



University of Illinois  
Institute of Natural Resource Sustainability  
William Shilts, Executive Director

ILLINOIS NATURAL HISTORY SURVEY  
Brian D. Anderson, Director  
1816 South Oak Street  
Champaign, IL 61820  
217-333-6830

## **Foraging Ecology of Fall Migrating Shorebirds in the Illinois River valley**

Randolph V. Smith, Joshua D. Stafford, Aaron P. Yetter,  
Christopher S. Hine, and Michelle M. Horath

Illinois Natural History Survey

Prepared for: U.S. Fish and Wildlife Service  
Upper Mississippi River and Great Lakes Region Joint Venture

Grant/Project Number: 301817G038  
Project Name: Shorebird Foraging Ecology

1 July 2007 to 30 June 2009  
Final Report



INHS Technical Report 2010 (23)  
Issue Date: 06/30/2010  
Unrestricted

ILLINOIS  
NATURAL  
HISTORY  
SURVEY

## **ACKNOWLEDGMENTS**

Funding for this project was provided by a grant/cooperative agreement from the U.S. Department of the Interior, Fish and Wildlife Service (USFWS) through the Upper Mississippi River and Great Lakes Region Joint Venture (UMRGLRJV). We are grateful for the help of B. Pardo (UMRGLRJV) and G. Soulliere (UMRGLRJV) in project development and support. Non-toxic ammunition (Hevi-Shot®) was donated by ENVIRON-Metal, Inc. Conversations with J. Vest (USFWS), A. Andrei (Lincoln University of Missouri), C. Davis (Oklahoma State University), and A. Pearse (U.S. Geological Survey) provided useful information that improved our research. We recognize M. Lemke (The Nature Conservancy) and E. DeWalt (Illinois Natural History Survey; INHS) for assistance with invertebrate identification. Finally, we thank the Illinois Department of Natural Resources (IDNR) site personnel (B. Douglass, E. Oest, and S. Weimer); USFWS site personnel (M. Sprenger); and private land owners and managers (D. Mitchell, D. Taylor, J. Roskelley, F. Hutchison, S. DeManis, E. Bouchez, and R. White) who allowed us access to their property.

## **DISCLAIMER**

Any opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the USFWS, INHS, IDNR, or the University of Illinois.

## EXECUTIVE SUMMARY

Populations of many shorebird species appear to be declining in North America. Food resources at stopover habitats are considered limiting factors in many migratory bird species. Thus, investigations of foraging habitats are priorities of the Upper Mississippi River and Great Lakes Region JV (hereafter, JV) and the U.S. Shorebird Conservation Plan, but few researchers have examined foraging ecology of shorebirds in mid-migration locations of the JV region. To address these research needs we investigated body condition of, and foraging habitat and diet selection by, the following 4 species of shorebirds in the central Illinois River valley (IRV) during fall migrations 2007 and 2008: Killdeer (*Charadrius vociferus*), Least (*Calidris minutilla*) and Pectoral (*Calidris melanotos*) sandpipers, and Lesser Yellowlegs (*Tringa flavipes*).

We collected 153 shorebirds in 2007 and 133 in 2008, though not all individuals were suitable for inclusion in each analysis. Our results indicated that 3 of the 4 species were in good to excellent condition based on size-corrected body mass and fat scores. Killdeer had low fat scores in each year, but size-corrected body mass estimates were within published ranges. Shorebird diets were dominated by taxa from Orders Diptera (flies) and Coleoptera (beetles). Additionally, the contribution of Orders Isopoda (pillbugs), Hemiptera (true bugs), Hirudinea (leaches), Nematoda (round worms), and Fish (*Gambusia* spp.) to diets varied by shorebird species and year. We evaluated habitat selection in the context of Johnson (1980) by comparing aggregate percent dry mass of food items in shorebird diets and core samples. We evaluated third-order selection by comparing food abundance at shorebird collection sites to random sites, and fourth-order selection by comparing diets to food abundance at collection sites. Invertebrate abundances at shorebird collection sites and random sites were typically not significantly

different, indicating no support for third-order selection. Conversely, we found considerable evidence of fourth-order selection for some forage taxa, and consistent avoidance of Oligochaeta.

Our results of apparent diet selectivity were somewhat surprising given that shorebirds are typically considered opportunistic foragers. Additionally, other studies have reported that Oligochaeta were important foods, or that they may have been important but were underestimated in diets. Our results conflict with these findings; Oligochaetes were the most abundant invertebrates in our core samples, but were always under-represented in shorebird diets. Relationships between the abundance, availability, and consumption of Oligochaetes for and by waterbirds are unclear, but should be the focus of future research given that they are often the most abundant wetland invertebrate. If Oligochaetes are truly avoided or not available for consumption, estimates of foraging carrying capacity would need to be revised accordingly.

We suspect that the diet selectivity we observed may have been a function of overall invertebrate biomass at our study sites. Several other studies have estimated invertebrate biomass for shorebird foraging habitats, but our study-period estimate ( $51.2 \pm 4.4$  (SE) kg/ha; dry mass) was as much as an order of magnitude greater than other reported estimates. However, our estimates were similar to those from other wetlands associated with the Illinois and Mississippi Rivers, perhaps indicating regionally abundant food resources. Regardless, we speculate that diet selectivity in shorebirds may follow tenants of optimal diet theory; that is, at low food abundances shorebirds may forage opportunistically, with the likelihood of selectivity increasing as food abundance or availability increases.

Our study area included important habitats for migrating shorebirds, especially Chautauqua National Wildlife Refuge, which is a Western Hemisphere Shorebird Reserve Network site. However, we conducted a large portion of our research on other publicly and

privately managed wetlands in the IRV floodplain. The value of these wetlands as shorebird staging areas is not well known, but all received considerable use by our target species.

Understanding the combined contribution of both private and public wetlands in the region to stopover habitat for migrating shorebirds would provide critical information for conservation planning, allocation, and restoration.

Finally, mid-continent stopover habitats are typically ephemeral to seasonal, but the current hydrology of the IRV can be highly variable within and among years. Regardless of ownership, most wetlands in the IRV are dewatered for moist-soil management in summer. However, the majority are not protected by large levees and may become completely inundated by unseasonal (i.e., summer or early fall) flooding that can eliminate shorebird foraging habitat in the region. Consequently, this flooding may drastically alter the ability of the region to meet annual conservation objectives. Our results suggest that the central IRV contains excellent habitat for fall-migrating shorebirds when water levels and management are appropriate, and we speculate the region may support a substantially larger population than previously thought. However, unpredictable hydrology may lead to seasonal habitat deficits, imposing additional migration stress on already depressed shorebird populations. Understanding the consequences of intra- and interannual variability in shorebird foraging habitat in the region will be important for targeted conservation planning and implementation.

## INTRODUCTION

Populations of many shorebird species appear to be declining throughout North America (Gratto-Trevor et al. 1998, Morrison et al. 2000). Causes of the declines have been attributed to habitat loss (Holmes and Pitelka 1998) and increased predation, but other evidence suggests only large population changes may be identifiable (e.g., 50% decline; Brown et al. 2001:11). Because shorebirds migrate long distances (e.g., >8,000 km each way) and may spend little time at individual staging areas, their energy demands should require them to forage efficiently and opportunistically (Skagen and Oman 1996, Davis and Smith 1998, Andrei et al. 2009). Further, research suggests that food shortages may lead to density-dependant mortality in birds (Lack 1954). Supporting this notion, Goss-Custard (1969) suggested migration was a critical period for population regulation in the Redshank (*Tringa totanus*). Schneider and Harrington (1981) reported that food availability was critical in shaping migratory patterns of shorebirds, and Morrison et al. (2007) concluded that fat reserves acquired immediately before migration lead to increased survival in Red Knots (*Calidris canutus*).

The U.S. Shorebird Conservation Plan identified several research priorities to stimulate investigation of these long-distance migrants (Brown et al. 2001). Many of these included some aspect of foraging ecology, including analyses of dietary requirements and preferences, and studies elucidating the relationship between wetland use and forage characteristics (Brown et al. 2001). Similarly, Oring et al. (2000; National Shorebird Research Needs) suggested investigation of resource use by highly congregated shorebirds was needed to improve our understanding of migratory stopover sites and the potential for foraging habitat to limit populations. Finally, the Upper Mississippi River and Great Lakes Region Joint Venture (hereafter, JV) Shorebird Conservation Strategy identified food abundance, diet, and energetic

carrying capacity for migrating shorebirds as specific research needs to improve shorebird conservation in this region (Potter et al. 2007:36).

Previous investigations of shorebird foraging ecology have been conducted on breeding areas (Holmes and Pitelka 1968, Baker 1977), migration regions such as the Texas High Plains (Baldassarre and Fischer 1984, Davis and Smith 1998, Andrei et al. 2009), or coastal areas (e.g., Baker and Baker 1973, Placyk and Harrington 2004). Conversely, few researchers have investigated foraging ecology of shorebirds in the mid-continent region (c.f., Rundle 1982, Eldridge et al. 2009), or existing studies were of limited scale (i.e., one small pond in Illinois; Brooks 1967). Hamer et al. (2006) identified a positive relationship between shorebird density and the amount of invertebrate biomass removed in central Illinois wetlands, but they did not sample individuals to determine food habits nor extract benthic samples specifically where birds were feeding. Indeed, we are unaware of shorebird foraging ecology studies that simultaneously document food habits, forage abundance at feeding sites (e.g., to estimate selection within patches), and forage abundance at randomly selected locations (e.g., to investigate patch selection). Such a study would provide conservation planners with information to improve an energy-based (*sensu* Guthery 1999) view of wetland conservation for shorebirds.

Despite the lack of intensive studies on shorebird foraging ecology in the mid-continent region, these wetlands are critically important to shorebirds as “refueling” habitats during migrations between Central American wintering areas and arctic breeding grounds (Skagen and Knopf 1994). Relevant to the JV, Chautauqua National Wildlife Refuge (hereafter CNWR) lies within the Illinois River valley (IRV) focus area (U.S. Fish and Wildlife Service 1998) and has been designated a Western Hemisphere Shorebird Reserve Network site. Chautauqua NWR may host 100,000–250,000 shorebirds annually during fall (Bailey 2003), and  $\geq 5\%$  of the global

Pectoral sandpiper (*Calidris melanotos*) population migrates through Illinois annually (Russell 2003). Understanding shorebird foraging ecology at this important bird area could help guide conservation planning throughout mid-latitude migration areas by identifying characteristics associated with use and selection (*see* Oring et al. 2000:20). Other IRV wetlands near CNWR are also used by migrant shorebirds; specifically, Clear, Rice, Big, Goose, Spring, Pekin, Crane, Anderson Lakes, and Jack and Grass Lakes (hereafter, Grand Island). Management of these lakes is typically favorable for migrating shorebirds and, although rarely surveyed, they may host a substantial number of individuals. When all wetlands in the region are considered, the area may be a very important mid-continent stopover destination.

In addition to wetlands currently important to shorebirds, many extensive wetland restoration and reclamation efforts are ongoing in the IRV. Recent examples include: 1) reclamation of the Hennepin-Hopper drainage and levee district in north-central Illinois by The Wetlands Initiative; 2) dredging of Peoria Lake by the U.S. Army Corps of Engineers (COE); 3) restoration of Chautauqua Lake by the U.S. Fish and Wildlife Service (USFWS) and COE; 4) reclamation of the Emiquon–Thompson Lake area by The Nature Conservancy (TNC) and USFWS, and; 5) reclamation of the Merwin Preserve at Spunky Bottoms by TNC and the Illinois Department of Natural Resources (IDNR). Further, the COE has proposed spending \$7.95 billion over 50 years to restore the IRV, including most backwaters, tributaries, and floodplain wetlands within the 78,000 km<sup>2</sup> watershed (U.S. Army Corps of Engineers 2004). Thus, the quantity and quality of stopover habitat for shorebirds in the region has likely increased and may continue to do so.

Clearly, conservation planning in the IRV would benefit from an investigation of shorebird foraging ecology. Many species of shorebirds migrate through the IRV during fall, but



ground-count data indicated that Pectoral and Least sandpipers (*Calidris minutilla*), Lesser Yellowlegs (*Tringa flavipes*), and Killdeer (*Charadrius vociferus*) likely occur in adequate abundance and regularity to allow investigation of foraging ecology (M. M. Horath, Illinois Natural History Survey, unpublished data). Additionally, Killdeer are specified as a focal species by the JV (Potter et al. 2007), and the other species represent a variety of body sizes and foraging guilds, which would provide a more complex evaluation to inform conservation actions. Therefore, we studied the foraging ecology of the aforementioned 4 species during fall migration to address questions related to the conservation of shorebirds and their habitats in the JV region. To accomplish this, we collected foraging shorebirds and core samples to estimate food abundance at shorebird-collection and random locations during falls 2007 and 2008 within selected wetlands in central IRV. Our objectives were to: 1) estimate body condition of migrating Least and Pectoral sandpipers, Lesser Yellowlegs, and Killdeer during fall; 2) identify foods consumed by the 4 target species and evaluate their relative importance, and; 3) use data on invertebrate foods from shorebird diets and core samples to investigate potential selection of foraging patches within wetlands (i.e., third-order selection; Johnson 1980) and diet items at specific foraging sites (i.e., fourth-order selection).

## **STUDY AREA**

Our study sites included backwater lakes and wetlands associated with the LaGrange Pool of the Illinois River (river miles 80.2–157.6) in Fulton, Mason, and Tazewell counties, Illinois. The importance of these floodplain wetlands to migratory waterbirds has been described in detail (Bellrose et al. 1983, Havera and Bellrose 1984, Havera 1999). Many wetlands in our study area were managed to promote moist-soil vegetation, an important food for migratory waterfowl (Fredrickson and Taylor 1982). Moist-soil management typically requires natural or

managed dewatering of wetlands to expose mud flats during the growing season. Thus, the region commonly provides abundant habitat for shorebirds during fall migration.

CNWR (Figure 1) was considered the most important of our collection sites and may host substantial numbers of shorebirds during migration (Bailey 2003). Other publicly- and privately-owned and managed wetlands in the IRV also receive considerable use by fall-migrating shorebirds. IDNR managed areas included: Rice Lake, Anderson Lake, and Spring Lake State Fish and Wildlife Areas (Figure 1). Privately-owned wetlands included Grand Island, Crane Lake and Clear Lake (Figure 1). Finally, unmanaged backwater wetlands occasionally drawdown naturally and attract foraging shorebirds. Therefore, we collected shorebirds at 1 unmanaged wetland, Quiver Lake, whose water levels were dictated by the Illinois River (Figure 1). Typical habitat features of these sites included at least one large (200–925 ha) bottomland lake that was at least partially intentionally dewatered during summer (all sites except Quiver Lake). Five sites (Anderson, Clear, Crane, Rice, and Spring Lakes) also had smaller (15–100 ha) leveed impoundments that were managed independently of the larger bottomland lakes. Water levels at all sites varied within and among years due to precipitation, fluctuating levels of the Illinois River, and site-specific management actions. Therefore, there were only 2 sites where we collected birds in both years (Grand Island, Clear Lake).

## **METHODS**

### **Field**

We collected foraging Killdeer, Least and Pectoral sandpipers, and Lesser Yellowlegs with shotguns and non-toxic shot (Hevi-shot ®, Environ-metal, Inc.) during July and August 2007–2008 (Table 1). We observed feeding shorebirds for  $\geq 10$  minutes prior to collection to ensure they had not been feeding at another location and that they contained sufficient food for

analysis. Immediately following collection, we injected a 10% buffered formalin solution into the upper digestive tract of each bird and secured a plastic zip-tie around the neck at the base of the head to prevent loss of ingesta. We labeled and bagged each bird uniquely and placed them in a cooler until we could transport them to the laboratory for processing ( $\leq 6$  hours). We recorded the location of each collected bird using a handheld GPS unit and removed a wetland substrate core sample from the collection location (5 cm diameter and 5 cm depth; Sherfy et al. 2000). Using a random numbers table, we then selected an easting and northing distance (m) for each bird and collected a random core sample from this location. Thus, each collected shorebird was paired with 2 core samples; one taken from the feeding site and one at a random location within the wetland (hereafter, “collection-site” and “random”, respectively). We marked random locations using GPS and preserved and stored all core samples in plastic bags with 10% buffered formalin solution stained with Rose Bengal until processed in the laboratory.

### **Laboratory Methods**

We weighed shorebirds and recorded structural measurements to compute size-corrected body mass (SCBM) indices and scored body fat content using the Monitoring Avian Productivity and Survivorship (MAPS) method (DeSante et al. 2008). We placed hemostats at the proximal end of the esophagus and distal end of the proventriculus to prevent mixing or loss of ingesta prior to removal. Gizzard contents were not examined due to differential rates of digestion (Swanson and Bartonek 1970). We considered only invertebrate food items because they are the primary prey of shorebirds and their abundance may influence shorebird distributions (e.g, Goss-Custard 1970, Davis and Smith 1998). Esophageal and proventricular contents were combined and rinsed through a #35 (500 $\mu$ m) mesh sieve to remove substrate and formalin. Core samples were processed similarly, except samples with a large number ( $>200$ ) of a single invertebrate

taxa were occasionally sub-sampled (up to  $\frac{1}{4}$ ) using a Folsom plankton splitter. We sorted all items remaining in sieves under dissecting microscopes and classified invertebrate food items to Family or the lowest meaningful taxonomic level (e.g., Oligochaeta) following Merritt and Cummins (1996), and Smith (2001). Individual taxa from each sample were dried to constant mass at 60°C and weighed on a digital balance ( $\pm 0.1$  mg).

Most invertebrates found in diet and core samples were small. Thus, we required several individuals of a single taxa to measure dry mass. Many taxa were too small and encountered too infrequently to weigh; thus, we computed an average mass per individual and multiplied it by the number of unweighed food items. We attempted to derive average masses using taxa within the same shorebird species, study site, and year. Collection-site and random sample averages were computed using data from other collection- and random-sites. However, diet samples occasionally did not contain enough material to compute average masses of taxa; in these cases, we used the average mass of food items from collection-site cores to estimate masses of these diet items. Finally, we encountered several taxa that were uncommon, only appearing in small numbers and in few samples. In these instances, we pooled samples by year and species, across study sites. In instances of very rare taxa, we pooled individual taxa by year, or pooled all samples to compute average mass per individual. Therefore, when taxa could not be weighed directly, we used the most appropriate average mass value to estimate the total dry mass of those taxa in diets or core samples.

We encountered a few instances where shorebirds consumed taxa that were not encountered in core samples. Because most of these taxa were too small to weigh, and often appeared as a single individual in a single shorebird, we were unable to measure or calculate the mass of these items. Therefore, we constrained our analyses to food items with  $\geq 5\%$  frequency

of occurrence for a given shorebird species and year. This strategy eliminated food items that occurred in single individuals and greatly reduced the number of zeros in our dataset.

Shorebirds of all species contained unidentifiable invertebrate material which we classified as “Unknown,” such as fragments of exoskeleton, legs, heads, or other parts, as well as a small number of whole, yet unidentifiable, invertebrates. Invertebrates may have been unidentifiable for several reasons, including: small size, missing key identifying feature (e.g., head), or poor condition (i.e., mangled). Most unidentified specimens were small, individual invertebrates that were not dried or weighed. Considered individually, these items comprised very small portions of diets by aggregate percent mass or percent occurrence. When combined into one category, Unknown items comprised notable proportions of diets in some cases. However, we did not believe their inclusion in analyses was meaningful and did not include these items in analyses.

We converted dry mass (measured or estimated) of important food items to aggregate percent dry mass (hereafter, APDM) for each shorebird or core sample. We also calculated percent occurrence of food items, but only include these data tabularly to show prevalence of taxa for each species and year combination (Swanson et al. 1974).

### **Statistical Procedures**

*Fat Scoring and Size-Corrected Body Mass*—We summarized annual MAPS scores of body fat using the MEANS procedure in SAS v9.2, and inferred interannual differences if 95% confidence intervals of mean MAPS scores did not overlap. We used the following morphometrics to compute SCBM of shorebirds: 1) head length ( $\pm 0.1$  mm); 2) culmen length ( $\pm 0.1$  mm); 3) tarsus length ( $\pm 0.1$  mm); 4) keel length ( $\pm 0.1$  mm), and; 5) wing-cord length ( $\pm 1$  mm). First, we conducted a principal-components analysis of all morphometric measurements

using the PRINCOMP procedure in SAS v9.2 (Anteau and Afton 2004, SAS Institute 2004). Then, we included the scores from the first principal component as a covariate in an analysis of variance for each species using the MIXED procedure and output least-squares mean estimates of body mass accounting for morphometrics (i.e., SCBM) as our index of body condition. As with fat scoring, we used 95% confidence intervals about averaged SCBM estimates to interpret interannual differences.

*Diet, Food Abundance, and Selection*—We endeavored to analyze aggregate percent dry mass of important invertebrate Orders found in shorebird diets, collection-site and random core samples; however, diet proportions were not independent due to the unit-sum constraint. Other studies have used compositional analysis to account for this lack of independence (Aebischer et al. 1993), but our data set contained many zeros, and this approach may have lead to severely inflated Type I error rates (Bingham and Brennan 2004, Badzinski and Petrie 2006).

Examination of residual plots indicated our errors were not multivariate-normal distributed and arcsine square-root transforming the data did not significantly improve error distributions and complicated interpretability. Therefore, we followed the approach of other avian diet studies and evaluated overall variation for important invertebrate Orders (i.e.,  $\geq 5\%$  occurrence) found in ingesta, collection-site and random cores using species- and year-specific multivariate analysis of variance using proportional APDM as the dependent variables (Afton et al. 1991, Ross et al. 2005, Badzinski and Petrie 2006).

We conducted analyses using the MANOVA statement in PROC GLM, SAS v9.2, and included wetland location as a random effect to account for dependence among characteristics within individual wetlands (SAS Institute 2004). We used Wilk's Lambda to evaluate statistical significance of each MANOVA because it is considered robust to violations of the assumption of

multivariate normality (Badzinski and Petrie 2006). If results indicated a significant ( $P \leq 0.05$ ) difference in composition of invertebrate Orders, we conducted Tukey-Kramer *post-hoc* comparison tests of least-squares means using the PDIFF option of the LSMEANS statement ( $P \leq 0.05$ ). Although contrasts were performed on least-squares means, we present arithmetic means in tables and text for easier interpretation. Finally, we interpreted results of pairwise contrasts in the sense of Johnson (1980). That is, we considered comparisons between collection-site and random core samples to be relevant to third-order selection (i.e., selection of specific foraging sites), whereas we considered comparisons of contents of ingesta and collection-site cores relevant to fourth-order selection (i.e., procurement of specific resources; Johnson 1980, Block and Brennan 1993).

We converted dry mass estimates in random core samples to kg/ha and used these data to estimate the average biomass of invertebrate foods found in random samples annually and overall. Biomass estimates are presented  $\pm 1$  SE and with 95% confidence intervals.

## **RESULTS**

Despite our efforts to collect actively foraging shorebirds, 20 (15%) birds in 2007 and 46 (31%) birds in 2008 contained no identifiable food items in their upper digestive tracts (esophagus and proventriculus) and were eliminated from diet analyses.

### **Body Condition**

*Sample Size*—We were able use the MAPS method (DeSante et al. 2008) to score body fat (scale of 0 to 7) of 153 shorebirds in 2007 and 133 in 2008. A few shorebirds sustained damage to body parts during collection that excluded them from analyses of SCBM; therefore, we included 149 shorebirds from 4 wetlands in 2007 and 131 shorebirds from 6 wetlands in 2008 in analyses of body condition (Table 1).

*MAPS Fat Scoring*—Killdeer had the lowest average fat scores of our 4 focal species, with average scores of  $0.5 \pm 0.1$  (SE; 95% CI: 0.4–0.7) in 2007 and  $1.2 \pm 0.1$  (SE; 95% CI: 1.0–1.4) in 2008. Confidence intervals indicated that Killdeer contained more body fat in 2008 than 2007, but were nearly devoid of fat in both years. Average fat score for Least sandpipers was also less in 2007 ( $3.5 \pm 0.2$  [SE]; 95% CI: 3.1–4.0) than 2008 ( $4.9 \pm 0.3$  [SE]; 95% CI: 4.4–5.5), but they generally had average to good amounts of fat. Although 95% confidence intervals did not overlap, Lesser Yellowlegs had a slightly lower average fat score in 2007 ( $4.4 \pm 0.3$  [SE]; 95% CI: 3.8–5.0) than 2008 ( $4.9 \pm 0.4$  [SE]; 95% CI: 4.2–5.6). Finally, Pectoral sandpipers had the greatest average fat score of any species in a given year, although the average estimate was lower in 2007 ( $4.6 \pm 0.2$  [SE]; 95% CI: 4.2–5.0) than 2008 ( $5.9 \pm 0.2$  [SE]; 95% CI: 5.4–6.4).

*Size-corrected Body Mass*—Estimated SCBM of Killdeer averaged  $92.5 \pm 1.0$ g (SE) in 2007 and  $88.6 \pm 0.9$ g (SE) in 2008. Thus, SCBM of Killdeer was 4.2% less in 2008 than 2007, and the 95% confidence intervals about the annual estimates did not overlap, indicating the difference may be statistically significant (Table 2). Estimated SCBM of Least sandpiper was  $27.0 \pm 0.6$ g (SE) in 2007 and  $28.4 \pm 0.9$ g (SE) in 2008 (Table 2), and confidence intervals about the estimates overlapped considerably. Likewise, estimated SCBM of Lesser Yellowlegs was similar among years, with annual estimates of  $113.3 \pm 3.4$ g (SE) in 2007 and  $112.2 \pm 3.5$ g (SE) in 2008 (Table 2). Finally, body condition of Pectoral sandpipers exhibited the greatest difference among years of our focal species. Specifically, SCBM was 13% greater in 2008 ( $102.9 \pm 2.5$ g [SE]) than in 2007 ( $91.5 \pm 2.2$ g [SE]) and 95% confidence intervals about the annual estimates did not overlap, suggesting a significant difference.



## **Diet and Food Availability**

### ***Killdeer***

We collected 35 Killdeer from 4 wetlands in 2007 and 34 Killdeer from 5 wetlands in 2008. Of these, 27 (77%) from 2007 and 18 (53%) from 2008 contained adequate amounts of invertebrate food items (i.e., percent occurrence  $\geq 5\%$ ) for analyses. We identified 13 taxa in Killdeer diets in 2007 and 6 taxa in 2008 (14 total). Coleoptera, Diptera, and Nematoda occurred most frequently in Killdeer diets during 2007 and 2008 (Table 3). Results of MANOVA indicated APDM of invertebrate Orders differed among Killdeer diets, collection-site and random core samples in 2007 (Wilks'  $\lambda = 0.15$ ;  $F_{22, 130} = 9.42$ ,  $P < 0.001$ ) and 2008 (Wilks'  $\lambda = 0.26$ ;  $F_{22, 74} = 3.20$ ,  $P < 0.001$ ).

*Third-order selection*—We found only one difference in APDM of invertebrate Orders found in collection-site and random core samples for Killdeer in 2007 and 2008, indicating weak support for selection of foraging sites. In 2007, APDM of Ostracoda was significantly greater at collection sites (5%) than random sites (0%; Table 4).

*Fourth-order selection*—Significant differences in APDM of invertebrate orders found in Killdeer diets and collection-site core samples indicated active selection or avoidance of some diet items. In both years, Killdeer consumed significantly more Nematoda than were found in collection site samples, whereas they consumed significantly fewer Oligochaetes compared with their high APDM at collection sites (Table 4). In 2007, Killdeer diets contained significantly greater APDM of Coleoptera than were found at collection sites; this trend was also present in 2008, but was not statistically significant. Finally, Killdeer consumed significantly less Ostracoda in 2007 than were present in collection site samples, although this difference (4% APDM) was relatively small.

### ***Least sandpiper***

We collected 36 Least sandpipers from 3 wetlands in 2007 and 29 Least sandpipers from 5 wetlands in 2008. Of these, 30 (83%) from 2007 and 17 (59%) contained adequate food in the upper digestive tract for analyses. Least sandpipers consumed 9 taxa in 2007 and 5 taxa in 2008 (10 total; Table 5). Diptera and Coleoptera were the most common taxa consumed in both years. Results of MANOVA indicated APDM of invertebrate orders differed among Least sandpiper diets, collection-site core samples, and random core samples in 2007 (Wilks'  $\lambda = 0.22$ ;  $F_{22, 150} = 7.77$ ,  $P < 0.001$ ) and 2008 (Wilks'  $\lambda = 0.19$ ;  $F_{22, 70} = 4.14$ ,  $P < 0.001$ ).

*Third-order selection*—Similar to Killdeer, results of pairwise comparisons revealed few differences in APDM of invertebrate Orders found in collection and random site core samples in 2007 or 2008. Statistically more Nematoda were found in collection-site than random core samples in 2007, although the mean difference was only 0.7 APDM. In 2008, APDM of Oligochaeta was significantly greater in collection-site than random samples. Overall, support for foraging-site selection was weak (Table 6).

*Fourth-order selection*—Significant differences in APDM of invertebrate Orders found in Least sandpiper diets and collection-site core samples indicated active selection or avoidance of some taxa. In both years, contrasts of least-squares means indicated that Least sandpipers avoided consuming Oligochaeta, but heavily selected Diptera (Table 6). In 2007 only, Least sandpipers consumed fewer Ostracoda and Nematoda than were found in collection-site samples, though both mean differences were relatively small (1.0–5.2 APDM; Table 6).

### ***Lesser Yellowlegs***

We collected 39 Lesser Yellowlegs from 3 wetlands in 2007, of which 34 (87%) contained food in the upper digestive tract. In 2008, we collected 32 Lesser Yellowlegs from 4

wetlands, of which 20 (63%) contained food in the upper digestive tract. We identified 11 taxa in Lesser Yellowleg diets in 2007 and 9 in 2008 (15 total; Table 7). Diptera were the most important food by APDM both years (Table 8). Coleoptera were important in 2007 but not in 2008, whereas fishes (*Gambusia* spp.) were important in 2008 but not 2007. Results of MANOVA indicated APDM of invertebrate Orders differed among Lesser Yellowleg diets, collection-site, and random core samples in 2007 (Wilks'  $\lambda = 0.24$ ;  $F_{24, 172} = 7.39$ ,  $P < 0.001$ ) and 2008 (Wilks'  $\lambda = 0.25$ ;  $F_{24, 88} = 3.60$ ,  $P < 0.001$ ).

*Third-order selection*—Pairwise comparisons revealed no differences in APDM of invertebrate Orders found in collection and random site core samples in 2007 or 2008, indicating no support for selection of foraging sites (Table 8).

*Fourth-order selection*—Pairwise comparisons of APDM of invertebrate Orders indicated selection or avoidance of some diet items, though results varied more by year than with other species, perhaps indicating greater diet plasticity. The only difference that was significant in both years was avoidance of Oligochaeta. Lesser Yellowlegs generally contained greater APDM of Hemiptera than found in collection-site cores, but the difference was only significant in 2007 (perhaps owing to greater sample size and, hence, power; Table 8). Also in 2007 only, Lesser Yellowleg diets contained significantly more Ostracoda and Coleoptera than were available in collection-site samples. In contrast, Lesser Yellowleg diets in 2008 contained significantly more Nematoda and Fish (*Gambusia* spp.) than found in collection-site samples, though the latter diet items were attributable to 4 individuals that had relatively great dry masses.

### ***Pectoral sandpiper***

We collected 39 Pectoral sandpipers from 3 wetlands in 2007, of which 37 (95%) contained food in the upper digestive tract. In 2008, we collected 36 Pectoral sandpipers, of

which 28 (78%) contained food in the upper digestive tract. We found 9 and 7 taxa in Pectoral sandpiper diets in 2007 and 2008, respectively (13 total; Table 9). Diptera, specifically Chironomidae, were the predominant food by APDM in both years (Table 10). Results of MANOVA indicated APDM of invertebrate Orders differed among Pectoral sandpiper diets, collection-site core samples, and core samples taken at random locations in 2007 (Wilks'  $\lambda = 0.36$ ;  $F_{22, 192} = 5.80$ ,  $P < 0.001$ ) and 2008 (Wilks'  $\lambda = 0.17$ ;  $F_{22, 136} = 8.97$ ,  $P < 0.001$ ).

*Third-order selection*—As with Lesser Yellowlegs, pairwise comparisons revealed no differences in APDM of invertebrate Orders found in collection-site and random core samples for Pectoral sandpipers in 2007 or 2008, indicating no support for selection of foraging sites (Table 10).

*Fourth-order selection*—Pairwise comparisons of APDM of invertebrate Orders indicated Pectoral sandpipers selected or avoided some diet items during 2007 and 2008 (Table 10). As with the other 3 species we collected, Pectoral sandpipers apparently avoided Oligochaetes in both years. Diptera were the most abundant diet item by APDM, which was statistically greater compared APDM in collection-sites samples in both years. Some year-specific differences in Pectoral sandpiper diets also existed. In 2007, diets contained significantly more Hemiptera than collection-sites samples, whereas selection for Isopoda at foraging sites occurred in 2008 (Table 10).

### **Invertebrate Biomass**

Estimated biomass of invertebrates found in core samples collected at random was  $47.0 \pm 4.3$  (SE) kg/ha (dry mass; 95% CI: 38.5–55.5) in 2007 and  $56.0 \pm 8.1$  (SE) kg/ha (dry mass; 95% CI: 40.0–72.1) in 2008. Confidence intervals about annual invertebrate biomass estimates

overlapped considerably; thus, estimated average biomass among all years and sites was  $51.2 \pm 4.4$  (SE) kg/ha (dry mass; 95% CI: 42.5–59.9).

## **DISCUSSION**

Mid-continent wetlands are critically important to shorebirds as “refueling” habitats during migrations between Central American wintering areas and arctic breeding grounds (Skagen and Knopf 1994). Relevant to the JV, the IRV is a prominent and important wetland system for shorebirds. Many similarly-managed wetlands exist within close proximity of each other (e.g., <1 km apart; Figure 1). Additionally, other complexes of large wetlands exist north and south of our study area within the river floodplain. Indeed, >30 unique backwater lakes exist within the LaGrange Pool of the IRV floodplain and, when conditions permit, nearly all are at least partially dewatered and provide foraging habitat during shorebird migration. Many of these wetlands are privately owned and have remained unidentified as important shorebird use areas. However, these wetlands can receive considerable use by migrating shorebird. Results of our study provide further evidence quantifying and emphasizing the importance and contribution of these of public and private wetlands in the IRV as stopover habitats for shorebirds in the mid-continent.

### **Foraging Site and Diet Selection**

*Third-order Selection*—A variety of studies have examined shorebird diets during different portions of the annual cycle; however, we are aware of few efforts that sampled foraging habitats randomly and thereby evaluated selection of foraging patches (i.e., third-order selection; Johnson 1980). We perceived individual wetlands in our study to be relatively homogeneous, but nonetheless we suspected that proximate cues, such as micro-topography, might have allowed shorebirds to select foraging sites that were more profitable than expected at

random. Further, previous research indicated abundance of benthic invertebrates was correlated with distributions of foraging shorebirds (Goss-Custard 1970, Colwell and Landrum 1993, Hamer et al. 2006).

Baldassarre and Fischer (1984) studied food habitats of fall-migrating shorebirds in the High Plains region of Texas, where they investigated shorebird ingesta and randomly-collected benthic samples simultaneously. They did not, however, collect benthic samples at shorebird foraging sites, so third-order selection could not be directly inferred. Further, they found only Chironomid larvae in benthic samples, excepting one or two individual Oligochaetes. Nonetheless, Baldassarre and Fisher (1984) concluded that the 9 shorebird species they studied appeared to select specific foraging sites where food was abundant. We suggest the authors presented sparse empirical evidence for this phenomenon.

Safran et al. (1997) evaluated biomass and abundance of benthic invertebrates at waterbird foraging and random locations in managed wetlands of the San Joaquin Valley, California, during January–April 1994 and 1995. Their results indicated some support for foraging-site selection for some shorebirds species. For example, Chironomid biomass was generally lower at foraging sites than random locations for Dowitchers (*Limnodromus* spp.), and Least and Western (*Calidris mauri*) sandpipers. Conversely, biomass of Oligochaetes was generally greater at foraging than random sites for the five shorebird species studied (also included American Avocet [*Recurvirostra americana*] and Dunlin [*Calidris alpine*]; Safran et al. 1997). Despite these patterns, few of the differences were statistically significant and variability about all estimates was substantial. Further, it was possible that lower biomasses identified at foraging sites could have been attributable to depletion. Finally, they suggested that the pattern of greater Oligochaete biomass at foraging locations was a ubiquitous pattern that suggested

either: 1) Oligochaetes were important and indicated high-quality foraging sites, or; 2) they were unimportant foods. They concluded that their results supported the notion that invertebrate biomass influenced foraging site selection.

Davis and Smith (1998) produced one of the most comprehensive evaluations of shorebird foraging ecology during migration. Their study included an investigation of food selection by 4 shorebirds species in relation to the abundance of those foods among and within individual wetlands in the Playa Lakes region of Texas. The authors reported that American Avocets, Long-billed Dowitchers (*Limnodromus scolopaceus*), and Least and Western sandpipers tended to use playa lakes with high invertebrate abundances in both fall and spring (Davis and Smith 1998:34). Although not relevant to specific taxa, this could be considered as support for second-order (i.e., selection of sites that constitute a home range) or third-order foraging habitat selection, depending on interpretation (Johnson 1980, Block and Brennan 1993).

Our study differed in important ways from many of the previous investigations of third-order habitat selection in shorebirds, but we believe our approach was as or more direct and comprehensive. We did observe some non-significant differences between APDM of some invertebrate taxa between random and collection-site samples and acknowledge that sample sizes may have been too low to detect differences if they existed in certain cases. For example, although not statistically different, APDM of Coleoptera was 232% greater in random samples (26.9%) than collection-site samples (8.1%) taken for Killdeer in 2008. Nonetheless, the directions of most qualitative differences were inconsistent and varied by shorebird species and year. Further, the magnitude of such differences was generally small compared to differences in APDM of diets and collection-site samples used to evaluate selection of specific diet items.

Thus, results of our analyses provided little support for third-order habitat selection at our study wetlands.

*Fourth-order Selection*—In contrast to studies of third-order foraging habitat selection in shorebirds, several studies have evaluated selection of diet items at collection sites (i.e., fourth-order selection). Weber and Haig (1997) collected Short-billed Dowitchers (*Limnodromus griseus*) and Lesser Yellowlegs during April in impounded wetlands in South Carolina. The authors concluded that the nerid polychaete *Laeonereis culveri* was the most important diet item and recommended management techniques to promote abundance of nerid polychaetes. However, no samples were taken at collection sites and ingesta were not preserved for  $\geq 30$  minutes after collection, thereby leaving only hard invertebrate parts; thus, inference from their results was severely limited.

More recently, Eldridge et al. (2009) evaluated feeding ecology of arctic-nesting sandpipers during spring migration in North Dakota by collecting foraging shorebirds and extracting core samples at collection sites. However, they summarized data as aggregate percent-frequency (rather than APDM), which ignores contribution of diet items relative to their size. Further, they only evaluated fourth-order selection for Diptera larva, pupa, and adults, which received essentially no support.

The aforementioned monograph by Davis and Smith (1998) also evaluated selection of invertebrate foods within individual playa lakes in Texas for 4 shorebirds species. They reported that differences in food selection among playas existed, but that all 4 species tended to select the most abundant invertebrate food more than expected or in proportion to its availability within each playa. Thus, the authors concluded that shorebirds foraged opportunistically, which we interpret as lacking support for strong fourth-order selection.



Andrei et al. (2009) conducted an intensive study of migrating Least sandpipers, American Avocets, Wilson's Phalaropes (*Phalaropus tricolor*), and Lesser Yellowlegs during spring and summer/fall in Saline Lakes of the Southern Great Plains. The authors collected foraging shorebirds and core samples at collection sites and compared APDM of prey in diet and availability samples for each species; hence, their approach was essentially the same as ours. As with other studies, Andrei et al. (2009) reported that the 4 shorebird species they studied generally selected invertebrate foods in proportion to availability in either season, suggesting little evidence for fourth-order selection overall. However, some shorebird species did select a few diet items more or less frequently than available. For example, they reported that Least sandpipers consumed fewer Ceratopogonidae but more Tipulidae (Order Diptera) than were available during fall. Our results appear to both support and contrast these findings. In our study, Least sandpipers consumed significantly more Diptera than were available, but Ceratopogonidae comprised relatively large portions of their diets in 2007 (20.7 APDM) and 2008 (14.0 APDM) when few were available in collection-site samples (Table 6). Andrei et al. (2009) noted that they collected benthic samples to a depth of 10 cm, which may have included invertebrates that were inaccessible to Least sandpipers. We suggest our 5 cm depth benthic core samples likely contained prey available to all species (Sherfy et al. 2000).

Our results provide considerable evidence for fourth-order selection of specific invertebrate prey and appear to contrast those of most other studies of food selection by migrating shorebirds. Indeed, a number of other investigations have concluded that shorebirds forage opportunistically, consuming prey in relation to their availability and with little relation to nutritional or energy value (Davis and Smith 1998, Andrei et al. 2009). Skagen and Oman (1996) reported dietary flexibility in many shorebirds of the Western Hemisphere, suggesting

that food choices were often compositional. An opportunistic approach to foraging should allow shorebirds to consume a variety of prey, which would be beneficial when foraging habitats may be highly variable, as is the case with many wetland habitats throughout North America (Skagen and Knopf 1994, Skagen and Oman 1996). Although our results indicated that the 4 shorebirds species we studied selected foraging sites opportunistically during fall, the evidence for active selection of specific diet items appears to be largely unique for shorebirds migrating through the midcontinent.

Several factors might explain selection of invertebrate taxa in our study, though none may be considered conclusive. In the past, results of shorebird diet studies were likely biased towards invertebrates with hard body parts, because soft-bodied invertebrates may continue to digest after birds have been collected and may only last a few minutes if not preserved (Dillery 1965, Swanson and Bartonek 1970, Hamer et al. 2006). Many taxa found in diet and food availability samples in our study may be considered soft bodied. If these invertebrates were consumed but not preserved prior to digestion, it is possible our analyses would indicate avoidance of these taxa. Of these, Oligochaetes were the primary soft-bodied taxa that were consumed considerably less than found in collection-site samples, which would not have been predicted if shorebirds foraged opportunistically. Other researchers have suggested that Oligochaetes may be underrepresented in waterbird diets because of their fragility and small size (Rundle 1982, Safran et al. 1997, Hamer et al. 2006). Further, it is difficult to imagine a functional reason for avoidance of Oligochaetes. For example, gross energy and crude protein of Oligochaetes is similar to or greater than that of Chironomids (Anderson and Smith 1998), which are readily consumed by many waterbird species. Although we cannot preclude the possibility that the apparent avoidance of Oligochaetes in our study was a function of methodology, we do

not believe this was the case. First, we were aware of potential post-mortem digestion of soft-bodied invertebrates and took painstaking steps to irrigate the upper digestive tract of each shorebird with a formalin solution as quickly as possible, often within only 1 or 2 minutes of collection. Further, Oligochaetes were common in diets (Tables 3, 5, 7, and 9) but greatly underrepresented in APDM, precluding the possibility that they were missed entirely. Thus, we suggest avoidance of Oligochaetes in our study was a real phenomenon.

Other researchers have also reported apparent avoidance or lack of consumption of Oligochaetes by shorebirds (Brooks 1967, Rundle 1982, Davis and Smith 1998, Gammonley and Laubhan 2002, Mitchell and Grubaugh 2005) and other waterbirds (Smith 2007), despite the fact they are often the most abundant taxa in benthic substrates. Thus, growing evidence that waterbirds consume Oligochaetes less than their availability begs the question: What ecological processes result in these observed diet patterns? One possibility is that shorebirds do not actively avoid Oligochaetes, but rather that Oligochaetes are able to avoid foraging shorebirds (Springett et al. 1970, Fisher and Beeton 1975), either by moving away from the forager or by avoiding detection (Gerritsen and Meijboom 1986). Predator avoidance in invertebrates is not universal; it has been demonstrated in some taxa (Kamermans and Huitema 1994, Piersma et al. 1995, Blackwell et al. 1998), but not in others (Persson and Svensson 2006). However, researchers have reported Oligochaetes have the ability to migrate in response to chemical (dissolved oxygen, Fisher and Beeton 1975) or physical (drying, Springett et al. 1970) stimuli. Thus, it seems plausible that Oligochaetes might be able to detect the presence of predators moving near them (e.g., pressure) and migrate away from the surface. Additionally, other researchers have reported that some shorebirds forage using fine sensory mechanoreceptors in their bill-tips capable of detecting small vibrations created by buried invertebrates (Gerritsen and Meijboom

1986), or through some other form of remote sensing (Piersma et al. 1995, 1998). Perhaps Oligochaetes do not produce these vibrations, or produce fewer or different frequencies of vibration, thereby making them functionally undetectable to foraging shorebirds except when encountered tactilely. Finally, Mitchell and Grubaugh (2005) reported that Oligochaetes were associated with plant roots and other organic material, perhaps making them difficult to exploit. Oligochaetes at our IRV sites appeared to be widely and relatively homogeneously distributed, although we did not specifically look for the subsurface associations discussed by Mitchell and Grubaugh (2005). We recommend targeted investigations that focus on relationships between abundance, movements, and spatial distributions of Oligochaetes and other wetland taxa in relation to shorebird foraging ecology. Such studies might be best accomplished through controlled experiments (Gerritsen and Meijboom 1986, Piersma et al. 1995, 1998).

Other than Oligochaetes, we found sparse evidence of avoidance of invertebrate foods, and those that were identified as statistically avoided typically had small APDM differences (e.g., Least sandpipers avoided Ostracods in 2007, but APDM at collection sites was only 5.5). Conversely, our results provide strong evidence for selection of Diptera (Pectoral and Least sandpipers), Coleoptera (Least sandpipers and Lesser Yellowlegs), Nematoda (Killdeer), and Hemiptera (Pectoral sandpipers and Lesser Yellowlegs). Several possible mechanisms could explain the selective foraging observed in our study, and each may have implications for conservation planning and habitat management.

Mitchell and Grubaugh (2005) reported they observed one instance of diet selection in shorebirds foraging in wetlands the lower Mississippi Alluvial Valley during late-summer. In this isolated case, it appeared that Chironomid larvae were either selected for despite not being the most abundant taxa. Although the authors did not have information on shorebird diets, this

result was similar to our overall findings of diet selection. The authors posited that shorebirds at their study sites either actively selected Chironomids, or the cost of consuming prey was not equal among taxa and that foraging was opportunistic with respect to this constraint.

Optimal diet theory generally predicts that absolute abundance of potential food items (controlling for handling time; i.e., equal availability of different food types) influences dietary specialization (Schoener 1971, Estabrook and Dunham 1976). Specifically, as total food abundance increases, foragers should increase selectivity to where, eventually, only one prey type might be consumed even if all were equally available. Of course, as the previous discussion of Oligochaete avoidance indicates, it is possible that not all prey in our study were equally available. Nonetheless, we speculate that absolute abundance of invertebrate foods at our study sites may explain the prey selection we observed.

Other studies have reported that the availability of benthic invertebrates (dry biomass) varies dramatically between wetland systems and seasons. Davis and Smith (1998) estimated total invertebrate biomass of playa lakes used by foraging shorebirds averaged 9.2 kg/ha (dry mass). Similarly, Gammonley and Laubhan (2002) estimated 9.0 kg/ha (dry mass) of invertebrates in shallow open areas of a wetland complex in southern Colorado. Taft and Haig estimated 1.8–4.2 kg/ha (dry mass) of invertebrate prey for wintering Dunlin and Killdeer in the Willamette Valley of Oregon. Hamer (2004) estimated weekly invertebrate biomass (dry) in shorebird foraging areas ranged from 5 to 53 kg/ha in IRV wetlands during late-March through mid-June. We acknowledge these estimates cannot be considered representative of all foraging habitat for migrating shorebirds. Nonetheless, our overall estimate of invertebrate prey biomass (51.2 kg/ha) for our study area appears exceptionally high compared to other studies, some of which collected core samples that were twice as deep as ours (i.e., 10 cm vs. 5 cm). Therefore,

we suggest that the abundant food resources found at our study sites could explain the diet selectivity we observed.

Although estimated invertebrate biomass during our study was considerably greater (e.g., by as much as an order of magnitude) than many previous investigations, other wetland studies in the Upper Mississippi River region have documented similar densities. Flinn et al. (2008) reported estimated macroinvertebrate biomass in July 2003 was ~60 kg/ha (dry mass; interpreted from a figure) on an area of Pool 25 of the Mississippi River that was managed for moist-soil vegetation. Similarly, D. Grulkowski (Southern Illinois University, unpublished data) reported invertebrate biomass during spring at Swan Lake, a managed IRV backwater wetland near the confluence of the Illinois and Mississippi Rivers, was 45.3 kg/ha (dry mass) in 2004 and 64.9 kg/ha (dry mass) in 2005. Thus, it seems plausible that bottomland wetlands associated with riverine systems, at least partly a function of natural and managed hydrologic cycling, may be especially productive with respect to benthic invertebrates and, therefore, particularly valuable to migratory waterbirds.

Results of fat scoring and SCBM also support the notion that IRV provided high-quality foraging habitats for shorebirds, given that Killdeer, Least and Pectoral sandpipers, and Lesser Yellowlegs were in good to excellent body condition during our study. Mass of Killdeer varies considerably (65–121g, Jackson and Jackson 2000, O'Brien et al. 2006), but our 2007 and 2008 SCBM estimates (Table 1) fell within the reported range. SCBM of Least sandpipers collected in 2007 and 2008 (Table 1) fell near the upper range of body mass reported by Cooper (1994; 19–30g). Lesser Yellowlegs' SCBM (Table 1) in both years was considerably greater than average masses reported by Tibbitts and Moskoff (1999; 67–94g). We attribute this body mass difference to a thick fat layer present in most birds. Using the MAPS method to score body fat

(comparative scale of 1 to 7; 1 = no fat and 7 = obese, DeSante et al. 2008), many ( $n = 18$ , 54.5%) Lesser Yellowlegs scored 6 or 7. Thus, we conclude that Lesser Yellowlegs were in good to excellent body condition at our study site. Pectoral sandpiper SCBM (Table 1) in 2007 and 2008 also fell within the reported range of body masses (50–105g, Holmes and Pitelka 1998). All collected shorebird SCBM estimates were within reported ranges, except Lesser Yellowlegs, whose values were greater than reported ranges.

We cannot ascertain if shorebirds acquired fat resources at our study wetlands or arrived with them, which would have been somewhat dependent on the time they had spent at our study site. Thomas (2008) reported that Least and Pectoral sandpipers arrived at stopover locations with excess fat stores, and fat stores and body condition were not a significant predictor of stopover duration. We did not evaluate stopover duration of shorebirds in our study, but suggest that high food abundance, coupled with the fact that some shorebird species can increase body mass by 70% or more at migratory stopovers (Atkinson et al. 2006), supports the notion that fat stores were gained at our study wetlands. Since fat stores acquired before migration can have a pronounced impact on survival (Morrison et al. 2007), fat acquisition at our study area would be indicative of high-quality foraging habitat.

Killdeer and Pectoral sandpiper SCBM differed between years. Differences in habitat conditions between years at our study sites could account for this, but it is difficult to draw strong conclusions since SCBM was higher for Killdeer in 2007 and Pectoral sandpiper in 2008. The duration of spring flooding associated with the Illinois River was greater in 2008 than in 2007. Floodwaters were receding as shorebirds arrived during fall migration (2008), and only the most protected wetlands (e.g., impoundments) were dewatered during our collection period. Throughout the study, Killdeer were often found in relatively dry, firm substrate microhabitats

that had been exposed for longer periods of time than the flocculent substrate found at the water edge. In 2007, floodwaters receded in May and remained low throughout summer; thus, large expanses of wetland substrate were dewatered and drying. Perhaps the drier conditions of 2007 favored Killdeer, whereas the wetter conditions of 2008 favored Pectoral sandpipers.

We did not specifically address prey depletion during our study, but several other authors have suggested shorebird foraging can reduce prey abundance over the course of migration. Schneider and Harrington (1981) reported prey densities were reduced 7–90% by Charadriid shorebirds at intertidal wetlands in Massachusetts during fall. Hamer et al. (2006) used enclosures to evaluate shorebird predation in the Illinois River valley and reported shorebird foraging reduced Oligochaete, but not Chironomid, densities during Spring. Davis and Smith (1998) reported potential depletion of shorebird prey items in playa lakes during one spring, but found sparse evidence for depletion during fall. Although we found sparse evidence for selection of specific foraging sites during our study, it is possible those quantitative and qualitative differences in APDM between foraging and random sites were due to depletion. However, the relative abundance of shorebird prey items and high body condition of birds in our study suggest that adequate fuel was acquired quickly before birds moved on (e.g., a short-hop strategy; Farmer and Wiens 1999, Hamer et al. 2006), and depletion was not significant. Regardless, understanding depletion and renewal of invertebrate prey items for migratory waterbirds is important to understanding foraging carrying capacity in space and time. We suggest the uncertain nature of invertebrate depletion by migrant shorebirds supports the need for intensive studies, and may benefit from an experimental approach using captive shorebirds under a variety of controllable scenarios (e.g., prey abundance, body condition).



## **Conservation and Management Implications**

A primary goal of the JV Shorebird Habitat Conservation Strategy is to maintain adequate landscape carrying capacity to support migrating shorebirds and meet regional population objectives, which are based on proportions of species-specific objectives under the continental shorebird plan (Potter et al. 2007:24). To meet these goals, habitat objectives must be met in target areas relative to population estimates. Most continental and regional estimates of shorebird population sizes are tenuous; therefore, it is difficult to provide precise and targeted recommendations regarding habitat availability and abundance. Despite these uncertainties, functional habitat is essential to support migrating shorebirds in mid-continent areas. We suggest our results of relatively high invertebrate biomass, diet selectivity, and generally good to excellent body condition demonstrate that when shorebird foraging habitat is available in the IRV (and perhaps other bottomland wetlands in the region) it is not only functional, but likely of high quality.

Safran et al. (1997) proposed that suitable water level may be a more important determinant of foraging habitat selection by shorebirds than food abundance or availability of specific foods. To this end, typical wetland management practices in the IRV (i.e., moist-soil management) yield water levels that provide extensive foraging habitat for migrating shorebirds. Because most wetlands in the region are managed for waterfowl hunting, they are usually dewatered annually during mid-summer. Our research concurs with the body of literature that suggests these draw-downs often provide expansive mud flats for foraging shorebirds (Rundle and Fredrickson 1981, Fredrickson and Taylor 1982, Hands et al. 1991), even though management for shorebirds is not likely a goal of private or even public land managers. However, abundance and availability of shorebird foraging habitat in the IRV can be incredibly

variable due to the dynamic and altered hydrology of the Illinois River (Bellrose et al. 1983, Havera 1999). Indeed, foraging habitat may vary within a season from >20 large (e.g., >100 ha) dewatered wetland basins in La Grange Pool with expansive mudflats to virtually zero in a matter of weeks or days. Such expansive flooding during late-spring through summer prevents managers from dewatering wetlands which effectively eliminates all shorebird foraging habitats in the IRV. Thus, the current hydrology of the Illinois River frequently results in an “all or nothing” scenario for shorebird foraging habitat.

Despite the fact that most wetland managers have the capability to dewater wetlands annually, few sites in La Grange Pool of the IRV have sufficient protective levees to abate intense floods. Additionally, site-specific management goals (e.g., control of woody vegetation) occasionally limit otherwise high quality habitat. These wide inter-annual fluctuations in habitat availability are of concern, as shorebirds have few mid-continent options for migration habitat (Thomas 2008). Therefore, we recommend conservation planning efforts for shorebirds consider the dynamic nature of important shorebird foraging habitats in the mid-continent and consider appropriate management options, such as acquisition or protection of alternate and compensatory habitats when traditional high-value habitats are not available.

Spatially clustered wetlands that form complexes, similar to those in the IRV, may be perceived by migrating shorebirds as single, large wetlands (Farmer and Parent 1997), thereby increasing their attractiveness over individual wetlands (Taft and Haig 2006). Most shorebird studies have been conducted on public lands, but our study included several private wetlands that were in close proximity to publicly-managed sites of known importance to migrating shorebirds. It is likely that some, or even most, of these private wetlands have not been surveyed for shorebirds in decades, if ever (e.g., Grand Island). Although we did not record shorebird

abundances, it was clear that substantial numbers of shorebirds used private wetlands in our study area, which may indicate that shorebird use in the region during fall migration is greater than previously believed. Furthermore, population deficits during migration have been identified for Killdeer, Lesser Yellowlegs, and Least sandpipers in the JV region (Potter et al. 2007), and significant numbers of each of these species were present at our study wetlands. We speculate that at least some of this deficit may be due to a lack of survey data for, or access to, lesser-known staging areas. Therefore, we recommend intensive surveys of migrating shorebirds in understudied areas be conducted in the JV region. Such an endeavor would provide critical information to refine, and perhaps even reduce, population and habitat objectives.

Our results indicated that foraging shorebirds appeared to avoid Oligochaetes. This result is not novel (Rundle 1982, Davis and Smith 1998, Mitchell and Grubaugh 2005), but also not unequivocal. Oligochaetes were the most common invertebrate encountered in benthic cores, and represented the largest individual invertebrate proportion of available biomass. If Oligochaetes are truly avoided or unavailable to migrating shorebirds, they should not be considered in estimates of forage biomass. In this scenario, our overall biomass estimate would be reduced by 51% to 25.0 kg/ha. We note, however, that each of our 4 focal shorebird species consumed Oligochaetes in at least 1 year (Tables 4, 6, 8, and 10), indicating that, although not preferred, foraging shorebirds will at least occasionally consume this common invertebrate. Further, other researchers have reported Oligochaetes in shorebird diets (Hamer et al. 2006, Eldridge et al. 2009) or that they were considered important shorebird foods (Taft and Haig 2005, 2006). Thus, it is likely not appropriate to dismiss Oligochaetes as food items, but research to understand the relationship between Oligochaete abundance, distribution (including

vertical), microhabitat associations, behavior, and shorebird foraging is needed to understand food availability and, hence, carrying capacity for migrating shorebirds.

Our biomass estimates originated from backwater wetlands of a large inland river system in the Midwestern United States, and our study wetlands had similar management strategies and histories. Thus, it may be inappropriate to apply our estimates of invertebrate biomass to other regions or drastically different aquatic systems. Conversely, similar estimates exist for backwater wetlands of the Illinois and Mississippi River systems south of our study region (Flinn et al. 2008, D. Grulkowski, Southern Illinois University, unpublished data). Thus, we believe our estimate of invertebrate biomass is appropriate to be incorporated into shorebird conservation plans for the Illinois River region and may be applicable to shorebird foraging habitats associated with large river systems (e.g., Mississippi and Wabash Rivers) in other parts of the JV region.

### **Literature Cited**

- Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radio tracking data. *Ecology* 74:1313–1325.
- Afton, A. D., R. H. Hier, and S. L. Paulus. 1991. Lesser scaup diets during migration and winter in the Mississippi Flyway. *Canadian Journal of Zoology* 69:328–333.
- Anderson, J. T., and L. M. Smith. 1998. Protein and energy production in playas: implications for migratory bird management. *Wetlands* 18:437–446.
- Andrei, A. E., L. M. Smith, D. A. Haukos, J. G. Surles, and W. P. Johnson. 2009. Foraging ecology of migrant shorebirds in saline lakes of the southern Great Plains. *Waterbirds* 32:138–148.

- Anteau, M., and A. Afton. 2004. Nutrient reserves of Lesser Scaup (*Aythya affinis*) during spring migration in the Mississippi flyway: a test of the spring condition hypothesis. *Auk* 121:917–929.
- Atkinson, P. W., Baker, A. J., Bennett, K. A., Clark, N. A., Clark, J. A., Cole, K. B., Dey, A., Duiven, A. G., Gillings, S., González, P. M., Harrington, B. A., Kalasz, K., Minton, C. D. T., Newton, J., Niles, L. J., Robinson, R. A., de Lima Serrano, I., and Sitters, H. P. 2006. Using stable isotope ratios to unravel shorebird migration and population mixing: a case study with Red Knot *Calidris canutus* in Waterbirds around the world. G.C. Boere, C.A. Galbraith & D.A. Stroud, editors. The Stationery Office, Edinburgh, UK. pp. 535–540.
- Badzinski, S. S. and S. A. Petrie. 2006. Diets of lesser and greater scaup during autumn and spring on the lower great lakes. *Wildlife Society Bulletin* 34:664–674.
- Bailey, S. D. 2003. Lake Chautauqua and counting shorebirds. *Meadowlark* 12:54.
- Baker, M. C. 1977. Shorebird food habits in the eastern Canadian Arctic. *Condor* 79:56–62.
- Baker, M. C., and A. E. Baker. 1973. Niche relationships among six species of shorebirds on their wintering and breeding ranges. *Ecological Monographs* 43:193–212.
- Baldassarre, G. A., and D. H. Fischer. 1984. Food habits of fall migrant shorebirds on the Texas High Plains. *Journal of Field Ornithology* 55:220–229.
- Bellrose, F. C., S. P. Havera, F. L. Paveglio Jr., and D. W. Steffeck. 1983. The fate of lakes in the Illinois River valley. Illinois Natural History Survey, Biological Notes 119. Champaign, IL, USA.
- Bingham, R. L., and L. A. Brennan. 2004. Comparison of Type I error rates for statistical analyses of resource selection. *Journal of Wildlife Management* 68:206–212.

- Blackwell, P. R. Y., P. D. O'Hara, and J. H. Christy. 1998. Prey availability and selective foraging in shorebirds. *Animal Behavior* 55:1659–1667.
- Block, W. M., and L. A. Brennan. 1993. The habitat concept in ornithology. Pages 35–91 in *Current Ornithology*, D. M. Power, editor. *Current Ornithology*, Volume 11. Plenum Press, New York, USA.
- Brooks, W. S. 1967. Food and feeding habits of autumn migrant shorebirds at a small Midwestern pond. *Wilson Bulletin* 79:309–315.
- Brown, S., C. Hickey, B. Harrington, and R. Gill, editors. 2001. The U.S. shorebird conservation plan. Second edition. Manomet Center for Conservation Sciences, Manomet, Massachusetts, USA.
- Colwell, M. A., and S. L. Landrum. 1993. Nonrandom shorebird distribution and fine-scale variation in prey abundance. *Condor* 95:94–103.
- Cooper, J. 1994. Least Sandpiper (*Calidris minutilla*), *The Birds of North America Online* (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online:  
<http://bna.birds.cornell.edu.proxy2.library.uiuc.edu/bna/species/115doi:bna.115>
- Davis, C. A., and L. M. Smith. 1998. Ecology and management of migrant shorebirds in the Playa Lakes region of Texas. *Wildlife Monographs* No. 140. 45pp.
- DeSante, D., K. Burton, P. Velez, D. Froehlich, and D. Kaschube. 2008. Instructions for the establishment and operation of constant-effort bird-banding stations as part of the monitoring avian productivity and survivorship (MAPS) program. Retrieved from; The Institute for Bird Populations.  
<http://www.birdpop.org/DownloadDocuments/manual/MAPSManual08.pdf>

- de Szalay, F., D. Helmers, D. Humburg, S. J. Lewis, B. Pardo, and M. Sheildcastle. 2000. Upper Mississippi Valley/Great Lakes Regional Shorebird Conservation Plan: Version 1.0. U.S. Shorebird Conservation Plan, 31 pp.
- Dillery, D. G. 1965. Post-mortem digestion of stomach contents of savannah sparrow. *Auk* 82:281.
- Eldridge, J. L., G. L. Krapu, and D. H. Johnson. 2009. Feeding ecology of arctic-nesting sandpipers during spring migration through the Prairie Pothole Region. *Journal of Wildlife Management* 73:248–252.
- Estabrook, G. F., and A. E. Dunham. 1976. Optimal diet as a function of absolute abundance, relative abundance, and relative value of available prey. *American Naturalist* 110:101–413.
- Farmer, A. H., and A. H. Parent. 1997. Effects of the landscape on shorebird movements at spring migration stopovers. *Condor* 99:698–707.
- 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.
- Fisher, J. A., and A. M. Beeton. 1975. The effect of dissolved oxygen on the burrowing behavior of *Limnodrilus hoffmeisteri* (Oligochaeta). *Hydrobiologia*. 47:273–290.
- Flinn, M. B., S. R. Adams, M. R. Whiles, and J. E. Garvey. 2008. Biological responses to contrasting hydrology in backwaters of the Upper Mississippi River Navigation Pool 25. *Environmental Management* 41:468–486.
- Fredrickson, L. H. and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. United States Department of the Interior, Fish and Wildlife Service Resource Publication 148. Washington, District of Columbia, USA.

- Gammonley, J. H., and M. K. Laubhan. 2002. Patterns of food abundance for breeding waterbirds in the San Luis valley of Colorado. *Wetlands* 22:499–508.
- Gerritsen, A. F. C., and A. Meijboom. 1986. The role of touch in prey density estimation by *Calidris alba*. *Netherlands Journal of Zoology*. 36:530–562.
- Goss-Custard, J. D. 1969. The winter feeding ecology of the Redshank (*Tringa tetanus*). *Ibis* 111:338–356.
- Goss-Custard, J. D. 1970. The responses of redshank (*Tringa tetanus* (L.)) to spatial variation in the density of their prey. *Journal of Animal Ecology* 39:91–113.
- Gratto-Trevor, C. L., V. H. Johnston, and S. T. Pepper. 1998. Changes in shorebird and eider abundance in the Rasmussen Lowlands, NWT. *Wilson Bulletin* 110:316–325.
- Guthery, F. S. 1999. Energy-based carrying capacity for quails. *Journal of Wildlife Management* 63:664–674.
- Hamer, G. L. 2004. Migrant shorebird ecology in the Illinois River valley. M.S. Thesis, University of Illinois, Urbana-Champaign, USA.
- 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. *The Wilson Journal of Ornithology* 118:152–163.
- Hands, H. M., M. R. Ryan, and J. W. Smith. 1991. Migrant shorebird use of marsh, moist-soil, and flooded agricultural habitats. *Wildlife Society Bulletin* 19:457–464.
- Havera, S. P. and F. C. Bellrose. 1984. The Illinois River: a lesson to be learned. *Wetlands* 4:29–41.
- Havera, S. P. 1999. Waterfowl of Illinois: status and management. *Illinois Natural History Survey Special Publication* 21. Champaign, IL, USA.



- Holmes, R.T., and F.A. Pitelka. 1998. Pectoral Sandpiper (*Calidris melanotos*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online:  
<http://bna.birds.cornell.edu.proxy2.library.uiuc.edu/bna/species/348doi:bna.348>
- Jackson, B. J., and J. A. Jackson. 2000. Killdeer (*Charadrius vociferus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online:  
<http://bna.birds.cornell.edu.proxy2.library.uiuc.edu/bna/species/517doi:bna.517>
- Johnson, D. H. 1980. The comparison of useage and availability measurements for evaluating resource preference. *Ecology* 61:65–71.
- Kamermans, P., and H. Huitema. 1994. Shrimp (*Crangon crangon* L.) browsing upon siphon tips inhibits feeding and growth in the bivalve *Macoma balthica* (L.). *Journal of Experimental Marine Biology and Ecology*. 175 59–75.
- Lack, D. 1954. The natural regulation of animal numbers. Clarendon Press, Oxford, U.K.
- Merritt, R. W. and K. W. Cummins. eds. 1996. An introduction to the aquatic insects of North America. Kendal/Hunt, Dubuque, IA, USA.
- 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., R. E. Gill, Jr., B. A. Harrington, S. Skagen, G. W. Page, C. L. Gratto-Trevor, and S. M. Haig. 2000. Population estimates of Nearctic shorebirds. *Waterbirds* 23:337–352.

- Morrison, R. I. G., N. C. Davidson, and J. R. Wilson. 2007. Survival of the fittest: body stores on migration and survival in red knots *Calidris canutus islandica*. *Journal of Avian Biology* 38:479–487.
- O'Brien, M., R. Crossley, and K. Karlson. 2006. *The Shorebird Guide*. Houghton Mifflin Company. New York, New York, USA.
- Oring, L., B. Harrington, S. Brown, and C. Hickey, eds. 2000. *National Shorebird Research Needs: A Proposal for a National Research Program and Example High Priority Research Topics*. Manomet Center for Conservation Sciences.  
<http://www.manomet.org/USSCP/files.htm>.
- Persson, A., and J. M. Svensson. 2006. Vertical distribution of benthic community responses to fish predators, and effects of algae and suspended material. *Aquatic Ecology* 40:85–95.
- Piersma, T., J. Van Gils, P. De Goeij, and J. Van Der Meer. 1995. Holling's functional response model as a tool to link the food-finding mechanism of a probing shorebird with its spatial distribution. *Journal of Animal Ecology* 64: 493–504.
- Piersma, T., R. van Aelst, K. Kurk, H. Berkhoudt, and L. R. M. Maas. 1998. A new pressure sensory mechanism for prey detection in birds: the use of principles of seabed dynamics? *Proceedings of the Royal Society B* 265:1377–1383
- Placyk, J. S. Jr., and B. A. Harrington. 2004. Prey abundance and habitat use by 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. 101pp.

- Ross, R. K., S. A. Petrie, S. S. Badzinski, and A. D. Mullie. 2005. Autumn diet of greater scaup, lesser scaup, and long-tailed ducks on eastern Lake Ontario prior to zebra mussel invasion. *Wildlife Society Bulletin* 33:81–91.
- Rundle, W. D. and L. F. Fredrickson. 1981. Managing seasonally flooded impoundments for migrant rails and shorebirds. *Wildlife Society Bulletin* 9:80–87.
- Rundle, W. D. 1982. A case for esophageal analysis in shorebird food studies. *Journal of Field Ornithology* 53:249–257.
- Russell, R. 2003. An initial estimate of Illinois shorebird numbers and implications for management. *Meadowlark* 12:42-45.
- SAS Institute. 2004. SAS/STAT 9.1 User's Guide. SAS Institute Inc., Cary, North Carolina.
- Safran, R. J., C. R. Isola, M. A. Colwell, and O. E. Williams. 1997. Benthic invertebrates at foraging locations of nine waterbird species in managed wetlands of the northern San Joaquin valley, California. *Wetlands* 17:407–415.
- Schneider, D. C., and B. A. Harrington. 1981. Timing of shorebird migration in relation to prey depletion. *Auk* 98:801–811.
- Schoener, T. W. 1971. Theory of feeding strategies. *Annual Review of Ecology and Systematics* 2:369–404.
- Sherfy, M. H., R. L. Kirkpatrick, and K. D. Richkus. 2000. Benthos core sampling and chironomid vertical distribution: implications for assessing shorebird food availability. *Wildlife Society Bulletin* 28:124–130.
- Skagen, S. K, and F. L. Knopf. 1994. Residency patterns of migrating sandpipers at a midcontinental stopover. *Condor* 96:949–958.

- Skagen, S. K., and H. D. Oman. 1996. Dietary flexibility of shorebirds in the western hemisphere. *Canadian Field-Naturalist* 110:419–444.
- Smith, D. G. 2001. Pennak's Freshwater Invertebrates of the United States, 4th Edition, Porifera to Crustacea. John-Wiley and Sons, Inc. New York, USA.
- Smith, R. V. 2007. Evaluation of waterfowl habitat and spring food selection by mallard and lesser scaup on the Swan Lake, Illinois habitat rehabilitation and enhancement project. M.S. Thesis. Southern Illinois University, Carbondale, USA.
- Springett, J. A., J. E. Brittain, and B. P. Springett. 1970. Vertical movement of Enchytraeidae (Oligochaeta) in moorland soils. *Oikos* 21:16–21.
- Swanson, G. A., and J. C. Bartonek. 1970. Bias associated with food analysis in gizzards of blue-winged teal. *Journal of Wildlife Management* 34:739–746.
- Swanson, G. A., G. L. Krapu, J. C. Bartonek, J. R. Serie, and D. H. Johnson. 1974. Advantages in mathematically weighting waterfowl food habits data. *Journal of Wildlife Management* 38:302–307.
- Taft, O. W., and S. M. Haig. 2005. The value of agricultural wetlands as invertebrate resources for wintering shorebirds. *Agriculture, Ecosystems and Environment* 110:249–256.
- Taft, O. W., and S. M. Haig. 2006. Landscape context mediates influence of local food abundance on wetland use by wintering shorebirds in an agricultural valley. *Biological Conservation* 128:298–307.
- Thomas, N. E. 2008. Shorebirds and wetlands in the Prairie Pothole Region: migration ecology and physiology. Ph.D. Dissertation. University of South Dakota, Vermillion, USA.
- Tibbitts, T., and W. Moskoff. 1999. Lesser Yellowlegs (*Tringa flavipes*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the

Birds of North America Online:

<http://bna.birds.cornell.edu.proxy2.library.uiuc.edu/bna/species/427doi:bna.427>

U.S. Fish and Wildlife Service. 1998. Upper Mississippi River and Great Lakes Region Joint

Venture of the NAWMP, 1998 Implementation Plan. USFWS, Fort Snelling, MN.

U.S. Army Corps of Engineers. 2004. Draft of Illinois River Basin restoration feasibility report and comprehensive plan.

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* 68:358–366.

Figure 1. Map depicting our study area within La Grange Pool (dotted line) of the Illinois River in central Illinois, and specific study wetlands (labeled).

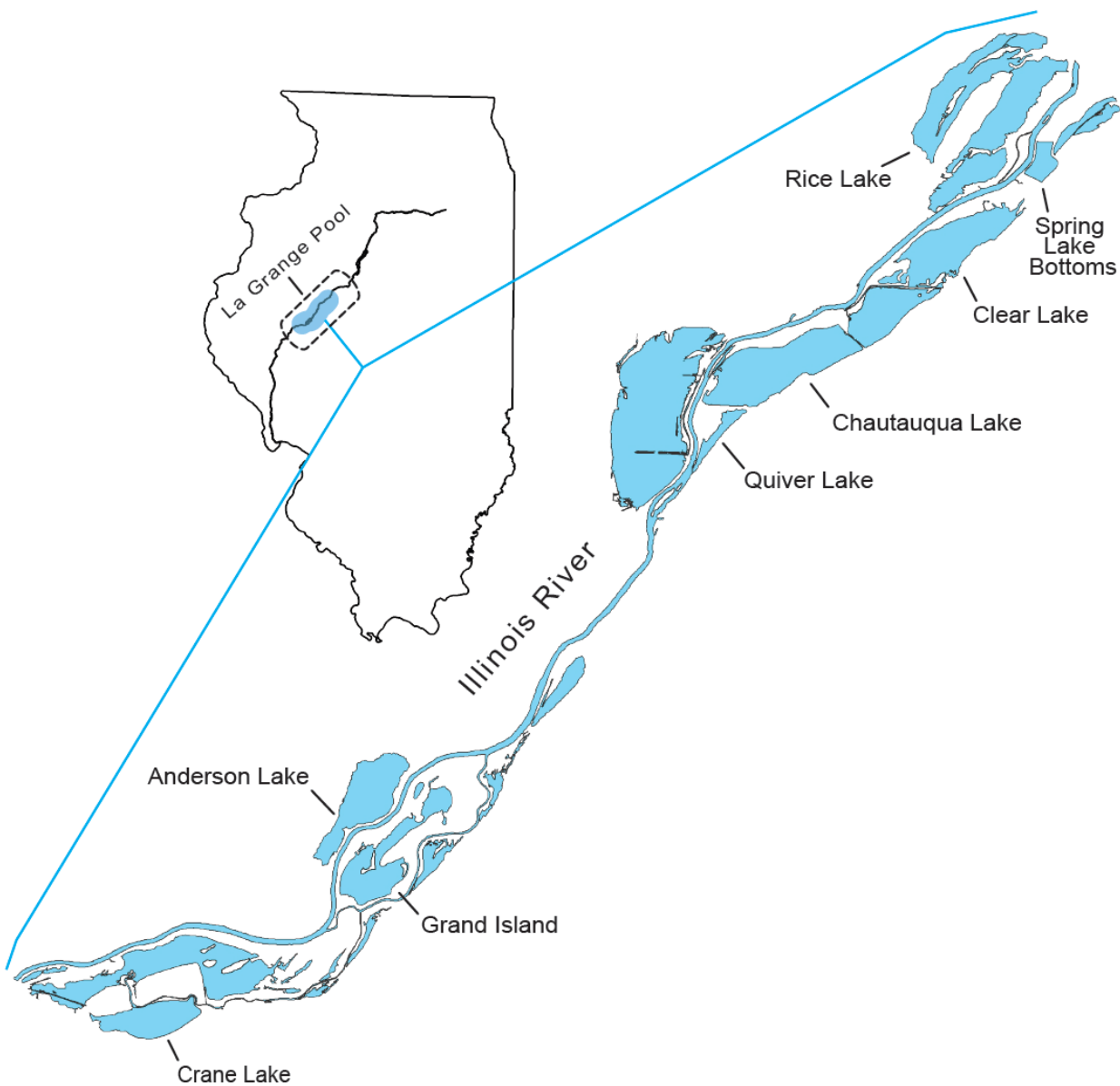


Table 1. Number of Killdeer (KILL), Least sandpipers (LESA), Lesser Yellowlegs (LEYE), and Pectoral sandpipers (PESA) collected and included in analyses of size-corrected body mass by site, year, and species.

Study Site	2007					2008				
	KILL	LESA	LEYE	PESA	Total	KILL	LESA	LEYE	PESA	Total
Anderson Lake	.	.	.	.	.	2	6	4	25	37
Chautauqua Lake	12	16	24	29	81	.	.	.	.	.
Clear Lake	5	0	3	6	14	7	13	12	0	32
Crane Lake	.	.	.	.	.	7	2	1	7	17
Grand Island	15	14	12	4	45	0	0	15	4	19
Quiver Lake	3	6	0	0	9	.	.	.	.	.
Rice Lake	.	.	.	.	.	6	5	0	0	11
Spring Lake	.	.	.	.	.	12	3	0	0	15
Total	35	36	39	39	149	34	29	32	36	131

Table 2. Size-corrected body mass (SCBM; grams), standard error (SE), and 95% confidence limits (LCL and UCL) of shorebirds collected in central IL during fall migrations 2007 and 2008.

Species	SCBM	SE	LCL	UCL
2007				
Killdeer	92.5	1.0	90.5	94.5
Least sandpiper	27.0	0.6	25.8	28.2
Lesser Yellowlegs	113.3	3.4	106.4	130.1
Pectoral sandpiper	91.5	2.2	87.1	96.0
2008				
Killdeer	88.6	0.9	86.7	90.4
Least sandpiper	28.4	0.9	26.5	30.2
Lesser Yellowlegs	112.2	3.5	105.1	119.3
Pectoral sandpiper	102.9	2.5	97.9	107.9



Table 3. Percent occurrence of diet items found in fall migrating Killdeer ingesta and core samples taken at collection and random sites in 2007 ( $n = 27$ ) and 2008 ( $n = 18$ ).

Taxa	2007			2008		
	Diet	Collection	Random	Diet	Collection	Random
<b>Amphipoda</b>	.	.	.	0.0	5.6	0.0
<b>Bivalvia</b>	0.0	10.0	16.7	0.0	0.0	5.6
Sphaeriidae	0.0	10.0	16.7	.	.	.
<b>Cladocera</b>	.	.	.	0.0	16.7	0.0
<b>Coleoptera</b>	36.7	23.3	53.3	16.7	38.9	11.1
Carabidae	0.0	6.7	0.0	.	.	.
Chrysomelidae	0.0	3.3	0.0	.	.	.
Curculionidae	6.7	0.0	3.3	.	.	.
Dytiscidae	.	.	.	0.0	5.6	0.0
Elmidae	0.0	3.3	13.3	.	.	.
Haliplidae	0.0	3.3	0.0	.	.	.
Heteroceridae	16.7	3.3	6.7	16.7	5.6	22.2
Hydrophilidae	13.3	6.7	33.3	0.0	22.2	22.2
Staphylinidae	0.0	3.3	13.3	0.0	5.6	5.6
<b>Diptera</b>	36.7	96.7	66.7	22.2	88.9	83.3
Ceratopogonidae	6.7	46.7	43.3	0.0	27.8	5.6
Chironomidae	16.7	46.7	26.7	11.1	44.4	44.4
Dolichopodidae	6.7	40.0	16.7	0.0	22.2	5.6
Empididae	10.0	13.3	0.0	0.0	5.6	0.0
Ephydriidae	0.0	3.3	6.7	0.0	11.1	0.0
Muscidae	0.0	0.0	3.3	0.0	5.6	0.0
Nymphomyiidae	0.0	3.3	0.0	.	.	.
Sciomyzidae	0.0	6.7	3.3	0.0	11.1	11.1
Stratiomyidae	.	.	.	11.1	5.6	5.6
Tabanidae	.	.	.	0.0	5.6	0.0
Tipulidae	0.0	3.3	0.0	.	.	.
<b>Ephemeroptera</b>	0.0	3.3	0.0	.	.	.
Baetidae	0.0	3.3	0.0	.	.	.
<b>Fish</b>	.	.	.	0.0	0.0	5.6
<i>Gambusia spp.</i>	.	.	.	0.0	0.0	5.6
<b>Gastropoda</b>	0.0	10.0	33.3	0.0	33.3	5.6
Lymnaeidae	.	.	.	0.0	5.6	5.6
Physidae	0.0	6.7	23.3	0.0	22.2	38.9
Planorbidae	0.0	3.3	13.3	0.0	11.1	16.7
<b>Hemiptera</b>	16.7	30.0	10.0	0.0	5.6	16.7
Corixidae	16.7	30.0	10.0	0.0	5.6	5.6
<b>Hirudinea</b>	6.7	10.0	13.3	16.7	0.0	5.6
Glossiphonidae	6.7	10.0	13.3	16.7	0.0	11.1
<b>Isopoda</b>	0.0	10.0	0.0	0.0	5.6	11.1

Table 3. Continued.

Taxa	2007			2008		
	Diet	Collection	Random	Diet	Collection	Random
<b>Nematoda</b>	66.7	76.7	60.0	55.6	50.0	50.0
<b>Odonata</b>	0.0	0.0	3.3	.	.	.
Anisoptera	0.0	0.0	3.3	.	.	.
<b>Oligochaeta</b>	6.7	100.0	100.0	11.1	100.0	94.4
<b>Ostracoda</b>	16.7	40.0	6.7	5.6	11.1	5.6
<b>Trichoptera</b>	6.7	6.7	6.7	0.0	11.1	0.0
Leptocerid	6.7	6.7	6.7	0.0	11.1	5.6
<b>Unknown</b>	30.0	16.7	20.0	0.0	11.1	5.6

Table 4. Aggregate percent mass (dry) of diet items found in fall migrating Killdeer ingesta and core samples taken at collection and random sites in 2007 ( $n = 27$ ) and 2008 ( $n = 18$ ). Values with different letters within Taxa Orders (rows) indicate significant differences of least-squares means (Tukey-Kramer test:  $P \leq 0.05$ ).

Taxa	2007						2008					
	Diet		Collection		Random		Diet		Collection		Random	
<b>Amphipoda</b>	.		.		.		0.0	A	0.3	A	0.0	A
<b>Bivalvia</b>	0.0	A	0.7	A	4.9	A	.		.		.	
Sphaeriidae	0.0		0.7		4.9		.		.		.	
<b>Cladocera</b>	.		.		.		0.0	A	2.0	A	0.0	A
<b>Coleoptera</b>	33.0	A	3.5	B	10.3	B	16.7	A	8.1	A	26.9	A
Carabidae	0.0		1.4		0.0		.		.		.	
Chrysomelidae	0.0		0.4		0.0		.		.		.	
Curculionidae	4.3		0.0		0.0		.		.		.	
Dytiscidae	.		.		.		0.0		0.7		0.0	
Elmidae	0.0		0.0		2.0		.		.		.	
Heteroceridae	16.8		0.0		1.5		16.7		1.9		20.0	
Hydrophilidae	12.0		1.5		6.8		0.0		2.8		6.9	
Staphylinidae	0.0		0.1		0.0		0.0		2.7		0.0	
<b>Diptera</b>	24.7	A	15.1	A	12.0	A	22.2	A	27.2	A	13.8	A
Ceratopogonidae	4.0		1.8		2.6		0.0		3.2		1.0	
Chironomidae	12.6		10.5		7.3		11.1		6.8		6.9	
Dolichopodidae	0.2		0.5		1.4		0.0		3.3		1.0	
Empididae	8.1		2.1		0.0		0.0		0.8		0.0	
Ephydriidae	0.0		0.1		0.7		0.0		1.2		0.0	
Sciomyzidae	0.0		0.1		0.0		0.0		6.3		4.7	
Stratiomyidae	.		.		.		11.1		4.6		0.1	
<b>Ephemeroptera</b>	0.0	A	0.3	A	0.0	A	.		.		.	
Baetidae	0.0		0.3		0.0		.		.		.	
<b>Fish</b>	.		.		.		0.0	A	0.0	A	Trace	A
<i>Gambusia spp.</i>	.		.		.		0.0		0.0		Trace	
<b>Gastropoda</b>	0.0	A	7.0	AB	13.8	B	0.0	A	10.7	AB	20.3	B
Lymnaeidae	.		.		.		0.0		1.9		0.8	
Physidae	0.0		3.5		7.0		0.0		3.8		16.5	
Planorbidae	0.0		3.5		6.7		0.0		5.0		3.0	
<b>Hemiptera</b>	9.1	A	3.7	A	0.4	A	0.0	A	0.1	A	2.6	A
Corixidae	9.1		3.7		0.4		0.0		0.1		2.6	
<b>Hirudinea</b>	6.7	A	1.5	A	1.8	A	16.3	A	0.0	A	5.4	A
Glossiphonidae	6.7		1.5		1.8		16.3		0.0		5.4	
<b>Isopoda</b>	0.0		2.3		0.0		0.0		0.2		0.0	
<b>Nemaotoda</b>	20.2	A	1.2	B	1.2	B	39.3	A	0.4	B	1.7	B
<b>Oligochaeta</b>	0.9	A	59.5	B	51.5	B	5.6	A	42.2	B	28.1	B
<b>Ostracoda</b>	1.0	A	5.0	B	0.0	A	0.0	A	0.1	A	0.0	A
<b>Trichoptera</b>	4.3	A	0.2	A	4.1	A	0.0	A	8.8	A	1.3	A
Leptoceridae	4.3		0.2		4.1		0.0		8.8		1.3	

Table 5. Percent occurrence of invertebrate foods found in fall migrating Least sandpiper ingesta and core samples taken at collection and random sites in 2007 ( $n = 30$ ) and 2008 ( $n = 17$ ).

Taxa	2007			2008		
	Diet	Collection	Random	Diet	Collection	Random
<b>Arachnida</b>	0.0	0.0	6.7	0.0	5.6	0.0
<b>Bivalvia</b>	0.0	10.0	23.3	0.0	0.0	5.6
Sphaeriidae	0.0	10.0	23.3	0.0	0.0	5.6
<b>Cladocera</b>	.	.	.	0.0	16.7	0.0
<b>Coleoptera</b>	30.0	13.3	26.7	11.1	11.1	11.1
Heteroceridae	23.3	0.0	3.3	11.1	11.1	5.6
Hydrophilidae	10.0	13.3	20.0	0.0	0.0	5.6
Staphylinidae	0.0	0.0	3.3	0.0	5.6	0.0
<b>Copepoda</b>	0.0	6.7	0.0	.	.	.
<b>Diptera</b>	70.0	93.3	73.3	77.8	83.3	83.3
Ceratopogonidae	30.0	40.0	36.7	16.7	22.2	5.6
Chironomidae	33.3	56.7	46.7	61.1	72.2	66.7
Dolichopodidae	0.0	40.0	10.0	0.0	11.1	5.6
Empididae	10.0	0.0	0.0	.	.	.
Ephydriidae	10.0	10.0	6.7	0.0	5.6	27.8
Muscidae	.	.	.	5.6	0.0	0.0
Syrphidae	0.0	3.3	0.0	.	.	.
Tabanidae	.	.	.	0.0	0.0	5.6
<b>Gastropoda</b>	0.0	13.3	6.7	0.0	5.6	5.6
Lymnaeidae	0.0	0.0	0.0	0.0	0.0	5.6
Physidae	0.0	13.3	6.7	0.0	5.6	0.0
Planorbidae	.	.	.	0.0	5.6	0.0
<b>Hemiptera</b>	3.3	20.0	10.0	0.0	0.0	16.7
Corixidae	0.0	20.0	10.0	0.0	0.0	16.7
<b>Hirudinea</b>	6.7	10.0	20.0	0.0	0.0	5.6
Glossiphonidae	6.7	10.0	20.0	0.0	0.0	5.6
<b>Isopoda</b>	0.0	6.7	0.0	0.0	5.6	11.1
<b>Nematoda</b>	0.0	63.3	43.3	0.0	77.8	50.0
<b>Oligochaeta</b>	6.7	100.0	96.7	5.6	100.0	94.4
<b>Ostracoda</b>	3.3	33.3	10.0	0.0	5.6	0.0
<b>Trichoptera</b>	0.0	10.0	10.0	0.0	16.7	0.0
Leptoceridae	0.0	10.0	10.0	0.0	16.7	0.0
<b>Unknown</b>	30.0	23.3	13.3	5.6	5.6	5.6

Table 6. Aggregate percent mass (dry) of invertebrate foods found in fall migrating Least sandpiper ingesta and core samples taken at collection and random sites in 2007 ( $n = 30$ ) and 2008 ( $n = 17$ ). Values with different letters within Taxa Orders (rows) indicate significant differences of least-squares means (Tukey-Kramer test:  $P \leq 0.05$ ).

Taxa	2007			2008		
	Diet	Collection	Random	Diet	Collection	Random
<b>Arachnida</b>	0.0 A	0.0 A	2.9 A	.	.	.
<b>Bivalvia</b>	0.0 A	2.1 A	1.1 A	0.0 A	0.0 A	0.4 A
Sphaeriidae	0.0	2.1	1.1	0.0	0.0	0.4
<b>Cladocera</b>	.	.	.	0.0 A	Trace A	0.0 A
<b>Coleoptera</b>	28.0 A	6.2 B	7.8 B	11.8 A	8.8 A	1.8 A
Heteroceridae	18.3	0.0	2.4	11.8	8.6	1.8
Hydrophilidae	9.7	6.2	5.4	.	.	.
Staphylinidae	.	.	.	0.0	0.2	0.0
<b>Diptera</b>	63.7 A	15.5 B	19.4 B	82.4 A	17.1 B	36.3 B
Ceratopogonidae	20.7	3.5	3.1	14.0	0.7	0.6
Chironomidae	27.9	8.8	11.6	62.4	15.3	31.0
Dolichopodidae	0.0	3.1	4.0	0.0	0.3	1.5
Empididae	7.4	0.0	0.0	.	.	.
Ephydriidae	7.7	0.1	0.8	0.0	0.9	3.2
Muscidae	.	.	.	5.9	0.0	0.0
<b>Gastropoda</b>	0.0 A	2.9 A	1.8 A	0.0 A	0.0 A	2.1 A
Lymnaeidae	.	.	.	0.0	0.0	2.1
Physidae	0.0	2.9	1.8	.	.	.
<b>Hemiptera</b>	0.3 A	1.6 A	0.9 A	0.0 A	0.0 A	4.0 A
Corixidae	0.0	1.6	0.9	0.0	0.0	4.0
<b>Hirudinea</b>	4.5 A	3.6 A	2.6 A	0.0 A	0.0 A	3.7 A
Glossiphonidae	4.5	3.6	2.6	0.0	0.0	3.7
<b>Isopoda</b>	0.0 A	1.1 A	0.0 A	0.0 A	0.2 A	4.1 A
<b>Nemaotoda</b>	0.0 A	1.0 B	0.3 A	0.0 A	0.6 A	6.1 A
<b>Oligochaeta</b>	3.5 A	60.2 B	59.3 B	5.9 A	72.7 B	41.5 C
<b>Ostracoda</b>	0.3 A	5.5 B	0.3 A	0.0 A	Trace A	0.0 A
<b>Trichoptera</b>	0.0 A	0.4 A	3.5 A	0.0 A	0.5 A	0.0 A
Leptoceridae	0.0	0.4	3.5	0.0	0.5	0.0

Table 7. Percent occurrence of diet items found in fall migrating Lesser Yellowlegs ingesta and core samples taken at collection and random sites in 2007 ( $n = 34$ ) and 2008 ( $n = 20$ ).

Taxa	2007			2008		
	Diet	Collection	Random	Diet	Collection	Random
<b>Bivalvia</b>	0.0	5.6	8.3	5.0	0.0	15.0
Sphaeriidae	0.0	5.6	8.3	5.0	0.0	15.0
<b>Cladocera</b>	0.0	2.8	5.6	0.0	40.0	0.0
<b>Coleoptera</b>	25.0	5.6	30.6	5.0	5.0	0.0
Carabidae	0.0	0.0	2.8	.	.	.
Chrysomelidae	5.6	0.0	0.0	.	.	.
Curculionidae	0.0	0.0	2.8	.	.	.
Haliplidae	0.0	2.8	0.0	.	.	.
Heteroceridae	5.6	0.0	0.0	.	.	.
Hydrophilidae	16.7	2.8	22.2	5.0	0.0	0.0
<b>Copepoda</b>	0.0	0.0	2.8	.	.	.
<b>Diptera</b>	33.3	94.4	88.9	40.0	95.0	90.0
Ceratopogonidae	11.1	36.1	33.3	0.0	10.0	5.0
Chironomidae	27.8	77.8	72.2	40.0	95.0	90.0
Dolichopodidae	0.0	11.1	5.6	.	.	.
Ephydriidae	0.0	2.8	0.0	.	.	.
Phoridae	0.0	5.6	0.0	.	.	.
Sciomyzidae	0.0	0.0	2.8	0.0	10.0	0.0
Syrphidae	0.0	0.0	5.6	.	.	.
Tipulidae	0.0	2.8	0.0	.	.	.
<b>Ephemeroptera</b>	2.8	0.0	0.0	.	.	.
Baetidae	2.8	0.0	0.0	.	.	.
<b>Fish</b>	.	.	.	20.0	0.0	0.0
<i>Gambusia spp.</i>	.	.	.	20.0	0.0	0.0
<b>Gastropoda</b>	0.0	13.9	11.1	0.0	0.0	15.0
Physidae	0.0	13.9	8.3	0.0	0.0	5.0
Planorbidae	0.0	5.6	2.8	0.0	0.0	10.0
<b>Hemiptera</b>	36.1	50.0	22.2	15.0	5.0	25.0
Corixidae	36.1	50.0	22.2	15.0	5.0	25.0
Mesoveliidae	0.0	2.8	0.0	.	.	.
<b>Hirudinea</b>	5.6	27.8	38.9	0.0	20.0	5.0
Glossiphonidae	5.6	27.8	38.9	0.0	20.0	5.0
<b>Isopoda</b>	0.0	0.0	2.8	5.0	20.0	20.0
<b>Nematoda</b>	22.2	66.7	58.3	35.0	70.0	50.0
<b>Odonata</b>	0.0	0.0	2.8	.	.	.
<b>Oligochaeta</b>	0.0	100.0	100.0	10.0	100.0	100.0
<b>Ostracoda</b>	50.0	8.3	13.9	5.0	5.0	0.0
<b>Trichoptera</b>	13.9	8.3	5.6	0.0	10.0	5.0
Leptoceridae	13.9	8.3	5.6	0.0	10.0	5.0
<b>Unknown</b>	22.2	8.3	8.3	0.0	0.0	15.0

Table 8. Aggregate percent mass (dry) of diet items found in fall migrating Lesser Yellowlegs ingesta and core samples taken at collection and random sites in 2007 ( $n = 34$ ) and 2008 ( $n = 20$ ). Values with different letters within Taxa Orders (rows) indicate significant differences of least-squares means (Tukey-Kramer test:  $P \leq 0.05$ ).

Order	2007						2008					
	Diet		Collection		Random		Diet		Collection		Random	
<b>Bivalvia</b>	0.0	A	0.6	A	0.4	A	4.2	A	0.0	A	2.1	A
Sphaeriidae	0.0		0.6		0.4		4.2		0.0		2.1	
<b>Cladocera</b>	0.0	A	Trace	A	0.0	A	0.0	A	0.1	A	0.0	A
<b>Coleoptera</b>	23.7	A	0.4	B	3.2	B	0.3	A	0.0	A	0.0	A
Chrysomelidae	1.5		0.0		0.0		.		.		.	
Heteroceridae	5.4		0.0		0.0		.		.		.	
Hydrophilidae	16.8		0.4		3.2		0.3		0.0		0.0	
<b>Diptera</b>	24.4	A	33.5	A	21.9	A	31.4	A	29.6	A	34.0	A
Ceratopogonidae	1.4		2.5		1.7		0.0		0.2		0.4	
Chironomidae	23.0		30.2		18.3		31.4		28.3		33.5	
Dolichopodidae	0.0		0.3		1.2		.		.		.	
Sciomyzidae	0.0		0.0		0.6		0.0		1.1		0.0	
Syrphidae	0.0		0.0		0.1		.		.		.	
<b>Ephemeroptera</b>	2.7	A	0.0	A	0.0	A	.		.		.	
Baetidae	2.7		0.0		0.0		.		.		.	
<b>Fish</b>	.		.		.		19.6	A	0.0	B	0.0	B
<i>Gambusia spp.</i>	.		.		.		19.6		0.0		0.0	
<b>Gastropoda</b>	0.0	A	5.7	A	5.6	A	0.0	A	0.0	A	1.0	A
Physidae	0.0		0.9		3.2		0.0		0.0		0.7	
Planorbidae	0.0		4.9		2.4		0.0		0.0		0.2	
<b>Hemiptera</b>	18.9	A	3.4	B	3.2	B	12.8	A	0.1	A	4.3	A
Corixidae	18.9		3.3		3.2		12.8		0.1		4.3	
Mesoveliidae	0.0		0.1		0.0		.		.		.	
<b>Hirudinea</b>	4.0	A	5.4	A	9.1	A	0.0	A	4.4	A	3.7	A
Glossiphonidae	4.0		5.4		9.1		0.0		4.4		3.7	
<b>Isopoda</b>	0.0	A	0.0	A	0.1	A	1.6	A	1.4	A	1.1	A
<b>Nemaotoda</b>	3.6	A	3.0	A	1.1	A	22.5	A	0.5	B	0.4	B
<b>Oligochaeta</b>	0.0	A	46.8	B	53.4	B	5.0	A	57.3	B	53.3	B
<b>Ostracoda</b>	13.4	A	0.2	B	0.2	B	2.6	A	0.0	A	0.0	A
<b>Trichoptera</b>	9.5	A	1.0	A	1.8	A	0.0	A	6.5	A	0.2	A
Leptoceridae	9.5		1.0		1.8		0.0		6.5		0.2	

Table 9. Percent occurrence of invertebrate foods found in fall migrating Pectoral sandpiper ingesta and core samples taken at collection and random sites in 2007 ( $n = 37$ ) and 2008 ( $n = 28$ ).

Taxa	2007			2008		
	Diet	Collection	Random	Diet	Collection	Random
<b>Arachnida</b>	0.0	5.3	0.0	0.0	0.0	3.6
<b>Bivalvia</b>	0.0	7.9	15.8	7.1	7.1	7.1
Sphaeriidae	0.0	7.9	15.8	7.1	7.1	7.1
<b>Cladocera</b>	0.0	0.0	2.6	0.0	7.1	3.6
<b>Coleoptera</b>	7.9	2.6	7.9	0.0	14.3	0.0
Chrysomelidae	0.0	2.6	0.0	0.0	7.1	0.0
Halplidae	0.0	0.0	2.6	.	.	.
Hydrophilidae	7.9	0.0	7.9	.	.	.
<b>Copepoda</b>	0.0	0.0	2.6	.	.	.
<b>Diptera</b>	73.7	94.7	97.4	82.1	89.3	75.0
Ceratopogonidae	13.2	31.6	18.4	7.1	14.3	3.6
Chironomidae	73.7	92.1	73.7	71.4	78.6	67.9
Dolichopodidae	0.0	5.3	5.3	0.0	3.6	0.0
Empididae	0.0	2.6	0.0	7.1	0.0	0.0
Ephydriidae	0.0	2.6	5.3	0.0	7.1	10.7
Muscidae	0.0	0.0	7.9	10.7	0.0	0.0
Phoridae	0.0	5.3	2.6	.	.	.
Sciomyzidae	0.0	0.0	5.3	0.0	7.1	0.0
Stratiomyidae	0.0	0.0	2.6	.	.	.
Tabanidae	0.0	2.6	2.6	0.0	7.1	0.0
<b>Gastropoda</b>	7.9	10.5	10.5	0.0	7.1	3.6
Physidae	7.9	5.3	10.5	0.0	7.1	3.6
Planorbidae	0.0	5.3	0.0	.	.	.
<b>Hemiptera</b>	18.4	34.2	21.1	0.0	7.1	10.7
Corixidae	18.4	34.2	21.1	0.0	7.1	10.7
<b>Hirudinea</b>	0.0	21.1	23.7	0.0	7.1	0.0
Glossiphoniidae	0.0	21.1	23.7	0.0	7.1	0.0
<b>Isopoda</b>	0.0	0.0	7.9	25.0	28.6	39.3
<b>Nematoda</b>	39.5	89.5	78.9	17.9	82.1	60.7
<b>Oligochaeta</b>	7.9	94.7	100.0	0.0	100.0	100.0
<b>Ostracoda</b>	26.3	13.2	2.6	0.0	3.6	0.0
<b>Trichoptera</b>	5.3	5.3	2.6	0.0	3.6	0.0
Leptoceridae	5.3	5.3	2.6	0.0	3.6	0.0
<b>Unknown</b>	15.8	0.0	5.3	0.0	0.0	14.3



Table 10. Aggregate percent mass (dry) of invertebrate foods found in Pectoral sandpiper ingesta and core samples taken at collection and random sites in 2007 ( $n = 37$ ) and 2008 ( $n = 28$ ). Values with different letters within Taxa Orders (rows) indicate significant differences of least-squares means (Tukey-Kramer test:  $P \leq 0.05$ ).

Taxa	2007						2008					
	Diet		Collection		Random		Diet		Collection		Random	
<b>Arachnida</b>	0.0	A	Trace	A	0.0	A	0.0	A	0.0	A	0.1	A
<b>Bivalvia</b>	0.0	A	3.0	A	2.6	A	3.4	A	3.6	A	0.9	A
Sphaeriidae	0.0		3.0		2.6		3.4		3.6		0.9	
<b>Cladocera</b>	.		.		.		0.0	A	Trace	A	0.0	A
<b>Coleoptera</b>	3.7	A	0.4	A	4.2	A	0.0	A	0.5	A	0.0	A
Chrysomelidae	0.0		0.4		0.0		0.0		0.5		0.0	
Hydrophilidae	3.7		0.0		4.2		.		.		.	
<b>Diptera</b>	67.1	A	38.3	B	30.7	B	72.9	A	24.3	B	21.7	B
Ceratopoginidae	3.2		4.9		1.8		2.1		0.4		0.2	
Chironomidae	63.9		32.1		27.1		65.5		21.7		20.1	
Dolichopodidae	0.0		0.1		0.8		0.0		0.2		0.0	
Empididae	0.0		0.7		0.0		0.9		0.0		0.0	
Ephydriidae	0.0		0.4		0.4		0.0		0.6		1.3	
Muscidae	.		.		.		4.3		0.0		0.0	
Phoridae	0.0		0.1		0.0		.		.		.	
Sciomyzidae	0.0		0.0		0.3		0.0		0.4		0.0	
Stratiomyidae	0.0		0.0		0.3		.		.		.	
Tabanidae	.		.		.		0.0		1.1		0.0	
<b>Gastropoda</b>	2.7	A	5.5	A	2.2	A	0.0	A	1.5	A	0.4	A
Physidae	2.7		0.7		2.2		0.0		1.5		0.4	
Planorbidae	0.0		4.8		0.0		.		.		.	
<b>Hemiptera</b>	13.6	A	3.8	B	0.9	B	0.0	A	0.1	AB	0.7	B
Corixidae	13.6		3.8		0.9		0.0		0.1		0.7	
<b>Hirudinea</b>	0.0	A	3.7	A	5.2	A	0.0	A	0.6	A	0.0	A
Glossiphonidae	0.0		3.7		5.2		0.0		0.6		0.0	
<b>Isopoda</b>	0.0	A	0.0	A	0.2	A	19.8	A	2.5	B	4.1	B
<b>Nemaotoda</b>	7.2	A	1.7	A	2.6	A	3.8	A	0.5	A	0.7	A
<b>Oligochaeta</b>	1.5	A	41.1	B	50.5	B	0.0	A	65.9	B	71.5	B
<b>Ostracoda</b>	2.7	A	0.8	A	Trace	A	0.0	A	Trace	A	0.0	A
<b>Trichoptera</b>	1.5	A	1.8	A	0.8	A	0.0	A	0.7	A	0.0	A
Leptoceridae	1.5		1.8		0.8		0.0		0.7		0.0	

Submitted by:

A handwritten signature in blue ink, appearing to read "Joshua D. Stafford". The signature is stylized with large, flowing letters and a prominent initial "J".

Joshua D. Stafford, Ph.D.  
Associate Research Professor  
Illinois Natural History Survey  
University of Illinois Urbana-Champaign

Date: 30 June 2010.