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THE RESPONSE OF SELECTED WILDLIFE TO MACROTOPOGRAPHIC ENHANCEMENTS OF A WETLAND RESERVE PROGRAM RESTORATION

Kacie A. Ehrenberger: Department of Forestry and Natural Resources, Purdue University, 195 Marstellar St, West Lafayette, Indiana 47907 USA

John B. Dunning, Jr.: Department of Forestry and Natural Resources, Purdue University, 195 Marstellar St, West Lafayette, Indiana 47907 USA

ABSTRACT. Private landowners control three-fourths of the remaining U.S. wetlands, which puts the fate of wetland resources largely in their hands. The Wetland Reserve Program (WRP) helps landowners restore and protect wetlands on agricultural lands through voluntary easements. Although the potential benefits of the WRP for wetland-associated wildlife are substantial, few studies have evaluated the response of wildlife to lands enrolled in the program. In this study we evaluated the role of changing a wetland's macrotopography, defined as the depth and shape of wetland basins, in enhancing a WRP restoration project in northwestern Indiana. In 2001 and 2002, we monitored the response of three indicator communities – migratory shorebirds, dabbling ducks, and breeding amphibians – to microhabitat features such as water depth and hydroperiod in areas with and without macrotopography enhancement. Wildlife responded positively to development of macrotopography, presumably because of longer hydroperiods and more diversity in microhabitats associated with areas within the restored basins. The wildlife response to these resources included greater use by migratory shorebirds and dabbling ducks, and greater anuran species richness as well as more successful breeding by the latter group. We recommend that the development of macrotopography be considered in future restoration activities designed to enhance wildlife benefits in WRP projects.

Keywords: Wetland restoration, macrotopography, shorebird, waterfowl, amphibian

Since the early 1880's, the United States has experienced widespread loss and large-scale alteration of wetland habitat (Dahl 1990). Private landowners control three-fourths of the remaining U.S. wetlands, which puts the fate of this resource largely in their hands (United States Department of the Interior 1994). To provide financial incentives for landowners to conserve wetland habitat, the U.S. Congress used the Food, Agriculture, Conservation, and Trade Act (Farm Bill) of 1990 to establish the Wetland Reserve Program (WRP). In the first 10 years of WRP, standard restoration practices included tile breaks, ditch plugs and levee work. Although beneficial in restoring areas to wetland habitat, these practices do not provide variation in topography or hydroperiod (duration of flooding). Since 2000, WRP-funded restorations in several states have gone beyond removing drainage tiles and plugging ditches to developing variation in depths and shapes by creating depressions within restored wetlands. The resulting "macrotopography treatments" alter wetland microhabitats and hydroperiods within a restored landscape (G. Roach, Natural Resource Conservation Service, pers. comm.).

In very flat landscapes such as those found in our study region, wetland hydroperiods are uniformly short in areas that lack macrotopography. Developing a greater diversity of microhabitats by creating new basins of different shape and size extends hydroperiods within a portion of the landscape (Stratman 2000). It is often assumed that this restoration technique provides wildlife habitat otherwise not found in restored landscapes. Although the potential benefits of WRP for wetland-associated wildlife are substantial, few studies have evaluated the response of wildlife to lands enrolled in the program (Rewa 2000).

To investigate the role of macrotopography in enhancing WRP restorations for wildlife, we

Correspondence: Kacie Ehrenberger, Rocky Mountain Bird Observatory, P.O. Box 1232, 14500 Lark Bunting Lane, Brighton, CO 80601; tel: 303 659 4348; fax: 303 654 0791 (e-mail: kacie.ehrenberger@rmbo.org).

surveyed the restored landscape of a WRP project in northwestern Indiana. We monitored breeding amphibians, migrating shorebirds, and migrating waterfowl to evaluate their response to macrotopographic enhancements within the restored landscape. We also measured vegetation structure and composition, water depth, and hydroperiod in altered and unaltered wetlands to describe the microhabitats created by this restoration technique.

The objective of this study was to determine if macrotopography development enhanced restoration effectiveness by increasing numbers of two migratory groups, shorebirds and dabbling ducks, and reproductive success for a third indicator group, amphibians. We compared control and experimental plots to see if variation in microhabitats and hydroperiods would increase wetland function within restored landscapes as measured by an increasing response by the indicator communities. We developed *a priori* hypotheses for these groups based on life-history characteristics (Colwell & Taft 2000). First, we predicted that opportunistic shorebirds and dabbling ducks would use any suitable microhabitat available in the landscape and that more appropriate conditions would exist in areas with macrotopography. Small shorebird abundance should increase with increasing area of available mudflats and open water <5 cm in depth (Colwell & Taft 2000). Larger shorebird abundance should increase with increasing area of available water depths of 5–10 cm, while dabbling ducks should increase with increasing area of available deep water (>10 cm) habitats (Colwell & Taft 2000). Second, we predicted that amphibians would attempt to breed throughout the landscape, but would successfully produce juveniles only in the areas with macrotopography because of longer hydroperiods.

METHODS

Site description.—Fieldwork took place in northwestern Indiana (Newton County, @1.2 km north of the town of Enos) from March–July in 2001 and 2002. The Kankakee Sands Restoration Project (hereafter, Kankakee Sands) is owned by The Nature Conservancy (TNC) and lies in the former prairie peninsula of Indiana near the eastern edge of North America's Tallgrass Prairie Ecoregion (O'Leary & Shuey 2003). After more than a century of agricultural use, the land was bought by TNC in 1996 to restore a large area (3000 ha) to native prairie and wetlands. As one of the largest prairie restorations east of the Mississippi River, Kankakee Sands connects three other pieces of state-owned remnant prairie and savanna habitats (Fig. 1). In 2002, about 1068 ha of the project were enrolled in WRP. Funds from WRP supported the re-establishment of a more natural hydrology through plugging of drainage ditches and thereby creating a mosaic of soil conditions from deep pockets of emergent wetlands to dry sand rises. Early attempts at wetland restoration failed to retain substantial water, so in 2001 TNC enhanced the restoration by establishing five wetland basins (here defined as macrotopography) in a portion of the WRP-enrolled acreage. These basins were developed by mechanically scraping soil to form shallow depressions with little variation in depths. Excavated soil was later used to plug agricultural drainage ditches. The macrotopographic features varied in size (approximately 0.3–1 ha) and shape (oval, rectangular or S-shaped). One basin's perimeter was planted with a species of *Juncus* but no other seeding took place throughout the WRP-enrolled section of Kankakee Sands until after this research was completed. There were no actively manipulated water control structures on the property (O'Leary & Shuey 2003).

Establishing plots.—In February 2001, we established ten 1.2-ha rectangular study plots in the WRP-enrolled section of Kankakee Sands. All plots and the surrounding landscape flooded each spring and were undergoing natural succession of the plant community to a wetland complex without active vegetation management (i.e., no seeding or planting). Five plots contained wetland basins (hereafter called experimental plots E1–E5), whereas the other five did not (control plots C6–C10). Control plots were located randomly located randomly in the 1068-ha WRP portion of the property by placing a numbered grid over a map of the area and using a random number generator to select the center of the control plots. We discarded any square selected by this procedure that was located within an experimental plot.

Plot size (1.2 ha) was determined by the size of the largest macrotopography basin, plus a 5-m buffer area surrounding it. In early spring, standing water covered each plot (both control and experimental), and therefore all 10 plots

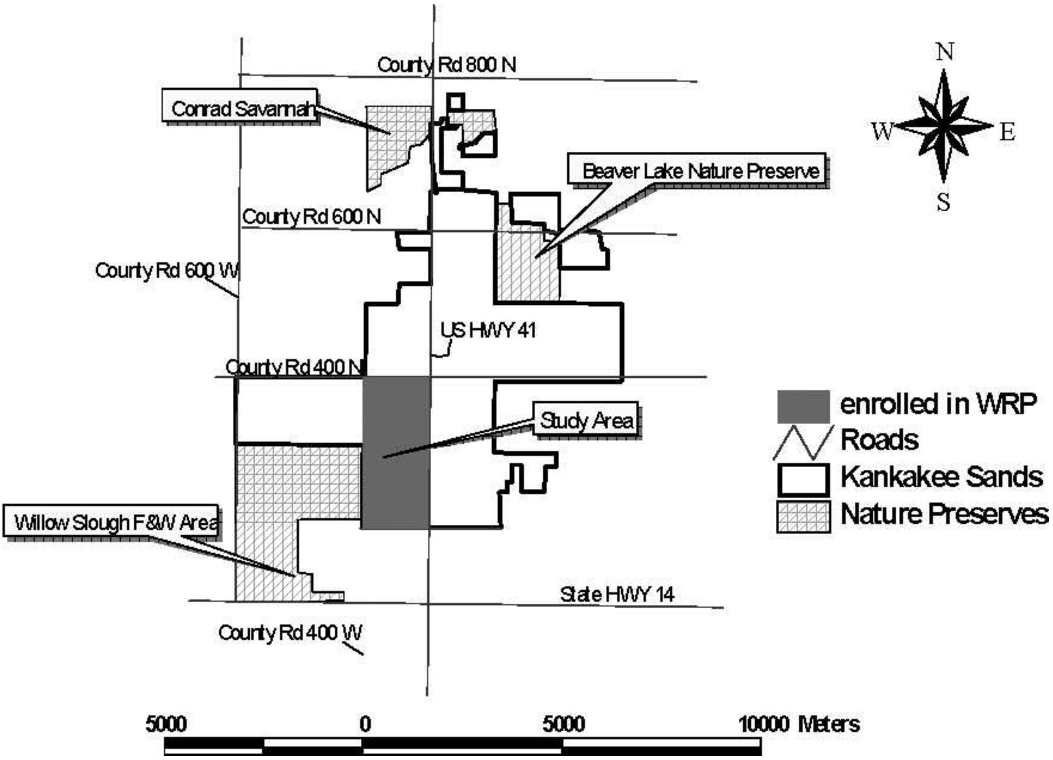


Figure 1.—Property map of the Kankakee Sands Restoration Project in Newton County, Indiana with adjacent state nature preserves. All fieldwork took place in the section enrolled in the Wetland Reserve Program (WRP).

could be considered equal areas of wetland habitat in initial stages of restoration. However, we expected the macrotopography to extend hydroperiods in experimental plots later in the year and thus we designed our study to test wildlife response to this factor. Our study therefore examined whether the presence of macrotopography increased wildlife use of the entire restoration and not the response of wildlife to the macrotopography itself.

In 2002, TNC increased the size of one wetland basin (study plot E4) so that it could flood up to 20 ha of the study area. This basin became too large and too deep to be considered a replicate of the remaining experimental plots. Since this new treatment was not replicated on the property, we removed this plot and a randomly selected control plot (C10) from the second year of our study, leaving eight study plots in 2002.

Microhabitat: hydroperiod and water depth.— In 2002, to estimate water depth and coverage, we established a grid of vertical PVC pipes, spaced 20 m apart, across all plots. Each pipe was marked with colored duct tape to indicate water depth levels with the zero point at ground level. We recorded water depth at these points every two weeks and entered these depths into Arc View (Environmental Systems Research Institute 1999). These pipes were present in all plots (controls and experimental) and therefore should not have introduced a systematic bias into the study (e.g., by attracting raptors to one type of plot). We estimated water depths and coverage in the plots in 2001 without the pipe grid (Ehrenberger 2003), but limit our presentation here to the more accurate measurements taken in 2002.

We converted point data into an integer grid using Inverse Distance Weighted (IDW) interpolation. IDW is commonly used in geographic information systems to create continuous surfaces from point data (Burrough & McDonnell 1998). IDW uses the distance between input points and the processing grid to weight final values (Environmental Systems Research Insti-

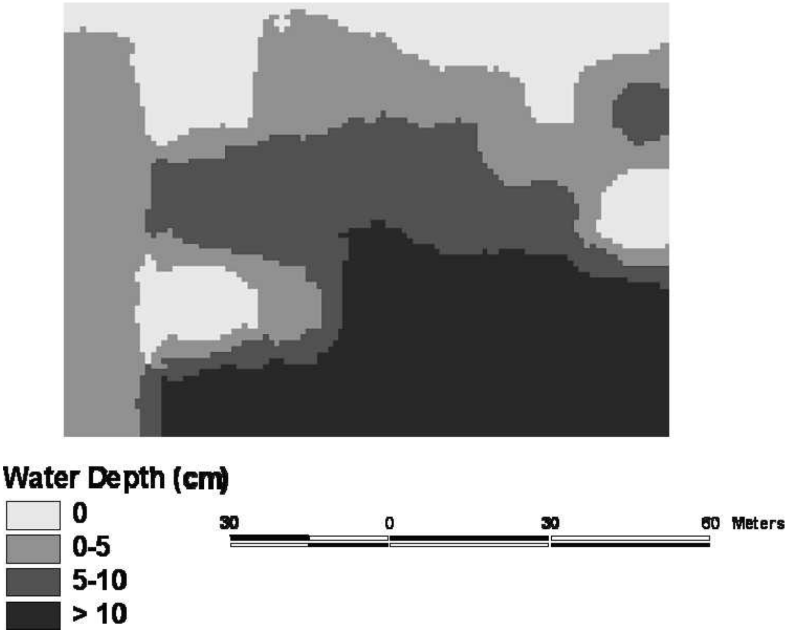


Figure 2.—Example of a plot's water depth map created using Inverse Distance Weighting interpolation in ArcView.

tute 1999). With the continuous surface maps (Fig. 2) for each plot and survey, we used a map calculator to calculate area of the plot in each of four water depth classes: no standing water (class 1, 0 cm), shallow water (class 2, 0–5 cm), moderate water (class 3, 5–10 cm), and deep water (class 4, >10 cm). Finally, we divided these areas by the total plot size to determine the proportional representation of each water-depth class in each plot.

Microhabitat: vegetation.—To examine vegetation composition and structure, we measured vegetation in 2001 and 2002 using the 'pole method' described by Mills et al. (1991). We held a 2-m pole marked in 1-dm sections perpendicular to the ground at each sampling point, and recorded the dominant plant species observed in each 1-dm section within a dm radius of the pole. In 2001, we measured 10 parallel transects with 10 sample points each (100 total points) in each plot. In 2002, we sampled vegetation at the same points used for water-depth measurements, which gave us approximately the same number of data points as collected in 2001. We kept notes on any changes in percent cover or height of the vegetation throughout each season.

Amphibian surveys.—To compare relative abundance and species richness of breeding anurans, we conducted call surveys throughout both field seasons using standard protocols established by the North American Amphibian Monitoring Program (NAAMP, Mossman et al. 1998). We conducted 1–2 surveys during each of three sampling windows as defined by the state of Indiana under NAAMP (early spring: end of February–March); late spring: mid-April–mid-May; and summer: mid-June–July) following Brodman & Kilmurray (1998). Each survey consisted of 3 min of listening at each plot and recording all observations using the NAAMP calling index. All surveys started 30 min after sunset and were completed before 2300h EST.

To confirm breeding success and further investigate species richness, we searched for egg masses and larvae. We walked through all standing water in each plot and recorded location and stage of development of eggs or tadpoles twice a week.

Bird surveys.—We conducted bird surveys twice a week by visiting each study plot and recording the number of shorebirds and waterfowl observed. Open areas of plots were first scanned using binoculars and a spotting scope. Then we walked through the entire plot to flush any birds not seen initially. Because the entire plot was searched thoroughly, we assumed equal survey effort and similar detectabilities among plots. Plots were visited during midday hours (0900–1400 h) except in summer. When temperatures >26°C were expected, surveys were conducted in morning hours (0600-100h) to avoid biasing visibility due to heat waves or birds seeking cover. No surveys were conducted in heavy rain or wind. As the area dried in June each year, the wettest plots were checked first; and if they were dry, we did not visit the remaining plots. We stopped surveying when all experimental and control plots were dry.

Data analysis: amphibian breeding success.—For anurans, calling adults indicate only breeding attempts and not successful reproduction; therefore, we used data from both the call counts and the egg mass/larvae searches to estimate use of the plots by anurans. We emphasized response by *Lithobates pipiens* (northern leopard frog) because it is the only "Species of Special Concern" (as defined by the Indiana Department of Natural Resources) expected in the area (Minton 2001). An individual was considered a juvenile after the development of all four legs and tail absorption. Because of the potential for inter-annual variability, we performed the analyses given below on data from each year separately.

Data analysis: avian response.—Our analysis of avian response was complicated by variation in both biotic data (response variables) and the environmental factors we wished to examine. First, some data violated assumptions of normality and equality of variance (Zolman 1993), so we could not use parametric tests. Second, we expected data for migratory birds, vegetation, and water levels to make predictable changes throughout the study period: migratory birds would come and go; vegetation would grow, wetlands would dry. These changes made it uninformative to try to relate avian sample means calculated over the entire study period to mean values of vegetation or water depth data. To deal with the complexity of our data, we consulted with several statisticians to design appropriate analyses. We broke the study period into the into five time periods: March–mid-April, mid-April–beginning of May, beginning of May–mid-May, mid-May–mid-June, and mid-June–July. We calculated separate water depth and vegetation variables for each period and then related these sets of environmental variables to the bird data collected for each period as described below.

Avian response to treatment.—To determine if bird use increased with macrotopography, we first divided bird species into guilds consistent with published literature on waterbird foraging behavior and water depth preferences. We categorized shorebirds into small and large species following published classifications (Brooks 1967; Skagen & Knopf 1993) and had a category for dabbling ducks (all species belonging to Tribe Anatini). For each survey, we calculated the average number of birds for each guild and converted observations to ranks for one-tailed Mann-Whitney U tests (MWU) in SPSS (SPSS, Inc. 2000). We conducted separate analyses for each year.

Microhabitat variables.—We used two-tailed MWU tests in SPSS to determine differences in the distribution of water depths between control and experimental plots throughout 2002. To evaluate changes in water depths over time (and later the relationship between bird presence and water depths)we determined the proportion of each plot in each depth class for every time period using the map calculator in ArcView. Proportion was entered for all plots and grouped by treatment and time period. All observations were combined and ranked with an average rank assigned for ties.

The set of MWU tests done for each time period included a separate test for each depth class and were considered a family. For each family we conducted the Holm simultaneous testing procedure (Holm 1979) to correct P-values for multiple significance tests. All P-values from the MWU were ranked with an average rank assigned for ties. Each P-value was then compared to the value $\alpha/(g-k+1)$, where α = 0.1, g = number of tests in the family (4), and k = rank. If the lowest ranking P-value was less than $\alpha/(g-k+1)$, we rejected Ho and evaluated the test for the second ranked P-value. This continued until a test's P-value was greater than $\alpha/(g-k+1)$, at this point Ho was not rejected for that test and all that remained in the family.

We also used MWU tests to evaluate compositional differences in vegetation between treatments. We calculated the percent of each plot dominated by the main vegetation types and grouped vegetation data for the plots by treatment.

Avian response to microhabitat variables.—We used stepwise multiple linear regression to evaluate the effect of variation in water depth on bird species richness. Evenness (EVEN), richness (RICH) and diversity (H) of water-depth classes were the variables used in models to predict bird species richness. EVEN measured the variation in water-depth classes and RICH represented the number of water-depth classes in each plot for each time period. We calculated H using:

$$H = -\sum_{i=1}^{q} p_i \log p_i$$

where

i = depth class,
q = number of depth classes,
p = proportion of plot in depth class i.

We used R^2 criteria to select the best model.

We also used water-depth classes to predict the presence or absence of our indicator guilds. Explanatory variables were the proportion of the plot in a given water-depth class. We selected water-depth classes for logistic regression models based on a priori hypotheses (Burnham & Anderson 1998). For example, we used classes 1 and 2 (the shallowest depths) in models to predict the presence of small shorebirds. The constant was included in all models. After fitting a hierarchy of models, we selected the most parsimonious model using the -2 log likelihood ($-2LL$) method. We examined the contribution of parameters to each model by comparing the predictive values of the model with and without the parameters. If the removal of a parameter did not significantly reduce the predictive power of the model (measured by change in $-2LL$) the parameter was excluded. All regressions used only 2002 data.

RESULTS

Over both field seasons, we observed 26 species of waterbirds and 7 species of amphibians (Table 1) in study plots. All species of amphibians and waterbirds found in control plots were observed in experimental plots, i.e., control-plot fauna was a nested subset of those in experimental plots.

Amphibian breeding success.—In 2001, two species used the control plots, and seven species used the experimental plots. *Lithobates pipiens* (northern leopard frog), the species of special concern in Indiana, was present only in the experimental plots in 2001 although we did detect one *L. pipiens* in a control plot in 2002. In 2002, we detected three species in control plots and seven species in the experimental plots. We observed *Lithobates catesbeianus* (American bullfrog), a species known to consume other frog species, only in experimental plots.

We observed juvenile anurans only in experimental plots. We found juvenile *Anaxyrus fowleri* (Fowler's toad) and *L. pipiens* in both 2001 and 2002. We also observed *Lithobates clamitans* (green frogs) in the froglet stage (two back legs present) in 2002.

Avian response.—In 2001, the experimental plots had a significantly greater number of individual small shorebirds (U = 3, P = 0.028), individual ducks (U = 1, P = 0.008), and total species (U = 1, P = 0.008) compared to control plots. No significant differences were detected in the number of individual large shorebirds (U = 6, P = 0.111).

In 2002 the experimental plots had a significantly greater number of individual small shorebirds (U = 0, P = 0.015) and total species (U = 1, P = 0.029; Fig. 3–4). No significant differences were detected in number of individual ducks (U = 2, P = 0.057) or large shorebirds (U = 8, P = 0.5).

Microhabitat variables.—The experimental plots (those with macrotopography) held water several weeks longer than the surrounding landscape. Over all time periods, experimental plots had significantly more area covered by deep water (depth class 4; U = 56, P = 0.0) and control plots had significantly more area without standing water (depth class 1; U = 110, P = 0.014). No significant differences were detected for shallow water (water-depth class 2; U = 159, P = 0.265) or moderate water (water-depth class 3; U = 158, P = 0.253; Fig. 5–8) areas.

In March through mid-April, there were no significant differences between experimental and control plots for any of the water-depth classes (Table 2), supporting our initial assumption that all plots were equal in wetland area early in the season. From mid-April to the beginning of May and mid-May through July, experimental plots had a significantly higher proportion of plots covered by deep water (depth class 4) than control plots (U = 0, 1 or 2 ; P-values from 0.014 to 0.047). In mid-May through mid-June control plots had a signifi-

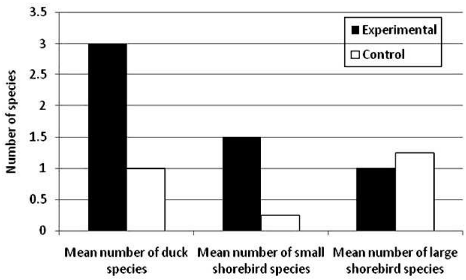
Table 1.—Species composition of indicator groups detected in experimental plots at Kankakee Sands in 2001 and 2002. * = species also observed in control plots.

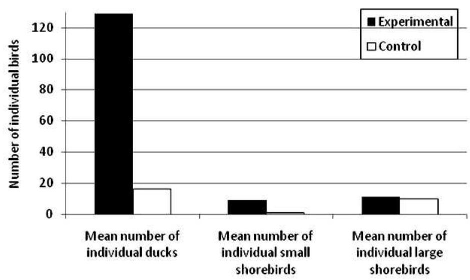
Common name	Scientific name	Guild
Amphibians		
Fowler's toad	*Anaxyrus fowleri*	
Western Chorus Frog*	*Pseudacris t. triseriata*	
Spring peeper*	*Pseudacris crucifer*	
Gray treefrog	*Hyla versicolor*	
Green frog	*Lithobates clamitans*	
American bullfrog	*Lithobates catesbeiana*	
Northern leopard frog*	*Litobates pipiens*	
Birds		
Canada Goose	*Branta canadensis*	
Wood Duck	*Aix sponsa*	dabbling duck
Gadwall	*Anas strepera*	dabbling duck
Mallard*	*Anas platyrhynchos*	dabbling duck
American Wigeon	*Anas americana*	dabbling duck
Northern Shoveler*	*Anas clypeata*	dabbling duck
Blue-winged Teal*	*Anas discors*	dabbling duck
Green-winged Teal	*Anas crecca*	dabbling duck
Killdeer*	*Charadrius vociferous*	large shorebird
Spotted Sandpiper	*Actitis macularia*	small shorebird
Greater Yellowlegs	*Tringa melanoleuca*	large shorebird
Lesser Yellowlegs	*Tringa flavipes*	large shorebird
Solitary Sandpiper	*Tringa solitaria*	large shorebird
Upland Sandpiper*	*Bartramia longicauda*	large shorebird
Semipalmated Sandpiper	*Calidris pusilla*	small shorebird
Western Sandpiper	*Calidris mauri*	small shorebird
Least Sandpiper	*Calidris minutilla*	small shorebird
White-rumped Sandpiper	*Calidris fuscicollis*	small shorebird
Pectoral Sandpiper*	*Calidris melanotos*	small shorebird
Dunlin	*Calidris alpina*	small shorebird
Short-billed Dowitcher	*Limnodromus griseus*	large shorebird
Long-billed Dowitcher	*Limnodromus scolopaceus*	large shorebird
Wilson's Snipe	*Gallinago delicta*	large shorebird
American Woodcock	*Scolopax minor*	large shorebird
Wilson's Phalarope	*Phalaropus tricolor*	small shorebird

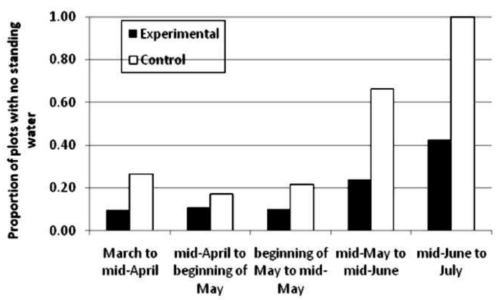
cantly higher proportion of the plots without standing water (depth class 1) than experimental plots ($U = 0$, $P = 0.021$). There was a significant difference between plots for all depth classes from mid-June until July (classes 1, 2 and 3: $U = 0$, $P = 0.014$; class 4: $U = 2$, $P = 0.047$) when all control plots had dried completely.

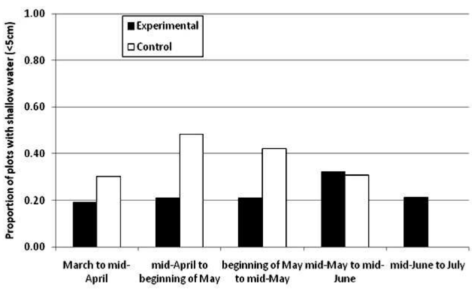
In both years, experimental plots had a greater percentage of bare ground than did control plots. In the portions of the plots that were vegetated in 2001, all plots had the same coverage of grasses, sedges, and rushes. In 2002, however, experimental plots had a somewhat greater percentage of the main vegetation groups (grasses, sedges, and rushes) than did controls, but the overall composition was not significantly different ($U = 4$, $P = 0.248$), so we assume the numerical differences in coverage of grasses, sedges, and rushes in experimental and control plots were not biologically significant. Vegetation categories other than grasses, sedges and rushes were mostly composed of species of Amaranthaceae, Asteraceae, Polygonaceae and Equisetaceae and were similar throughout the landscape in both years.

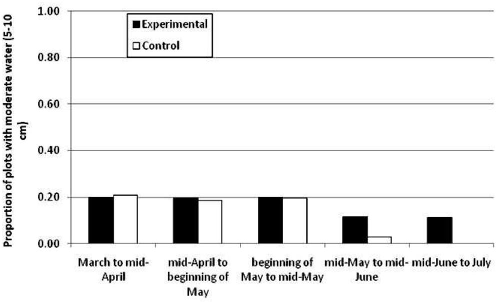
Avian response to microhabitat variables.—The Mann-Whitney U tests described in the previous section established that there were significant differences in avian response to treatment but that there were not differences in vegetation composition between treatment types. Therefore, we assumed avian response to microhabitat would be related to water pres-











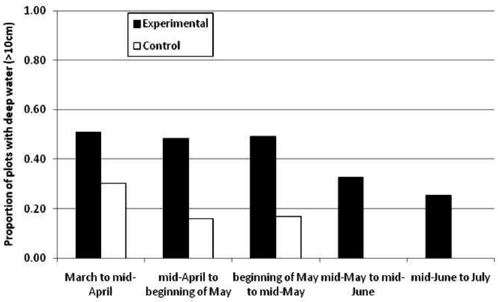


Figure 3.—Mean number (totalled over all surveys) of avian species observed in experimental and control plots at Kankakee Sands Restoration Project, Newton County, Indiana in 2002.

Figure 4.—Mean number (totalled over all surveys) of individual birds observed in experimental and contral plots at Kankakee Sands Restoration Project, Newton County, Indiana in 2002.

Figure 5–8. Proportion of control and experimental plots in each water depth class in 2002 at Kankakee Sands Restoration Project, Newton County, Indiana.

ence and depths, and so did not include vegetation as a variable in linear or logistic regressions.

In the stepwise multiple linear regression the independent variables EVEN and RICH were significantly negatively correlated (Spearman's Rho = -0.71, $P = 0.00$). These two variables are the components of H, the diversity variable. The best model ($R^2 = 0.29$, $P < 0.001$, $F_{1,38} = 15.20$) used only H to predict bird species richness.

The occurrence of small shorebirds was most associated with the proportion of the plots in class 1 (Table 3). Large shorebird occurrence was associated with class 3 and ducks with class 4. All models selected correctly predicted 73–83% of the observations and the Hosmer and Lemeshow goodness of fit test showed these models adequately fit the data (P-values ranged from 0.256 to 0.601).

DISCUSSION

This study demonstrates that several wildlife taxa positively responded to macrotopography in a WRP-funded restoration, presumably

Table 2.—P-values for Mann-Whitney U (MWU) tests conducted on 2002 water depth data and decisions from the Holms procedure conducted on each family of tests where P_k = MWU p-value, α = 0.1, g= 4 (number of tests in a family), k = rank, H_O = null hypothesis, and H_A = alternate hypothesis. Patterns are considered significantly different from random for the rank where Pk > $\alpha/(g-k+1)$ and all higher ranks.

Time period	Depth classes tested	Rank (k)	P_k	$\underline{\alpha}$ $(g-k+1)$	Decision
(1) March to	4	1	0.083	0.025	H_O
mid-April	1,2	2.5	0.248		
	3	4	0.773		
(2) mid-April to	4	1	0.020	0.025	H_A
early May	2	2	0.043	0.033	H_O
	1	3	0.386		
	3	4	1.000		
(3) early May to	4	1	0.042	0.025	H_O
mid-May	2	2	0.083		
	1	3	0.386		
	3	4	0.773		
(4) mid-May to	4	1	0.014	0.025	H_A
mid-June	1	2	0.021	0.033	H_A
	3	3	0.080	0.050	H_O
	2	4	0.773		
(5) mid-June to	1, 2, 3	2	0.014	0.033	H_A
July	4	4	0.047	0.100	H_A

because it provided habitat otherwise not available in the restored landscape. Even though the entire WRP-enrolled section of Kankakee Sands underwent hydrologic restoration, macrotopography offered additional benefits for breeding amphibians and migrating shorebirds and waterfowl. Plots with macrotopography had a longer hydroperiod and more diversity in microhabitats than areas without macrotopography. The wildlife response to these resources included greater use by small migratory shorebirds and dabbling ducks, and greater anuran species richness and breeding success.

Amphibian response to the restoration followed expected trends with hydroperiod length affecting reproduction. Many breeding amphibians in Indiana need breeding sites to hold water until at least mid-July (Stratman 2000), and at Kankakee Sands, early drying through-

Table 3.—Logistic regression using water depth classes to predict the presence of avian guilds observed at Kankakee Sands Restoration Project, Newton County, Indiana. The most parsimonious model was selected using the −2 log liklihood ($-2LL$) method. Nagelkere R^2 values are given for models chosen as the best fit.

Model	Dependent variable: −2LL	df	Nagelkere R^2
Small shorebirds			
Class 1 + class 2 + class 1*class 2	40.13	3	
Class 1 + class 2	42.99	2	
Class 1	44.03	1	0.207
Class 2	50.39	1	
Large shorebirds			
Class 2 + class 3 + class 2*class 3	43.11	3	
Class 2 + class 3	43.11	2	
Class 2	52.2	1	
Class 3	43.025	1	0.293
Ducks			
Class 4	35.58	2	0.518

out the landscape resulted in poor recruitment. Snodgrass et al. (2000) advocate a landscape approach to wetland conservation that maintains a diversity of hydroperiods across a gradient from early drying to permanence. Rapid drying and pond permanence represent the 2 ends of a disturbance continuum – amphibian species diversity maximizes at intermediate levels of this continuum (Kolozsvary & Swihart 1999). As observed in our study, early pond drying results in the desiccation of larvae before metamorphosis occurs (Semlitsch 2000). However, wetland designs should not include extensively deepening ponds because permanent water can be detrimental to amphibian populations by providing habitat for predators such some fish species (Griffiths 1997). Only those species with adaptations to avoid predators (i.e., distasteful larvae) would be able to reproduce in wetlands with permanent water.

The microhabitats provided by the macrotopography included deeper open water for dabbling ducks and open mudflats for shorebirds. The Kankakee Sands restoration demonstrated that bird species diversity increased with increasing diversity of available water depths. As expected, the three guilds used in analyses each responded to different depth classes. The occurrence of small shorebirds was predicted by proportion of the plot with open mudflats (depth class 1) where short-legged shorebirds (e.g., *Calidris* spp.) could probe for invertebrates. Larger shorebirds (e.g., *Tringa melanoleuca* [Greater Yellowlegs]) occurred where 5–10 cm of water (depth class 3) was available. This microhabitat provided opportunities for individuals to feed from the water surface or bottom substrate. The occurrence of dabbling ducks was predicted by the availability of deep water (class 4).

Although the birds appeared to use these areas opportunistically, the availability of appropriate microhabitats continuously varied. These variations are consistent with midcontinental wetlands that fluctuate because of seasonal and annual variations in weather (Skagen 1997). Another Indiana study found that no single wetland type met all the requirements of waterfowl and shorebirds migrating through the state (Mast 1999).

As with amphibians, waterbird communities require a diversity of habitats to be available at any time. Although the extent of wetlands varied temporally, the Kankakee Sands landscape was very flat and little variation existed prior to the restoration. It was not unusual for seasonal drying of most areas to occur over a short time period (i.e., deep water quickly became dry ground) resulting in few opportunities for shorebirds to use intermediate water depths. Because there are interspecific differences in foraging habitat among waterbirds, a diverse community of waterbirds requires wetlands flooded to an average depth of 10–20 cm that varies enough to allow a range of depths (Colwell & Taft 2000).

During both years of fieldwork at Kankakee Sands, similar hydroperiods occurred despite annual differences in weather patterns. For northwestern Indiana, the Palmer Drought Severity Index (PDSI) showed a moderate drought in 2001 but above normal moisture for all of spring 2002 (Climate Prediction Center 2002). PDSI reflects any abnormal moisture deficiencies or excesses by region. Heavy rains in late spring 2002 limited availability of shallow water and mudflat habitats, while drought conditions in 2001 limited water presence.

An early recognition of hydroperiod problems led TNC to change the enhancement in one area of existing macrotopography in 2002. This enhancement was then deeper and larger than the other macrotopographic features and attracted species not seen in experimental plots. For example, *Fulica americana* (American Coot), *Anas acuta* (Northern Pintail), *Oxyura jamaicensis* (Ruddy Duck), and *Chen caerulescens* (Snow Goose) all used this modified wetland. *Phalaropus tricolor* (Wilson's Phalarope) bred in this section of the property – the first documentation of breeding by this species in Indiana in >60 yr (Brock 2002). Additionally, the number of individuals in experimental plots was reduced in 2002, and it appeared this was because shorebird and waterfowl flocks were attracted to the larger wetland (K. E., pers. obs.). The hydroperiod for this wetland was different from the original macrotopography because the larger basin held water for two weeks longer than some experimental plots and had greater diversity in microhabitats.

In 2002, invading dense vegetation began to restrict the availability of open water and bare mud flats on all plots. Control of vegetation should be a management priority to alter wetland plant succession that would eliminate appropriate wetland habitats for migratory birds. TNC plans for botanical restoration (i.e., succession control and/or seeding of the area) at Kankakee Sands will alter the plant community. In addition, any change in wetland design could modify the timing of flood cycles that in turn may modify the plant community. Further management through burning or herbicides may be required.

The Nature Conservancy (TNC) continues to use the results of this study and others at Kankakee Sands to evaluate the restoration project (J. Shuey, TNC, pers. comm.). The results of experimentation and monitoring are components of adaptive management when used systematically to improve a project and direct future management decisions (Gibbs et al. 1999; Margoluis & Salafsky 1998). To develop the science of restoration, we need monitoring to make informed decisions regarding restoration activities. Each time a restoration project is not evaluated, biologists lose valuable ecological information and potentially risk repeating expensive mistakes (Moerke & Lamberti 2004). Wetland Reserve Program projects are an excellent arena for such monitoring.

Although rarely tested, a key assumption of restoration is that it will provide favorable conditions for native biota (Block et al. 2001). The vertebrate communities studied at Kankakee Sands responded to restored wetland habitat in a manner similar to how these species use natural wetlands.

Locally, Kankakee Sands is meeting management goals of providing connectivity with other protected areas. This landscape is rare in Indiana, because it provides a large wetland complex. Amphibian abundance has increased since restoration activities began, signifying that individuals are able to migrate from nearby ponds and terrestrial habitat. In 2003 *Ambystoma tigrinum* were discovered on the property for the first time (R. Brodman, pers. comm.).

Because of land-use changes over the last 100 years, the simple removal of drainage tile or plugging of ditches did not guarantee hydrologic restoration at Kankakee Sands. We recommend that the development of macrotopography be considered in wetland restoration projects to extend hydroperiods and create microhabitat diversity (Stratman 2000). Gentle slopes within wetland basins provide the greatest diversity of water depths and vegetative zones (Colwell & Taft 2000). Stratman (2000) provides a detailed description on appropriate design options for wetland restoration projects. The straightforward monitoring described here can easily be duplicated for other WRP-enrolled sites to establish an understanding of how WRP lands benefit wildlife. With continued modification and development of macrotopography, as well as other restoration practices, WRP offers a chance for our nation's wetland-dependent wildlife to recover from centuries of habitat destruction and modification.

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