA, the most abundant species were Killdeer (N = 282), Least Sandpipers (N = 210), Semipalmated Sandpipers (N = 116), Semipalmated Plovers (N = 81), and Dunlins (N = 66). At Sloughs WMA, Pectoral Sandpipers (N = 1118), Killdeer (N = 707), Greater Yellowlegs (N = 586), Dunlins (N = 506), and Semipalmated Plovers (N = 439) were the most abundant species.

Among study sites, the most species and greatest number of shorebirds were observed at Ballard WMA (Table 2, Figures 1, 2, 3, and 4). Overall, I observed 22 species and 6729 individuals (54.7% of all birds) at Ballard WMA. During spring migration, shorebirds observed at Ballard WMA included Lesser Yellowlegs (N = 294), Greater Yellowlegs (N = 248), Pectoral Sandpipers (N = 52), and Killdeer (N = 34; Table 2). During fall migration, shorebirds observed most frequently at Ballard WMA were Killdeer (N = 3111), Pectoral Sandpipers (N = 1701), Least Sandpipers (N = 466), and Lesser Yellowlegs (N = 172; Table 2).

I observed a total of 19 species and 4666 individuals (37.9%) at Sloughs WMA. During spring migration, shorebirds observed most frequently were Pectoral Sandpipers (N = 998), Greater Yellowlegs (N = 562), Lesser Yellowlegs (N = 363), and Least Sandpipers (N = 189; Table 2). During fall migration, Killdeer (N = 564) were observed most frequently, followed by Least Sandpipers (N = 189), Pectoral Sandpipers (N = 120), and Lesser Yellowlegs (N = 63; Table 2).

I observed 18 species and 912 individuals (7.4%) at Peabody WMA, with Least Sandpipers (N = 66), Killdeer (N = 51), and Greater Yellowlegs (N = 42) observed most frequently during spring migration (Table 2). During fall migration, I observed Killdeer (N = 231), Least Sandpipers (N = 144), and Pectoral Sandpipers (N = 39) most often (Table 2).

At Ballard WMA, I observed the most shorebirds at Mitchell Lake (Table 1), with 22 species and 5900 individuals recorded. In terms of numbers of birds observed, Mitchell Lake was the most productive site in my study (46% of all individuals observed). The slough adjacent to CR 268 (Table 1) was the most productive location at Sloughs WMA, with 18 species and 3024 individual shorebirds observed. At Peabody WMA, most species (N = 13) and individuals (N = 547) were observed on a mudflat adjacent to the S-7 road (Table 1).

Among areas specifically designed to attract shorebirds, I observed only seven species and 213 individuals (3.2% of all the individuals observed at Ballard WMA) at the Ballard shorebird unit. At the Sloughs shorebird unit, I observed 15 species and 1397 individuals (30% of all birds observed at the Sloughs WMA). At Peabody WMA, I observed 12 species and 216 individuals (23.6% of all the birds observed at Peabody

WMA) at the Holmstead shorebird unit, but only two species and nine individuals (1.0% of all birds observed at Peabody WMA) at the Sinclair shorebird unit. Overall, only 14.9% of all shorebirds observed during my study were located in the four shorebird units.

Shorebird surveys – timing of migration

Overall, during spring migration, shorebird numbers at the three WMAs were highest during the period from mid-April to mid-May (Table 3). During fall migration, shorebird numbers were highest in late July-early August, but shorebirds were observed through the end of October (Table 4). Thus, the fall migration period for shorebirds in Kentucky was more prolonged than spring migration (Table 3, Table 4).

During spring migration at Ballard WMA, shorebird numbers peaked in mid-March, then again from mid-April through early May (Table 3); during fall migration, the main peak occurred during late July and early August (Table 4). At Sloughs WMA, the main peak in numbers during spring migration was during mid-April, with a secondary peak during mid-May (Table 3). During fall migration, there was a peak at Sloughs WMA during early to mid-September and another peak in late October (Table 4). At Peabody WMA, the spring peak in numbers occurred during mid-May (Table 3). During fall migration, I observed small peaks in numbers of shorebirds during mid- to late August, early September, and mid-October (Table 4).

Among species of shorebirds observed in the greatest numbers, I found interspecific variation in the timing of peak migration. During the spring, peak migration of Greater and Lesser yellowlegs occurred during mid-March and again in late April and early May (Figure 6). Numbers were highest from mid- to late April for Semipalmated Plovers (Figure 6), and from late April through mid-May for Least Sandpipers (Figure 5). Numbers of Dunlins (Figure 6) and Pectoral Sandpipers (Figure 5) peaked during early to mid-May (Figure 6), whereas Killdeer numbers were similar from mid-March through mid-June (Figure 5).

During fall migration, several species of shorebirds were observed in similar numbers during the period from mid- to late July through October, including Least Sandpipers (Figure 7), Greater and Lesser yellowlegs (but with a slight peak in early-August; Figure 8), and Semipalmated Plovers (Figure 8). In contrast, numbers peaked in late July and early August for Killdeer and Pectoral Sandpipers (Figure 7), and in mid- to late October for Dunlins (Figure 8).

Habitat use

For all species of shorebirds combined, the most commonly used foraging microhabitats during 2004 and 2005 were wet mud (2832 of 11936 observations, or 23.7%), open water 5 - 15 cm deep (2383 of 11936 observations, or 20.0%), and dry mud (2354 of 11936, or 19.7%). Less frequently used habitats included sand-water film (116 of 11936, or 1.0%) and emergent wetland vegetation (287 of 11936, or 2.4%). Wet and dry sand were not used as foraging habitat by shorebirds during my study.

Use of foraging habitat differed among species (Table 5). Killdeer foraged primarily on dry mud (2320 of 4034, or 57.5%) and wet mud (904 of 4034, or 22.4%). Smaller shorebirds typically foraged on either wet mud or shallow water, with Semipalmated Plovers primarily observed on wet mud (595 of 608, or 97.9%) and Least

Sandpipers on either wet mud or wet mud/open water < 5 cm deep (1049 of 1226, or 85.6%). Larger, longer-legged shorebirds, including Pectoral Sandpipers, Greater Yellowlegs, and Lesser Yellowlegs, were often observed foraging in open water 5-15 cm deep, but foraged in a number of other habitats as well (Table 5). Dunlins, although having relatively short legs compared to Pectoral Sandpipers and the two species of yellowlegs, were also often observed foraging in open water 5-15 cm deep (Table 5).

Microhabitat sampling

I found no significant difference between years ($F_{1, 432} = 0.4$, $P = 0.56$) in mean invertebrate biomass (2004: mean = 0.113 ± 0.023 [SE] mg; 2005: mean = 0.060 ± 0.011 mg). There was also no significant difference between open (mean = 0.042 ± 0.011 mg) and closed (mean = 0.076 ± 0.017 mg) stations in mean invertebrate biomass. However, I found significantly greater invertebrate biomass (Wilk's lambda = 0.64, $F_{6, 65} = 6.0$, $P < 0.0001$) at locations where shorebirds were observed foraging (mean = 0.316 ± 0.097 mg) than at randomly located, apparently unused locations (mean = 0.109 ± 0.040 mg). Stepwise discriminant analysis was used to determine which of the six habitat variables (water depth, water temperature, herbaceous cover, submerged vegetative cover, detritus depth, and detritis cover; Table 6) best discriminated between sites where shorebirds were observed foraging and randomly selected, apparently unused sites. Water depth was the most important variable (mean = 1.67 ± 0.26 cm for used sites and 3.80 ± 0.66 cm for unused sites). Classification analysis revealed that water depth correctly classified 36 of 41 sites (87.8%) as sites where birds were observed foraging. For random sites, 23 of 38 sites (60.5%) were correctly classified as random sites.

I obtained 366 invertebrate samples at Ballard, Sloughs, and Peabody WMAs. Samples were taken during spring (26 April- 12 June) and fall (19 July - 25 October) at the three WMAs in 2004 and 2005. The overall mean biomass per sample was 0.088 ± 0.013 [SE] mg (Table 7). Sloughs WMA had the highest mean biomass values per sample (0.148 ± 0.029 mg; Table 7) and Ballard WMA had the lowest mean biomass value per sample (0.016 ± 0.003 mg).

Invertebrate samples from Peabody and Sloughs WMAs were dominated by annelids, whereas samples from Ballard WMA were dominated by insects (Table 8). Overall, about 47% of all invertebrates collected were insects, about 28% were oligochaetes, and about 13% were gastropods (Table 9). I identified nine orders of insects in the samples. About 34% of all invertebrates in the samples were in the insect order Diptera (Table 9), with eight families of diptera represented in the samples. Approximately 29% of all invertebrates in the samples were chironomids (family Chironomidae; Table 9). I identified gastropods representing three different families in the samples, including Valvatidae (N = 26), Planorbidae (N = 48), Physidae (N = 638), and bivalves representing two different families, including Corbiculidae (N = 2) and Sphaeridae (N = 148). Other invertebrates in the samples were in the subphylum Crustacea and included the orders Decapoda (N = 5), Amphipoda (N = 4), and Isopoda (N = 1), the class Ostrocoda (N = 70), and the subclasses Copapoda (N = 150), and Branchiura (N = 16).

IV. DISCUSSION

Shorebird surveys – seasonal variations

I observed 25 species of shorebirds during my study (Table 2). Similarly, Loesch et al. (2000) suggested that 28 species of shorebirds use the MAV as a migratory corridor. Among the species listed by Loesch et al. (2000), I did not observe American Avocets (*Recurvirostra americana*), Red Knots (*Calidris canutus*), Marbled Godwits (*Limosa fedoa*), Upland Sandpipers (*Bartramia longicauda*), Piping Plovers (*Charadrius melodus*), or Ruddy Turnstones (*Arenaria interpres*). Palmer-Ball (2003) noted that all six of these species are rarely observed in Kentucky. Species I observed that were not listed by Loesch et al. (2000) included Short-billed (*Limnodromus griseus*) and Long-billed (*Limnodromus scolopaceus*) dowitchers and American Woodcock (*Scolopax minor*). Woodcock are typically found in wooded habitats (Keppie and White 1994) and, therefore, are less likely to be observed in the open habitats typically used by migrating shorebirds. Short- and Long-billed dowitchers are regularly observed in areas of Kentucky with suitable shorebird habitat (Palmer-Ball 2003).

Shorebirds observed most often during my study were Killdeer (33.6%), Pectoral Sandpipers (23.7%), and Least Sandpipers (9.2%) (Table 2). Similarly, Killdeer were the most common overwintering shorebird reported in east Tennessee (Laux 2008) and in managed wetlands in the MAV (Twedt et al. 1998). In addition, previous work in the MAV indicates that Killdeer are among the top three most commonly observed shorebirds (Least Sandpipers, 30% of birds in the MAV; Pectoral Sandpipers, 24%; Killdeer, 18%; MAV/WGCP 2000). Killdeer use upland habitats more than other shorebirds (Skagen and Knopf 1994); most Killdeer (57.5%) in my study were recorded in dry mud habitat. Thus, the high number of Killdeer observed in my study may have been due, at least in part, to the widespread availability of dry mud habitat in my study areas. One possible reason for the high overall numbers of Killdeer in my study is that they are widespread partial migrants that often remain at sites as long as water is available (Jackson and Jackson 2000). Although common in my study, recent studies suggest Killdeer populations may be declining in North America (Brown et al. 2001, Sanzenbacher and Haig 2001). However, Killdeer are still among the most abundant shorebirds in North America, with an estimated total population of about 1 million (Morrison et al. 2006).

I observed more Killdeer during fall migration than during spring migration (Table 2) and; during the fall, most were observed at Mitchell Lake in the Ballard WMA. Because water levels were much lower at Ballard WMA during the fall, one possible reason for the greater numbers may have been increased availability of suitable habitat. Skagen and Knopf (1993) determined regional shorebird use as it relates to body size and migration distance (short, intermediate, and long distance). In the central plains, it was determined that small-bodied shorebirds were highly dependent on the central plains as well as, long- and intermediate-distance migrants during spring migration and short distance migrants during fall migration. Similarly, Killdeer (short distance migrants; Skagen et al. 1999) were the most common shorebird in Kentucky in the fall, but were less common during spring migration (Table 2). Additionally, small-bodied species, such as Least Sandpipers (the third most common shorebird in my study) as well as Semipalmated Sandpipers and Semipalmated Plovers, were common species in my study.

Greater and Lesser yellowlegs are considered intermediate-distance migrants and were among the three most common shorebirds observed during spring migration in Kentucky (Table 2). Following this same pattern, large-bodied shorebirds were not common in the Great Plains, but were common in the Intermountain Region (Skagen et al. 1999). In my study, the only three large-bodied shorebirds observed were Black-necked Stilts (*Himantopus mexicanus*; N = 5), Willets (*Tringa semipalmata*; N = 4), and American Woodcocks (N = 1).

Pectoral Sandpipers were the second most abundant shorebird overall in my study and the most commonly observed during spring migration (Table 2). Interior wetlands in North America are thought to be particularly important for calidridine sandpipers (including Pectoral Sandpipers) during spring (northward) migration (Skagen et al. 1999, Skagen 2006). During spring migration, Pectoral Sandpipers concentrate in a relatively narrow corridor extending east from 100°W to the Mississippi Valley (Holmes and Pitelka 1998); with fewer typically migrating along the east coast (Clark et al. 1993, Placyk and Harrington 2004). In contrast, Pectoral Sandpipers migrate across North America in a wide front during the fall, particularly juveniles (Holmes and Pitelka 1998). However; even during fall migration, Loesch et al. (2000) estimated that about 121,000 Pectoral Sandpipers use the MAV, and were second only to Least Sandpipers in abundance. Thus, during migration, particularly spring migration, the Mississippi Alluvial Valley and Western Gulf Coast Plain are likely as important to Pectoral Sandpipers as any other region (MAV/WGCPWG 2000).

Least Sandpipers were the third most abundant shorebird in my study, with more observed during fall migration (799 of 1138, or 70.2%) than during spring migration (339 of 1138, or 29.8%). Based on a variety of sources, Loesch et al. (2000) hypothesized that Least Sandpipers might be the most abundant shorebird in the MAV and estimated that ~ 151,000 individuals may migrate through the MAV during fall migration. My results, and the estimates of Loesch et al. (2000), suggest that the MAV is an important migratory pathway for Least Sandpipers.

Although Least Sandpipers in North American are estimated to be more abundant (~600,000) than Pectoral Sandpipers (~400,000), I observed fewer Least Sandpipers than Pectoral Sandpipers. However, in contrast to Pectoral Sandpipers that are found primarily at interior locations, particularly during spring migration, Least Sandpipers use both interior and coastal sites during spring and fall migration (Nebel and Cooper 2008). This difference in migration routes likely contributed to the difference in numbers of Least and Pectoral sandpipers observed during my study. Most Least Sandpipers in my study were observed during fall migration. One factor potentially contributing to the greater numbers observed during the fall is that Least Sandpipers may remain at stopover sites longer during fall migration (one week to one month) than during spring migration (Nebel and Cooper 2008). As a result, some individuals in my study were more likely to have been counted more than once during fall migration than during spring migration.

Greater and Lesser yellowlegs were the fourth and fifth most common shorebirds, respectively, observed during my study (Table 2), and both species were observed in greater numbers during spring migration (90.4% of Greater Yellowlegs and 73% of Lesser Yellowlegs observed) than fall migration. Numbers of Lesser Yellowlegs were likely greater during spring migration because they migrate primarily in the interior of North America during spring migration, but are found both on the Atlantic coast and the interior during fall migration (Tibbitts and Moskoff 1999). Greater Yellowlegs migrate across much of the Americas during both spring and fall migration (Elphick and Tibbitts 1998), but numbers are generally reduced in interior locations during fall migration (Bent 1927).

Overall, I observed nearly twice as many shorebirds during fall migration than during spring migration. Similarly, Short (1999) also found more shorebirds during fall migration than during spring migration in western Tennessee. Twedt et al. (1999) found a similar trend in the MAV, with greater species abundance and richness during fall migration. Twedt et al. (1999) hypothesized that the local abundance of birds in managed wetlands was likely due to the scarcity of foraging habitat elsewhere in the region. Loesch et al. (2000) also suggested that, due to floodwaters, more shallow-water and mudflat habitat is available for shorebirds in the spring than in the fall when there is generally less precipitation. As a result, shorebirds are likely limited to fewer areas of suitable habitat in the fall, with a greater concentration of birds in those areas contributing to the greater numbers observed.

Shorebird surveys – yearly variations

I observed nearly five times as many shorebirds during spring 2005 than during spring 2004. During spring migration, shorebird habitat in the MAV is dynamic and unpredictable compared to shorebird habitat in coastal areas (Skagen and Knopf 1994, Brown et al. 2001). Despite flood control structures, agricultural land is often inundated during the spring (Twedt et al. 1998), creating shorebird habitat in unpredictable locations. The potential increase of foraging habitat throughout the region potentially disperses shorebirds from managed wetlands. Two of my study areas, the Ballard and Sloughs WMAs, were inundated during spring 2004 due to rain and flooding of both the Mississippi and Ohio Rivers and, therefore, little mudflat (wet mud) and shallow-water habitat was available. In contrast, water levels were lower during spring 2005, increasing the amount of available habitat.

I observed about 1.5 times more shorebirds during fall 2004 than during fall 2005. The most important site during fall migration was Mitchell Lake at the Ballard WMA. During fall 2005, the water levels at Mitchell Lake were lowered before migration began, drying out the substrate and allowing vegetation to grow, discouraging shorebird use of the site. In contrast, during fall 2004, water levels at Mitchell Lake were lowered slowly throughout migration, providing suitable habitat throughout the migration period. According to Hands et al. (1991), shorebirds varied their use of sites according to the timing of drawdown and the amount of available habitat. Furthermore, Skagen and Knopf (1993) concluded that shorebird movement through the Great Plains, in contrast to more predictable coastal areas, is based on opportunism.

Overall, I observed more shorebirds during 2005 than during 2004. Although Killdeer numbers were lower in 2005, Greater Yellowlegs, Least Sandpipers, Dunlins, Wilson's Snipes (*Gallinago delicata),* Long-billed Dowitchers, and Short-billed Dowitchers were all more abundant during 2005. My results indicate that shorebird numbers were higher during 2005 due primarily to the greater availability of higher quality habitat during spring 2005 at Sloughs WMA.

Shorebird surveys – site differences

Among my study areas, I observed the greatest number of shorebirds at Ballard WMA (Table 2). Habitat availability for shorebirds at Ballard WMA, the western-most site and the only site located in the MAV, is influenced by the Mississippi River flood pulses. Sparks (1995) noted that the Mississippi River floodplain is an important migratory corridor for shorebirds and, despite the alteration of the Mississippi River over the last century, flood pulses still occur in parts of the Mississippi River floodplain. During spring, the lateral overflow of the Mississippi River creates shorebird habitat through flooding and ponding (Brown et al. 1999), and the habitat created is dynamic and dispersed. Thus, the greater number of shorebirds observed at Ballard WMA in my study may have been due to the availability of suitable habitat as well as its proximity to the Mississippi River. In contrast, Mitchell and Grubaugh (2004) and Short (1999) hypothesized that differences in the abundance of shorebirds at sites in and near the MAV were most likely due to habitat suitability, not distance from the Mississippi River.

Because of flooding, I found that habitat availability for shorebirds at Ballard WMA during spring migration was often limited. However, during fall migration, I observed the greatest number of shorebirds at Ballard WMA in both 2004 and 2005 (Table 2). At Ballard WMA, most shorebirds were observed at Mitchell Lake (~85% of the birds at Ballard WMA and 46% of all shorebirds). Mitchell Lake was the largest site at Ballard WMA and was very open, with few bald cypress (*Taxodium distichum*) and sparse wetland vegetation. Other locations in the Ballard WMA, such as the Olmstead Unit, were smaller and more vegetated than Mitchell Lake, thus reducing the amount of suitable shorebird habitat.

At Sloughs WMA, availability of suitable shorebird habitat during my study was dependent on flood pulses of the Ohio River. One site (the slough adjacent to State Route 268) was open and sparsely vegetated during migration. Other sites at Sloughs WMA, such as Hardee Slough and Muddy Slough, were more vegetated and less open and therefore attracted fewer shorebirds.

Peabody WMA, a reclaimed coal mine land, consists of a series of ridges and strip-mine pits, with the strip-mine pits being the only available shorebird habitat. Thus, overall, the Peabody WMA had less suitable habitat for shorebirds than either Ballard or Sloughs WMA. However, although used by relatively few shorebirds, Peabody WMA and the smaller sites at the Sloughs and Ballard WMAs should still be maintained for shorebirds to provide a diversity of stopover sites throughout migration and during seasons with unusual hydrologic patterns.

Overall, the shorebird units, especially at the Ballard and Peabody WMAs, did not provide much suitable habitat for shorebirds during my study. At Ballard WMA, the shorebird unit was much smaller than Mitchell Lake. The unit also dried out early in the fall, providing no wet mud or shallow water habitat. The shorebird unit at Sloughs WMA did provide suitable habitat during spring migration. The Sloughs shorebird unit likely attracted fewer birds than the 268 slough because it was much smaller and was also flooded by the land manager before the end of each migration period. The Sinclair shorebird unit at Peabody WMA was not an effective unit for shorebirds. The unit was designed to collect rainwater at the base of a hill, but had very little wet or dry mud and often had no shallow water. The other shorebird unit at the Peabody WMA, the Holmstead Unit, did provide some shallow water and wet mud habitat, but for shorter periods than that provided at more frequently used sites such as Mitchell Lake at the Ballard WMA. Likely due to their size, management regimes (early flooding of sites), and early colonizing wetland vegetation, the Sloughs and Peabody WMA shorebird units did not provide as much wet mud and shallow water habitat as some of the sites more frequently used by shorebirds (e.g., Mitchell Lake).

Shorebird surveys – timing of migration

During spring migration, I observed shorebirds over a 91-day period, with peak numbers during a four week period from mid-April through mid-May. During fall migration, I observed shorebirds over a longer period (113 days) and, with the exception of Killdeer and Pectoral Sandpipers, peaks in numbers of shorebirds over that period were generally less apparent. Similar results, with fall migration of shorebirds occurring over a longer period than spring migration, have been reported by other investigators (e.g., Smith et al. 1991, Andrei et al. 2006). Fall migration of shorebirds generally occurs over a longer period because adults migrate earlier in the fall and juveniles migrate later (Colwell et al. 1988). For example, in Alberta, Canada, male Pectoral Sandpipers moving south from breeding areas arrive in July, most females arrive in late July and into August, and juveniles arrive in September and October (Semenchuk 1992). Similar delays by juveniles in initiating migration have been reported for other species of shorebirds that were observed in the greatest numbers during my study, including Least Sandpipers (Nebel and Cooper 2008), Lesser Yellowlegs (Tibbitts and Moskoff 1999), and Semipalmated Sandpipers (Hicklin and Gratto-Trevor 2010).

Among the shorebirds observed in the greatest numbers during my study, Greater and Lesser yellowlegs exhibited early peaks in the spring (mid-March to mid-April), closely followed by Pectoral Sandpipers (beginning in mid-April). Similarly, Smith et al. (1991) reported that Greater and Lesser yellowlegs and Pectoral Sandpipers were the first shorebirds to appear at their study site in Arkansas, first arriving in numbers in mid-March. All three of these species breed at relatively high latitudes (Greater Yellowlegs: 48 - 58°N, Elphick and Tibbitts 1998; Lesser Yellowlegs: 51 - 69°N, Tibbitts and Moskoff 1999; Pectoral Sandpiper, primarily above the Arctic circle at 66.33°N, Holmes and Pitelka 1998) and initiate spring migration early to permit timely arrival on their breeding grounds.

During fall migration in my study, numbers for most species of shorebirds were generally similar during the period from mid-July through October. However, peak Dunlin migration was later than that of other species of shorebirds (mid- to late October). Palmer-Ball (2003) also noted that Dunlins were late fall migrants in Kentucky, with late records extending into December. Warnock and Gill (1996) noted that Dunlins were generally one of the last shorebird species to leave the breeding grounds (coastal Alaska and Canada) and, in contrast to most other shorebirds, most adults and juveniles migrate together.

Habitat use

Habitats used most by shorebirds during my study were wet mud, dry mud, and open water between 5 and 15 cm deep. In the prairie pothole region, Skagen and Knopf (1994) found that approximately 80% of shorebirds observed were in wet mud/shallow water habitat, with 20% in dry mud/uplands/pond margin habitat. I found that wet mud was especially important for Semipalmated Plovers and Least Sandpipers, with 98% of Semipalmated Plovers observed in wet mud habitat. Killdeer in my study were most often observed in dry mud habitat, and Skagen and Knopf (1994) also found that Killdeer preferred dry mud/upland/ pond margin habitat. Open water between 5 and 15 cm deep was especially important for Pectoral Sandpipers, Greater Yellowlegs, Lesser Yellowlegs, and Dunlins in my study, and similar observations were reported by Skagen and Knopf (1994).

Short (1999) found that shorebird species with longer legs used flooded foraging substrates more often (Greater and Lesser yellowlegs used flooded substrates 75 – 90% of the time), whereas species with shorter legs used mud stubstrates more often (Least Sandpipers used mud 50 – 90% of the time). I also found that shorter- and longer-legged species of shorebirds typically used different habitats. However, some species used a variety of habitats. For example, Lesser Yellowlegs in my study were observed using several habitat types, including wet mud, open water less than 5 cm deep, open water 5 – 15 cm deep, and open water greater than 15 cm deep. Short (1999) also found that habitat preferences varied among species seasonally and by year. Similarly, Hands et al. (1991) found that the most frequently used habitats by shorebirds in Missouri were wet mud (Least and Semipalmated sandpipers), wet mud, open water less than 3.5 cm deep (Pectoral Sandpipers), and open water less than 6 cm deep (Lesser Yellowlegs). Because of interspecific and intraspecific differences in habitat use among shorebird species, good shorebird habitat must include a variety of habitat types throughout both fall and spring migration.

Microhabitat sampling

I found no difference between open and closed sampling stations in mean invertebrate biomass present. Similarly, Mitchell and Grubaugh (2005) conducted exclosure experiments at five National Wildlife Refuges in the Lower Mississippi Alluvial Valley and found that shorebird foraging had no significant impact on macroinvertebrate abundance. Ashley et al. (2000) reported similar results in an exclosure experiment conducted at a wetland in Nevada. In an exclosure experiment conducted in Illinois, Hamer et al. (2006) found that shorebirds did not locally deplete invertebrate populations, but also noted that densities of oligochaetes were reduced by shorebird foraging. Overall, these results suggest that shorebird foraging in the MAV and other inland wetlands appears to have little or no effect on invertebrate abundance. In contrast, exclosure experiments at some coastal locations indicate that shorebird predation can reduce densities of invertebrate prey (e.g., Schneider and Harrington 1981, Szekely and Bamberger 1992, Mendonça et al. 2007). One explanation for such differences between inland and coastal locations is that most inland shorebirds migrate in short hops (e.g., Skagen and Knopf 1994, Farmer and Wiens 1999) and, therefore, do not need to accumulate large fat reserves at stopover sites. In contrast, at some coastal locations, migrating shorebirds must accumulate fat reserves before departing on long flights, e.g., from the Bay of Fundy to South America during fall migration (Hicklin 1987) and, therefore, may forage more intensely and for longer periods. Another possible explanation for the differences between inland and coastal locations is that shorebird densities at some coastal locations may be much higher than at many inland locations. For example, Hamer et al. (2006) reported that shorebird densities at their study site in

Illinois averaged 6.3 birds/ha. In contrast, at some coastal locations, densities can be much higher, e.g., 100 birds/ha in South Carolina (Weber and Haig 1997) and 4500 birds/ha in coastal Venezuela (Mercier and McNeil 1994). Of course, shorebird densities at some coastal locations are not higher than those at inland sites (e.g., Hockey et al. 1992), but, where densities are high, reduction in invertebrate densities is more likely.

I found that invertebrate biomass was greater at locations where shorebirds were observed foraging than at randomly selected, apparently unused locations. Similarly, Andrei et al. (2007) found that the saline lakes preferred by shorebirds in the Great Plains had a greater invertebrate biomass and density values than those lakes not preferred by shorebirds, and concluded that invertebrate availability was important in determining where shorebirds foraged. Other investigators have also reported that shorebird densities are typically higher in locations with greater densities of invertebrates (e.g., Placyk and Harrington 2004, Spruzen et al. 2008, Finn et al. 2008).

Among six habitat variables measured in this study (water depth, water temperature, herbaceous cover, submerged vegetative cover, detritus depth, and detritis cover), water depth best discriminated between sites where birds were seen foraging and randomly selected, apparently unused sites. Mean water depth where shorebirds were observed foraging in my study was less than half that at apparently unused sites (1.67 cm for used sites and 3.80 for unused sites). Previous studies have also revealed that most shorebirds prefer water ≤ 5 cm deep (e.g., Fredrickson and Taylor 1982, Weber and Haig 1996). Short (1999) found that use of habitats by shorebirds decreased with increasing water depth in western Tennessee. Baker (1979) examined habitat selection by six species of shorebirds and found that mean water depth at foraging sites was lower than in surrrounding areas and that leg length was positively correlated with the depth of water where each species foraged. Dafunsky and Colwell (2003) suggested that shorebirds may find more prey at sites with standing water; but deeper water may decrease available foraging area if it is too deep for birds to use.

I found that annelids (mostly oligochaetes) dominated the invertebrate samples at the Sloughs (47% annelids) and Peabody (39% annelids) WMAs. Similarly, oligochaetes were the most abundant invertebrate along the Illinois River (Hamer et al. 2006), and one of the most abundant in the lower Mississippi Alluvial Valley (Mitchell and Grubaugh 2005). Ballard WMA had the lowest overall mean biomass value and was dominated by insects (68% insects). At other locations, including the southern Great Plains (Andrei et al. 2007) and the lower MAV (Mitchell and Grubaugh 2005), insects (mostly chironomids) were found to dominate biomass samples.

Conclusions

My study areas in western Kentucky provided habitat for several species of shorebirds, but primarily small to medium-sized species that tend to migrate intermediate distances (Appendix B), such as Killdeer, Pectoral Sandpipers, Least Sandpipers, and Greater and Lesser yellowlegs. In addition to these more commonly observed species, I observed one highly imperiled species (Buff-breasted Sandpiper, *Tryngites subruficollis*), seven high concern species, including American Golden Plover (*Pluvialis dominica*), Solitary Sandpiper (*Tringa solitaria*), Western Sandpiper (*Calidris mauri*), Short-billed Dowitcher, American Woodcock, Wilson's Phalarope (*Phalaropus tricolor*), and Sanderling (*Calidris alba*), and eleven moderate concern species, including Black-bellied

Plover (*Pluvialis squatarola*), Killdeer, Black-necked Stilt, Greater Yellowlegs, Lesser Yellowlegs, Willet, Semipalmated Sandpiper, Least Sandpiper, Dunlin, Stilt Sandpiper (*Calidris himantopus*), and Wilson's Snipe (U. S. Shorebird Conservation Plan 2004). The Mississippi Alluvial Valley, including Kentucky, may become increasingly important for migrating shorebirds because shorebirds may increasingly use inland locations due to human disturbance in coastal areas (Lafferty 2001), the effects of climate change (Barleen and Exo 2007), or habitat loss in other migratory corridors. In addition, Skagen and Knopf (1993) suggested that smaller sites that are currently visited less frequently by shorebirds may prove essential for shorebirds in the future because of unpredictable hydrologic patterns.

Both natural and managed wetlands provide stopover sites for shorebirds during spring and fall migration in Kentucky and, given that populations of many species are declining, it is important that these wetlands be preserved and better managed and that additional habitat be created. Skagen and Knopf (1994) concluded that the number of sites available to shorebirds during migration should be sufficient to assure a high probability that suitable stopover habitat will be available regardless of weather conditions during migration. Similarly, Helmers (1993) suggested that a single wetland cannot provide resources for all species in a single year, but a series of wetlands, each in a different phase of its hydrologic cycle, may provide habitat for all waterbirds. Therefore, to ensure the presence of suitable habitat for migrating shorebirds in Kentucky, I recommend that: 1) additional areas outside of the three WMA's surveyed in my study be assessed for the presence of potentially suitable shorebird habitat (both managed and natural), 2) additional shorebird habitat be provided at the Ballard and

Slough's WMAs to ensure that, regardless of water levels in the Mississippi River, some suitable habitat is available for shorebirds, and 3) shorebird units be managed properly (see below).

Moist soil unit recommendations

To best manage moist soil units, natural wetland fluctuations should be closely followed (Brown et al. 2001); and units should be managed in a manner that ensures that adequate habitat is always available for shorebirds during migration. Fluctuations in water levels drive wetland processes such as plant growth, decomposition, and the accumulation of detritus for invertebrates. When water levels drop slowly (less than 1 cm/week, Laux 2008; 2-3 cm/week, Helmers 1992) during appropriate times of the year, succession is slowed and shorebirds are attracted to the available invertebrates (Eldridge 1992).

Disking in moist soil management units keeps the community of plants in early succession and drives detritus growth. For example, at Cheyenne Bottoms, Kansas, Kostecke et al. (2004) determined that cattails (*Typha* spp.) were best controlled through disking or high-intensity grazing followed by controlled burning. Additionally, Laubham (1995) found that burning moist soil units in the summer best controlled vegetation and appeared to provide habitat to shorebirds, whereas burning in the spring was best for providing habitat for waterfowl.

In preparation for spring migration, moist soil management units should be flooded one month before the first heavy freeze in the fall, and should be kept flooded until spring migration begins (mid-March in Kentucky). During migration, units should have extensive areas of open water and should be drawn down slowly (less than 1 cm/week; Laux 2008). Having more than one unit is best because manipulations can be staggered to extend the availability of habitat (Eldridge 1992, Helmers 1992). Managers should assess habitat availability throughout migration and manipulate water levels based on rainfall and evaporation rates.

In preparation for fall migration, moist soil management units that remained flooded during spring migration should be slowly drawn down (start drawdown in mid-July), and units that were drained should be shallowly flooded 2-3 weeks before fall migration begins; with drawdown beginning in early July (Helmers 1992). Furthermore, upland habitat adjacent to wetlands can be managed for nesting shorebirds, such as Killdeer, by burning before the nesting season (March) to set back succession, prevent disturbance to nests (Helmers 1992), and maintain a healthy ecotone (Eldridge 1992).

LITERATURE CITED

Andrei, A. E., L. M. Smith, D. A. Haukos, and J. G. Surles. 2006. Community composition and migration chronology of shorebirds using the saline lakes of the southern Great Plains, USA. Journal of Field Ornithology 77: 372-383.

Ashley, M. C., J. A. Robinson, L. W. Oring, and G. A. Vinyard. 2000. Dipteran standing stock biomass and effects of aquatic bird predation at a constructed wetland. Wetlands 20: 84-90.

Bairlein, F., and K. M. Exo. 2007. Climate change and migratory waterbirds in the Wadden Sea. Wadden Sea Ecosystem 23:43-52.

Baker, M. C. 1979. Morphological correlates of habitat selection in a community of shorebirds (Charadriiformes). Oikos 33: 121-126.

Bent, A. C. 1927. Life histories of North American shore birds, Pt. 1. U.S. National Museum Bulletin No. 142, Washington, D.C.

Brown, C. R., C. Baxter, and D. N. Pashley. 1999. The ecological basis for the conservation of migratory birds in the Mississippi Alluvial Valley. In: Strategies for bird conservation: the partners in flight planning process (R. Bonney, D. N. Pashley, R. J. Cooper, and L. Niles, eds.), pp. 3-6. Cornell Lab of Ornithology, Ithaca, NY.

Brown, S., C. Hickey, B. Harrington, and R. Gill (eds.). 2001. The U.S. Shorebird Conservation Plan, 2nd ed. Manomet Center for Conservation Sciences, Manomet, MA.

Clark, K. E., L. J. Niles, and J. Burger. 1993. Abundance and distribution of migrant shorebirds in Delaware Bay. Condor 95:694-705.

Colwell, M. A., S. D. Fellows, and L. W. Oring. 1988. Chronology of shorebird migration at Last Mountain National Wildlife Area, Saskatchewan, Canada. Wader Study Group Bulletin 52: 18-22.

Colwell, M. A., and S. L. Landrum. 1993. Nonrandom shorebird distribution and fine-scale variation in prey abundance. Condor 95:94-103.

Dafunsky, T., and M.A. Colwell 2003.Winter shorebird communities and tidal flat characteristics at Humbolt Bay, California. Condor 105:117-129.

Dahl, T.E., and C.E. Johnson. 1991. Status and trends of wetlands in the conterminous United States, mid-1970s to mid-1980s. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C.

de Szalay, F., P. Helmers, D. Humburg, S. J. Lewis, B. Pardo, and M. Shieldcastle. 2000. U.S. Shorebird Conservation Plan: Upper Mississippi Valley/ Great Lakes Regional Shorebird Conservation Plan, version 1.0. Manomet Center for Conservation Sciences, Manomet, MA.

Eldridge J. 1992. Waterfowl management handbook. Management of habitat for breeding and migration shorebirds in the Midwest. Fish and Wildlife Leaflet 13.2.14. Minneapolis, MN.

Elphick, C. S., and T. L. Tibbitts. 1998. Greater Yellowlegs (*Tringa melanoleuca*). In: The Birds of North America Online (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca, NY. Retrieved from the Birds of North America Online: <http://bna.birds.cornell.edu/bna/species/355>

Farmer, A. H., and J. A. Wiens. 1999. Models and reality: time-energy trade-offs in Pectoral Sandpiper (*Calidris melanotos*) migration. Ecology 80: 2566-2580.

Finn, P. G., C. P. Catterall, and P. V. Driscoll. 2008. Prey versus substrate as determinants of habitat choice in a feeding shorebird. Estuarine, Coastal and Shelf Science 80: 381-390.

Fredrickson, L. H., and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. Resource Publication 148, U. S. Fish and Wildlife Service, Washington, D.C.

Hamer, G. L., E. J. Heske, J. D. Brawn, and P. W. Brown. 2006. Migrant shorebird predation on benthic invertebrates along the Illinois River, Illinois. Wilson Journal of Ornithology 118: 152-163.

Helmers, D. L. 1992. Shorebird management manual. Western Hemisphere Shorebird Reserve Network, Manomet, MA.

Helmers, D. L. 1993. Management of wetlands for migrant shorebirds. In: Transactions of the 58th North American Wildlife & Natural Resources Conference (Wildlife Management Institute Publications Department, ed.), pp. 335-344. Wildlife Management Institute, Washington, D.C.

Hicklin, P. W. 1987. The migration of shorebirds in the Bay of Fundy. Wilson Bulletin 99: 540-570.

Hicklin, P., and C. L. Gratto-Trevor. 2010. Semipalmated Sandpiper (*Calidris pusilla*). In: The Birds of North America Online (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca, NY. Retrieved from the Bird of North America Online <http://bna.birds.cornell.edu/bna/species/006>

Hockey, P. A. R., R. A. Navarro, B. Kalejta, and C. R. Velasquez. 1992. The riddle of the sands: why are shorebird densities so high in southern estuaries? American Naturalist 140: 961-979.

Holmes, R. T., and F. A. Pitelka. 1998. Pectoral Sandpiper (*Calidris melanotos*). In: The Birds of North America Online (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca, NY; Retrieved from the Birds of North America Online <http://bna.birds.cornell.edu/bna/species/348>

Jackson, B. J., and J. A. Jackson. 2000. Killdeer (*Charadrius vociferus*). In: The Birds of North America Online (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca, NY; Retrieved from the Birds of North America Online <http://bna.birds.cornell.edu/bna/species/517>

Keppie, D. M., and R. M. Whiting, Jr. 1994. American Woodcock (*Scolopax minor*). In: The Birds of North America Online (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca, NY; Retrieved from the Birds of North America Online: <http://bna.birds.cornell.edu/bna/species/100>

Kostecke, R.M., L.M. Smith and H.M. Hands. 2004. Vegetation response to cattail management at Cheyenne Bottoms, Kansas. Journal of Aquatic Plant Management 42:39-45.

Lafferty, K. D. 2001. Birds at a southern California beach: seasonality, habitat use, and disturbance by human activity. Biodiversity and Conservation 10:1949-1962.

Laubham, M. K. 1995. Effects of prescribed fire on moist soil vegetation and soil macronutrients. Wetlands 15:159-166.

Laux, J. W. 2008. Waterbird responses to drawdown of two East Tennessee River Valley reservoirs. M.S. thesis, University of Tennessee, Knoxville, TN.

Loesch, C. R., D. J. Twedt, K. Tripp, W. C. Hunter, and M. S. Woodrey. 2000. Development of management objectives for waterfowl and shorebirds in the Mississippi Alluvial Valley. In: Strategies for bird conservation: the Partners in Flight planning process (R. Bonney, D. N. Pashley, R. J. Cooper, and L. Niles,eds.), pp.8-11. U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

MAV/WGCP (Mississippi Alluvial Valley/West Gulf Coastal Plain) Working Group. 2000. U. S. Shorebird conservation plan: Lower Mississippi Valley/Western Gulf Coastal Plain (L. Elliott and K. McKnight, coordinators). Manomet Center for Conservation Sciences, Manomet, MA.

Mendonça, V. M., D. G. Raffaelli, and P. R. Boyle. 2007. Interactions between shorebirds and benthic invertebrates at Culbin Sands lagoon, NE Scotland: effects of avian predation on their prey community density and structure. Scientia Marina 71: 579-591.

Mercier, F., and R. McNeil. 1994. Seasonal variations in intertidal density of invertebrate prey in a tropical lagoon and effects of shorebird predation. Canadian Journal of Zoology 72: 1755-1763.

Merritt, R. W., and K. W. Cummins (eds.). 1996. An introduction to the aquatic insects of North America, third edition. Kendall/Hunt, Dubuque, IA.

Mitchell, D. W., and J. W Grubaugh. 2005. Impacts of shorebirds on macroinvertebrates in the lower Mississippi Alluvial Valley. American Midland Naturalist 154:188-200.

Morrison, R. I. G., B. J. McCaffery, R. E. Gill, S. K. Skagen, S. L. Jones, G. W. Page, C. L. Gratto-Trevor, and B. A. Andres. 2006. Population estimates of North American shorebirds, 2006. Wader Study Group Bulletin 111: 67-85.

Moskoff, W. 1995. Solitary Sandpiper (*Tringa solitaria*). In: The Birds of North America Online (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca, NY. Retrieved from the Birds of North America Online <http://bna.birds.cornell.edu/bna/species/156>

Mueller, A. J., D. J. Twedt, and C. R. Loesch. 2000. Development of management objectives for breeding birds in the Mississippi Alluvial Valley. In: Strategies for bird conservation: the Partners in Flight planning process (R. Bonney, D. N. Pashley, R. J. Cooper, and L. Niles, eds.). pp. 12-17. Proceedings of the 3rd Partners in Flight Workshop, USDA Forest Service, Rocky Mountain Research Station, Ogden, UT.

Mueller, A. J. 1996. Development of a conservation strategy for forest breeding birds in the Mississippi Alluvial Valley. In: Proceeding of the Delta: connecting points of view for sustainable natural resources (P. Heard, ed.), pp. 81-94. Memphis, Tennessee.

Mueller, H. 1999. Wilson's Snipe (*Gallinago delicata*). In: The Birds of North America Online (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca, NY. Retrieved from the Birds of North America Online: <http://bna.birds.cornell.edu/bna/species/417>

Murray, B., A. Jenkins, R. Kramer, and S. P. Faulkner. 2009. Valuing ecosystem services from wetland restoration in the Mississippi Alluvial Valley. Ecosystem Services Series, Nicholas Institute for Environmental Policy Solutions, Duke University, Durham, NC.

Myers, J. P. 1983. Conservation of migrating shorebirds: staging areas, geographic bottlenecks and regional movements. American Birds 37:23-25.

Myers, J. P., R. I. G. Morrison, P. Z. Antas, B. A. Harrington, T. E. Lovejoy, M. Sallaberry, S. E. Senner, and A. Tarak. 1987. Conservation strategy for migratory species. American Scientist 75:19-26.

Nebel, S. and J. M. Cooper. 2008. Least Sandpiper (*Calidris minutilla*). In: The Birds of North America Online (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca, NY. Retrieved from the Birds of North America Online: <http://bna.birds.cornell.edu/bna/species/115>

Nol, E., and M. S. Blanken. 1999. Semipalmated Plover (*Charadrius semipalmatus*). In: The Birds of North America Online (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca, NY. Retrieved from the Birds of North America Online: <http://bna.birds.cornell.edu/bna/species/444>

Palmer-Ball, B., Jr. 2003. Annotated checklist of the birds of Kentucky. Kentucky Ornithological Society, Louisville, KY.

Peterson, R. T., and V. M. Peterson. 2002. A field guide to the birds of eastern and central North America. Houghton Mifflin Co., Boston, MA.

Placyk, J. S., and B.A. Harrington 2004. Prey abundance and habitat use by migratory shorebirds at coastal stopover sites in Connecticut. Journal of Field Ornithology 75:223-231.

Potter, B. A., R. J. Gates, G. J. Soulliere, R. P. Russell, D. A. Granfors, and D. N. Ewert. 2007. Upper Mississippi River and Great Lakes Region Joint Venture Shorebird Habitat Conservation Strategy. U. S. Fish and Wildlife Service, Fort Snelling, MN.

Recher, H. F. 1966. Some aspects of the ecology of migrant shorebirds. Ecology 47:393-407.

Sanzenbacher, P. M., and S. M. Haig. 2001. Killdeer population trends in North America. Journal of Field Ornithology 72:160-169.

SAS Institute. 1999. SAS user's guide: statistics. SAS Institute Inc., Cary, NC.

Schneider, D. C., and B. A. Harrington. 1981. Timing of shorebird migration in relation to prey depletion. Auk 98: 801-811.

Semenchuk, G. P. 1992. The atlas of breeding birds of Alberta. Federation of Alberta Naturalists, Edmonton, AB, Canada.

Sherfy, M. H. 1999. Nutritional value and management of waterfowl and shorebird foods in Atlantic coastal moist-soil impoundments. Ph. D. thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Short, M. R. 1999. Shorebirds in western Tennessee: migration and ecology and evaluation of management effectiveness. M.S. thesis, University of Tennessee, Knoxville, TN.

Sibley, D. A. 2000. The Sibley guide to birds. Chanticleer Press Inc., New York, NY.

Skagen, S. K. 2006. Migration stopovers and the conservation of Arctic-breeding calidridine sandpipers. Auk 123: 313-322.

Skagen, S. K., and F. L. Knopf. 1993. Toward conservation of mid-continental shorebird migrations. Conservation Biology 7:533-544.

Skagen, S. K., and F. L. Knopf. 1994. Migrating shorebirds and habitat dynamics at a prairie wetland complex. Wilson Bulletin 106:91-105.

Skagen, S. K., P. B. Sharpe, R. G. Waltermire, and M. B. Dillon. 1999. Biogeographical profiles of shorebird migration in midcontinental North America. U.S. Geological Survey Biological Science Report 2000-0003, Washington, D.C..

Skagen, S. K., C. P. Melcher, and J. Bart. 2003. Managers' monitoring manual: ground counts of shorebirds at non-breeding sites. U.S.G.S. Patuxent Wildlife Research Center, Patuxent, MD.

Smith, K. G., J. C. Neal, and M. A. Mlodinow. 1991. Shorebird migration at artificial fish ponds in the prairie-forest ecotone of northwestern Arkansas. Southwestern Naturalist 36 : 107-113.

Sparks, R. E. 1995. Need for ecosystem management of large rivers and their floodplains. BioScience 45 : 168-182.

Spruzen, F. L., A. M. M. Richardson, and E. J. Woehler. 2008. Influence of environmental and prey variables on low tide shorebird habitat use within the Robbins Passage wetlands, Northwest Tasmania. Estuarine, Coastal and Shelf Science 78:122-134.

Szekely, T., and Z. Bamberger. 1992. Predation of waders (Charadrii) on prey populations: an exclosure experiment. Journal of Animal Ecology 61: 447-456.

Thomas G. H., R. B. Lanctot and T. Szekely. 2006. Can intrinsic factors explain population declines in North American breeding shorebirds? A comparative analysis. Animal Conservation 9:252-258.

Thorpe, J. A., and A. P. Covich (eds.). 2001. Ecology and classification of North American freshwater invertebrates. Academic Press, San Diego, CA.

Tibbitts, T. L., and W. Moskoff. 1999. Lesser Yellowlegs (*Tringa flavipes*). In: The Birds of North America Online (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca, NY; Retrieved from the Birds of North America Online: <http://bna.birds.cornell.edu/bna/species/427>

Tsipoura, N., and J. Burger. 1999. Shorebird diet during spring migration stopover on Delaware Bay. Condor. 101:635-644.

Twedt, D. J., C. O. Nelms, V. E. Rettig, and S. R. Aycock. 1998. Shorebird use of managed wetlands in the Mississippi Alluvial Valley. American Midland Naturalist 140:140-152.

U.S. Shorebird Conservation Plan. 2004. High priority shorebirds─2004. U. S. Fish and Wildlife Service, Arlington, VA.

Warnock, N. D., and R. E. Gill. 1996. Dunlin (*Calidris alpina*). In: The Birds of North America Online (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca, NY; Retrieved from The Birds of North America Online: <http://bna.birds.cornell.edu/bna/species/203>

Weber, L. M., and S. M. Haig. 1996. Shorebird use of South Carolina managed and natural coastal wetlands. Journal of Wildlife Management 60:73-82.

Weber, L. M., and S. M. Haig. 1997. Shorebird diet and size selection of nereid polychaetes in South Carolina coastal diked wetlands. Journal of Field Ornithology 61: 445-452.

Wilson, J. R. 1981. The migration of High Arctic shorebirds through Iceland. Bird Study 28: 1, 21 -32.

APPENDIX A: TABLES

Table 1. Names, locations, and area (ha) of sites surveyed for shorebirds at three wildlife management areas in Kentucky.

WMA	Site Name	Longitude, Latitude	Area (ha)
Ballard	Olmstead unit[a]	10°48'18.016"E,9°47'46.568"N	7
	Swan Lake 1[a]	10°46'52.84"E, 9°45'2.479"N	2.5
	Swan Lake 2[a]	10°47'4.113"E, 9°44'36.175"N	5
	Ballard Shorebird Unit[b]	10°47'29.165"E, 9°42'52.21"N	8
	Mitchell Lake[a]	10°51'52.208"E, 9°51'52.075"N	158
	B-2[a]	10°50'21.788"E, 9°51'14.78"N	4
	Happy Hollow[a]	10°49'57.711"E, 9°51'15.353"N	25.5
	B-3[a]	10°50'13.189"E, 9°50'17.741"N	2.6
Peabody	Peabody Sinclair Shorebird Unit[b]	12°28'19.674"E, 9°54'35.998"N	1
	Slough adjacent to S-7 road[a]	12°30'32.684"E, 9°54'32.662"N	15.5
	Paradise Slough[a]	12°30'38.939"E, 9°54'20.57"N	2.2
	Peabody Holmstead Shorebird Unit[b]	12°32'56.953"E, 9°54'26.824"N	1
Sloughs	Slough adjacent to State Route 268[a]	11°52'19.834"E, 10°32'31.59"N	41
	Slough adjacent to State Route 136[a]	11°51'58.05"E, 10°32'9.054"N	25
	Sloughs Shorebird Unit[b]	11°54'1.994"E, 10°31'20.478"N	6.5
	Muddy slough[a]	11°54'18.27"E, 10°31'25.736"N	32
	Hardy slough[a]	11°54'22.526"E, 10°31'1.198"N	9

[a] Denotes that area was calculated using ArcGIS 9.3

[b] Denotes area calculations were provided by Kentucky Department of Fish and Wildlife Resources

Table 2. Numbers of shorebirds of various species observed during spring (S) and fall (F) migration in 2004 and 2005 at the Ballard, Sloughs, and Peabody Wildlife Management Areas (WMAs), Kentucky.

	Ballard WMA				Sloughs WMA				Peabody WMA					
	2004		2005		2004		2005		2004		2005			
	S	F	S	F	S	F	S	F	S	F	S	F	total	%
Killdeer	10	2010	24	1101	30	293	113	271	19	99	32	132	4134	33.6%
Pectoral Sandpiper	2	1312	50	389	23	74	975	46	0	17	2	22	2912	23.7%
Least Sandpiper	0	231	3	235	9	86	261	103	5	71	61	73	1138	9.3%
Greater Yellowlegs	62	24	186	33	97	2	465	22	6	3	36	6	942	7.7%
Lesser Yellowlegs	198	45	96	127	183	5	180	58	0	2	8	9	911	7.4%
Semipalmated Plover	2	33	34	7	0	7	421	11	0	26	55	0	596	4.8%
Dunlin	0	9	0	5	21	149	336	0	0	46	20	0	586	4.8%
Semipalmated Sandpiper	0	98	31	35	5	21	20	20	17	55	32	12	346	2.8%
Solitary Sandpiper	5	58	7	64	4	2	13	21	6	4	3	0	187	1.5%
Common Snipe	6	0	21	19	0	1	18	36	0	0	0	1	102	< 1.0 %
Spotted Sandpiper	1	17	5	20	0	10	6	12	0	1	14	1	87	< 1.0 %
Short-billed Dowitcher	0	1	9	1	0	0	82	4	0	0	0	0	97	< 1.0 %
Stilt Sandpiper	0	21	0	32	9	1	2	0	0	0	0	0	65	< 1.0 %
Yellowleg spp.[a]	1	0	1	0	5	0	42	0	0	0	0	1	50	< 1.0 %
Long-billed Dowitcher	0	0	0	0	0	11	38	0	0	0	0	0	49	< 1.0 %
Peeps[b]	0	0	9	0	22	0	0	0	0	0	0	0	31	< 1.0 %
White-rumped Sandpiper	0	0	8	1	0	0	8	0	0	0	2	0	19	< 1.0 %
American Golden Plover	0	0	0	8	0	0	2	0	0	0	0	0	10	< 1.0 %
Wilson's Phalarope	0	1	1	3	0	1	2	0	0	0	0	1	9	< 1.0 %

Table 2 continued.

	Ballard WMA				Sloughs WMA				Peabody WMA					
	2004		2005		2004		2005		2004		2005			
	S	F	S	F	S	F	S	F	S	F	S	F	total	%
Western Sandpiper	0	5	0	0	0	0	0	0	0	0	0	3	8	< 1.0 %
Dowitcher spp.[c]	0	0	0	3	0	0	4	0	0	0	0	0	7	< 1.0 %
Black-necked Stilt	0	0	0	0	3	0	0	0	0	2	0	0	5	< 1.0 %
Western Sandpiper	0	5	0	0	0	0	0	0	0	0	0	3	8	< 1.0 %
Baird's Sandpiper	0	1	0	1	0	0	0	0	0	2	0	0	4	< 1.0 %
Buff-breasted Sandpiper	0	4	0	0	0	0	0	0	0	0	0	0	4	< 1.0 %
Willet	0	0	0	0	0	0	0	0	0	4	0	0	4	< 1.0 %
Sanderling	0	0	0	1	0	0	0	0	0	1	0	0	2	< 1.0 %
Black-bellied Plover	0	1	0	0	0	0	0	0	0	0	0	0	1	< 1.0 %
American Woodcock	0	0	0	1	0	0	0	0	0	0	0	0	1	< 1.0 %
total	2291	3871	2490	2086	2415	663	4993	604	2057	333	2270	261	12307	

[a] Yellowleg spp. included Greater and Lesser yellowlegs

[b] Peeps included Least Sandpipers, Semipalmated Sandpipers, Western Sandpipers, and White-rumped Sandpipers

[c] Dowitchers spp. included Short-billed and Long-billed dowitchers

Table 3. The mean number of shorebirds observed per 10-day survey period at the Ballard, Sloughs, and Peabody Wildlife Management Areas (WMAs) during spring migration in Kentucky, 2004 and 2005.

Period	Ballard WMA	Peabody WMA	Sloughs WMA	Overall mean
11-20 Mar	86	0	16.3	27.0
21-31 Mar	39	0.5	13.5	13.4
1-10 Apr	33.3	3	14.8	19.7
11-20 Apr	97	3.5	92.7	82.1
21-30 Apr	78.5	21	44.3	50.9
1-10 May	75.5	15.5	169.4	120.3
11-20 May	9	85.2	38.7	50.5
21-31 May	8.7	12.5	5	9.3
1-10 June	0	5	6.7	3.8
11-20 June	0	0	1	0.3

Table 4. The mean number of shorebirds observed per 10-day survey period at the Ballard, Sloughs, and Peabody Wildlife Management Areas (WMAs) during fall migration in Kentucky, 2004 and 2005.

Period	Ballard WMA	Peabody WMA	Sloughs WMA	Overall mean
11-20 July	13	24.5	20.8	21.4
21-31 July	601.3	7	30.5	271.8
1-10 Aug	1039	25.5	16.3	402.1
11-20 Aug	238.7	22.8	14.2	58.4
21-31 Aug	237.3	12.5	14.4	80.9
1-10 Sept	213	39	23.8	57.8
11-20 Sept	23.8	9.5	22.8	39.6
21-30 Sept	59	16.3	11.6	22.8
1-10 Oct	51	6	12.3	23.8
11-20 Oct	100	45.3	13.8	43.4
21-31 Oct	42	26	38.8	36.9

Table 5. Percentage of Killdeer (N = 4034), Pectoral Sandpipers (N = 2610), Least Sandpipers (N = 1226), Greater Yellowlegs (N = 873), Lesser Yellowlegs (N = 928), Semipalmated Plovers (N = 608), and Dunlins (N = 358) observed foraging in each habitat type at the Ballard, Peabody, and Sloughs Wildlife Management Areas in Kentucky. The highest percentage for each species is indicated by bold font.

	Species[a]						
Habitat type[b]	KILL	PESA	LESA	GRYE	LEYE	SEPL	DUNL
SWF	2.0	0.7	0.7	0	0	0.7	0
DM	**57.5**	0	0	0	0	0	0
WM	22.4	5.9	**48.8**	5.5	8.7	**97.9**	13.1
DM and WM	0	26.8	4.0	0	0	0	0
MWF	4.8	0.3	6.3	0.6	0.5	1.3	0
OW < 5	2.0	0.8	2.3	7.4	12.0	0.1	16.8
WM and OW < 5	7.7	7.8	36.8	14.0	10.8	0	19.6
OW 5-15	0.6	**48.5**	0	**40.4**	**38.7**	0	**50.5**
OW < 5, OW 5-15	0	0	0	26.1	19.0	0	0
OW > 15	0.4	8.4	0	1.4	0.9	0	0
EWV	2.6	0.8	1.1	4.6	9.5	0	0

[a] KILL = Killdeer, PESA = Pectoral Sandpipers, LESA = Least Sandpipers, GRYE = Greater Yellowlegs, LEYE = Lesser Yellowlegs, SEPL = Semipalmated Plovers, and DUNL = Dunlins

[b]SWF = sand-water film, DM = dry mud, WM = wet mud, DM & WM = dry mud and wet mud, MWF = mud water film, OW < 5 = open water less than 5 cm, WM & OW < 5 = wet mud and open water less than 5 cm, OW 5-15 = open water 5-15 cm, OW <5, OW

5-15 cm = open water less than 5 cm and open water 5 – 15 cm, OW > 15 = open water greater than 15 cm, and EWV = emergent wetland vegetation

Table 6. Mean (± SE) water depth, detritus depth, water temperature, herbaceous plant cover, submerged plant cover, and detritus cover at locations where shorebirds were observed foraging and at random locations in western Kentucky.

Variable	**Foraging locations**	**N**	**Random locations**	**N**
Water depth (cm)	1.67 (± 0.26)	41	3.80 (± 0.66)	38
Detritus depth (cm)	0.93 (± 0.17)	41	0.62 (± 0.26)	39
Water temperature (°C)	25.07 (± 0.66)	40	23.94 (± 1.08)	33
Herbaceous cover	0.04 (± 0.02)	41	0.18 (± 0.05)	39
Submerged vegetative cover	0.20 (± 0.05)	41	0.25 (± 0.05)	39
Detritus cover	0.45 (± 0.06)	41	0.26 (± 0.05)	39

Table 7. The number of invertebrates, mean biomass (± SE) and number of samples taken (N) at survey locations at the Ballard, Peabody, and Sloughs Wildlife Management Areas (WMAs) during spring and fall migration in Kentucky, 2004 and 2005.

Location	Number of invertebrates	Mean biomass (mg ± SE)	N
Ballard WMA	2546	0.0155 (± 0.0034)	118
Peabody WMA	1614	0.0268 (± 0.0066)	139
Sloughs WMA	1279	0.1478 (± 0.0291)	109
Overall	5439	0.0594 ± 0.0096	366

Table 8. The number individuals of each invertebrate group at survey locations at Ballard, Sloughs, and Peabody Wildlife Management Areas (WMAs) during spring and fall migration in Kentucky, 2004 and 2005.

	Number of invertebrates				
Location	Annelida	Bivalvia	Gastropoda	Crustacea	Insecta
Ballard WMA	451	91	42	219	**1725**
Peabody WMA	**629**	58	393	17	512
Sloughs WMA	**608**	2	277	10	353

Table 9. The number of individuals and percentage of each orders of insects, and the number of individuals and percentage of non-insect invertebrates, identified in samples collected at the Ballard, Sloughs, and Peabody Wildlife Management Areas (WMAs), Kentucky.

	Invertebrate taxa	Number of invertebrates	Percentage of total
Insect Orders	Coleoptera	38	< 1.0
	Collembola	1	< 1.0
	Diptera	2387	43.9
	Ephemeroptera	7	< 1.0
	Hemiptera	51	< 1.0
	Megaloptera	40	< 1.0
	Odonata	3	< 1.0
	Plecoptera	3	< 1.0
	Trichoptera	6	< 1.0
	Unknown Insects	54	< 1.0
	Total insects	**2590**	**47.6**
Invertebrate taxa	Bivalvia	151	2.8
	Crustacea	246	4.5
	Gastropoda	712	13.1
	Hirudinidea	130	2.4
	Oligochaeta	1515	27.9
	Other Annelida	43	< 1
	Other non-insects	52	< 1
	Total non-insects	**2849**	**52.4**
	Total invertebrates	**5439**	**100.0%**

Table 10. Families in the insect order Diptera identified in samples obtained at the Ballard, Sloughs, and Peabody Wildlife Management Areas (WMAs), Kentucky.

Dipteran Families	Number of Individuals	Percent of total invertebrates
Athericidae	2	< 1.0
Ceratopogonidae	393	7.2
Chironomidae	1599	29.4
Dixidae	5	< 1.0
Ephydridae	1	< 1.0
Simulidae	1	< 1.0
Tabanidae	5	< 1.0
Tipulidae	276	5.1
Unknown	105	1.9
Total Diptera	2387	43.9%

APPENDIX B: FIGURES

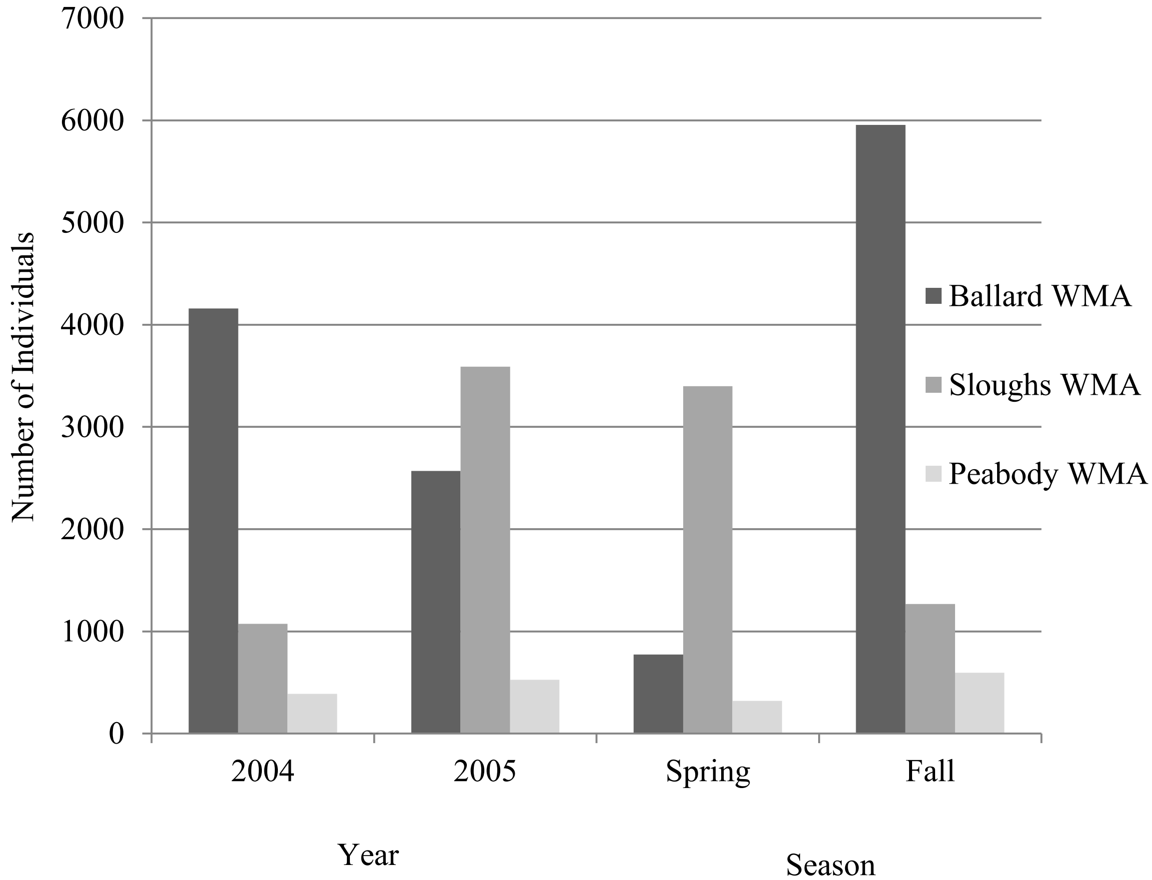

Figure 1. The total number of individual shorebirds recorded in Kentucky at the Ballard, Sloughs, and Peabody Wildlife Management Areas (WMAs) by year and season.

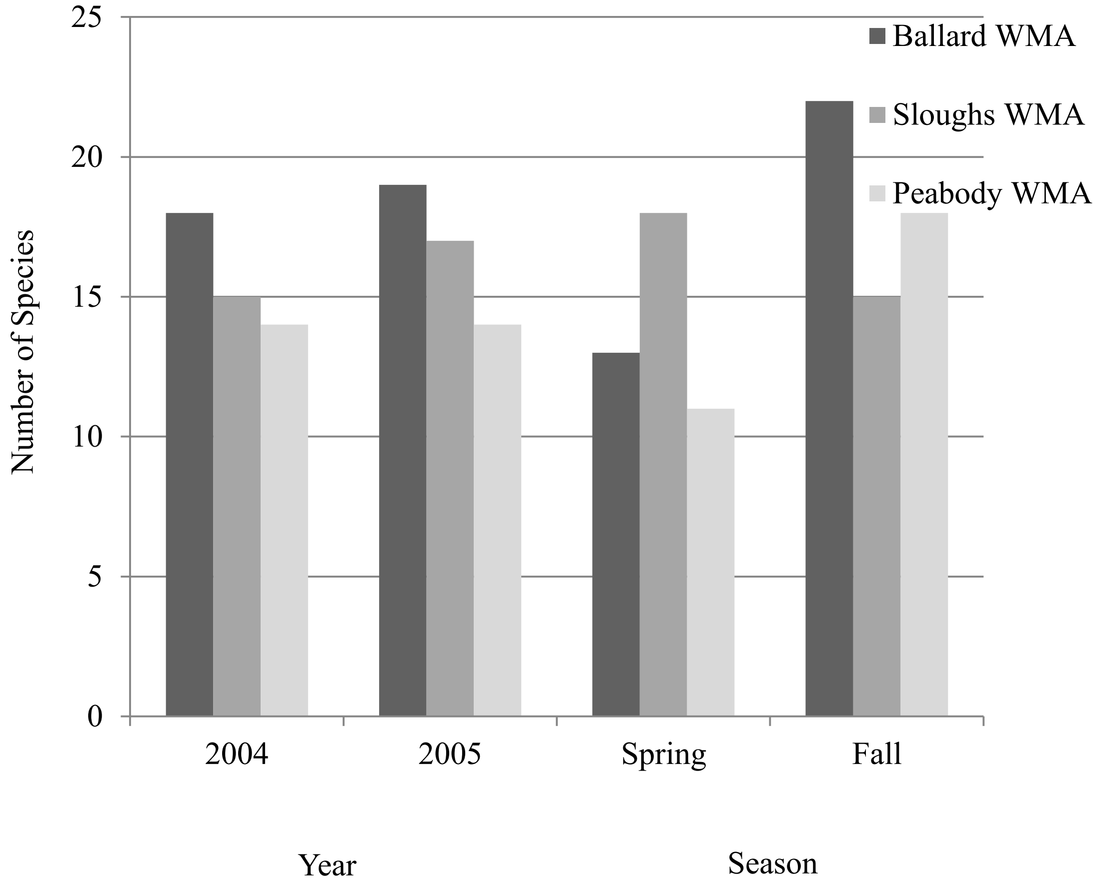

Figure 2. The total number of species of shorebirds observed in Kentucky at the Ballard, Sloughs, and Peabody Wildlife Management Areas (WMAs) by year and season.

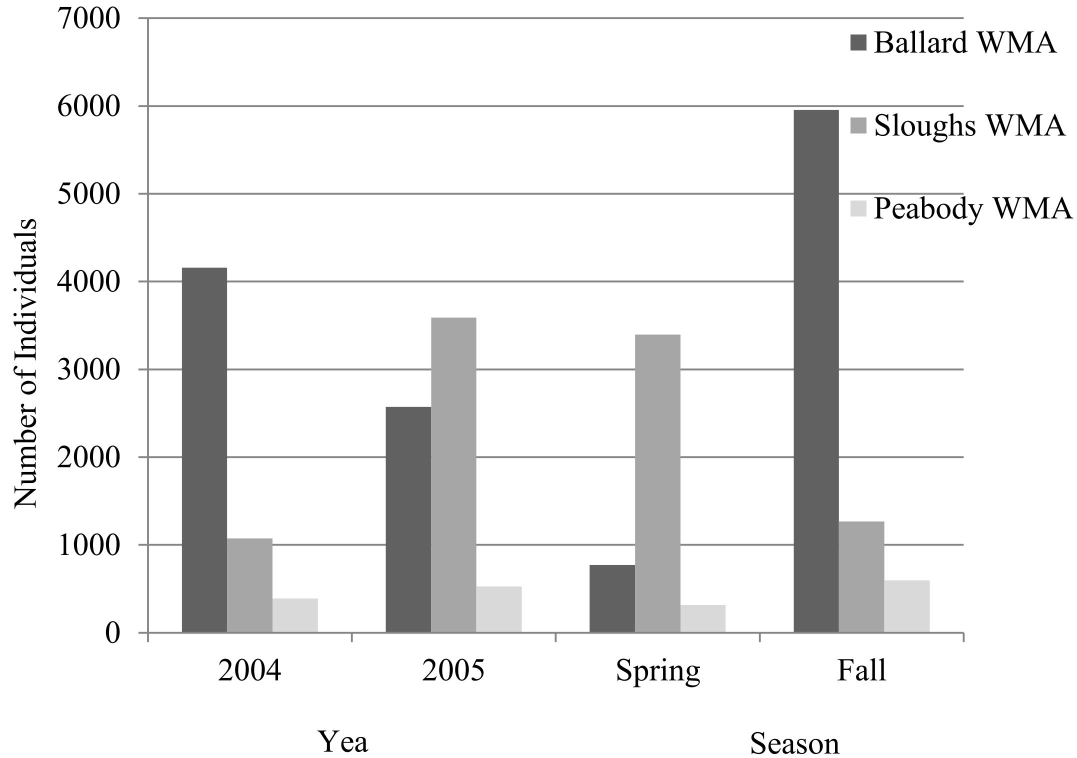

Figure 3. The total number of individual shorebirds recorded in Kentucky at the Ballard, Sloughs, and Peabody Wildlife Management Areas (WMAs) during spring and fall migration, 2004 and 2005.

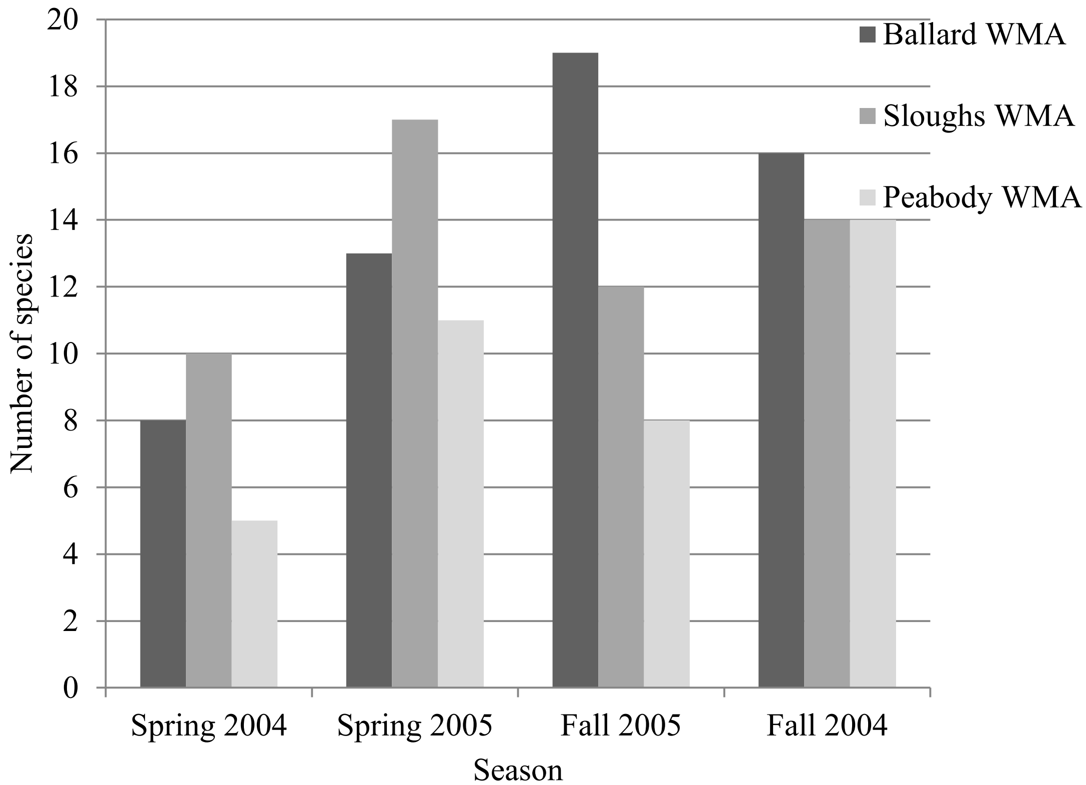

Figure 4. The number of species of shorebirds recorded in Kentucky at the Ballard, Sloughs, and Peabody Wildlife Management Areas (WMAs) during spring and fall migration, 2004 and 2005.

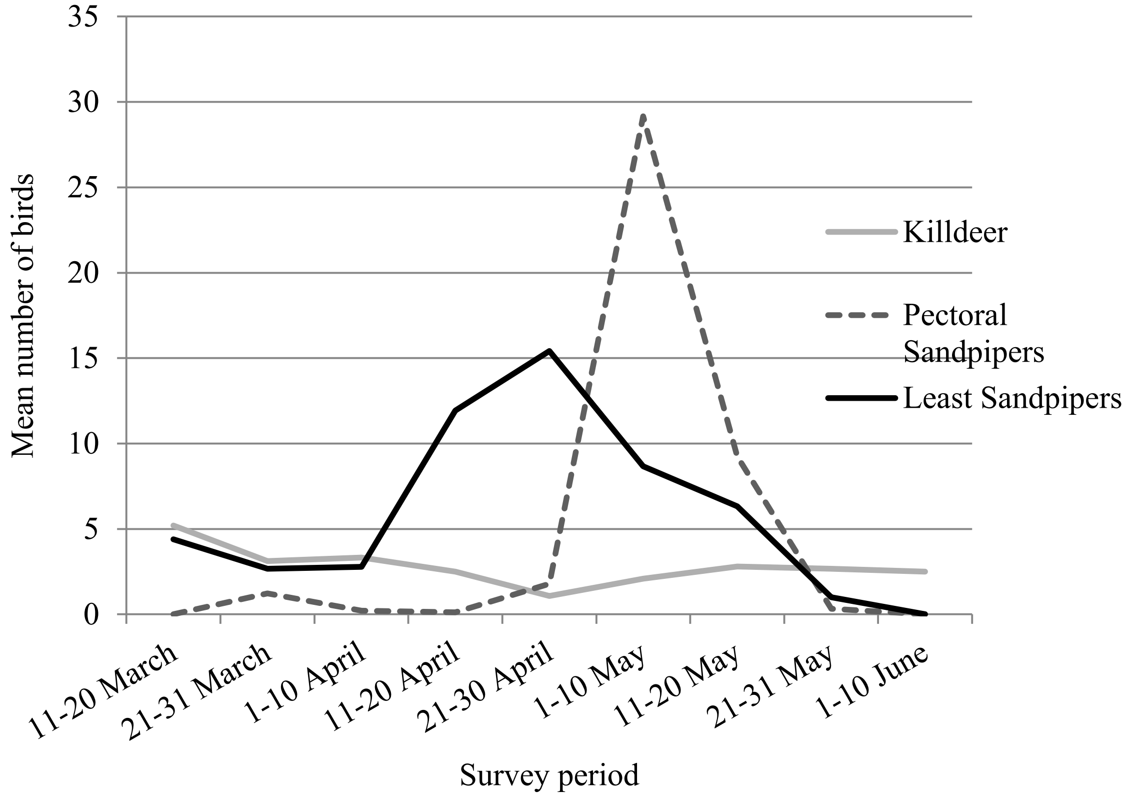

Figure 5. The mean number of Killdeer, Pectoral Sandpipers, and Least Sandpipers observed per 10-day survey period at three Kentucky wildlife management areas during spring migration, 2004 and 2005.

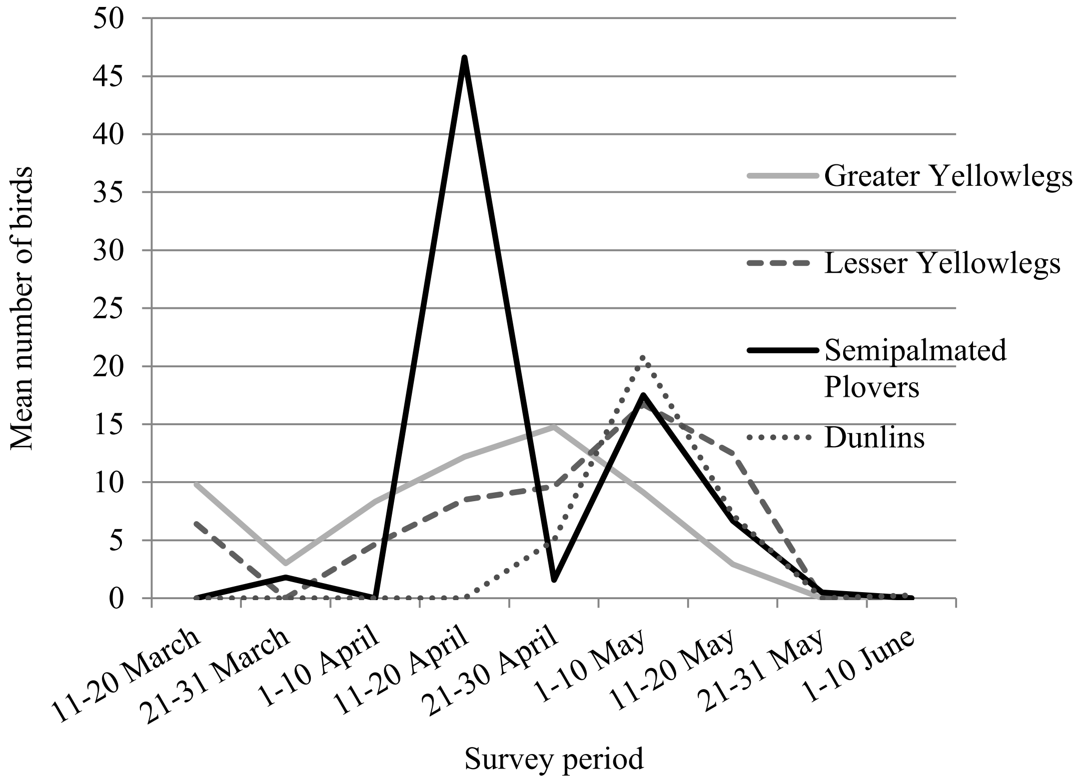

Figure 6. The mean number of Greater Yellowlegs, Lesser Yellowlegs, Semipalmated Plovers, and Dunlins observed per 10-day survey period at three Kentucky wildlife management areas during spring migration, 2004 and 2005.

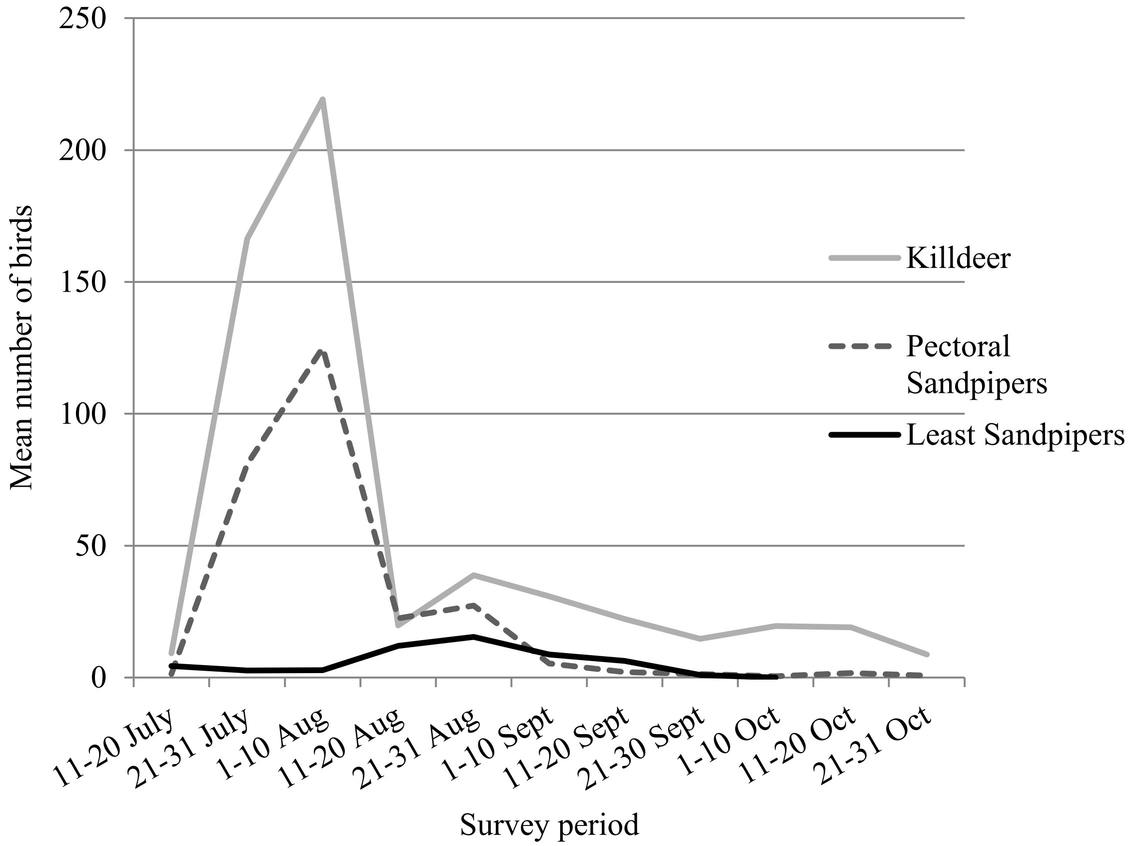

Figure 7. The mean number of Killdeer, Pectoral Sandpipers, and Least Sandpipers observed per 10-day survey period at three Kentucky wildlife management areas during fall migration, 2004 and 2005.

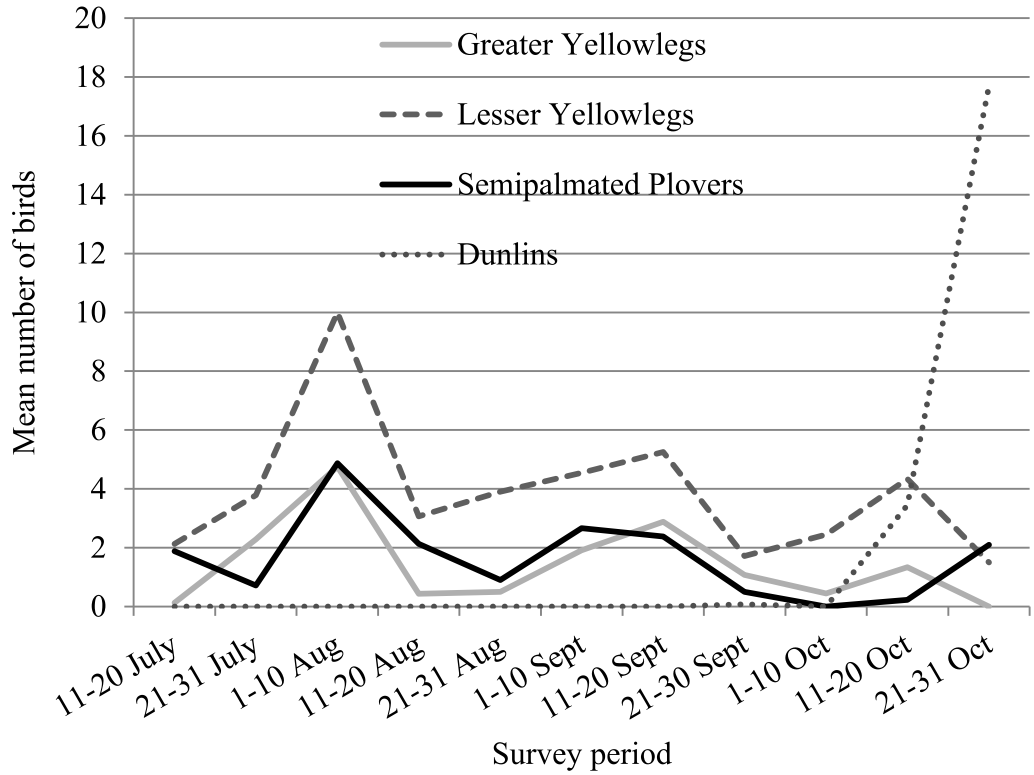

Figure 8. The mean number of Greater Yellowlegs, Lesser Yellowlegs, Semipalmated Plovers, and Dunlins observed per 10-day survey period at three Kentucky wildlife management areas during fall migration, 2004 and 2005.

APPENDIX C: BODY SIZE, MIGRATION DISTANCE, AND MIGRATORY PATTERN OF THE SHOREBIRDS OBSERVED IN THIS STUDY (Skagen and Knopf 1993).

	Body size[a]	Migration distance[b]	Migration pattern[c]
Killdeer	medium	short	widespread
Pectoral Sandpiper	medium	long	narrow band
Least Sandpiper	small	intermediate	narrow/widespread
Greater Yellowlegs	medium	intermediate	narrow band
Lesser Yellowlegs	medium	intermediate	narrow band
Semipalmated Plover	small	intermediate	narrow band
Dunlin	medium	intermediate	jump
Semipalmated Sandpiper	small	intermediate	narrow band
Solitary Sandpiper	medium	intermediate	widespread
Wilson's Snipe	medium	short	N/A
Spotted Sandpiper	medium	intermediate	widespread
Short-billed Dowitcher	medium	intermediate	narrow band
Stilt Sandpiper	medium	long	narrow band
White-rumped Sandpiper	small	long	narrow band
Long-billed Dowitcher	medium	intermediate	widespread
Western Sandpiper	small	intermediate	crossband
Wilson's Phalarope	medium	intermediate	widespread
Black-necked Stilt	large	short	N/A
American Golden Plover	medium	long	narrow band
Baird's Sandpiper	small	long	narrow band
Buff-breasted Sandpiper	medium	long	narrow band
Willet	large	short	widespread
Sanderling	medium	intermediate	jump
Black-bellied Plover	medium	intermediate	widespread
American Woodcock	large	short	widespread

[a] small denotes body length < 190 mm; medium denotes body length 195 – 350 mm, and large denotes body length > 350 mm

[b] migration distance is based on an index calculated by Skagen and Knopf (1993) using the shortest distance between wintering and breeding areas, the distance between midpoints of breeding and wintering areas and the distance between the extremes of breeding and wintering areas

[c] narrow band indicates the birds were located between 90º W and 100 º W longitudes; jump includes species that winter along the Texas coast and breed in Canada with few stopping in the Great Plains; widespread migrants occur broadly throughout the focal area and crossband migrants winter along the coasts of the southern U. S., Central America, and northern South America and breed in northwestern Alaska

VITA

Nicole Ranalli was born and raised in West Chester, Pennsylvania. After graduating from Unionville High School in May 1997, she attended the University of Delaware where she obtained a B.S. in Animal Science with a minor in Wildlife Conservation in May 2001. In September 2003, she entered graduate school at Eastern Kentucky University. She is currently employed with the Florida Fish and Wildlife Conservation Commission as a wildlife biologist in Lake Placid, FL.