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HABITAT PREFERENCES OF MIGRATORY SHOREBIRDS AND WATERFOWL ON THE EAST SHORELINE OF REND LAKE REFUGE

Alan Woolf
Southern Illinois University Carbondale

Jack R. Nawrot
Southern Illinois University Carbondale

Laura Kirk
Southern Illinois University Carbondale

Elise Elliot-Smith
Southern Illinois University Carbondale

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HABITAT PREFERENCES OF MIGRATORY SHOREBIRDS AND WATERFOWL ON THE EAST SHORELINE OF REND LAKE REFUGE

FINAL REPORT

Federal Aid Project W-141-R-1

Submitted by:

Cooperative Wildlife Research Laboratory, SIUC

Presented to:

Division of Wildlife Resources
Illinois Department of Natural Resources

Principal Investigators

Alan Woolf
Jack R. Nawrot

Graduate Research Assistants

Laura Kirk
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FINAL REPORT

STATE OF ILLINOIS

W-141-R-1

Project Period: 1 January 2001 - 30 June 2003

Project: Habitat preferences of migratory shorebirds and waterfowl on the east shoreline of Rend Lake Refuge

Prepared by Jack Nawrot
Cooperative Wildlife Research Laboratory
Southern Illinois University Carbondale

NEED: The east shoreline of the Rend Lake Refuge is characterized by open vistas and large expanses of relatively flat topography. During summer and fall, lake levels typically recede exposing mud-flats that are used by wildlife. This area of Rend Lake is thought to provide important foraging and secure loafing areas for migratory shorebirds and waterfowl throughout fall and spring migration. The topography at Rend Lake Refuge ensures that foraging habitat for shorebirds is usually available throughout the entire migratory period and between years with variable lake levels. Consequently, the east shoreline at Rend Lake Refuge is known as one of southern Illinois' most important areas for migratory shorebirds and waterfowl.

Despite the regional importance of Rend Lake Refuge for shorebirds and waterfowl during fall and spring migration, resource managers at Rend Lake, and throughout Illinois, have limited information on the habitat preferences of migratory shorebirds and waterfowl that use large mudflat habitats on Illinois reservoirs. In the absence of this information, it is difficult to predict how subsidence caused by longwall, subsurface coal extraction will impact the quantity and quality of available habitat for migratory wetland birds. Information is needed to document the current timing of mud-flat exposure and size of available foraging areas before and after subsidence occurs. This requires an understanding of migration chronology, bird species composition and abundance, foraging and loafing habitat requirements, and invertebrate food availability.

OBJECTIVES:

1. Estimate the amount of, and model temporal changes in, foraging and loafing habitat available to migratory shorebirds and waterfowl on the east side of Rend Lake Refuge during fall and spring migration.
2. Document migration chronology, abundance, and habitat use patterns of migratory shorebirds and waterfowl during fall and spring migration.
3. Estimate benthic invertebrate biomass available to migratory shorebirds during late summer and fall.
4. Evaluate how mining subsidence influences the availability of foraging habitat using habitat models and field observations.

EXECUTIVE SUMMARY

Job 1.1: Estimate Habitat Availability

The objective of this job was to assess habitat quality and availability of subsided and unsubsided wetlands on the west shoreline (Ward Branch) and east shoreline of Nason Point at Rend Lake. Hydroperiod (frequency and duration of inundation) is the principal factor affecting wetland habitat diversity and distribution within the reservoir. As Rend Lake has no method for water level management within the main reservoir, seasonal and annual variability in water levels determines the availability of waterfowl and shorebird habitat and associated food resources.

We compiled long term (~25 yr) lake level elevation data to document the annual hydroperiod (by month) within the main basin. Short term annual and seasonal water levels were also documented to define the weekly drawdown occurrence for the ~25 year data set and the weekly drawdown history for the duration of this study.

Vegetation response to shoreline topography (subsided and unsubsided) and seasonal hydroperiod determines waterfowl moist-soil food resources. We compared plant community diversity and cover within exposed shorelines, unsubsided coves, and subsided coves. No significant differences were found in the percent cover of waterfowl foods occurring in transects associated with subsided and unsubsided coves, or exposed (unsubsided) shorelines. Changes in hydroperiod associated with subsidence results in a shift of moist soil and open water wetland plant communities and the adjacent upland plant communities. Moist soil vegetation communities will shift from their current location along Nason Point to the post-subsidence seasonally inundated zone after subsidence.

Job 1.2: Species Composition, Abundance and Chronology

This job's objective was to quantify shorebird and waterfowl use of Rend Lake Refuge to assess the value of the habitat provided by the Nason Point and Ward Branch subsided and unsubsided wetlands. We conducted shorebird and waterfowl surveys within subsided and unsubsided shoreline habitats during late summer and fall of 2000 and 2001, and spring 2002, respectively. A total of 22,038 dabbling ducks were surveyed; there was no difference in the total number of ducks per meter of shoreline at subsided coves, unsubsided coves, and exposed (unsubsided) shorelines.

We recorded a total of 10,102 shorebirds (3,780 in 2000; 6,382 in 2001) using the Rend Lake subsided and unsubsided study areas during late summer-fall migration. Species richness was higher at Ward Branch (22 species) compared to Nason Point (13 species) during 2000, but species richness was similar at the 2 sites in 2001. During both years (2000 and 2001) we observed ~4-12 times more shorebirds in unsubsided compared to subsided habitats at Ward Branch; area of unsubsided habitat was ~3-4 times greater than subsided habitat. Shorebird habitat utilization included wet mud (61%), shallow water (25%), vegetated flats (4%), dry mud (3%), and flooded vegetation (1%). We found no between year or site trends (subsided - unsubsided) in habitat use patterns.

Job 1.3: Benthic Invertebrate Biomass

The objective of this job was to evaluate the availability of benthic invertebrate food resources during late summer and early fall. Quality of shorebird migration stopover habitats depends on the density and biomass of invertebrates in the mud-water interface of exposed mudflats. We extracted 280 sediment cores (5cm diam x 5 cm deep) from subsided and unsubsided habitats at Ward Branch and Nason Point during fall 2000 and 2001. We did not detect a between year difference in invertebrate density (*P* = 0.070), and biomass was only slightly greater in 2000 than 2001 (t_{278} = 2.308, *P* = 0.022). Invertebrate density was greater in the southern portion of Nason Point (median = 34, 030 invertebrates/m^2) compared to the northern portion (12,838 invertebrates/m^2, *F* = 14.31, *P* = 0.0002), and invertebrate density was significantly higher in subsided wetlands at Ward Branch (46,600/m^2) compared to unsubsided areas (39,565 invertebrates/m^2, *F* = 8.83, *P* = 0.004). However, there was no difference in invertebrate biomass of subsided vs unsubsided areas (*P* > 0.020). Invertebrate density and biomass values compared favorably to values reported for nearby shorebird habitats.

Job 1.4: Subsidence Assessment and Modeling

This job's objective was to evaluate how mine subsidence affects habitat availability using pre- and post subsidence models and field observation. Changes in the distribution and extent of shoreline habitat is affected by topographic change associated with subsidence panels. We evaluated habitat change associated with Ward Branch subsidence wetlands. A fine scale (15 cm) topographic survey of a proposed Nason Point longwall panel (Panel 2K) was completed during 2001 to serve as a benchmark of pre-subsidence conditions.

JOB 1.1: ESTIMATE HABITAT AVAILABILITY

Objective: Estimate the amount of, and model temporal changes in, foraging and loafing habitat available to migratory shorebirds and waterfowl on the east side of Rend Lake Refuge during fall and spring migration.

INTRODUCTION

Human population growth and development have led to the destruction and alteration of natural habitat. Wetlands, in particular, have experienced profound declines. More than half of the 89,505,000 ha of wetlands that existed in the U.S. prior to European settlement have been converted to upland or deep water habitat (Dahl and Johnson 1991). In addition, most remaining wetlands have been degraded or altered. Of the original 3,240,000 ha of natural wetland habitat in Illinois, 90% has been converted to other land uses, primarily agriculture (Suloway and Hubbell 1994). More than 25% of the 507,826 ha of remaining wetlands in Illinois are modified or man-made (Suloway and Hubbell 1994). Impoundments constructed on river channels are the second most common altered wetland type in Illinois, and represent 19% of the total surface water acreage (Suloway and Hubbell 1994).

Shorebird

Wetland degradation and destruction have negatively impacted numerous fish and wildlife species that depend on wetlands during some stage of their life cycle including shorebirds (*Charadriiformes*). Fifty-three shorebird species rely on U.S. wetlands during some portion of their annual cycle to provide breeding, wintering and migration stopover habitat (Brown et al. 2000). Although accurate population estimates and trends are lacking for most species, it has been suggested that at least 19 of the 53 species have declined (Brown et al. 2000, Morrison et al. 2000).

Few shorebird species breed or winter at mid-latitude, interior portions of the U.S., but 40 species migrate through the midwestern U.S. (Eldridge 1992) and they require high quality stopover sites to replenish fat reserves. Sparsely vegetated mudflat and shallow water areas are required characteristics of shorebird stopover habitat; however, food availability and predation risk determine habitat quality. Shorebirds may be physiologically stressed during migration due to high energetic demands (Helmers 1991, Skagen and Knopf 1994*a*, Davis and Smith 1998, De Leon and Smith 1999), and acquisition of invertebrate resources is essential to shorebird survival and breeding success. Behavior studies indicate shorebirds spend most of their diurnal time at inland stopover sites foraging (Davis and Smith 1998, De Leon and Smith 1999, Elphick 2000) and total invertebrate biomass and abundance has been closely associated with shorebird abundance at stopovers across the U.S. (Helmers 1991, Weber and Haig 1997, Ashley et al. 2000). Predation risk affects habitat quality by directly influencing survival; however, the behavioral response of shorebirds to predation threat may also affect survival by reducing foraging time. An increase in predator presence or perceived risk may also induce metabolic costs from movement associated with joining a flock and escaping a predator (Shanewise and Herman 1979, Myers 1980). Therefore, shorebirds may have to balance the risk of predation with the risk of starvation (Weissburg 1986, Dekker 1998).

Habitat characteristics such as topography and hydrology may influence habitat quality. Shoreline retreat is reduced by steep slopes and stable or rising water levels; there is some evidence that invertebrate resources are low under these conditions (Mihuc et al. 1997). Shoreline topography and hydrology also determines mudflat width which may limit flock size and influence flock shape, affecting predator avoidance behavior. Individual vigilance and time spent scanning increases as flock size decreases or becomes more linear in shape, which may leave less time for foraging activities (Abramson 1979, Caraco et al.1980, Bekoff 1995, Barbosa 1997, Dekker 1998). Birds may also spend more time alert and scan more frequently if their visibility is obstructed (Metcalfe 1984).

Compared to coastal stopover sites, hydrologic variability at inland areas render shorebird habitat less predictable, both seasonally and annually (Skagen and Knopf 1994b, Farmer and Parent 1997, Haig et al. 1998). Therefore, large numbers of shorebirds may be found every year at a single coastal wetland, while abundance is less predictable at inland stopovers (Isleib 1979).

As precipitation patterns dictate habitat suitability in inland areas, stopover areas are more often comprised of a complex of permanent and ephemeral wetlands. Therefore, within the complex or region, shorebird use may be consistent, but habitat availability at any single wetland is subject to substantial seasonal and annual variation (Skagen and Knopf 1994*b*).

Agricultural conversion of floodplains and other wetland types in the midwestern U.S. may necessitate habitat construction, rehabilitation and management, to provide surrogate environments for shorebird species that were originally dependent on natural areas. Moist soil units can provide inland shorebird habitat when managed properly, and can simulate natural complexes of ephemeral wetlands. However, reservoirs are also abundant in the interior U.S. (Dahl and Johnson 1991) and may have potential to provide reliable shorebird habitat. Fluctuating water levels limit vegetation establishment on reservoir shorelines and droughts do not lead to complete dessication of exposed substrates (Allen and Klimas 1986).

Despite the abundance of large impoundment and man-made lakes in the U. S., few studies have documented their use by shorebirds or investigated whether reservoirs provide high quality habitat (Taylor et al. 1993, Mihuc et al. 1997). Previous research has demonstrated shorebird use of moist-soil units in the midwestern U. S., and management strategies have been developed to target shorebird species and their prey (Rundle and Fredrickson 1981, Hands et al. 1991, Eldridge 1992, Helmers 1992). Since hydrology and topography differ greatly between moist-soil units and reservoirs, determining the value of reservoirs to migrating shorebirds is essential, and system-specific management strategies may be required.

Rend Lake, a reservoir in southern Illinois, may offer man-made shorebird habitat in a state that has experienced some of the greatest declines in natural wetland habitat (Dahl and Johnson 1991). Shorebird dependence on sparsely vegetated shallow water wetlands and mudflats suggests that habitat associated with shallow shorelines of reservoirs may buffer the loss of natural areas.

Although Rend Lake is not managed specifically for shorebirds, gently sloping banks on the northwest side of the lake and the east side of Nason Point attract many shorebird species during fall migration and some spring migrants (Robinson 1996, McMullen and Zoanetti 1999). However, shorebird use and habitat availability has not been quantified, and the relationship between lake hydrology and shorebird habitat availability is unclear. Furthermore, the effect of hydrology on the timing, amount, and quality of habitat provided (based on prey availability and predation risk) has never been examined at Rend Lake or any other reservoir in Illinois.

Waterfowl

States along the Mississippi River that provide important waterfowl habitat (U.S. Fish and Wildlife Service et al. 1986) have lost an average of 68.8% of their wetlands; and, Illinois has lost more than 85% (Dahl 1990). In response to the decrease in waterfowl populations and wetland habitats, the North American Waterfowl Management Plan (NAWMP) established guidelines and recommendations to help increase waterfowl populations to the levels observed during the 1970s (U.S. Fish and Wildlife Service et al. 1986, U.S. Fish and Wildlife Service et al. 1998). Specifically, NAWMP recommends studying how agriculture and industry such as dam construction and coal mining influence wintering and migration areas used by waterfowl (U.S. Fish and Wildlife Service et al. 1986).

Wetland losses caused by dam construction have been identified as a threat to waterfowl (Kozulin et al. 1998); however, existing reservoirs may provide wetland habitat (Schmidt and Haugen 1966). As of 1988, there were approximately 2,700 major (>2,023 ha) reservoirs and controlled freshwater lakes in the United States. The total area of freshwater lakes and reservoirs increased 46,000 ha from 1986 to 1996 (Dahl 2000). Five hundred and eighty-seven reservoirs exist in the states bordering the Mississippi River, the backbone of the Mississippi Flyway; and, 53 major reservoirs exist in Illinois. These reservoirs and their managed sub-impoundments could affect waterfowl populations by increasing the amount of habitat available for use throughout the year. As the number of reservoirs and associated wetlands increase, more research is needed to evaluate the dynamics of wetland habitats within reservoirs.

Shoreline habitats within reservoirs can contribute to the nutritional needs of waterfowl. Moist soil and wetland vegetation along reservoir margins and natural wetlands are important to spring migrating ducks because they provide nutrients needed for the breeding season. Foods high in lipids, proteins, and carbohydrates are sought out by spring migrating ducks because as winter ends, ducks need to build nutritional reserves necessary for use during the breeding season (Jorde 1981). Females need to obtain lipids and proteins to support egg production (Krapu 1981). Northern pintail (*Anas acuta*) hens arriving on the breeding grounds in North Dakota had large sub-cutaneous and visceral fat reserves (Krapu 1974). Prior to arriving on the breeding grounds, mallard (*A. platyrhynchos*) hens stored lipids for egg formation (Krapu 1981). Mallards lost weight during the winter, but regained their pre-winter weight at a spring staging area in Nebraska by ingesting foods high in needed nutrients (Jorde 1981). Ingesting grains and plant material provides ducks lipids, carbohydrates, and a small amount of protein (Baldassarre et al. 1983). Animal matter supplies a large amount of protein and small amounts of lipids and carbohydrates (Krapu and Swanson 1975).

Relatively little is known about the foods eaten by spring migrating dabbling ducks compared to the winter or breeding season. A few studies have identified some plant foods consumed by migrating ducks. Mallards in Missouri consumed smartweed (*Polygonum* spp.), chufa (*Cyperus esculentus*), and rice cutgrass (*Leersia oryzoides*) during spring migration (Gruenhagen and Fredrickson 1990). Plants composed 35% of the aggregate weight of food found in spring migrating blue-winged teal (*Anas discors*) collected in Missouri (Taylor 1978). Genera found included *Brasenia*, *Cephalanthus*, *Digitaria*, *Diodia*, *Eleocharis*, *Leersia*, *Ludwigia*, *Panicum*, *Polygonum*, *Sida,* and *Ulmus* (Taylor 1978). All habitats, including reservoir shorelines, that provide these moist soil annuals and perennials should be considered important areas for waterfowl during the spring.

Upper reaches of reservoirs normally develop gradual slopes and mudflats from sedimentation caused by the inflow of the swifter flowing river into the slow moving reservoir waters (Morris and Fan 1998). These habitats can support moist soil and wetland plants communities. However, within these upper reaches, the community composition and growth are affected by the shoreline sinuosity and the elevational gradient (Collins and Wein 1995). Coves protected from wind and wave action may support different vegetation communities than exposed shorelines (Hankla 1952, Kolar 1978, Caffrey and Roslett 1989, Collins and Wein 1995). Coves also can serve as a collection area for seeds (Collins and Wein 1995). Many factors affect the composition and growth of moist soil and wetland vegetation communities. Evaluating and understanding factors affecting reservoir vegetation can improve management practices that increase food availability for spring migrating ducks.

In addition to food resources, temperature, wind speed, and habitat structure are conditions that affect non-breeding ducks. Habitat structure within reservoirs can be highly variable and greatly influence the effect of wind speed and temperature. As temperature decreases and wind increases, ducks meet energy and thermoregulatory demands by increasing food consumption (Cain 1973, Hickey and Titman 1983, Dabbert and Martin 1994, Michot et al. 1994), decreasing exposure of body parts (Brodsky and Weatherhead 1984), and moving to areas protected from the wind (Brodsky and Weatherhead 1984, Jorde et al. 1984, Gruenhagen 1987, Esler et al. 2000). During colder winter weather, mallards in Nebraska sought out warmer but lower quality habitats as defined by decreased space and food (Jorde et al. 1984) and increased risk of predation (Jorde 1981). As wind increased in unprotected areas, mallards spent more time resting or moved to protected areas (Gruenhagen 1987). Barrow's goldeneyes (*Bucephala islandica*) used protected areas more than areas subjected to wind and waves (Esler et al. 2000). During windy conditions, American black ducks (*A. rubripes*) roosted 3 kilometers away from their feeding site at a protected area that provided an 8 kph decrease in wind speed (Brodsky and Weatherhead 1984). Windbreak effectiveness depends on habitat and vegetation structure. The orientation of cove openings, vegetation location, and cove topography affects windbreak effectiveness. Terrestrial vegetation surrounding coves (Baker et al. 2000) and trees on the edge of water bodies can be important windbreaks for waterfowl (Bennett and Bolen 1978, Jorde et al. 1984). Dabbling ducks may use vegetated coves to decrease their thermoregulatory energy expenditure during spring migration.

Subsidence Effects

Since commercial mining for coal began in Illinois in 1810, more than 72,000 ha of underground area have been affected; however, the extent of subsidence affected upland or wetland habitats is generally unknown. In the Orient Bottoms area of southern Illinois, approximately 400 ha of emergent wetlands resulted from subsidence associated with the underground mining of coal during the early to mid-1950s (Nawrot et al. 1995). Subsidence can alter the vegetation of upland and wetland habitats by lowering of ground elevations and shifting of the hydroperiod to inundation events characterized by greater frequency and duration (Nawrot et al. 1995). Subsided upland habitats can undergo succession to moist soil and emergent wetlands, while subsided moist soil and emergent wetlands may shift to scrub-shrub and open water wetlands. Underground mining for coal has occurred under and adjacent to portions of Rend Lake for more than 50 years. Recent longwall coal mining at Ward Branch, on the west side of Rend Lake, produced several wetland subsidence basins in previous upland and shoreline habitats (Owen 1992, Barkley 2000).

Wetland habitat development was evaluated in the Ward Branch longwall subsidence basins (Owen 1992); however, the effects of subsidence on waterfowl and shorebirds using Rend Lake's shoreline habitats was unknown. Therefore, impacts of future underground mining activities on waterfowl and shorebird habitat was identified as the focus of this research project. Baseline research was needed to determine waterfowl and shorebird use, lake hydrology, habitat availability and overall habitat quality. Job1.1 provides a compilation and review of the principal factors associated with the short term and long term seasonal hydrology; and, the plant communities of the subsided and unsubsided shoreline habitats of the Rend Lake study area.

STUDY AREA

History and Current Management

Rend Lake is a man-made reservoir located in Jefferson and Franklin counties, Illinois (38°N, 88°E; Fig. 1). The U. S. Army Corps of Engineers (USACE) began reservoir construction in 1965 and by May 1972 Rend Lake was completed. Rend Lake was designed to alleviate local water supply problems. Prior land use was characterized by bottomland hardwood forest and upland agriculture. The reservoir, located in the Mt. Vernon hill country of the Till Plains Section (Leighton et al. 1948), is characterized by Bonnie, Sharon, and Belknap soils (Miles and Parks 1965). These soils have a high clay content and slow permeability rates (Miles and Parks 1965). Groundwater does not affect the study area because the clay soils beneath the lake acted as a barrier.

Rend Lake functions as a multi-purpose area providing wildlife habitat, recreational opportunities, and flood control. The USACE owns the 7,695 ha reservoir and approximately 8,100 ha of adjacent land between 123.4 m (405 ft) and 126.9 m (416 ft). The Illinois Department of Natural Resources (IDNR) manages approximately 6,075 ha of land and water including the 1,215 ha Wayne Fitzgerrell State Park and the 2,025 ha Nason Point Wildlife Refuge. This study focused on northern portions of the main impoundment at Nason Point (Fig. 2) and Ward Branch shorelines (Fig. 3).

Consolidation Coal Company (CONSOL) owns the mineral rights under a portion of Rend Lake and has extracted coal from the 1.83 m (6 ft) thick coal seam, lying 183 m (600 ft) below the surface of Rend Lake (Mehnert et al. 1997) using underground longwall mining techniques. Consolidation Coal Company completed longwall mining at Ward Branch and the western shoreline of Nason Point during 1999. Longwall mining began on the eastern shoreline

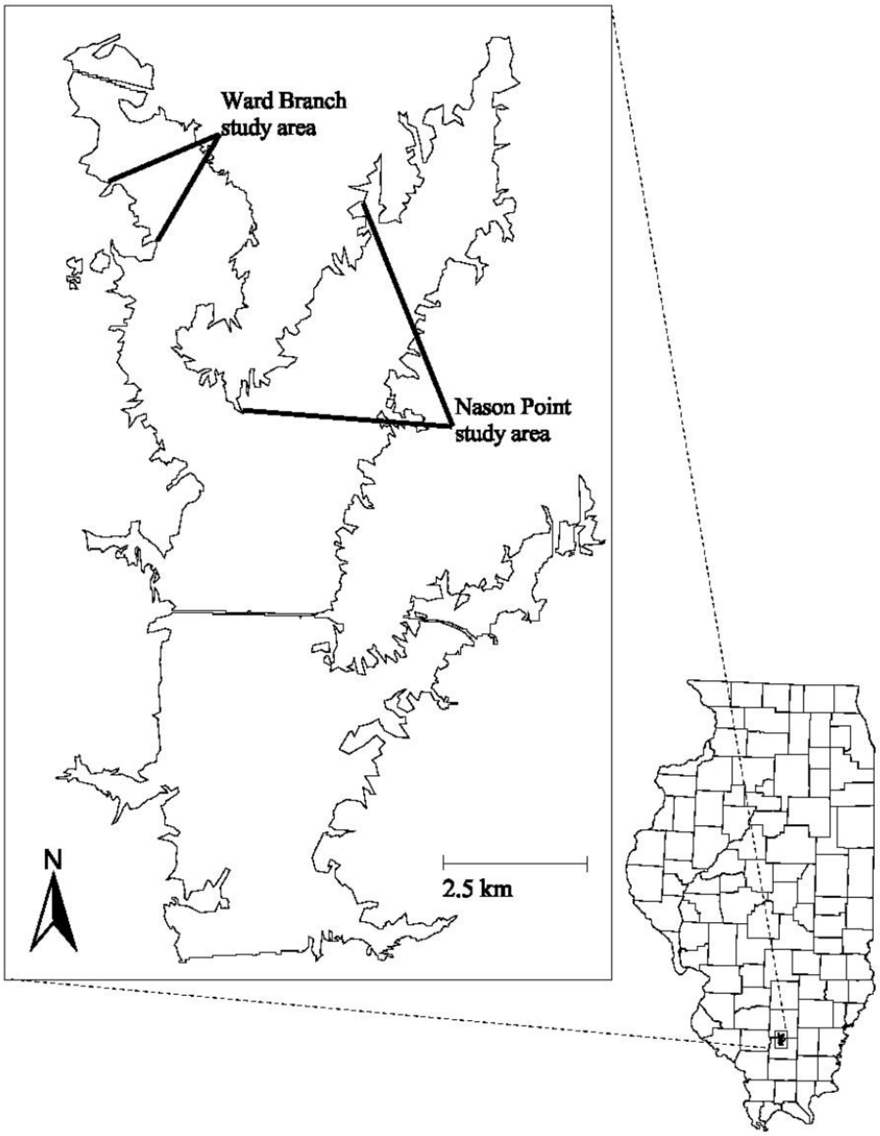

Figure 1. Location of Rend Lake reservoir in Illinois.

of Nason Point during 2000 but stopped during 2002 due to the depressed coal market. The mine is currently idle.

Reservoir Hydrology

Between joint use and flood control pool elevations of 123.44 m (405 ft) and 124.97 m (410 ft) National Geodetic Vertical Datum (NGVD), respectively, the surface area of the lake is 7,654.5-10,044 ha with a total water storage capacity of 228,190,000-362,640,000 m^3. At 123.44 m (405 ft) NGVD maximum water depth is 10.6 m and shoreline length is 261 km (162 mi) (USACE, unpublished data). Rend Lake inflows are from direct precipitation, runoff, and several tributaries including the Big Muddy River and Casey Fork. Total watershed area is 188.4 km^2. Discharge from Rend Lake enters the Big Muddy River through the main spillway at 124.97 m (410 ft, NGVD) and the auxiliary spillway at 126.49 m (415 ft, NGVD). Other outflows include seepage, evaporation, and municipal withdrawal. Water levels are controlled by 3 structures; the Big Muddy Subimpoundment Dam and Casey Fork Subimpoundment Dam control inflow; Rend Dam at the spillway controls outflow (USACE, unpublished data).

Mean annual hydrograph of Rend Lake exhibits increasing water levels throughout the winter and spring, and decreasing water elevation in summer and fall (Fig. 4). Throughout the fall shorebird migration season (1 Jul-31 Oct), weekly lake drawdown averages ~4 cm (0.13 ft); however, weekly change in lake level is highly variable among years, particularly at the beginning and end of the migration season (Fig. 5). Lake level variation during the spring waterfowl migration period can also be extremely variable; however, high water elevations generally coincide with the upper pool seasonal elevation (124.97 m) (Table 1, Fig. 6).

Reservoir Topography

Slopes are gradual on east-facing portions of Nason Point and the adjacent northwest portion of Rend Lake (<5% slope), but steep on westward facing shorelines. Shallow water habitat is generally associated with these gently sloping areas. Small changes in lake level may

Table 1. Comparison of mean February, March, and April 2002 lake level, temperature, wind speed, and wind direction with historical averages recorded at Rend Lake College, Ina, Illinois. Values in parentheses represent SD.

Variable	Date	February	March	April
Temperature (°C)[a]	1991-2001	1.16 (6.65)	4.87 (5.96)	11.70 (5.13)
	2002	1.17	4.47	13.26
Wind speed (kph)[a]	1991-2001	3.77 (2.05)	4.68 (2.09)	4.50 (1.95)
	2002	3.53	4.14	3.76
Wind direction[ab]	1991-2001	2.54 (1.11)	2.47 (1.12)	2.31 (1.04)
	2002	2.43	2.39	2.18
Lake level (m)[c]	1974-2001	124.18 (0.65)	124.36 (0.56)	124.52 (0.52)
	2002	124.46	124.79	124.99

[a] Daily 8 am temperature and wind data obtained from Illinois State Water Survey, Rend Lake College weather station.

[b] Wind direction was converted from degrees into 4 wind quadrants; 1= 46° to 135°(NE-SE), 2= 136° to 225°(SE-SW), 3= 226° to 315°(SW-NW), and 4= 316° to 45°(NW-NE).

[c] Obtained from US Army Corps of Engineers

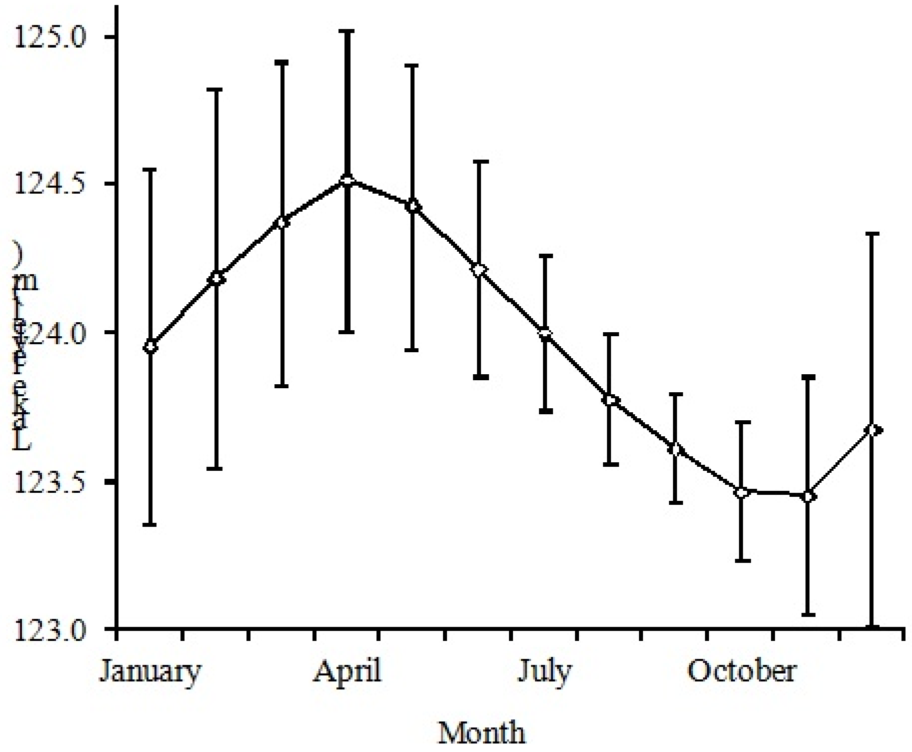

Figure 4. Hydroperiod of Rend Lake, Illinois (1974-2001). Error bars represent SD.

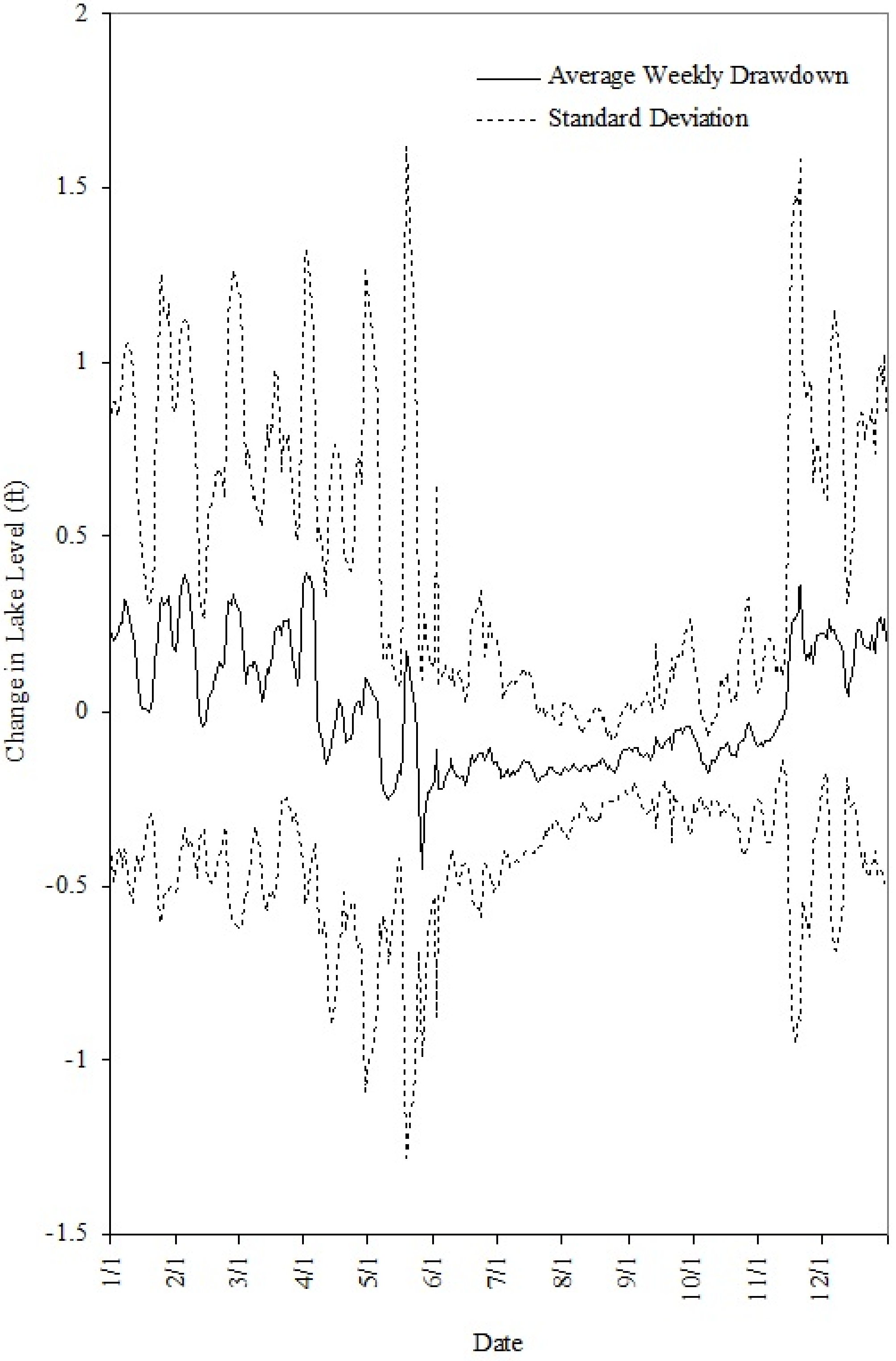

Figure 5. Weekly change in Rend Lake, Illinois water level. Means and standard deviations are based on 27 years of data (1975-2001).

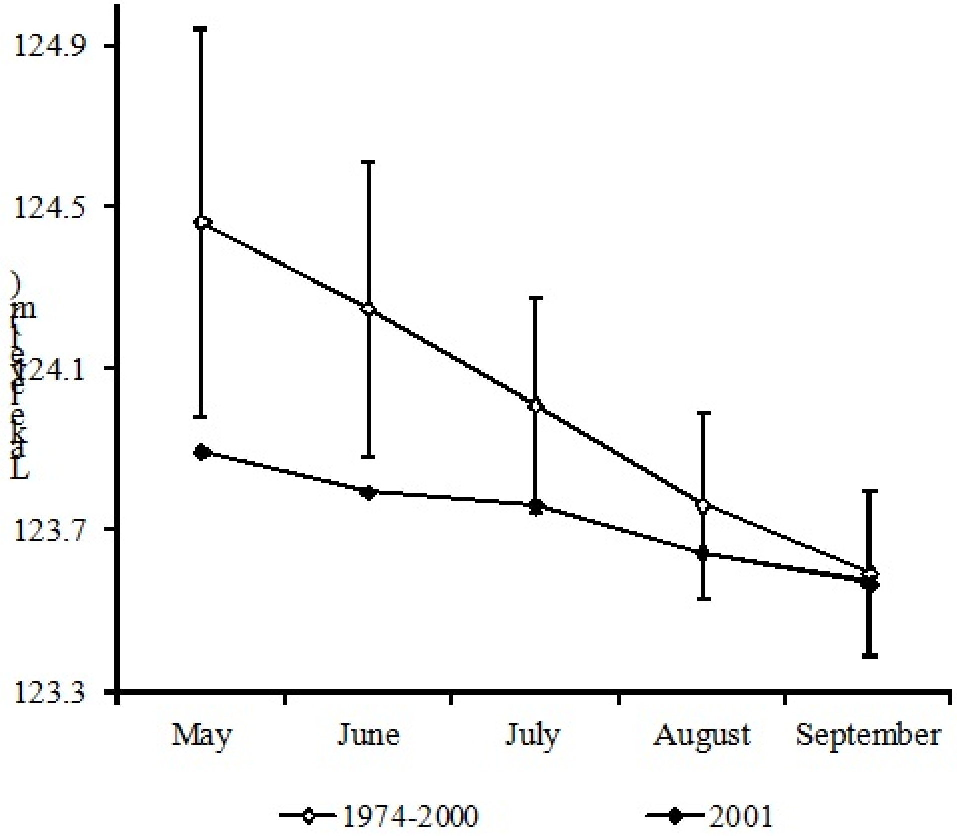

Figure 6. Comparison of May, June, July, August, and September 27 year (1974-2000) average lake levels and May, June, July, August, and September 2001 average lake levels. Error bars represent SD.

have little effect on steep shores, but when slope is gradual a small change in lake level may correspond with inundation or exposure of a large area.

Prior to subsidence of the Ward Branch area in 1988, its topography closely resembled that of the east side of Nason Point (Owen 1992) . The northwest shoreline was characterized by gentle slopes and extensive mudflat; however, the subsidence of 3 long-wall mining panels altered the shape and slope of this area. Shortly after extraction, the ground above a panel subsides, producing a depression on the surface of the land. Approximately 90% of subsidence occurs within 3 months of mining. Maximum subsidence occurs in the center of the depression; depth in the subsidence basin is about 70% of the height of underground seam, or approximately 2 m for panels at Rend Lake (Mehnert et al. 1997).

Subsidence panels run perpendicular to the northwest shoreline of Rend Lake; therefore, subsidence increased the length of the northwest shoreline. Slope is approximately 0.5-1.5 % along the longitudinal axes of subsidence panel basins, and approximately 0.1-0.3 % in areas between troughs representing unmined mudflat topography. Slopes on the east side of Nason Point are generally < 1.0 %, with the widest portion of mudflat habitat occurring on the northeast end of Nason Point (≤0.5%). Slope associated with the northeast Nason Point wetland observation tower was less than 0.2 % in contrast to slopes of subsided wetland than ranged from 0.28 to 1.05% (Table 2).

METHODS

Hydrology and Habitat Availability

To characterize hydrologic patterns associated with the fall shorebird migration segment of this project, daily water levels recorded at the main spillway during late summer and fall (1 Jul-31 Oct) for 2000 and 2001,were compared to the mean water level elevations for 1975-2001. The weekly change in lake level for each day of the shorebird study was calculated by subtracting the previous weeks water level. We also calculated mean daily drawdown for

Table 2. Longitudinal axis transect lengths (m) and slope[a] (%) and side transect lengths (m) at Ward Branch and Nason Point, Rend Lake, Illinois.

Location	Primary habitat	Longitudinal axis transect length	Slope	Side transect length
NP 2	exposed shoreline	115	0.49	
NP 5	exposed shoreline	50	1.38	
NP TOWER	exposed shoreline	426	0.15	
WB 3 E	exposed shoreline	333	0.15	
NP 23	unsubsided cove	240	0.31	70
NP 4	unsubsided cove	102	0.61	106
NP 45	unsubsided cove	215	0.23	70
NP 6A	unsubsided cove	146	0.49	93
NP SUB	subsided cove	56	1.05	36
WB 1	subsided cove	33	0.94	40
WB 2	subsided cove	60	0.93	60
WB 3[b]	subsided cove	260	0.28	53
Mean	exposed shoreline	231	0.54	
	unsubsided cove	176	0.41	85
	subsided cove	102	0.80	47

[a] Slope was not calculated for side transects.

[b] WB3's longitudinal axis transect length was greater than the other 3 subsided coves because this cove was at maximum drawdown

1975-2001. The 27-year average drawdown was then plotted with the daily change in lake level during fall 2000 and 2001.

Since fine scale topographic data for Rend Lake did not exist it was not possible to calculate the exact area of mudflat and shallow water habitat for different water levels observed during the shorebird study field seasons. However, an aerial photograph of Rend Lake, taken on 30 August 1999 (lake level 123.63 m [405.6 ft]), was used in conjunction with ARCVIEW (Environmental System Research Institute, Redlands, California, USA) to estimate the shoreline length and area of exposed mudflat for all portions of the shorebird observation study areas. An enlarged portion of the photograph was used to determine shoreline length within the subsided and unsubsided study areas (Appendix A and B). Area associated with mudflat habitat was delineated for each survey day. The extent of mudflat habitat for the entire study area was calculated from the sum of the individual study area segments. Although these methods did not yield the exact availability of habitat for each survey day, it did provide information about the relative size of the shorebird survey areas.

Vegetation

Vegetation assessments were conducted for the principal habitats associated with the waterfowl utilization segment of this project. Vegetation surveys were conducted along transects located at 4 subsided coves, 4 unsubsided coves, and 4 exposed shorelines (Figs. 7, 8, 9, and 10) during September 2001. Exposed shorelines had 1 longitudinal axis transect, oriented approximately perpendicular to the shoreline at 123.4 m (Fig. 11). All exposed shoreline transects began at the water's edge (~124.3 m) during September 2001. The upslope end point was the tree line, agricultural crop, or upland herbaceous vegetation (~124.0 m). Unsubsided coves and subsided coves had 2 transects which ran approximately through the cove's longitudinal axis (Collins and Wein 1995) and perpendicular to the midpoint of the longitudinal axis, hereafter called side transects (Fig. 11). Locations of the longitudinal axes were estimated in the field using aerial photographs of Rend Lake at full pool (124.9 m). All longitudinal axis

Figure 7. Locations of primary habitats on the eastern shoreline of Nason Point, Rend Lake, Illinois. Photo date: 30 August 1999. Lake level: 123.6 m.

Figure 8. Locations of primary habitats on the eastern shoreline of Nason Point, Rend Lake, Illinois. Photo date: 18 March 1999. Lake level: 124.96 m.

Figure 9. Locations of primary habitats on the western shoreline of Rend Lake at Ward Branch, Illinois. Photo date: 30 August 1999. Lake level: 123.6 m.

Figure 10. Locations of primary habitats on the western shoreline of Rend lake at Ward Branch, Illinois. Photo date: 18 March 1999. Lake level 124.96 m.

Figure 11. Example of vegetation transect orientation at coves and exposed shorelines at Rend Lake, Illinois. Photo date: 30 August 1999. Lake level: 123.6 m.

cove transects began at the water's edge (~123.4 m) during September 2001. Three subsided cove side transects began at the water's edge (~123.4 m) during September 2001. Subsided cove Ward Branch 3 (WB3; Appendix B) side transect began at the middle of the longitudinal axis transect (Fig. 11). The WB3 side transect did not start at the water's edge because this subsided area was at maximum drawdown during the vegetation surveys. Lake water was not present within the WB3 experimental unit boundary (Appendix B). All side transects at unsubsided coves began at the midpoint of the longitudinal axis transects (Fig. 11). The upslope end point for subsided cove and unsubsided cove longitudinal axis transects and side transects was the tree line, agricultural crop, or upland herbaceous vegetation (~124.0 m). All transects lengths varied (Table 2). At 5 equally spaced points including the beginning and ending points of each transect, a 0.25 m^2 (0.5 x 0.5 m) aluminum sample plot was alternately tossed to the left or right of the transect. Within each sample plot, we measured percent cover for each genus separately and total vegetation cover in 10% increments; and, vegetation height (cm) at the center of the plot, and the height of the tallest vegetation (cm) within the plot. Prior to analysis, percent data were transformed using arcsin square root (Sokal and Rohlf 1995). We tested for differences in vegetation height and percent cover at longitudinal axis transects between exposed shorelines, subsided coves, and unsubsided coves using one-way ANOVA. We tested for differences in vegetation height and percent cover at side transects between subsided coves and unsubsided coves using one-way ANOVA. A significance level of $\alpha = 0.05$ was used for all tests.

RESULTS

Hydrology and habitat availability

During shorebird surveys conducted in 2000, lake levels were higher than the long term average; 2001 water levels were below average in late summer and early fall, but slightly higher than average in late fall (Fig. 12). Although fall is typically a time of drawdown, lake levels

Figure 12. Mean daily lake levels during the shorebird migration period (Jul-Oct) at Rend Lake, Illinois, and lake levels observed during the 2000 and 2001 field seasons. Average water levels were calculated from 27 years of data (1975-2001).

increased during July and early August 2000. During the remainder of fall 2000, Rend Lake was continually drawing down (Fig. 13). Water levels fluctuated in 2001; however, there was 1 continual period of gradual drawdown from early September to early October which contributed to exposed mudflats (Fig. 13). Because of high water levels in July 2000, the start of shorebird observations was delayed until 15 August, when mudflat habitat first became available. In 2001, mudflat habitat was available on 3 July, which coincides with the beginning of fall shorebird migration in southern Illinois.

Spring waterfowl habitat availability during 2002 was considered to be representative of normal hydroperiod effects, as lake levels during the February, March, and April 2002 dabbling duck surveys were similar to the previous 10 years (Table 1). However, May and June 2001 lake levels were lower than the 27 year (1974-2000) average lake levels (Fig. 6). Hydroperiod variation during the previous years growing season (July, August, and September 2001) was within the standard deviation of the 27 year (1974-2000) average (Fig. 6)

At a lake elevation of 123.63 m (405.6 ft), shoreline length was about twice as long at Ward Branch compared to Nason Point; however, potential shorebird habitat area was slightly greater at Nason Point (Table 3). Shoreline length in the northern region of Nason Point was slightly greater than in the south, but habitat area was 3-4 times greater in the northern portion of Nason Point compared to the southern region. At Ward Branch, unsubsided shorelines were almost equal in length to subsided shorelines but unsubsided area was 3-4 times larger than subsided habitat (Table 3).

Vegetation

We recorded 22 plant genera; 12 at exposed shorelines, 16 at unsubsided coves, and 18 at subsided coves (Tables 4 and 5). The average percent cover of *Cyperus*, *Echinochloa*, *Eleocharis*, *Leersia*, and *Polygonum* were combined to test for differences between subsided and unsubsided habits because these genera represented ≥5% of the total organic volume or ≥5% aggregate weight of food eaten by dabbling ducks (Anderson 1959, Taylor 1978). No significant

Table 3. Shoreline length and mudflat habitat area for shorebird study areas at Rend Lake, Illinois. Habitat measurements were estimated from an aerial photograph taken on 30 August 1999, at a lake elevation of 123.63 m (405.6 ft). Study areas are separated by site and correspond to shoreline segments and mudflat habitats associated with ground survey areas.

	Nason Point			Ward Branch		
Measurement	North	South	Combined	Subsided	Unsubsided	Combined
Length (m)	1,300	1,030	2,330	2,254	2,191	4,445
Area (ha)	22.0	5.6	27.6	5.1	18.0	23.1

Table 4. Average vegetation percent cover recorded along longitudinal axis transects at exposed shorelines, unsubsided coves, and subsided coves during September 2001 at Nason Point and Ward Branch, Rend Lake, Illinois.

Genus/species	Exposed shoreline	Unsubsided cove	Subsided cove
Ammania sp.	10.0	13.5	7.0
Cyperus spp.	11.0	3.0	17.0
Echinochloa sp.	0.0	0.5	1.0
Eclipta alba	0.0	6.5	1.5
Eleocharis spp.	21.5	30.5	44.0
Eragrostis spp.	32.5	33.0	21.0
Euphorbia supina	2.5	0.0	0.5
Heteranthera sp.	0.0	0.0	4.0
Leersia sp.	0.0	0.5	11.0
Lemna sp.	0.0	0.0	4.5
Leptochloa panicoides	0.0	0.0	1.5
Ludwigia sp.	0.0	4.5	3.5
Panicum spp.	2.5	13.0	8.5
Paspalum sp.	0.0	0.0	1.5
Phyla lanceolata	0.5	0.0	0.0
Polygonum spp.	20.5	10.5	12.5
Rotala sp.	8.5	1.5	4.0
Sagittaria spp.	2.0	6.5	8.5
Salix nigra	0.5	2.5	0.0
Scirpus sp.	0.0	1.0	0.0
Xanthium strumarium	3.5	15.0	24.0
Relative cover	81.5	78.5	83.5

Table 5. Average vegetation percent cover recorded along side transects at unsubsided coves and subsided coves during September 2001 at Nason Point and Ward Branch, Rend Lake, Illinois.

Genus/species	Unsubsided cove	Subsided cove
Ammania sp.	1.5	20.0
Amaranthus sp.	0.5	0.0
Cyperus spp.	14.0	7.0
Echinochloa sp.	4.0	2.0
Eclipta alba	1.5	2.0
Eleocharis spp.	19.0	63.5
Eragrostis spp.	33.0	13.0
Euphorbia supina	6.0	0.0
Leersia sp.	6.0	1.5
Leptochloa panicoides	0.0	7.0
Ludwigia sp.	5.0	3.0
Panicum spp.	42.0	1.5
Polygonum spp.	16.5	10.0
Rotala sp.	0.0	2.5
Sagittaria spp.	0.5	8.0
Xanthium strumarium	10.5	29.0
Relative cover	88.0	91.5

Figure 13. Mean weekly drawdown during the shorebird migration period (July-October 1975-2001) at Rend Lake, IL, and drawdowns observed during my field seasons (2000, 2001).

differences were found in the percent cover of these waterfowl foods between exposed shorelines, subsided coves, and unsubsided coves for both longitudinal axis transects and side transects (Table 6). Differences in the relative percent vegetation cover and vegetation height were also not significant at longitudinal axis transects or side transects (Table 6). In general, the summer 2001 drawdown which enhanced this moist soil vegetation establishment represented an average summer drawdown for Rend Lake (Fig. 3).

The Sørensen coefficient (Sørensen 1978) was used to test for community similarity of the subsided and unsubsided habits. The coefficient of community similarity (CC_S) is derived from the formula

$$CC_S = 2c/(s^1 + s^2)$$

where c is the number of species found in both communities and s is the total number of species found in each community. Values for genera were substituted for species values in the equation. Unsubsided and subsided cove side transects were the most similar (Table 7). Exposed shorelines and subsided cove longitudinal axis transects were the least similar (Table 7). *Ammania*, *Eleocharis*, *Eragrostis*, *Polygonum*, *Rotala*, and *Sagittaria* were common genera in longitudinal axis transects, occurring in ≥75% of the transects. *Cyperus*, *Eleocharis*, *Eragrostis*, and *Polygonum* were common genera in cove side transects, occurring in ≥75% of the transects. Aquatic genera such as *Heteranthera* and *Lemna* were found only in subsided coves. Grasses such as *Echinochloa, Leptochloa*, and *Paspalum* were found only in coves. *Cephalanthus* and *Acer* were observed within the boundaries of the experimental units but were not recorded in the transects.

DISCUSSION

Wetlands are defined by hydroperiod: the frequency and duration of flooding. Subsidence results in a change in the hydroperiod due to the decrease in surface elevation. After underground longwall coal mine subsidence, there will be changes in the area of shallow water

Table 6. One-way ANOVA of moist soil vegetation community measurements at longitudinal axis transects and side transects at Ward Branch and Nason Point, Rend Lake, Illinois.

Transect	Variable	Num DF	Den DF	F Ratio	*P*-value
Longitudinal axis	Percent cover of 5 dabbling duck foods[a]	2	9	1.68	0.24
	Relative percent vegetation cover[a]	2	9	0.41	0.67
	Vegetation height (middle) (cm)[a]	2	9	1.05	0.39
	Vegetation height (tallest) (cm)[a]	2	9	0.43	0.66
Side	Percent cover of 5 dabbling duck foods[b]	1	6	1.88	0.22
	Relative percent vegetation cover[b]	1	6	0.03	0.87
	Vegetation height (middle) (cm)[b]	1	6	0.88	0.38
	Vegetation height (tallest) (cm)[b]	1	6	0.14	0.72

[a] comparison of vegetation on longitudinal axis transects located at 4 exposed shorelines, 4 subsided coves, and 4 unsubsided coves

[b] comparison of vegetation on side transects located 4 subsided coves and 4 unsubsided coves

Table 7. Sørensen Community Coefficients, a measure of community similarity (% similar) for vegetation genera surveyed along longitudinal axis and side transects at exposed shorelines, unsubsided coves, and subsided coves during September 2001 at Nason Point and Ward Branch, Rend Lake, Illinois.

Comparison	Sørensen Community Coefficient	
	Longitudinal axis	Side
Exposed shoreline vs. subsided cove	66.7	-
Exposed shoreline vs. unsubsided cove	74.1	-
Subsided cove vs. unsubsided cove	78.8	85.7

habitat along Nason Point's shoreline. CONSOL estimated a net increase of 11.6 ha in post-subsidence land between 123.4 and 124.9 m above sea level above 3 proposed coal panels along Nason Point's shoreline (unpub. data).

Although a net increase in shallow water habitat was predicted for post-subsidence habitats, it is the diversity and vegetative cover of the post-subsidence plant community that determines the habitat quality for spring dabbling ducks. Based on current knowledge of spring migrating dabbling duck habitat needs, this project investigated subsidence effects by assessing the moist soil vegetation community and the distribution of spring migrating dabbling ducks at subsided and unsubsided habitats at Nason Point and Ward Branch. No difference was found in the plant community or spring waterfowl utilization of subsided and unsubsided habitats in the Ward Branch and Nason Point study areas.

Changes in hydrology associated with subsidence results in a shift of moist soil and open water wetland plant communities and the adjacent upland plant communities. Portions of Nason Point's seasonally inundated moist soil vegetation community will shift to occupy the intermittently inundated post-subsidence zone because of the decreased elevation and the increased frequency and duration of flooding after subsidence. The post-subsidence moist soil vegetation community at Ward Branch resembled the pre-subsidence moist soil vegetation community (Owen 1992). The community Owen (1992) observed shifted from the pre-subsidence seasonally inundated zone to the post-subsidence seasonally inundated zone within 3 years after subsidence. Nawrot et al. (1995) observed a shift to annual and perennial moist soil vegetation, seasonally inundated palustrine forested habitat, and permanently inundated scrub-shrub and open water wetlands in subsided areas that had previously supported bottomland forest. The results of the current project suggested that wetland plant community succession will also occur along Nason Point's shoreline. The 5 common dabbling duck food genera, *Cyperus*, *Echinochloa*, *Eleocharis*, *Leersia*, and *Polygonum*, will shift from their current location along Nason Point to the post-subsidence seasonally inundated zone after subsidence.

In summary, the hydrologic regime is the principal variable affecting both natural or constructed wetlands. The frequency and duration of flooding affects the vegetation and wildlife community composition and abundance. Current moist soil zones along Nason Point will subside and portions of these habitats will be permanently inundated, while upland habitat, supporting herbaceous and woody species, will subside and shift to support moist soil wetland species such as *Polygonum* spp. The hydrologic regime as determined by seasonal water level fluctuations within Rend Lake will remain the same but will affect previously upland areas. Moist soil vegetation and spring migrating dabbling duck communities will shift to occupy the post-subsidence seasonally inundated zone on Nason Point's shoreline after subsidence. Subsidence will not negatively impact the moist soil vegetation or spring migrating dabbling duck communities along Nason Point's shoreline. However, we should continue to assess Rend Lake's recently subsided areas to evaluate the interaction of shoreline configuration and long-term hydrologic variation on wetland successional development and wildlife utilization.

JOB 1.2: SPECIES COMPOSITION, ABUNDANCE AND CHRONOLOGY

Objective: Document migration chronology, abundance, and habitat use patterns of migratory shorebirds and waterfowl during fall and spring migration.

INTRODUCTION

Quantifying shorebird and waterfowl use of Rend Lake Refuge is essential to assess the importance of the habitat provided by the Nason Point and Ward Branch subsided and unsubsided wetlands. Assessments of waterfowl and shorebird abundance, distribution, and behavior provide insight on habitat function and quality. The gently sloping shoreline and seasonally exposed mudflats on the east side of Nason Point attract migrating shorebirds and waterfowl; however, use has not been quantified for most species during fall and spring. This project included an assessment of shorebird and waterfowl utilization of unsubsided and subsided wetland habitats associated with the Ward Branch and Nason Point study areas. Comprehensive studies of shorebird and waterfowl utilization were conducted in conjunction with 2 graduate research projects: shorebirds (Elliott-Smith 2003) and waterfowl (Kirk 2003).

METHODS

Waterfowl

Waterfowl distribution surveys were conducted from 1 February to 25 April 2002, using 8x32 binoculars and a 20-60x spotting scope. Experimental units surveyed included 4 subsided coves, 4 unsubsided coves, and 4 exposed shorelines at Nason Point and Ward Branch (Figs. 2 and 3). Starting points for each survey were alternated between the north end of Nason Point (NP) and the Ward Branch (WB2) subsidence wetlands (Appendices A and B) to remove any time of day bias. In addition to dabbling ducks, the abundance of other waterfowl and waterbirds were recorded. All dabbling ducks were recorded by species in 1) subsided coves, unsubsided coves, and exposed shorelines; and 2) percent of each species in secondary habitats (Table 8) within these primary habitats. Secondary habitat categories for Nason Point and Ward Branch

Table 8. Definitions of secondary habitat variables used during dabbling duck surveys conducted at Nason Point and Ward Branch, Rend Lake, Illinois during spring migration.[a]

Hydrologic condition	Secondary habitat	Definition
Not inundated	Dry mud	Visual appearance of mud is dry, <30% vegetation cover, and vegetation height <30 cm
	Wet mud	Visual appearance of mud is moist or wet, <30% vegetation cover, and vegetation height <30 cm
	Vegetated flats	Visual appearance of mud is dry or wet, >30% vegetation cover, and vegetation height >30 cm
Inundated	Flooded vegetation	Visual appearance of standing water, >30% vegetation cover, and vegetation height >30 cm
	Shallow water	Water-covered land above ~123.4 m
	Open water	Water-covered land below ~123.4 m
Either	Woody	Woody plant species present, little or no herbaceous emergent vegetation present

[a] adapted from Dugger and Nawrot 2001.

included dry mud, wet mud, vegetated flats, shallow water, flooded vegetation, woody shoreline, and open water (Table 8).

The location of open water and shallow water habitats were estimated in the field using aerial photographs of Rend Lake at ~123.4 and ~124.9 m pool elevations. Lake level for each survey date was obtained from the USACE St. Louis office (Appendix C). The parameter, birds per meter of shoreline (Suter 1994), was used to standardize experimental unit size. Shoreline was defined as the land water interface within the boundaries of each experimental unit (Appendices A and B). The shoreline of each experimental unit was measured at 3 lake levels: 124.30, 124.60, and 124.90 m (Appendix D). During the waterfowl surveys, the lake level rose from <124.30 to >124.90 m, which changed the length of shoreline available within and between experimental units. To use shoreline length to standardize experimental units temporally and spatially, the number of dabbling ducks in an experimental unit was divided by the experimental unit's shoreline length. Shoreline lengths measured at lake level 124.30 m were applied to all surveys taken during lake levels 124.20 to 124.50 m. Shoreline lengths at lake level 124.60 m were applied to all surveys taken during lake levels 124.51 to 124.81. Shoreline lengths at 124.90 were applied to all surveys during lake levels 124.82 to 125.11 m. Prior to analysis, the data were transformed using ln (Y+C) (Steel et al. 1997) where Y equals the number of dabbling ducks per meter of shoreline and C equals the smallest Y greater than 0 observed in the data. Differences in primary habitat use by dabbling ducks were tested for using mixed models repeated measures ANOVA, modified for measurements unequally spaced in time (Littell et al. 1996). Analysis of secondary habitat use was restricted to descriptive statistics because no effort was made to estimate the amount of each secondary habitat at each experimental unit for each survey day. The area of secondary habitats at each experimental unit changed daily depending on lake level, wind speed, and wind direction. Attempts to accurately measure secondary habitat area each day would have caused an unacceptable level of disturbance to the ducks.

Shorebird - Field Surveys

Fall Migration Chronology and Habitat Use.–Weekly shorebird surveys were conducted along the east side of Nason Point and Ward Branch during late summer and fall of 2000 and 2001 to document the southward migration chronology and habitat use patterns of shorebirds. All areas of potential shorebird habitat surrounding the 4 subsidence troughs in the Ward Branch area were surveyed by foot (Fig. 3). Two sites along the northeast and southeast side of Nason Point, representing very gradual slope (average ≤0.5%) in the north and moderate (>0.5%, but ≤1.0%) slopes in the south, were surveyed by foot (Fig. 2). Observations were made using 10x40 binoculars or a 20-60x spotting scope. All shorebirds were counted and potential shorebird predators detected during each survey were also recorded. Any shorebird within 5 m of a conspecific or bird of a closely related species was considered part of a flock (Davis and Smith 1998). The location of each individual or flock was recorded on an aerial photograph of the study site.

For all solitary birds and for each individual within a small flock (<50 birds) the microhabitat type at the spot each shorebird was standing was recorded. For large flocks (>50 birds), the percent of flock in each habitat type was visually estimated. Microhabitat was classified based on vegetation and inundation as dry mud (parched substrate, <30% cover of vegetation >10cm tall), wet mud (wet substrate, <30% cover >10cm), shallow water (standing water, <30% cover >10cm), vegetated flats (dry or moist substrate, >30% cover >10 cm), and flooded vegetation (emergent vegetation, >30% cover >10 cm).

Ground surveys were supplemented by kayak surveys, conducted during the beginning of fall migration (10 Jul-22 Sep 2000 and 2001). Kayak surveys covered the areas along the east side of Nason Point not surveyed by foot. During kayak surveys, we identified and recorded all shorebirds and predators using 10x40 binoculars. Time, location, flock size, and microhabitat use were also recorded according to the ground survey protocol. Kayak surveys were used to identify other areas on Nason Point important to shorebirds and to obtain a total bird count for the area.

Fall Shorebird Microhabitat Use and Behavior.–Shorebird microhabitat use and associated behavior data were collected during August and September 2000 and 2001. An effort was made to collect observations at a variety of locations representing the range of mudflat widths and habitat types available on the study area. To account for potential diurnal variations in shorebird behavior, observations were conducted during morning (sunrise-1100 hr), afternoon (1101-1500 hr), and evening periods (1501 hr-sunset). Seven common shorebird species representing small and large birds in both pecking and probing foraging guilds (Helmers 1991) were chosen for behavioral observations: least sandpiper (*Calidris minutilla*), semipalmated sandpiper (*C. pusilla*), pectoral sandpiper (*C. melanotos*), semipalmated plover (*Charadrius semipalmatus*), killdeer (*C. vociferus*), lesser yellowlegs (*Tringa flavipes*), and greater yellowlegs (*T. melanoleuca*).

Focal-animal sampling was used to examine individual shorebird behavior (Altmann 1974). An individual was observed for a maximum of 5 min; and behaviors were dictated into a micro cassette recorder at 10 sec intervals. Alert behavior was measured continuously with a different stopwatch and total time spent alert was recorded (to the nearest sec) at the end of the observation session. Behavioral activities were separated into 6 categories: feeding, sleeping, alert, body maintenance, aggression, and locomotion (Davis and Smith 1998, De Leon and Smith 1999). After the observation session, the birds distance to water, distance to upland cover (>30% vegetation cover) and distance to predator perch was measured using a range finder. At close range (<10 m) distance to water and distance to upland cover was visually estimated. An individual shorebird was selected for observation by aiming a spotting scope at a flock and choosing a bird in the viewing field; if more than 1 individual of the 7 study species was present in the viewing field the most central bird was chosen. For each session, the size of the associated flock was documented at the beginning of the observation. Habitat type was recorded every 10 sec in one of 5 categories described for survey methods. For individuals in shallow water, water depth relative to the leg and body of each bird was recorded (water level at lower tarsometatarsal joint (LTMJ), between LTMJ and upper tarsometatarsal joint (UTMJ), at UTMJ, between UTMJ and belly, at belly, and swimming; Helmers 1991).

Shorebird Data Analysis

Shorebird Abundance and Migration Chronology.–Shorebird counts were summed for each survey, for each year, and for all portions of both Nason Point and Ward Branch; species richness also was calculated for each site and year. Yearly abundance and species composition were illustrated by a cumulative bar graph for each year and site. Overall temporal trend in shorebird abundance was displayed graphically by plotting weekly totals for each survey.

Habitat Use Patterns.–Shorebird survey data were used to calculate the percent of shorebirds in each habitat type for each year and site. To estimate the water depths used by shorebirds, percent time spent in different water depth categories was calculated for each individual that used shallow water habitat during behavioral sessions. Although all species that occurred at Rend Lake were not included in behavioral observations, those species observed during focal-animal sampling were considered to be representative of the shorebird community.

For each bird observed during a behavioral observation, the percent time spent wading in each of 4 water depth categories: ≤3.0 cm, ≤6.0 cm, ≤9.0 cm, >9.0 cm was calculated. Percentages were calculated by summing the number of intervals a bird spent in each category and dividing by the total intervals spent wading; we then calculated average percent time spent in each depth category, analyzing species separately but grouping year and site. We recorded water depth relative to the leg of the bird; therefore, depth categories reflect the maximum depth that the birds may have been using. However, these categories are not discreet because some species leg length spans 2 water depth categories. For example, observations of lesser yellowlegs wading between their lower and upper tarsometatarsal joints corresponds to a water depth between about 0.5-5.1 cm; although some of these observations may have been of birds wading at ≤3.0 cm, they were all placed in the ≤6.0 cm category. Survey data was also used to calculate the relative abundance of each of the focal species by summing individuals of each species and dividing by the total number of birds counted. We then calculated the product of species relative abundance, proportion of species observed in water on surveys, and the proportion of time wading birds spent in each water depth category. By summing the products for all species an estimate of the proportion of the shorebird community in each "maximum depth" category was obtained. A cumulative percent graph estimating the proportion of the shorebird community in each habitat was also prepared.

RESULTS

Waterfowl Survey

A total of 39 dabbling duck distribution surveys were completed between 1 February and 25 April 2002 (Appendices E and F). In addition to waterfowl, waterbirds using the study area were also recorded. Divers (Tribe Aythyini) such as ring-necked ducks (*Aythya collaris*) and sea ducks (Tribe Mergini) such as common mergansers (*Mergus merganser*) were most abundant at exposed shorelines (Table 9). Snow geese (*Chen caerulescens*) and Ross's geese (*C. rossii*) used the open areas of the lake for loafing during migration. Within the experimental units, geese were most abundant at unsubsided coves (Table 9). American coot (*Fulica americana*), grebes, and wading birds were most abundant at subsided areas (Table 9). Total dabbling ducks surveyed was 22,038 (Table 9): 431 American black ducks, 1,722 American wigeon (*Anas americana*), 958 blue-winged teal, 292 gadwall (*A. streptera*), 3,730 green-winged teal (*A. crecca*), 11,063 mallards, 3,477 northern pintails, and 365 northern shovelers (*A. clypeata*). Dabbling duck abundance peaked on 25 March at 1,855. Species abundance peaked on different surveys. Most species peaked during March (Table 10). After standardizing experimental unit sizes, the total number of ducks per meter of shoreline at exposed shorelines, subsided coves, and unsubsided coves was similar (Table 11). The repeated measures analysis showed no significant

Table 9. Avian groups observed during 39 surveys from 1 February to 25 April 2002 at Nason Point and Ward Branch, Rend Lake, Illinois.

Primary habitat	Avian groups												Total
	Dabbling ducks [a]	Diving ducks [b]	Sea ducks [c]	Stiff-tailed ducks [d]	Perching ducks [e]	Geese [f]	Swans [g]	Wading birds [h]	Shorebirds [i]	Grebes [j]	Pelicans [k]	Coot [l]	
Exposed shoreline	4,231	228	160	14	0	4,805	3	13	56	2	34	1,043	10,589
Subsided cove	7,620	139	250	0	0	288	0	53	3	39	0	3,864	12,256
Unsubsided cove	10,187	0	86	2	2	9,912	2	51	39	13	235	647	21,176
Total	22,038	367	496	16	2	15,005	5	117	98	54	269	5,554	44,021

[a] American black duck (*Anas rubripes*), American wigeon (*A. americana*), blue-winged teal (*A. discors*), gadwall (*A. streptera*), green-winged teal (*A. crecca*), mallard (*A. platyrhynchos*), northern pintail (*A. acuta*), and northern shoveler (*A. clypeata*)

[b] lesser scaup (*Aythya affinis*), redhead (*A. americana*), and ring-necked duck (*Aythya collaris*)

[c] bufflehead (*Bucephala albeola*), common goldeneye (*B. clangula*), common merganser (*Mergus merganser*), hooded merganser (*M. cucullatus*), and red-breasted merganser (*M. serrator*)

[d] ruddy duck (*Oxyura jamaicensis*)

[e] wood duck (*Aix sponsa*)

[f] Canada goose (*Branta canadensis*), greater white-fronted goose (*Anser albifrons*), Ross's goose (*Chen rossii*), and snow goose (*C. caerulescens*)

[g] mute swan (*Cygnus olor*) and tundra swan (*C. columbianus*)

[h] American bittern (*Botaurus lentiginosus*), great egret (*Ardea alba*), green heron (*Butorides virescens*), and great blue heron (*A. herodias*)

[i] killdeer (*Charadrius vociferus*), greater yellowlegs (*Tringa melanoleuca*), and lesser yellowlegs (*T. flavipes*)

[j] pied-billed grebe (*Podilymbus podiceps*) and red-necked grebe (*Podiceps grisegena*)

[k] American white pelican (*Pelecanus erythrorhynchos*)

[l] American coot (*Fulica americana*)

Table 10. Numbers and dates of peak dabbling duck abundance by species during spring 2002 at Nason Point and Ward Branch, Rend Lake, Illinois.

Species	Peak date	Peak number
American black duck (*Anas rubripes*)	10 February	43
American wigeon (*A. americana*)	1 May	193
Blue-winged teal (*A. discors*)	21 March	162
Gadwall (*A. streptera*)	21 March	46
Green-winged teal (*A. crecca*)	25 March	578
Mallard (*A. platyrhynchos*)	18 March	1,273
Northern pintail (*A. acuta*)	19 February	754
Northern shoveler (*A. clypeata*)	25 March	90

Table 11. Species abundance per 1,000 m of shoreline at primary habitats during spring 2002, Nason Point and Ward Branch, Rend Lake, Illinois.

Species	Primary habitat		
	Exposed shoreline	Subsided cove	Unsubsided cove
American black duck (*Anas rubripes*)	5	1	3
American wigeon (*A. americana*)	7	13	8
Blue-winged teal (*A. discors*)	2	8	5
Gadwall (*A. streptera*)	2	1	2
Green-winged teal (*A. crecca*)	24	7	29
Mallard (*A. platyrhynchos*)	56	83	49
Northern pintail (*A. acuta*)	27	13	21
Northern shoveler (*A. clypeata*)	1	3	2
Total	124	128	119

difference in the distribution of the dabbling ducks between exposed shorelines, subsided coves, and exposed shorelines during spring migration, regardless of day of year (Table 12). The repeated measures analysis also showed that dabbling duck abundance did not significantly change at exposed shorelines, subsided coves, and unsubsided coves as migration progressed (Table 12). As expected, the number of dabbling ducks across the entire study area was significantly related to day of year (Table 12) because, in general, duck numbers increase, peak, and decrease at consecutive locations along their migratory path during migration. Regardless of primary habitat, shallow water habitat was used the most by American black duck, American wigeon, blue-winged teal, gadwall, green-winged teal, mallard, northern pintail, and northern shovelers (Table 13).

Illinois Department of Natural Resources completed 3 aerial waterfowl surveys of Rend Lake and the subimpoundments during February 2002. They recorded 0.74 (6,900 dabbling ducks), 0.43 (4,050 dabbling ducks), and 0.67 (6,240 dabbling ducks) dabbling ducks per ha on 6, 11, and 18 February, respectively. A survey completed on 11 February; and, the data from 4 surveys conducted as part of this study on the days before and after the 6 and 18 February IDNR aerial surveys were averaged to obtain approximate values for 6 and 18 February. At Nason Point and Ward Branch combined, there were 4.25 (462 dabbling ducks), 7.13 (774 dabbling ducks), and 12.00 (1,304 dabbling ducks) dabbling ducks per ha on 6, 11, and 18 February, respectively.

Shorebird Surveys

Chronology and Habitat Use.–A total of 3,780 shorebirds representing 23 species were observed between 15 August and 29 November 2000; and 6,382 shorebirds representing 21 species between 3 July and 26 October 2001 (Table 14; Appendix G-I). Killdeer was the most common shorebird species during 2000 followed by least sandpiper, pectoral sandpiper, semipalmated sandpiper, dunlin (*Calidris alpina*), lesser yellowlegs, and greater yellowlegs. In 2001, pectoral sandpiper was the most common shorebird species followed by killdeer, least

Table 12. Mixed models repeated measures ANOVA (Littell et al. 1996) for dabbling duck distribution at Ward Branch and Nason Point, Rend Lake, Illinois during spring 2001.

Effect	Num DF	Den DF	F value	*P*-value
Primary habitat[a]	2	84.1	0.53	0.5927
Day of year	38	189	4.03	<0.0001
Primary habitat[a]*Day of year	76	189	1.13	0.2597

[a] 4 exposed shorelines, 4 subsided coves, and 4 unsubsided coves

Table 13. Percent distribution of dabbling duck species[a] in the secondary habitats at exposed shorelines, subsided coves, and unsubsided coves at Nason Point and Ward Branch, Rend Lake, Illinois during spring 2002.

Primary habitat	Secondary habitat	Species								Total
		ABDU	BWTE	AMWI	GADW	GWTE	MALL	NOPI	NOSH	
Exposed shoreline	Flooded vegetation	6	0	0	0	12	0	0	0	2.25
	Shallow water	94	100	100	100	88	81	100	100	95.37
	Vegetated flats	0	0	0	0	0	19	0	0	2.38
Subsided cove	Dry mud	0	0	4	0	0	0	0	0	0.50
	Flooded vegetation	0	0	0	0	0	7	9	0	2.00
	Open water	0	0	14	18	0	3	0	0	4.37
	Shallow water	100	100	76	73	100	73	91	100	89.13
	Vegetated flats	0	0	0	0	0	4	0	0	0.50
	Wet mud	0	0	2	0	0	4	0	0	0.75
	Woody shore	0	0	4	9	0	9	0	0	2.75
Unsubsided cove	Flooded vegetation	13	7	11	0	15	16	21	7	11.25
	Shallow water	87	93	71	100	85	61	79	86	82.75
	Vegetated flats	0	0	0	0	0	19	0	3	2.75
	Wet mud	0	0	18	0	0	4	0	4	3.25

[a] ABDU= American black duck (*Anas rubripes*), AMWI= American wigeon (*A. americana*), BWTE= blue-winged teal (*A. discors*), GADW= gadwall (*A. streptera*), GWTE=green-winged teal (*A. crecca*), MALL= mallard (*A. platyrhynchos*), NOPI= northern pintail (*A. acuta*), NOSH= northern shoveler (*A. clypeata*)

Table 14. Total shorebirds counted during 2000 and 2001 along different portions of shoreline at Rend Lake, Illinois. Yearly totals for Ward Branch and the northern and southern portions of Nason Point are the sum of 16 walking surveys in 2000 and 18 in 2001. Totals for areas of Nason Point other than the northern and southern sections, are summed from 4 kayak surveys in 2000 and 3 in 2001.

Year	Nason Point			Ward Branch		Total
	North	South	Other Areas	Subsided	Unsubsided	
2000	1,092	152	144	445	1,979	3,812
2001	3,065	470	538	175	2,134	6,382
Combined	4,157	621	682	620	4,082	10,194

sandpiper, lesser yellowlegs, semipalmated sandpiper, greater yellowlegs, and dunlin (Fig. 14). The 6 species chosen for behavioral observations accounted for 91.1% and 94.2% of all shorebirds counted during 2000 and 2001, respectively. More individuals were counted at Ward Branch (2,393) than Nason Point (1,387) in 2000; this pattern was reversed in 2001 (2,309 vs. 4,073).

Species richness was higher at Ward Branch (22 species) compared to Nason Point (13 species) during 2000, but species richness was similar at the 2 sites during 2001 (16 species at Nason Point vs. 18 species at Ward Branch). Combining both years, there were 5 species observed only at Ward Branch, but in many cases these observations represented only 1 or 2 individuals (Appendix I). A single piping plover (*Charadrius melodus*) was observed at Ward Branch in 2000 and a single ruddy turnstone (*Arenaria interpres*) was observed in both years. Two American avocets (*Recurvirostra americana*) and 7 buff-breasted sandpipers (*Tryngites subruficollis*) were observed in 2000 and 1 individual of each species was seen in 2001; a few sanderlings (*Calidris alba*) were seen at Ward Branch in both years (Appendix I).

Although density could not be calculated, shorebirds were most abundant along the broad mudflats in the northern portion of Nason Point and the unsubsided areas of Ward Branch (Table 14). In 2000, more than 4 times as many shorebirds were observed on unsubsided portions of Ward Branch compared to subsided portions; in 2001, shorebirds were 12 times more common on unsubsided areas (Table 14). During both years, about 7 times as many shorebirds were observed on the northern portion of Nason Point compared to the southern survey area (Table 14). Shorebirds were observed along all portions of Nason Point, however, no additional areas (supporting large numbers of shorebirds) were identified by kayak surveys.

Total shorebird abundance peaked in August during both years, but was slightly earlier in 2001 compared to 2000 (Fig. 15). Migration chronology and shorebird abundance was consistent for guilds and species (Figs. 16-19). Although migration chronology varied slightly by species,

Figure 14. Total number of shorebirds counted during weekly surveys at Ward Branch and Nason Point combined, during fall migration 2000 and 2001, Rend Lake, Illinois. Species that represented <1.5 % of the annual total were included in the portion of the bar labeled “other”.

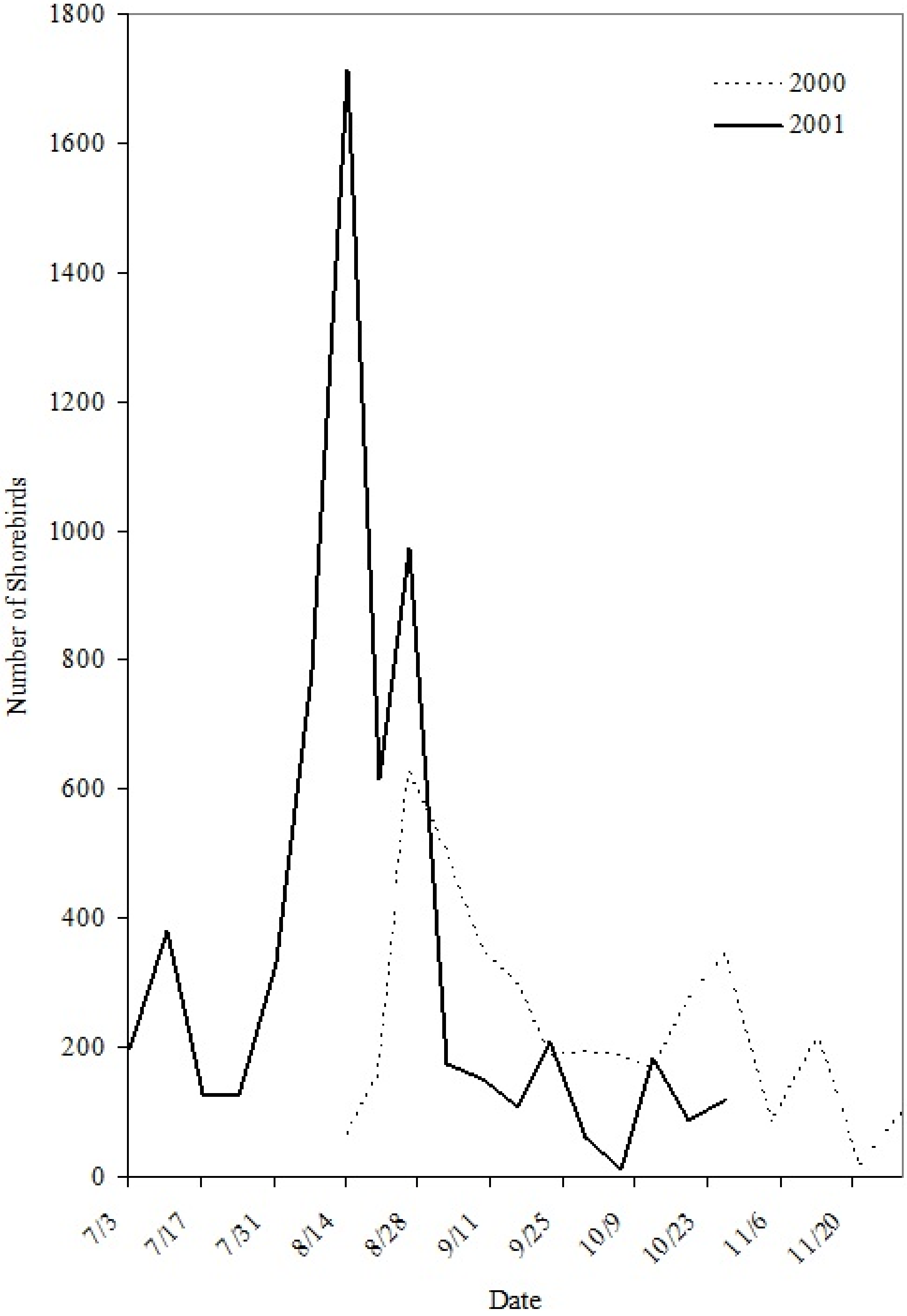

Figure 15. Seasonal and annual trends in shorebird abundance during fall migration 2000 and 2001, at Ward Branch and Nason Point combined, Rend Lake, Illinois. Lines connect shorebird totals for each survey period.

Figure 16. Migration chronology of small probers during fall 2000 and 2001, at Rend Lake, Illinois. The box encompasses the 25th to 75th quantiles, representing the period in which 50% of all birds of that species were counted. A horizontal line through a box represents the median or the date on which 50% of the species total for that season was attained. Lines extend beyond the boxes to 1.5 times the range of the quantiles. Dashes represent actual observations. Species for which boxes, medians, or lines are missing occurred in low numbers; thus, all calculations were not possible.

Figure 17. Migration chronology of large probers during fall 2000 and 2001, at Rend Lake, Illinois. The box encompasses the 25th to 75th quantiles, representing the period in which 50% of all birds of that species were counted. A horizontal line through a box represents the median or the date on which 50% of the species total for that season was attained. Lines extend beyond the boxes to 1.5 times the range of the quantiles. Dashes represent actual observations. Species for which boxes, medians, or lines are missing occurred in low numbers; thus, all calculations were not possible.

Figure 18. Migration chronology of small gleaners during fall 2000 and 2001, at Rend Lake, Illinois. The box encompasses the 25th to 75th quantiles, representing the period in which 50% of all birds of that species were counted. A horizontal line through a box represents the median or the date on which 50% of the species total for that season was attained. Lines extend beyond the boxes to 1.5 times the range of the quantiles. Dashes represent actual observations. Species for which boxes, medians, or lines are missing occurred in low numbers; thus, all calculations were not possible.

Figure 19. Migration chronology of large gleaners during fall 2000 and 2001, at Rend Lake, Illinois. The box encompasses the 25th to 75th quantiles, representing the period in which 50% of all birds of that species were counted. A horizontal line through a box represents the median or the date on which 50% of the species total for that season was attained. Lines extend beyond the boxes to 1.5 times the range of the quantiles. Dashes represent actual observations. Species for which boxes, medians, or lines are missing occurred in low numbers; thus, all calculations were not possible.

most species overlapped, both across and within guilds, and almost every species was present at Rend Lake during late August or early September (Figs. 16-19). One species that migrated late during both years was dunlin; it was only present in October and November (Fig. 17).

Habitat was classified for 94% of the shorebirds surveyed. Considering all species and years together, the majority of shorebirds used wet mud (61%) followed by shallow water (25%), vegetated flats (4%), dry mud (3%), and flooded vegetation (1%). Habitat use was unknown for 6%. However, habitat use patterns varied among species (Figs. 20-25). Killdeer predominantly used wet mud (Fig. 23); in contrast, most yellowlegs used shallow water (Figs. 24-25). Pectoral sandpipers and killdeer (Figs. 22-23) used dry mud and vegetated flats more often than other species and yellowlegs and killdeer used flooded vegetation more commonly (Figs. 23-25). Between site and between year variability indicate that some species such as killdeer and pectoral sandpipers exhibit flexibility in habitat use; semipalmated and least sandpipers seem to have the most restricted habitat requirements with > 97% using wet mud or shallow water at both sites during both years (Figs. 20-21). There were no between year or site trends in habitat use patterns. When shorebirds used shallow water, none occurred in water deeper than 10.4 cm, and most used considerably shallower depths corresponding with their upper tarsometatarsal joint (Table 15). The habitat used by the majority of birds was wet mud, shallow water ≤3 cm and shallow water ≤6 cm (Fig. 26).

Shorebird behavior

Shorebird behavioral data was collected between 30 August and 18 October 2000 (*n* = 57 sessions) and between 5 August and 14 September 2001 (*n* = 78 sessions). Shorebirds spent an average (± SE) of 78.4% ± 2.5 of their time feeding. Feeding time ranged from a low of 63.0% in killdeer to a high of 90.3% in small probers (Table 16). Alert was the second most common behavior. Average time spent alert was 10.9% ± 2.0 and ranged from 6.7% for small

Table 15. Mean percent time (± SE) 6 species waded at depths relative to leg morphometrics (cm), during behavioral observations at Rend Lake, Illinois. Time spent at lower tarsometatarsal joint (LTMJ) represents a film of water. Wading between LTMJ and upper tarsometatarsal joint (UTMJ) corresponds to depths ≤ tarsometatarsus length; wading above UTMJ represents depths ≤ combined tarsometatarsal (TM) and tibiotarsal (TT) length.

Species	Water Depth			Leg Measurement (cm)	
	LTMJ	LTMJ - UTMJ	> UTMJ	TM	TM and TT
Least sandpiper (*Calidris minutilla*)	29.4 ± 12.2	36.9 ± 12.8	33.6 ± 16.0	1.8	3.3
Semipalmated sandpiper (*C. pusilla*)	15.9 ± 14.1	39.1 ± 12.9	45.1 ± 13.6	2.1	3.8
Pectoral sandpiper (*C. melanotos*)	19.1 ± 5.3	64.7 ± 5.4	16.3 ± 3.9	2.7	4.7
Killdeer (*Charadrius vociferus*)	42.0 ± 9.7	55.9 ± 9.4	2.1 ± 2.1	4.1	7.5
Lesser yellowlegs (*Tringa flavipes*)	8.8 ± 6.0	70.3 ± 6.5	20.8 ± 5.4	5.1	9.0
Greater yellowlegs (*T. melanoleuca*)	7.2 ± 4.8	70.5 ± 7.9	22.3 ± 8.8	5.9	10.4

Table 16. Percent of time (± SE) that focal shorebird species spent engaged in different activities at Rend Lake, Illinois during 2000 and 2001. Percent alert time was based on continuous observation; all other percentages were based on the proportion of 10 sec intervals observed in each activity.

Species or Guild	*n*	Activity Feeding	Alert	Body Maintenance	Aggression	Sleeping	Locomotion	Vocalization
Small probers	24	90.3 ± 4.1	6.7 ± 4.1	0.01 ± 0.00	0.00	0.00	0.02 ± 0.01	0.00
Pectoral sandpipers (*Calidris melanotos*)	46	82.1 ± 3.7	6.9 ± 2.2	0.07 ± 0.03	0.00	0.00	0.03 ± 0.01	0.00
Killdeer (*Charadrius vociferus*)	29	63.0 ± 6.2	23.7 ± 5.8	0.07 ± 0.04	0.01 ± 0.00	0.00	0.04 ± 0.01	0.01 ± 0.00
Yellowlegs	26	78.3 ± 5.5	7.8 ± 3.6	0.06 ± 0.04	0.00	0.00	0.08 ± 0.02	0.00
Combined	125	78.4 ± 2.5	10.9 ± 2.0	0.05 ± 0.02	0.00	0.00	0.04 ± 0.01	0.00

Figure 20. Least sandpiper habitat use determined from survey data collected at Nason Point and Ward Branch, Rend Lake, IL, during fall 2000 and 2001.

Figure 21. Semipalmated sandpiper habitat use determined from survey data collected at Nason Point and Ward Branch, Rend Lake, IL, during fall 2000 and 2001.

Figure 22. Pectoral sandpiper habitat use determined from survey data collected at Nason Point and Ward Branch, Rend Lake, IL, during fall 2000 and 2001.

Figure 23. Killdeer habitat use determined from survey data collected at Nason Point and Ward Branch, Rend Lake, IL, during fall 2000 and 2001.

Figure 24. Lesser yellowlegs habitat use determined from survey data collected at Nason Point and Ward Branch, Rend Lake, IL, during fall 2000 and 2001.

Figure 25. Greater yellowlegs habitat use determined from survey data collected at Nason Point and Ward Branch, Rend Lake, IL, during fall 2000 and 2001.

Figure 26. Estimated habitat use patterns for the shorebird community using Nason Point and Ward Branch, Rend Lake, IL during fall 2000 and 2001. Habitat designations include: DM - dry mud, WM - wet mud, SW - shallow water, VF - vegetated flats, FV - flooded vegetation.

probers to 23.7% for killdeer (Table 16). All other behaviors combined comprised an average of 10.5% ± 1.6 of shorebird time (Table 16).

DISCUSSION

Waterfowl

The purpose of this study was to determine if subsided habitats along Rend Lake's shoreline were used by spring migrating dabbling ducks. Direct effects of subsidence on wildlife habitat use on a reservoir has not been formally assessed prior to this investigation.

Spring migrating dabbling ducks use habitats that supply food because ducks need to eat to obtain energy for migration and for storage of nutrients to use on the breeding grounds (LaGrange and Dinsmore 1988). Areas providing food, located between the wintering and breeding grounds, are important to waterfowl (Heitmeyer and Fredrickson 1981). Dabbling ducks are limited to feeding in shallow water areas by their body morphology: total body size and neck length. Euliss and Harris (1987) found northern pintails feeding in 17 cm of water and green-winged teal feeding in 12 cm of water. DeRoia (1989) surveyed spring migrating green-winged teal and blue-winged teal in 12 cm and 21 cm of water, respectively. Johnson and Rowher (2000) observed mallard and green-winged teal feeding in shallow water.

Because dabbling ducks use shallow water, it was logical to postulate that the subsidence of shallow water habitat at Rend Lake may affect dabbling ducks. Based on current knowledge of spring migrating dabbling duck habitat needs, this study attempted to determine a subsidence effect level by assessing the moist soil vegetation and wetland plant community; and, the distribution of spring migrating dabbling ducks at subsided and unsubsided habitats at Nason Point and Ward Branch.

Changes in hydrology associated with subsidence resulted in a shift of moist soil and open water wetland plant communities and the adjacent upland plant communities. Portions of Nason Point's seasonally inundated moist soil vegetation community shifted to occupy the intermittently inundated post-subsidence zone because of the decreased elevation and the increased frequency and duration of flooding after subsidence. The post-subsidence moist soil vegetation community at Ward Branch resembled the pre-subsidence moist soil vegetation community (Owen 1992). The community Owen (1992) observed shifted from the pre-subsidence seasonally inundated zone to the post-subsidence seasonally inundated zone within 3 years after subsidence. Nawrot et al. (1995) observed a shift to annual and perennial moist soil vegetation, seasonally inundated palustrine forested habitat, and permanently inundated scrub-shrub and open water wetlands in subsided wetland areas in southern Illinois. The results of our Rend Lake study suggested that wetland plant community succession will also occur along the Nason Point shoreline following subsidence. The 5 common dabbling duck food genera, *Cyperus*, *Echinochloa*, *Eleocharis*, *Leersia*, and *Polygonum*, will shift from their current moist soil zones along Nason Point to the post-subsidence seasonally inundated zone after subsidence. Therefore, dabbling duck habitat will be available throughout the successional process associated with subsidence and wetland habitat development.

Distribution of spring migrating dabbling ducks at the Ward Branch and Nason Point subsided and unsubsided study areas was not different, suggesting that subsidence does not impact dabbling duck habitat at Rend Lake. Other than Rend Lake, the effects of wetland subsidence on waterfowl populations have not been investigated. However, subsidence-induced topography alteration is similar to topography changes due to wetland construction. There are numerous studies on the effectiveness of man-made wetlands to support the physical and chemical processes which define natural wetlands; and, on assessing how organisms respond to the constructed wetlands. Most studies evaluating waterfowl response to constructed wetlands were conducted on the breeding grounds, resulting in conclusions that constructed wetlands are suitable nesting and brood rearing habitat (Ratti et al. 2001, Stevens et al. 2003). To improve constructed wetland use during the non-breeding season an adequate water depth (6 to 24 cm) should be available for feeding (Fredrickson 1991). This guideline can be applied to spring migration habitat evaluation at Rend Lake. Rend Lake's subsided and unsubsided habitats during the spring provided an adequate water depth for dabbling ducks to successfully feed. Exposed shorelines, subsided coves, and unsubsided coves supported gradual slopes (<1%) (Appendix C) which were flooded during the spring. Shallow inundated habitats provided adequate feeding water depths of 0 to 24 cm at both subsided and unsubsided areas during spring 2002.

In summary, the hydrologic regime is the principal variable affecting natural or constructed wetlands. The frequency and duration of flooding affects the vegetation and wildlife community composition and abundance. Moist soil vegetation and spring migrating dabbling duck communities will shift to occupy the post-subsidence seasonally inundated zone on Nason Point's shoreline after subsidence. Subsidence will not negatively impact the moist soil vegetation or spring migrating dabbling duck communities along Nason Point's shoreline. Dabbling ducks were chosen for this study because they feed in shallow water, the habitat hypothesized to be the most affected by subsidence. However, other avian species such as the great blue heron, green heron, great egret, and pied-billed grebe were also observed in the subsided areas of Rend Lake suggesting that the subsidence wetlands also contribute to wading bird habitat needs. Therefore further research should also include more wetland associated avian species, as well as wetland dependent mammals and amphibians that use subsided habitats. Older mine subsidence wetlands (>50 years old) in England provide diverse habitat for waterfowl, wading birds, songbirds, small mammals, and amphibians. Therefore, we should continue to assess Rend Lake's recently subsided areas to evaluate the interaction of shoreline configuration and long-term hydrologic variation on wetland successional development and wildlife utilization.

Shorebird - Species Composition, Abundance, and Chronology

Shorebird abundance at Rend Lake was almost twice as high in 2001 compared to 2000. This difference was driven by an increase in pectoral sandpipers which were 6 times more abundant in 2001 than 2000. At stopovers similar in latitude to Rend Lake, the typical migration peak for this species occurs in early-mid August (Skagen et al. 1999); during 2001 when lake levels were low throughout most of the migration season (Fig. 6), a peak in pectoral sandpiper abundance was recorded during mid August (Fig. 16). Because of high lake level in 2000 (Fig. 12), there was little habitat available in early-mid August and pectoral sandpipers, in addition to other shorebirds, likely passed over Rend Lake. Other early migrating species (Skagen et al. 1999) such as lesser and greater yellowlegs also were more abundant in 2001 compared to 2000. Counts for dunlin, a late migrant (Skagen et al. 1999), were higher in 2000 than 2001. However, for many species, counts were similar for both years.

In addition to the annual difference in shorebird abundance, the relative abundance between sites was not consistent between years. Ward Branch supported almost twice as many shorebirds than Nason Point in 2000; however, the reverse was true in 2001. This difference does not appear to be directly related to the increase in pectoral sandpipers in 2001; pectoral sandpipers were relatively common at both sites during both years. Although increased invertebrate resources at Ward Branch may have attracted higher number of shorebirds to the area in 2000, there was no between site difference in invertebrate resources during 2001.

Although habitat assessments for the shorebird study were not detailed, the general descriptors of habitat availability do not appear capable of explaining the between site difference in shorebird numbers during 2001. During most of the 2001 migration period, lake levels were close to 123.63 m (405.6 ft). At this lake level, mudflat area is only slightly greater at Nason Point than Ward Branch and shoreline length at Ward Branch is almost twice that of Nason Point (Table 3).

One factor that may explain between site differences in shorebird abundance is vegetation growth patterns. Although no quantitative assessment of vegetation structure or abundance was conducted, vegetation cover was dense at Nason Point in 2000, particularly in the early part of the season, while Ward Branch was characterized by broad areas of bare mud with some short grass and forbs emerging in the fall. During 2001, Ward Branch was vegetated throughout most of the season, except for relatively narrow bands of mudflat along portions of the shoreline; in contrast, Nason Point was largely unvegetated in 2001. Since most shorebirds prefer bare mudflats and use only sparsely vegetated areas (Bradstreet et al. 1977, Hands 1988, Helmers 1991, Alexander and Gratto-Trevor 1997), the between site differences in shorebird abundance likely reflect shorebird response to vegetation differences.

During both years, the gradually sloping portions of both sites (north area of Nason Point and unsubsided portion of Ward Branch) had higher numbers of shorebirds than other areas (southern Nason Point and subsided shorelines on Ward Branch). The mudflat area calculations reflect this difference in habitat availability, yet the degree of difference in habitat area is smaller than the difference in shorebird abundance (Tables 3 and 15). This suggests that habitat availability is only partially capable of explaining the difference in shorebird abundance.

Species richness was higher at Ward Branch than Nason Point during both years. Habitat requirements for the 5 species observed only at Ward Branch are no different than species observed at both sites (Recher 1966, Bradstreet et al. 1977, Alexander and Gratto-Trevor 1997) and the habitats present at Ward Branch appeared similar to those at Nason Point. Ward Branch is a more complex or diverse area topographically, with subsidence wetlands and sandbar islands, yet none of the species unique to Ward Branch were seen using these areas. Since number of individuals observed was low for all 5 species, their presence at Ward Branch or absence at Nason Point was likely a matter of chance and not indicative of any habitat difference between sites.

Compared to other migration stopover sites in the United States, Rend Lake does not attract large numbers of shorebirds and would not qualify as a site important to shorebirds based on criteria established by the Western Hemisphere Shorebird Reserve Network (WHSRN; Harrington and Perry 1995). It seems that habitat availability at Rend Lake may limit shorebird numbers in some years (e.g., early August 2000), but invertebrate resources are comparable to WHSRN sites. The geographic location of Rend Lake may be the principal reason it receives substantially lower numbers than WHSRN requirements. Most interior migrating species concentrate along a narrow band about 322 km (200 mi) west of Rend Lake (Skagen et al. 1999); therefore, only individuals on the eastern fringe of the migration pathway could potentially use Rend Lake as a stopover. It should be pointed out that the WHSRN designation may be of little importance in inland areas where shorebirds do not tend to concentrate at single wetlands. Although Rend Lake does not meet WHSRN criteria, it receives more shorebirds than any other site in southern Illinois, which attests to it being a locally important stopover.

Species richness at Rend Lake during both years of the shorebird study was higher than that reported for Chatauqua National Wildlife Refuge (CNWR), which is ranked as a site of "international" importance, receiving over 100,000 birds annually. During the surveys of the Ward Branch and Nason Point study areas 23 of the 37 species that have been documented in southern Illinois (Robinson 1996) were recorded. Additionally, Rend Lake hosts many species of concern (Brown et al. 2000, U.S. Fish and Wildlife Service 2002). Two species common to Rend lake, least and semipalmated sandpipers, are declining (Brown et al. 2000) in addition to several species less common to Rend Lake, such as black-bellied plovers (*Pluvialis squatarola*), sanderlings, and buff-breasted sandpipers. There is also concern for the conservation of lesser golden plovers (*Pluvialis dominica*), solitary sandpipers (*Tringa solitaria*), stilt sandpipers (*Calidris himantopus*), and short-billed dowitchers (*Limnodromus griseus*; U.S. Fish and Wildlife Service 2002).

Despite differences in shorebird abundance between years and differences in timing of peak abundance, August and September appear to be the critical months for most shorebird species using Rend Lake. The only exception to this pattern were dunlin which were abundant in October and November. During both years, the survey data indicated no distinct migration peaks for any species at Rend Lake. There were no specific dates on which a particular species was extremely abundant; rather, it appears that birds used Rend Lake over an extended period and species migration chronology overlapped extensively (Figs. 16-19). Other studies have reported staggered migration chronologies within guilds and have hypothesized that this is due to competition for resources among species with similar feeding niches (Recher 1966, Helmers 1991, Alexander and Gratto-Trevor 1997). Multiple species may have been able to use Rend Lake simultaneously because numbers were low and interspecific aggression was uncommon. Therefore, providing habitat during August and September would support the full assemblage of species that use Rend Lake, excepting dunlin which require habitat in October and November.

Habitat Use Patterns

Wet mud was the habitat most commonly used by shorebirds at Rend Lake, followed by shallow water ($\leq$6.0 cm). Despite slight differences in habitat use patterns of focal species, these 2 habitat types were the most important for all species observed during behavioral observations and on surveys. The only species that used dry mud consistently were killdeer and other plovers. The only species to regularly use vegetated flats were pectoral sandpipers and killdeer, both of which have higher tolerances for vegetation than small sandpipers and plovers (Rundle 1980, Hands 1988). However, even killdeer and pectoral sandpipers were most commonly observed using wet mud, followed by shallow water.

Other studies also have suggested that mudflat and shallow water are the most important habitat for shorebirds, but the depth of water that has been reported as important to shorebirds has varied between studies. Helmers (1991) suggested that water <18 cm can be used by shorebirds, but other shorebird management suggestions have indicated that water <5 cm should be provided (Rundle and Fredrickson 1981, Hands et al. 1991). Foraging locations for most species range from saturated mud to water depths corresponding with the length of the tarsus and tibiotarsus (Baker 1979, Rundle 1980, Eldridge 1987, Hands 1988, Helmers 1991, Alexander and Gratto-Trevor 1997). Tarsus length predicted 91% of the variance in foraging depth between 9 species at a North Dakota stopover (Eldridge 1987). Similarly, shorebird species observed in this study spent more time wading at or below their upper tarsometatarsal joint than between the upper tarsometatarsal joint and belly. Greater than 95% of wading birds at Rend Lake used water

≤6.0 cm; while, wet mud and shallow water ≤6.0 cm accounted for more than 90% of habitat use.

Shorebird behavior

Foraging was the most common behavior for shorebirds at Rend Lake; these results are similar to other studies of migrating shorebirds at inland stopover sites in California and the midwestern U.S. All shorebirds using California wetlands and rice fields spent the majority of their time feeding (Elphick 2000) and species using Texas playas and North Dakota prairie potholes foraged for 55-80% of daylight hours (Davis and Smith 1998, De Leon and Smith 1999). It is not surprising that most species spend the majority of their time foraging because ability to acquire adequate energy to complete migration is essential to survival. Fall migrants do not appear to be constrained by food depletion on breeding grounds or the necessity of arriving on their winter grounds by a certain date (Schneider and Harrington 1981). However, during fall, shorebirds may face the challenge of accomplishing migration prior to the depletion of prey at stopover sites (Schneider and Harrington 1981), and energy reserves may offer protection if unfavorable conditions are encountered (O'Reilly and Wingfield 1995).

Time that shorebirds at Rend Lake allocated to activities other than foraging also supports previous research on shorebird behavior at migration stopovers. Previous studies documented average alert time to be <10% for most species and observation locations (Davis and Smith 1998, De Leon and Smith 1999, Elphick 2000); however, killdeer spent more than 30% of their time alert in California (Elphick 2000). Average alert time at Rend Lake was about 10%, and killdeer spent the greatest proportion of time alert compared to other species. Other behaviors such as body maintenance and aggression were uncommon (<10%) among all species in my study and in other studies of migrating shorebirds (Davis and Smith 1998, De Leon and Smith 1999, Elphick 2000).

Unlike other studies, sleeping behavior was not regularly observed. Although most of the species observed in this study have not been previously reported to spend large portions of time sleeping (some species have been observed spending 30-40% of time sleeping, but most spend <5%), fewer than 50 sleeping birds were observed during behavior sessions and surveys combined. Current research methods were similar to studies which detected sleeping birds, suggesting that either time constraints effected sleep behavior at Rend Lake, or sleep behavior occurred at other times and was not recorded.

Analyses of shorebird behavior and habitat associations were also conducted for shorebird guilds using the Rend Lake study areas (Table 17). Detailed behavioral and habitat association discussions are summarized in Elliott-Smith (2003).

Table 17. Parameter estimates (β), standard errors, and confidence intervals for the best approximating models explaining time spent alert by 4 shorebird guilds during fall 2000 and 2001 at Rend Lake, Illinois.

Guild or Species	Variables	Parameter Estimate	Standard Error	95% Confidence Interval
Small probers	Flock Size	2.532	2.306	(-2.279)-(7.342)
	Distance to Cover	-0.325	0.153	(-0.645)-(-0.006)
	Flock Size*Distance to Cover	-1.208	0.487	(-2.224)-(-0.193)
Pectoral	Flock Size	3.403	0.976	1.434-5.372
sandpiper	Distance to Cover	-0.214	0.075	(-0.364)-(-0.063)
(*Calidris melanotos*)	Flock Size*Distance to Cover	-0.840	0.425	(-1.698)-(0.019)
Yellowlegs	Flock Size	5.788	0.886	3.958-7.618
Killdeer (*Charadrius vociferus*)	Flock Size	2.309	2.711	(-3.254)-(7.872)

JOB 1.3: BENTHIC INVERTEBRATE BIOMASS

Objective: Estimate benthic invertebrate biomass available to migratory shorebirds during late summer and fall.

INTRODUCTION

Examination of invertebrate availability is integral to assessing the quality of Rend Lake Refuge habitat for shorebirds. Shorebirds spend the majority of their time feeding at migration stopover sites, and survival during migration depends on a shorebird's ability to acquire adequate invertebrate resources (Davis and Smith 1998, De Leon and Smith 1999, Elphick 2000). Total invertebrate biomass is capable of explaining as much as 80% of the variance in shorebird abundance at a site (Helmers 1991, Weber and Haig 1997, Ashley et al. 2000). Therefore, evaluation of invertebrate density and biomass in the Ward Branch subsidence wetlands and along the east shoreline of Rend Lake Refuge can identify the highest quality foraging habitat and increase our understanding of temporal variability in habitat quality. Furthermore, a comparison of invertebrate density and biomass at Rend Lake with similar data from well known shorebird stopover sites elsewhere in the U.S. will identify the overall quality of Rend Lake as a shorebird stopover site.

METHODS

Invertebrate Sampling.–Invertebrates were sampled along 5 transects on the northeast shoreline of Nason Point representing very gradual slopes, and 5 transects representing the somewhat gradual slopes that occur on the southeast shoreline of Nason Point (Fig. 2). Ten transects were established on the Ward Branch area, 5 representing previously subsided areas and 5 located on unsubsided areas between the subsidence wetlands (Fig. 3). Permanent stakes were placed in the ground above the high water level, marking the origin of each transect. Sampling stations for each sampling interval were established along the transect between the origin and the mud-water interface. Two cores of sediment were extracted at the mud water interface within a 1-m^2 quadrat using a 5-cm diameter core sampler to a depth of 5 cm (Swanson 1983). Sample stations were flagged to prevent re-sampling during future periods. In areas where the water level did not change between sampling periods, cores were extracted from sediment adjacent to the previous sampling location. Samples were preserved in 9% formalin solution, stained with phloxine B, and transported to the lab for processing.

In the lab, each sample was washed and all invertebrates were counted and weighed. All samples were washed with a number 35 standard sieve (500 μm). Invertebrates were picked from the remaining sediment and vegetative material. All intact invertebrates and invertebrate pieces representing more than ½ of an individual were counted. Samples were then dried at 50-60^{O}C for 24 hrs, cooled for 24 hrs in a desiccator, and weighed to the nearest mg. For a randomly selected subset of 20 samples from each year, all insects were identified to family and non-insects were usually identified to order.

Since invertebrate density and biomass were both skewed, the median was used as the best measure of central tendency. Overall median invertebrate density (number/m^2) and biomass (g/m^2) were calculated for the entire study area and for Nason Point and Ward Branch separately, during each sampling period. Both density and biomass were normalized by a natural log transformation to examine differences between years using ANOVA. Multiple regression was used to investigate the influence of site and date on invertebrate resources.

RESULTS

A total of 280 core samples were collected during 4 sampling periods between 8 September and 22 October 2000, and 3 sampling periods between 21 August and 23 October 2001. Combining years, sites, and sample periods, the median (range) invertebrate density was 26,096 (0-1,096,880; n = 280) invertebrates/m^2 and the median biomass was 2.40 (0-62.25; n = 280) g DM/m^2 (Tables 18-21).

Oligochaeta were the most frequently encountered taxa, occurring in 100% of 40 samples examined, followed by Nematoda (82.5%), Chironomidae (62.5%), Ceratopogonidae (27.5%), and Nematomorpha (25%). Oligochaeta also were the most abundant taxa, averaging 76.5%

Table 18. Median invertebrate density (invertebrates/m^2) for each sample date at Nason Point and Ward Branch during fall 2000. Overall median and mean density for each site and for combined regions.

Site	Date				Combined	
	9/8	9/20	10/07	10/22	Median	Mean
Nason Point	11,575	28,622	23,360	16,205	17,047	27,085
Ward Branch	42,301	61,873	42,721	50,719	47,983	126,719
Combined	18,730	47,983	30,515	24,413	26,096	76,589

Table 19. Median invertebrate density (invertebrates/m^2) for each sample date at Nason Point and Ward Branch during fall 2001. Overall median and mean density for each site and for combined regions.

Site	Date			Combined	
	8/21	9/24	10/23	Median	Mean
Nason Point	13,751	60,606	12,223	21,645	38,613
Ward Branch	21,645	52,457	29,030	31,067	45,191
Combined	16,297	57,550	15,279	26,483	41,902

Table 20. Median invertebrate biomass (g DM/m^2) for each sample date at Nason Point and Ward Branch during fall 2000. Overall median and mean biomass for each site and for combined regions.

Site	Date				Combined	
	9/8	9/20	10/07	10/22	Median	Mean
Nason Point	1.98	1.16	2.46	3.34	2.00	3.20
Ward Branch	1.92	4.97	2.95	5.11	2.88	8.44
Combined	1.92	1.77	2.82	4.38	2.38	5.82

Table 21. Median invertebrate biomass (g DM/m^2) for each sample date at Nason Point and Ward Branch during fall 2001. Overall median and mean biomass for each site and for combined regions.

Site	Date			Combined	
	8/21	9/24	10/23	Median	Mean
Nason Point	0.89	5.09	0.69	1.71	3.43
Ward Branch	3.11	6.83	0.99	2.90	5.18
Combined	1.86	6.29	0.79	2.42	4.31

(± 2.9 SE) of individuals in each sample; the next most abundant taxa were Nematoda (13.3% ± 2.5) and Chironomidae (5.7% ± 1.5). Ceratopogonidae and Nematomorpha only averaged 0.9% and 0.6% of invertebrates per sample, respectively. Fourteen additional aquatic invertebrate taxa and 3 terrestrial taxa were identified, but none of these taxa were present in $\geq$12.5% of samples and combined, these additional taxa made up 2.9% of invertebrates (Table 22).

We did not detect a between year difference in invertebrate density ($P = 0.070$), and biomass was only slightly higher in 2000 than 2001 ($t_{278} = 2.308$, $P = 0.022$). Median density was 26,096 (421-1,096,880) invertebrates/m^2 in 2000 (n =160), and 26,483 (0-284,696) invertebrates/m^2 in 2001 (n = 120). Median biomass was 2.38 (0.42-62.25) g DM/m^2 in 2000 and 2.42 (0-36.42) g DM/m^2 in 2001.

Density varied according to the quadratic function of date in both 2000 ($P = 0.044$, $R^2 = 0.222$) and 2001 ($P < 0.0001$, $R^2 = 0.223$). Invertebrate density peaked at the end of September during both years. Comparing sites within years, density ($P = 0.003$) and biomass ($P = 0.0007$) were higher at Ward Branch than Nason Point in 2000; there were no between site differences in 2001 ($P \geq 0.269$).

Combining years and periods, invertebrate density was greater in the southern portion of Nason Point (median = 34,093 invertebrates/m^2) compared to the northern portion (12,838 invertebrates/m^2, $F = 14.31$, $P = 0.0002$), and invertebrate density was significantly higher in the subsided areas of Ward Branch (46,600 invertebrates/m^2) compared to unsubsided areas (39,565 invertebrates/m^2, $F = 8.83$, $P = 0.004$). Invertebrate biomass was also greater in the southern region of Nason Point (2.78) compared to the north (1.35, $F = 8.63$, $P = 0.004$). There was no difference in invertebrate biomass of subsided versus unsubsided regions ($P > 0.20$).

DISCUSSION

Compared to other shorebird stopover areas, benthic macroinvertebrates at Rend Lake appear to be at least equally abundant. Invertebrate density at the Nason Point and Ward Branch

Table 22. Invertebrate taxa at Rend Lake, Illinois. Data obtained from 40 randomly selected samples, with 20 samples from each site and from both 2000 and 2001.

Phylum	Class	Order	Family	Percent Occurrence	Average Abundance	Standard Error of Abundance
Annelida	Oligochaeta			100.0	76.5	2.9
Nematoda				82.5	13.3	2.5
Nematomorpha				25.0	0.6	0.2
Arthropoda	Malacostraca	Amphipoda		2.5	0.2	0.2
	Crustacea	Copepoda (subclass)		2.5	0.0	0.0
	Arachnida	Actinedida	Hydracarina (group)	2.5	0.0	0.0
	Insecta	Collembola		2.5	0.1	0.1
		Diptera	Chironomidae	62.5	5.7	1.5
			Muscidae	10.0	1.2	0.9
			Ceratopogonidae	27.5	0.9	0.4
		Trichoptera	Leptoceridae	5.0	0.0	0.0
			Hydroptilidae	7.5	0.1	0.1

Table 22. Continued.

Phylum	Class	Order	Family	Percent Occurrence	Average Abundance	Standard Error of Abundance
		Coleoptera	Hydrophilidae	2.5	0.0	0.0
		Odonata	Coenagrionidae	2.5	0.0	0.0
Mollusca	Bivalvia			5.0	0.2	0.2
	Gastropoda	Unidentified		2.5	0.2	0.2
		Limnophila	Physidae	12.5	0.2	0.1
			Lymnaeidae	2.5	0.0	0.0
			Ancylidae	2.5	0.0	0.0
Terrestrial Invertebrates				15.0	0.7	0.4

study sites during both years ranged from a median of 28,011-56,023 invertebrates/m^2. The range of mean density estimated in other studies was 3,000-84,000 invertebrates/m^2 (Rehfisch 1994, Mihuc et al. 1997, Weber and Haig 1997, Farmer and Wiens 1999, Ashley et al. 2000). Rend Lake compares favorably to 2 nearby fresh water habitats in western Tennessee where mean density estimates were 46,539 and 47,225 invertebrates/m^2 (Augustin et al. 1999). Invertebrate density at Rend Lake was higher than Cheyenne Bottoms, a well known shorebird staging site and the only inland site receiving "hemispheric" designation by WHSRN; density estimates for 2 seasons at Cheyenne Bottoms were 8,888 invertebrates/m^2 in 1 year and 11,182 invertebrates/m^2 during the second year (Helmers 1991).

Biomass estimates at Rend Lake (1.7-2.9 g DM/m^2) also compare favorably to estimates for other staging sites where mean biomass estimates ranged from approximately 1-28 g/m^2, with most estimates around 2.0 g/m^2. In western Tennessee, biomass estimates for 2 sites were 2.15 g/m^2 and 2.17 g/m^2 (Augustin et al. 1999). Biomass estimates at Cheyenne Bottoms were 2.68 g/m^2 in 1 year and 6.26 g/m^2 during the second year (Helmers 1991). Due to great variability in sampling and processing methodology, it is difficult to make strict comparisons between this study and previous studies. Some researchers collected cores to a depth of 10 cm instead of 5 cm, used different mesh sizes for sorting, and reported biomass as ash-free dry mass or calculated biomass from length-weight regression equations. After attempting to correct for these differences using information about vertical distribution of invertebrates (Sherfy et al. 2000) and differences related to biomass estimation, Rend Lake invertebrate density and biomass still compared favorably to other shorebird staging sites. Another factor confounding direct comparison of the Rend Lake data with other studies was that our project reported median values; despite high spatial and temporal variability, most other studies report means. However, in most cases, means for both density and biomass at Rend Lake were more than twice as large as the median values reported (Tables 18-21); therefore, our project estimates tend to be more conservative than others.

Invertebrate size may be important to shorebirds (Helmers 1991); however, since invertebrates were not measured during this investigation, only average size can be inferred by looking at biomass in conjunction with density. The size structure of invertebrates at Rend Lake appears to have been similar to western Tennessee because both density and biomass are very similar (Augustin et al. 1999). Although biomass estimates at Cheyenne Bottoms were slightly higher than Rend Lake, invertebrate density was lower (Helmers 1991). This suggests that average invertebrate size was larger in Cheyenne Bottoms; however, we used a slightly smaller mesh size than Helmers (1991). Therefore, some very small invertebrates in our samples might have passed through a larger mesh. Although these smaller invertebrates may not have increased our biomass estimates appreciably, they might account for the higher density that we observed in comparison to Cheyenne Bottoms.

Oligochaeta were the most abundant benthic invertebrates at Rend Lake, yet Diptera and Coleoptera were the most common invertebrates at most inland stopover sites (Rundle 1980, Baldassarre and Fischer 1984, Eldridge 1987, Skagen and Oman 1996). Chironomidae (Diptera) in particular, are an important shorebird food resource at many inland stopovers, comprising as much as 100% of available invertebrates (Helmers 1991, Eldridge 1987, Mihuc et al. 1997, Farmer and Wiens 1999, Ashley et al. 2000); Chironomidae were present in most of the Rend Lake study area samples, yet on average they only accounted for 5.7% of the total number of invertebrates. Chironomidae were the dominant invertebrate taxa across studies from a wide geographic area; however, within southern Illinois and the surrounding area, Oligochaeta may be a more important food resource. In western Tennessee Oligochaeta and Ceratopogonidae also were the most abundant taxa. Since caloric values do not differ greatly between Oligochaeta and Chironomidae, they should provide similar energetic values to migrating shorebirds (Cummins and Wuycheck 1971).

The annual and seasonal variability in invertebrate abundance and biomass observed at the Nason Point and Ward Branch study areas mirrors other invertebrate studies. It is not uncommon for invertebrate resources to differ between years and exhibit a curvilinear pattern during the late summer and fall (Helmers 1991, Ashley et al. 2000). Because invertebrate samples were not collected on a weekly basis it is difficult to determine exactly when invertebrate density and biomass peaked. However, both appear to have increased later in 2000 compared to 2001. Hydrologic variability can determine differences in invertebrate abundance in ephemeral systems, and it is possible that higher than average water levels in late summer 2000 delayed invertebrate growth (Magee et al. 1999). Since Rend Lake is a permanent deep water habitat, invertebrate availability may be more closely dependent on temperature than hydrology. Average temperature in Mt. Vernon, Illinois, which neighbors Rend Lake, was 1.4° C (2.5° F) lower in July 2000 compared to 2001 and 0.4° C (0.7° F) lower in August (Illinois State Water Survey unpublished data); this trend may explain the delayed increase in invertebrate availability and biomass during 2000.

The site difference in invertebrate density and biomass during 2000 is difficult to explain. Invertebrate resources would be expected to have been higher at Nason Point compared to Ward Branch because vegetation density was greater at Nason Point; however, the reverse trend was observed. Vegetation abundance, of *Polygonum* in particular, has been associated with a higher abundance of nectonic invertebrates (Magee et al. 1999). However, if vegetation growth shades the underlying benthos, water temperature might be slightly lower, thereby slowing benthic invertebrate production.

The within site differences in invertebrate resources are also difficult to interpret. Both the Ward Branch and Nason Point experienced identical hydrologic regimes. There were not noticeable vegetation differences between most portions of Nason Point or the subsidence wetlands at Ward Branch. However, invertebrate density was lower in regions where slope was more gradual; at Nason Point, invertebrate biomass also was higher in steeper sloped regions. High shorebird abundance has been shown to cause depletion at some staging sites (Schneider and Harrington 1981, Helmers 1991, Mihuc et al. 1997, Weber and Haig 1997). Prior to this investigation, it was assumed that steeply sloped areas might be prone to invertebrate depletion since drawdowns only expose narrow zones of additional habitat. However the lower shorebird numbers in steeper sloped regions could not be expected to contribute to significant invertebrate depletion. It was also not plausible that shorebird density was high enough in the northern portion of Nason Point and the unsubsided areas of Ward Branch to substantially deplete resources. Exposed shorelines along the east side of Nason Point experience greater wave energy and sediment disturbance than the protected vegetated zones within the subsidence wetland basins. Therefore, stable substrate environments within the subsidence wetlands may explain the greater density of invertebrates at the Ward Branch study area.

JOB 1.4: SUBSIDENCE ASSESSMENT AND MODELING

Objective: Evaluate how mining subsidence influences the availability of foraging habitat using habitat models and field observations.

INTRODUCTION

Subsidence may increase or decrease the amount of wetland habitat for waterfowl and shorebirds. Since dabbling ducks feed in areas <0.6 meters (2 ft) deep, and shorebirds feed on exposed or shallow inundated (<9cm) mudflats, topographic surveys were needed to delineate feeding depths at different lake levels. Existing pre- and post-subsidence topographic maps prepared by CONSOL provided 2-foot contour interval accuracy used for large scale pre-and post-subsidence habitat modeling (IDNR unpublished data). Pre- and post-subsidence habitat change predicted for varying lake levels useful for assessing the dynamics of shorebird and waterfowl habitat availability. Modeling of habitat change within ~7.6 cm (3 in) increments could help define general shifts in the distribution and extent of shorebird habitat at a scale that was relevant to shorebird foraging depths; however, fine scale (~7.6 cm) topographic data is not necessary for general waterfowl habitat assessments. To refine existing topographic data and to provide benchmark elevation data for future subsidence habitat assessments, Panel 2K located on the east side of Nason Point, was surveyed by the Civil Engineering Department at Southern Illinois University Carbondale to develop a topographic map with ~15cm (0.50 ft) contour intervals.

METHODS

A topographic survey of Nason Point Panel 2K was initiated 10 November 2001. Engineering staff (Roy Frank, assistant professor of Civil Engineering at SIUC) and students established elevation benchmarks at Panel 2K for post-subsidence topographic surveys and future wetland assessments. The topographic survey of the western 2/3 of Panel 2K was completed during December 2001. The Panel 2K survey was completed during April 2001. Field engineering data were transformed and processed using AutoCAD Land Developer software to generate digital map data files and a topographic map.

Assessments of pre- and post-subsidence habitat change for Panel 2K were also conducted using ArcView to generate 7.6 cm (3 in) contour intervals. Pre- and post-subsidence habitat maps were prepared to illustrate coarse scale (60 cm, 2 ft) habitat change at a lake level of 122.4 m (408 ft). Assessment of both coarse scale (60 cm) and fine scale (7.6 cm) habitat availability was conducted using ArcView.

RESULTS

The Panel 2k topographic survey produced a detailed topographic map (6 in contour interval; scale 1 inch = 100 ft) and digital map files (Rend.dwg 2D and Rend1.dwg 3D; Appendix J) for future habitat evaluation and modeling of the post-subsidence basin. Modeling of a fine scale habitat change for the 122.4 m (± 60 cm) lake level predicted a 1.8-2.6 ha increase in shorebird habitat for proposed Panel 2K (Appendix J).

DISCUSSION

Assessment of post-subsidence wetland habitat availability can be predicted using the fine-scale (15 cm, 6 in) Panel 2K pre-subsidence topographic survey (Appendix J). Post-subsidence assessment and monitoring of changes in wetland habitats can now be directly linked to both the predicted and actual changes in the post-subsidence hydroperiod by conducting long term habitat monitoring of Panel 2K. Shifts in the distribution and extent of wetland habitats can be predicted for both the short term post-subsidence period as well as longer term successional habitat shifts resulting from many annual cycles of seasonal water level fluctuations within the Rend Lake basin.

Habitat modeling using extrapolated fine scale (~7.6 cm) contour intervals documented the utility and flexibility of GIS tools to predict dynamic habitat shifts that occur in response to a one-time predictable event (subsidence) as well as constant and somewhat unpredictable and highly variable annual and seasonal cycles of water level change within the Rend Lake basin.

The topographic habitat modeling tools provided capability for predicting both the extent and distribution of waterbird habitat for any chosen fine scale (7.6 cm) elevation increment. However, in reality, the habitat modeling exercise cannot predict with any fine scale accuracy where the shorebird habitat will be during any given time period. Extreme annual and seasonal variation in Rend Lake water levels represent the dominant and the most dynamic variable controlling shoreline-wetland habitat quality and distribution.

No methods exist to manage Rend Lake water levels through drawdowns; therefore, no means exist to enhance or manage shorebird habitat at any specific lake level or location without intensive management practices provided by constructed shallow water-mudflat habitats maintained by embankments and pumps. However, since the pre- and post-subsidence modeling indicates no negative change in habitat area, then specific management practices should not be necessary to offset the shift in the location of post-subsidence waterfowl and shorebird habitats.

Similar to the benefits of establishing a pre- and post-subsidence ecological monitoring program for Panel 2K, it is recommended that long term monitoring of the Ward Branch subsidence wetlands be continued. Although detailed habitat evaluations of the Ward Branch wetlands were not incorporated in the shorebird and waterfowl assessments of the current project, the short term wetland successional trends documented by Owen (1992) were seen as sustainable trends (> 10 years post-subsidence) during this study. Habitat shifts from upland to wetland at Ward Branch are now stable relative to the dynamic equilibrium established by hydroperiods during the past 12 years. The Ward Branch study area (Owen 1992) should continue to serve as a long term ecological benchmark for wetland development in subsidence basins. Therefore, the initial Ward Branch subsidence assessment, pre- and post-subsidence monitoring maps, and habitat data (Owen 1992) are included in this report for future reference (Appendix K). Similar to the benchmark study of Ward Branch wetlands, the Nason Point Panel 2K benchmark topographic survey and the ArcView habitat model (Appendix J) will provide the necessary topographic framework for future post-subsidence habitat assessments at Nason Point.

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APPENDICES

Appendix C. Environmental variables and start and finish times for spring 2002 dabbling duck surveys at Rend Lake, Illinois.

Date	Start[a]	Finish[a]	Water level (m)	Temperature (°C)	Wind speed (kph)	Wind direction (°)	Solar radiation[b]
1 Feb	1305	1805	124.33	1.8	18.51	280	0.014
2 Feb	1405	1815	124.48	-1.3	4.99	126	0.214
3 Feb	1300	1700	124.57	3.0	5.63	206	0.019
4 Feb	1330	1715	124.57	-4.9	13.36	333	0.268
5 Feb	1256	1640	124.57	-3.5	4.99	146	0.027
7 Feb	1315	1620	124.54	0.8	7.24	297	0.032
8 Feb	1300	1625	124.52	0.4	3.38	180	0.129
9 Feb	1440	1830	124.51	8.7	17.38	141	0.459
10 Feb	1315	1645	124.50	6.7	10.14	253	0.009
11 Feb	1410	1715	124.48	0.4	4.80	330	0.279
13 Feb	1250	1620	124.46	-1.5	8.37	338	0.101
14 Feb	1420	1720	124.43	0.6	6.12	178	0.352
15 Feb	1245	1605	124.40	5.4	10.62	210	0.077
16 Feb	1353	1630	124.40	5.4	13.36	225	0.290
17 Feb	1320	1600	124.42	2.2	6.44	321	0.125
19 Feb	1430	1655	124.40	10.7	10.30	173	0.068
20 Feb	1240	1600	124.42	12.3	10.30	208	0.035
21 Feb	1355	1640	124.44	5.7	13.68	252	0.143
22 Feb	1248	1550	124.45	0.0	7.24	314	0.122
24 Feb	1410	1630	124.44	7.9	11.43	155	0.352
25 Feb	1320	1530	124.43	8.6	7.40	237	0.095

Appendix C. Continued.

Date	Start[a]	Finish[a]	Water level (m)	Temperature (°C)	Wind speed (kph)	Wind direction (°)	Solar radiation[b]
26 Feb	1430	1630	124.47	-5.9	22.53	273	0.272
27 Feb	1340	1550	124.44	-8.0	17.06	276	0.321
1 Mar	1320	1522	124.43	0.1	8.21	132	0.166
4 Mar	1415	1640	124.44	-10.5	11.43	256	0.361
6 Mar	1550	1810	124.40	13.1	17.54	204	0.709
8 Mar	1440	1650	124.41	17.6	14.81	189	0.319
11 Mar	1550	1745	124.72	6.6	17.70	127	0.623
12 Mar	1610	1820	124.75	6.8	8.05	44	0.261
19 Mar	1315	1625	124.86	9.2	10.94	63	0.030
21 Mar	1420	1620	125.04	-4.9	14.00	311	0.529
25 Mar	1335	1630	125.05	4.4	9.33	337	0.055
28 Mar	1430	140	125.12	8.1	14.32	150	0.333
1 Apr	1325	1545	125.06	10.3	11.59	148	0.565
4 Apr	1255	1520	125.02	2.9	6.60	14	0.401
9 Apr	1315	1620	124.95	12.2	10.30	336	0.181
12 Apr	1325	1615	124.90	18.7	9.01	114	0.184
18 Apr	1315	1520	124.85	25.0	7.89	176	0.576
25 Apr	1400	1515	124.83	10.0	6.44	302	0.485

[a] Greenwich mean time.
[b] kilowatts per meter^2.

Appendix D. Shoreline lengths measured (m) at Ward Branch and Nason Point, Rend Lake, Illinois during 3 lake levels (m).

Location	Habitat	Lake Level		
		124.3 (408 ft)	124.6 (409 ft)	124.9 (410 ft)
NP 2	exposed shoreline	460	293	114
NP 5	exposed shoreline	311	212	307
NP TOWER	exposed shoreline	149	67	28
WB 3 E	exposed shoreline	189	133	69
NP 23	unsubsided cove	485	647	1,108
NP 4	unsubsided cove	612	446	857
NP 45	unsubsided cove	174	275	543
NP 6A	unsubsided cove	508	546	803
NP SUB	subsided cove	476	419	450
WB 1	subsided cove	243	135	522
WB 2	subsided cove	158	219	564
WB 3	subsided cove	378	420	841
Mean	exposed shoreline	277	176	130
	unsubsided cove	445	479	828
	subsided cove	314	298	594

Appendix E. Total number of each species of dabbling duck surveyed at each experimental unit[a] during spring migration 2002 at Rend Lake, Illinois.

Date	Location	A OU[b] species code							
		ABDU	AMWI	BWTE	GADW	GWTE	MALL	NOPI	NOSH
1 Feb	NP 2	2	-[c]	-	-	-	2	-	-
	NP 23	-	-	-	-	6	-	-	-
	NP 4	-	-	-	-	-	9	-	-
	NP 45	-	-	-	-	-	12	-	-
	NP 5	-	-	-	-	-	5	-	-
	NP SUB	5	-	-	-	1	59	1	-
	NP TOWER	3	-	-	-	20	53	27	-
	WB 3 E	2	48	-	25	57	15	16	-
2 Feb	NP 5	2	-	-	2	-	-	-	-
	NP TOWER	-	-	-	-	-	3	-	-
	WB 1	-	-	-	3	-	-	-	-
	WB 2	-	-	-	2	-	-	-	-
3 Feb	NP 23	-	-	-	-	-	2	-	-
	NP 4	-	-	-	-	-	4	-	-
	NP 6A	-	-	-	-	15	-	-	-
	NP SUB	2	2	-	2	4	48	-	-
	NP TOWER	-	-	-	-	-	4	-	-
	WB 3 E	-	-	-	-	-	2	10	-
4 Feb	NP 2	-	-	-	-	-	1	-	-
	NP 6A	-	-	-	-	17	-	-	-
	NP SUB	-	-	-	-	6	71	-	-
	NP TOWER	-	1	-	-	-	4	-	-
	WB 1	-	-	-	-	2	-	-	-
	WB 2	-	-	-	4	-	2	-	-
	WB 3	-	-	-	-	-	1	-	-
	WB 3 E	-	31	-	16	9	2	32	-
5 Feb	NP 2	-	-	-	-	-	2	-	-
	NP 23	-	-	-	2	-	31	41	-
	NP 4	25	-	-	-	10	10	33	-
	NP 5	-	-	-	-	-	4	-	-
	NP SUB	3	2	-	-	22	132	7	-
	NP TOWER	2	1	-	1	-	11	4	-
	WB 1	-	9	-	-	-	39	-	-
	WB 2	-	-	-	-	6	30	10	-
	WB 3 E	-	39	-	-	96	16	-	-
7 Feb	NP 2	-	-	-	-	-	-	-	-
	NP 23	-	10	-	-	19	41	38	-
	NP 4	-	-	-	1	2	2	2	-

Appendix E. Continued.

Date	Location	A OU[b] species code							
		ABDU	AMWI	BWTE	GADW	GWTE	MALL	NOPI	NOSH
	NP 6A	-	-	-	-	-	1	-	-
	NP SUB	-	1	-	-	-	17	1	-
	NP TOWER	-	-	-	2	-	8	4	-
	WB 1	-	16	-	-	2	42	-	-
	WB 3	-	49	-	-	5	73	-	-
8 Feb	NP 2	-	-	-	-	-	2	-	
	NP 23	-	-	-	-	17	14	17	-
	NP 4	-	-	-	2	-	3	4	-
	NP 6A	-	-	-	-	-	12	-	-
	NP SUB	-	10	-	1	-	155	1	-
	NP TOWER	-	-	-	-	-	22	-	-
	WB 1	-	-	-	-	-	5	-	-
	WB 2	-	-	-	-	-	4	-	-
	WB 3 E	-	29	-	-	-	-	-	-
9 Feb	NP 2	7	14	-	-	-	9	-	-
	NP 23	-	-	-	-	-	80	125	-
	NP 4	19	6	-	-	78	46	53	-
	NP SUB	-	3	-	-	-	71	-	-
	NP TOWER	-	2	-	-	1	21	2	-
	WB 1	-	3	-	-	-	5	-	-
	WB 2	-	-	-	2	-	-	-	-
	WB 3	-	98	-	2	27	63	17	-
	WB 3 E	-	-	-	-	18	-	-	-
10 Feb	NP 2	12	6	-	6	2	6	-	-
	NP 23	-	26	-	11	11	178	178	-
	NP 4	27	4	-	2	104	78	107	-
	NP 45	4	-	-	-	-	-	-	-
	NP 5	-	-	-	-	-	2	-	-
	NP 6A	-	-	-	-	-	59	-	-
	NP SUB	-	5	-	-	-	44	-	-
	NP TOWER	-	21	-	7	-	325	23	-
	WB 3 E	-	8	-	-	52	4	15	-
	WB 3	-	74	-	4	-	95	23	-
11 Feb	NP 2	11	-	-	-	13	10	-	-
	NP 23	-	8	-	-	2	156	292	-
	NP 4	-	-	-	-	9	2	17	-
	NP 45	2	-	-	-	-	16	-	-
	NP SUB	-	11	-	-	-	8	-	-
	NP TOWER	-	-	-	-	3	30	10	-
	WB 1	-	-	-	-	-	9	-	-

Appendix E. Continued.

Date	Location	AOU[b] species code							
		ABDU	AMWI	BWTE	GADW	GWTE	MALL	NOPI	NOSH
	WB 2	-	-	-	-	3	20	-	-
	WB 3	-	15	-	-	-	97	-	-
	WB 3 E	-	5	-	-	11	8	6	-
13 Feb	NP 2	-	-	-	-	12	6	-	-
	NP 23	-	-	-	-	-	2	20	-
	NP 4	4	-	-	2	81	31	34	-
	NP 45	-	-	-	-	50	50	4	-
	NP 5	3	-	-	-	-	9	-	-
	NP 6A	-	2	-	-	1	114	32	-
	NP SUB	2	30	-	-	-	37	2	-
	NP TOWER	-	-	-	-	-	43	18	-
	WB 1	-	-	-	-	10	116	-	-
	WB 2	-	-	-	-	20	88	-	-
	WB 3	-	-	-	-	-	60	-	-
14 Feb	NP 2	2	-	-	-	-	-	-	-
	NP 23	-	-	-	-	-	11	-	-
	NP 4	-	-	-	-	5	25	17	-
	NP 6A	-	-	-	-	10	39	-	-
	NP SUB	2	11	-	-	-	43	-	-
	NP TOWER	-	-	-	-	-	42	37	-
	NP45	-	-	-	-	3	-	-	-
	WB 1	-	-	-	-	-	245	13	-
	WB 2	-	50	-	-	5	214	106	-
	WB 3	-	-	-	-	-	250	100	-
	WB 3 E	-	-	-	-	10	120	40	-
15 Feb	NP 2	-	1	-	1	9	8	8	-
	NP 23	1	-	-	-	-	35	10	-
	NP 4	19	4	-	14	130	106	72	-
	NP 45	7	-	-	-	18	35	-	-
	NP 5	-	-	-	-	-	5	4	-
	NP 6A	-	-	-	-	10	11	-	-
	NP SUB	-	14	-	-	-	68	-	-
	NP TOWER	-	-	-	-	-	70	10	-
	WB 1	-	-	-	-	-	200	35	-
	WB 2	-	36	-	-	-	229	42	-
	WB 3	-	-	-	-	-	15	-	-
	WB 3 E	-	5	-	-	-	-	2	-
16 Feb	NP 2	9	-	-	-	2	11	-	-
	NP 23	-	-	-	-	1	-	-	-
	NP 4	14	12	-	-	91	75	81	-

Appendix E. Continued.

Date	Location	A OU[b] species code							
		ABDU	AMWI	BWTE	GADW	GWTE	MALL	NOPI	NOSH
	NP 45	-	-	-	-	-	3	3	-
	NP 5	-	-	-	-	-	1	-	-
	NP 6A	-	-	-	-	8	8	36	-
	NP TOWER	4	2	-	2	-	115	82	-
	WB 1	-	-	-	-	-	187	2	-
	WB 2	-	25	-	-	-	60	80	-
	WB 3	-	-	-	-	-	157	-	-
	WB 3 E	-	-	-	-	20	36	40	-
17 Feb	NP 2	-	-	-	-	15	6	1	-
	NP 23	-	-	-	-	4	11	-	-
	NP 4	6	-	-	-	64	-	87	-
	NP 45	-	-	-	-	-	15	-	-
	NP 6A	-	-	-	-	13	-	3	-
	NP SUB	-	1	-	-	-	-	-	-
	NP TOWER	13	2	-	-	3	207	68	-
	WB 1	-	-	-	-	-	5	-	-
	WB 2	-	6	-	-	6	100	25	-
	WB 3	-	20	-	-	-	75	100	-
	WB 3 E	-	2	-	-	2	4	32	-
19 Feb	NP 2	-	-	-	-	-	2	-	-
	NP 23	1	2	-	-	9	247	301	-
	NP 4	26	3	-	-	158	67	55	-
	NP 45	-	-	-	1	-	155	40	-
	NP 6A	-	-	-	-	-	-	8	-
	NP SUB	1	-	-	-	-	15	-	-
	NP TOWER	3	-	-	-	-	110	90	-
	WB 1	-	-	-	-	-	2	-	-
	WB 2	-	15	-	-	-	77	18	-
	WB 3	-	15	-	-	-	30	120	-
	WB 3 E	-	4	-	-	-	15	122	-
20 Feb	NP 2	14	-	-	-	-	9	19	-
	NP 23	-	-	-	-	1	51	-	-
	NP 4	8	-	-	-	120	20	20	2
	NP 45	-	-	-	-	77	156	19	-
	NP 5	-	-	-	-	-	3	-	-
	NP 6A	-	-	-	-	31	2	-	-
	NP SUB	3	6	-	-	1	36	-	-
	NP TOWER	2	-	-	2	-	18	27	-
	WB 1	-	-	-	-	-	9	-	-
	WB 2	-	48	-	-	-	11	-	-
	WB 3	-	2	-	-	-	38	-	-
	WB 3 E	-	5	-	1	35	28	-	-

Appendix E. Continued.

Date	Location	AOU[b] species code							
		ABDU	AMWI	BWTE	GADW	GWTE	MALL	NOPI	NOSH
21 Feb	NP 4	8	-	-	-	49	15	-	-
	NP 5	2	-	-	-	-	2	-	-
	NP SUB	-	5	-	-	-	11	-	-
	NP TOWER	-	-	-	-	-	14	9	-
	WB 2	-	16	-	2	3	8	-	-
	WB 3 E	-	-	-	1	-	2	-	-
22 Feb	NP 2	-	-	-	-	-	2	-	-
	NP 5	2	-	-	-	-	5	-	-
	NP 6A	-	-	-	-	25	-	-	-
	NP SUB	2	-	-	-	-	12	-	-
	NP TOWER	2	-	-	-	-	1	10	-
	WB 1	-	-	-	-	-	2	-	-
	WB 2	-	16	-	-	1	-	-	-
24 Feb	NP 2	10	-	-	-	13	-	-	-
	NP 4	-	-	-	-	74	-	-	6
	NP TOWER	2	-	-	-	5	16	17	-
	WB 2	-	3	-	-	-	-	-	-
25 Feb	NP 2	4	-	-	-	28	20	7	-
	NP 23	-	-	-	-	-	2	-	-
	NP 4	-	-	-	-	55	-	-	-
	NP 45	2	-	-	-	-	-	-	-
	NP 5	-	-	-	-	-	2	-	-
	NP 6A	-	-	-	-	6	-	-	-
	NP SUB	-	-	-	-	-	2	-	-
	NP TOWER	8	-	-	-	-	5	17	-
	WB 2	-	12	-	-	-	1	-	-
	WB 3 E	-	-	-	-	33	-	-	-
26 Feb	NP 2	-	-	-	-	28	4	-	-
	NP 4	-	-	-	-	3	-	-	-
	NP SUB	2	-	-	-	-	2	-	-
	NP TOWER	4	-	-	-	-	8	6	-
	WB 2	-	9	-	-	-	-	-	-
	WB 3 E	-	-	-	-	11	-	8	-
27 Feb	NP 45	-	-	-	-	2	-	-	-
	NP 5	-	-	-	-	-	1	-	-
	NP SUB	-	-	-	-	-	2	-	-
	WB 1	-	-	-	-	-	8	-	-
	WB 2	-	7	-	-	-	1	-	-
	WB 3 E	-	-	-	-	1	2	24	-

Appendix E. Continued.

Date	Location	A OU[b] species code							
		ABDU	AMWI	BWTE	GADW	GWTE	MALL	NOPI	NOSH
1 Mar	NP 2	2	2	-	-	105	7	-	-
	NP 4	4	-	-	-	26	3	-	-
	NP SUB	-	-	-	-	-	1	-	-
	NP TOWER	2	5	-	-	1	12	18	-
	WB 2	-	15	-	-	-	2	-	-
	WB 3 E	-	-	-	-	-	1	12	-
4 Mar	NP 5	-	-	-	-	-	34	-	-
	WB 1	-	4	-	2	-	16	-	-
	WB 3 E	-	-	-	-	6	-	-	-
6 Mar	NP 2	-	-	-	-	41	3	-	-
	NP 4	2	-	-	-	21	4	-	-
	NP SUB	2	-	-	-	-	-	-	-
	NP TOWER	4	-	-	-	-	16	8	-
	WB 2	-	6	-	-	-	-	-	-
	WB 3 E	-	-	-	-	-	-	4	-
8 Mar	NP 2	12	-	-	-	-	9	8	-
	NP SUB	2	-	-	-	-	-	-	-
	NP TOWER	-	1	-	-	1	26	8	-
	WB 2	-	1	-	-	-	2	-	-
	WB 3 E	-	5	-	-	2	1	6	-
11 Mar	NP 2	-	-	-	-	13	-	-	-
	NP 4	2	-	-	-	-	-	-	-
	NP 6A	-	-	-	-	-	4	-	-
	NP TOWER	4	-	-	-	-	-	-	-
	WB 1	-	-	-	-	-	2	-	-
	WB 3	-	-	-	2	19	38	-	-
12 Mar	NP 4	2	-	-	-	-	-	-	-
	NP 5	-	-	-	-	7	1	-	-
	NP 6A	-	-	-	-	-	2	-	-
	NP SUB	-	-	-	-	-	2	4	-
	WB 2	-	-	-	-	-	2	-	-
	WB 3	-	15	-	4	2	101	2	2
19 Mar	NP 2	6	-	-	-	41	96	-	-
	NP 23	-	-	-	2	-	28	4	-
	NP 4	4	-	5	-	7	-	-	-
	NP 45	2	10	25	15	39	125	-	-
	NP 5	4	-	-	-	-	5	-	-
	NP 6A	-	27	-	6	5	698	4	-

Appendix E. Continued.

Date	Location	A OU[b] species code							
		ABDU	AMWI	BWTE	GADW	GWTE	MALL	NOPI	NOSH
	NP SUB	-	-	-	-	-	207	-	-
	NP TOWER	2	-	-	-	29	12	-	-
	WB 1	-	-	-	-	-	4	-	-
	WB 2	2	-	17	-	-	25	-	3
	WB 3	-	10	-	-	12	69	30	-
	WB 3 E	-	-	-	-	-	4	-	-
21 Mar	NP 2	3	-	-	-	6	9	-	-
	NP 23	3	32	-	22	12	45	5	4
	NP 4	10	-	35	-	20	102	3	-
	NP 45	2	7	52	2	22	35	2	-
	NP 6A	4	34	-	4	-	96	-	-
	NP SUB	-	10	-	-	-	326	-	-
	NP TOWER	-	3	1	3	-	2	-	-
	WB 1	-	-	45	4	11	51	-	-
	WB 2	2	-	15	-	-	2	-	-
	WB 3	-	3	14	11	16	126	-	5
	WB 3 E	-	-	-	-	2	-	-	-
25 Mar	NP 2	4	-	-	-	-	40	-	-
	NP 23	-	23	16	5	112	19	29	37
	NP 4	2	11	2	2	4	52	5	-
	NP 45	-	22	1	-	266	197	2	-
	NP 6A	4	10	1	19	47	310	7	13
	NP SUB	-	-	-	-	22	195	-	-
	NP TOWER	1	2	4	4	2	6	-	12
	WB 1	-	1	15	-	65	10	-	4
	WB 2	-	-	51	-	2	25	-	5
	WB 3	-	1	21	4	58	55	9	19
28 Mar	NP 2	-	-	10	-	34	28	-	-
	NP 23	4	129	34	39	113	26	1	20
	NP 4	2	12	-	2	54	2	-	-
	NP 45	-	20	20	-	175	4	-	-
	NP 6A	2	10	-	-	2	86	-	-
	NP SUB	-	-	-	-	-	20	-	-
	WB 1	-	-	-	-	-	2	-	-
	WB 2	-	-	41	-	-	-	-	-
	WB 3	-	-	18	-	26	44	2	-
1 Apr	NP 2	-	2	24	-	-	17	-	-
	NP 23	-	18	28	-	39	7	3	6
	NP 4	-	7	2	-	17	8	-	-
	NP 45	-	157	3	-	-	45	-	-

Appendix E. Continued.

Date	Location	A OU[b] species code							
		ABDU	AMWI	BWTE	GADW	GWTE	MALL	NOPI	NOSH
	NP 6A	-	-	-	-	2	38	-	-
	NP SUB	-	-	4	-	-	8	-	-
	WB 1	-	-	26	-	-	2	-	-
	WB 2	-	-	5	-	-	-	-	2
	WB 3	-	9	10	-	2	2	2	-
	WB 3 E	-	-	2	-	-	3	-	-
4 Apr	NP 2	-	-	-	-	8	51	-	-
	NP 23	-	12	28	-	12	4	2	11
	NP 4	-	59	-	-	14	51	-	-
	NP 45	-	-	-	-	2	37	-	-
	NP 6A	-	-	5	-	2	47	2	-
	NP SUB	-	-	-	-	2	40	-	-
	WB 1	-	-	-	-	9	2	-	-
	WB 2	-	-	38	-	-	2	-	7
	WB 3	-	25	12	7	4	7	-	42
	WB 3 E	2	1	1	-	-	2	-	-
9 Apr	NP 2	2	-	1	-	2	6	-	1
	NP 23	-	19	24	-	41	4	1	2
	NP 4	-	-	-	-	10	6	-	-
	NP 45	-	-	-	-	-	45	-	-
	NP 6A	-	1	-	-	-	9	-	-
	NP SUB	2	1	-	-	10	29	-	-
	NP TOWER	-	-	7	-	-	-	-	1
	WB 1	-	2	6	-	7	-	-	5
	WB 2	-	-	54	-	-	-	-	22
	WB 3	2	-	12	2	20	2	-	6
	WB 3 E	-	-	7	-	-	-	-	2
12 Apr	NP 2	-	-	-	-	14	4	-	-
	NP 23	-	2	27	8	9	3	2	18
	NP 4	-	-	11	-	10	-	-	15
	NP 45	-	-	2	-	4	2	-	-
	NP 6A	-	-	4	-	-	11	-	15
	NP SUB	-	-	8	-	-	2	-	-
	WB 1	-	-	1	-	-	2	-	4
	WB 2	-	-	45	-	-	-	-	8
	WB 3	-	12	39	-	7	-	-	22
	WB 3 E	-	-	4	-	10	-	-	2
18 Apr	NP 2	-	-	-	-	-	2	-	-
	NP 23	-	-	23	-	-	2	-	8
	NP 4	-	-	5	-	-	4	-	15

Appendix E. Continued.

Date	Location	A OU[b] species code							
		ABDU	AMWI	BWTE	GADW	GWTE	MALL	NOPI	NOSH
	NP 45	2	9	26	-	-	-	-	8
	NP 6A	-	-	-	-	-	-	-	2
	NP TOWER	-	-	2	-	-	-	-	-
	WB 1	-	-	2	-	-	-	-	-
	WB 2	-	-	5	-	-	1	-	2
	WB 3	-	-	-	-	-	-	-	1
25 Apr	NP 23	-	-	2	-	-	2	-	-
	NP 4	-	-	6	-	-	2	-	6
	NP 45	-	7	4	-	-	2	-	-
	NP 6A	-	-	-	-	2	-	-	-
	WB 3	-	-	-	-	1	2	-	-

[a] see appendices A and B for locations; experimental units containing 0 dabbling ducks were excluded from this listing but were included in the analysis.

[b] ABDU= American black duck (*Anas rubripes*), AMWI= American wigeon (*A. americana*), BWTE= blue-winged teal (*A.discors*), GADW= gadwall (*A. streptera*), GWTE= green-winged teal (*A. crecca*), MALL= mallard (*A. platyrhynchos*), NOPI=Northern pintail (*A. acuta*), NOSH= Northern shoveler (*A. clypeata*).

[c] - = zero.

Appendix F. Total dabbling ducks per meter of shoreline surveyed at each experimental unit[a] during spring migration 2002 at Rend Lake, Illinois.

Date	Water level (m)	Shoreline length (m)	Primary habitat	Location	Total dabbling ducks	Total dabbling ducks (m)
1 Feb	124.33	459.91	exposed shoreline	NP 2	4	0.00870
		311.37	exposed shoreline	NP 5	5	0.01606
		148.54	exposed shoreline	NP TOWER	103	0.69342
		189.25	exposed shoreline	WB 3 E	163	0.86130
		476.07	subsided cove	NP SUB	66	0.13863
		484.77	unsubsided cove	NP 23	6	0.01238
		612.18	unsubsided cove	NP 4	9	0.01470
		174.02	unsubsided cove	NP 45	12	0.06896
2 Feb	124.48	148.54	exposed shoreline	NP TOWER	3	0.02020
		311.37	exposed shoreline	NP 5	4	0.01285
		157.86	subsided cove	WB 2	2	0.01267
		243.32	subsided cove	WB 1	3	0.01233
3 Feb	124.57	67.05	exposed shoreline	NP TOWER	4	0.05965
		132.89	exposed shoreline	WB 3 E	12	0.09030
		419.38	subsided cove	NP SUB	58	0.13830
		646.75	unsubsided cove	NP 23	2	0.00309
		445.90	unsubsided cove	NP 4	4	0.00897
		545.57	unsubsided cove	NP 6A	15	0.02749
4 Feb	124.57	293.20	exposed shoreline	NP 2	1	0.00341
		67.05	exposed shoreline	NP TOWER	5	0.07457
		132.89	exposed shoreline	WB 3 E	90	0.67727
		419.99	subsided cove	WB 3	1	0.00238
		135.32	subsided cove	WB 1	2	0.01478
		218.53	subsided cove	WB 2	6	0.02746
		419.38	subsided cove	NP SUB	77	0.18360
		545.57	unsubsided cove	NP 6A	17	0.03116
5 Feb	124.57	293.20	exposed shoreline	NP 2	2	0.00682
		211.83	exposed shoreline	NP 5	4	0.01888
		67.05	exposed shoreline	NP TOWER	19	0.28336
		132.89	exposed shoreline	WB 3 E	151	1.13631
		218.53	subsided cove	WB 2	46	0.21050
		135.32	subsided cove	WB 1	48	0.35470
		419.38	subsided cove	NP SUB	166	0.39582
		646.75	unsubsided cove	NP 23	74	0.11442
		445.90	unsubsided cove	NP 4	78	0.17493
7 Feb	124.54	67.05	exposed shoreline	NP TOWER	14	0.20879
		419.38	subsided cove	NP SUB	19	0.04530

Appendix F. Continued.

Date	Water level (m)	Shoreline length (m)	Primary habitat	Location	Total dabbling ducks	Total dabbling ducks (m)
		135.32	subsided cove	WB 1	60	0.44338
		419.99	subsided cove	WB 3	127	0.30239
		545.57	unsubsided cove	NP 6A	1	0.00183
		445.90	unsubsided cove	NP 4	7	0.01570
		646.75	unsubsided cove	NP 23	108	0.16699
8 Feb	124.52	293.20	exposed shoreline	NP 2	2	0.00682
		67.05	exposed shoreline	NP TOWER	22	0.32810
		132.89	exposed shoreline	WB 3 E	29	0.21823
		218.53	subsided cove	WB 2	4	0.01830
		135.32	subsided cove	WB 1	5	0.03695
		419.38	subsided cove	NP SUB	167	0.39820
		445.90	unsubsided cove	NP 4	9	0.02018
		545.57	unsubsided cove	NP 6A	12	0.02200
		646.75	unsubsided cove	NP 23	48	0.07422
9 Feb	124.51	132.89	exposed shoreline	WB 3 E	18	0.13545
		67.05	exposed shoreline	NP TOWER	26	0.38775
		293.20	exposed shoreline	NP 2	30	0.10232
		218.53	subsided cove	WB 2	2	0.00915
		135.32	subsided cove	WB 1	8	0.05912
		419.38	subsided cove	NP SUB	74	0.17645
		419.99	subsided cove	WB 3	207	0.49286
		445.90	unsubsided cove	NP 4	202	0.45302
		646.75	unsubsided cove	NP 23	205	0.31697
10 Feb	124.50	311.37	exposed shoreline	NP 5	2	0.00642
		459.91	exposed shoreline	NP 2	32	0.06958
		189.25	exposed shoreline	WB 3 E	79	0.41744
		148.54	exposed shoreline	NP TOWER	376	2.53131
		476.07	subsided cove	NP SUB	49	0.10293
		377.87	subsided cove	WB 3	196	0.51869
		174.02	unsubsided cove	NP 45	4	0.02299
		508.39	unsubsided cove	NP 6A	59	0.11605
		612.18	unsubsided cove	NP 4	322	0.52599
		484.77	unsubsided cove	NP 23	404	0.83338
11 Feb	124.48	189.25	exposed shoreline	WB 3 E	30	0.15852
		459.91	exposed shoreline	NP 2	34	0.07393
		148.54	exposed shoreline	NP TOWER	43	0.28949
		243.32	subsided cove	WB 1	9	0.03699
		476.07	subsided cove	NP SUB	19	0.03991
		157.86	subsided cove	WB 2	23	0.14570

Appendix F. Continued.

Date	Water level (m)	Shoreline length (m)	Primary habitat	Location	Total dabbling ducks	Total dabbling ducks (m)
		377.87	subsided cove	WB 3	112	0.29639
		174.02	unsubsided cove	NP 45	18	0.10344
		612.18	unsubsided cove	NP 4	28	0.04574
		484.77	unsubsided cove	NP 23	458	0.94477
13 Feb	124.46	311.37	exposed shoreline	NP 5	12	0.03854
		459.91	exposed shoreline	NP 2	18	0.03914
		148.54	exposed shoreline	NP TOWER	61	0.41067
		377.87	subsided cove	WB 3	60	0.15878
		476.07	subsided cove	NP SUB	71	0.14914
		157.86	subsided cove	WB 2	108	0.68414
		243.32	subsided cove	WB 1	126	0.51784
		484.77	unsubsided cove	NP 23	22	0.04538
		174.02	unsubsided cove	NP 45	104	0.59763
		508.39	unsubsided cove	NP 6A	149	0.29308
		612.18	unsubsided cove	NP 4	152	0.24829
14 Feb	124.43	459.91	exposed shoreline	NP 2	2	0.00435
		148.54	exposed shoreline	NP TOWER	79	0.53185
		189.25	exposed shoreline	WB 3 E	170	0.89829
		476.07	subsided cove	NP SUB	56	0.11763
		243.32	subsided cove	WB 1	258	1.06034
		377.87	subsided cove	WB 3	350	0.92623
		157.86	subsided cove	WB 2	375	2.37549
		174.02	unsubsided cove	NP 45	3	0.01724
		484.77	unsubsided cove	NP 23	11	0.02269
		612.18	unsubsided cove	NP 4	47	0.07677
		508.39	unsubsided cove	NP 6A	49	0.09638
15 Feb	124.40	189.25	exposed shoreline	WB 3 E	7	0.03699
		311.37	exposed shoreline	NP 5	9	0.02890
		459.91	exposed shoreline	NP 2	27	0.05871
		148.54	exposed shoreline	NP TOWER	80	0.53858
		377.87	subsided cove	WB 3	15	0.03970
		476.07	subsided cove	NP SUB	82	0.17224
		243.32	subsided cove	WB 1	235	0.96581
		157.86	subsided cove	WB 2	307	1.94474
		508.39	unsubsided cove	NP 6A	21	0.04131
		484.77	unsubsided cove	NP 23	46	0.09489
		174.02	unsubsided cove	NP 45	60	0.34479
		612.18	unsubsided cove	NP 4	345	0.56356
16 Feb	124.40	311.37	exposed shoreline	NP 5	1	0.00321

Appendix F. Continued.

Date	Water level (m)	Shoreline length (m)	Primary habitat	Location	Total dabbling ducks	Total dabbling ducks (m)
		459.91	exposed shoreline	NP 2	22	0.04784
		189.25	exposed shoreline	WB 3 E	96	0.50727
		148.54	exposed shoreline	NP TOWER	205	1.38010
		377.87	subsided cove	WB 3	157	0.41548
		157.86	subsided cove	WB 2	165	1.04522
		243.32	subsided cove	WB 1	189	0.77676
		484.77	unsubsided cove	NP 23	1	0.00206
		174.02	unsubsided cove	NP 45	6	0.03448
		508.39	unsubsided cove	NP 6A	52	0.10228
		612.18	unsubsided cove	NP 4	273	0.44595
17 Feb	124.42	459.91	exposed shoreline	NP 2	22	0.04784
		189.25	exposed shoreline	WB 3 E	40	0.21136
		148.54	exposed shoreline	NP TOWER	293	1.97254
		476.07	subsided cove	NP SUB	1	0.00210
		243.32	subsided cove	WB 1	5	0.02055
		157.86	subsided cove	WB 2	137	0.86785
		377.87	subsided cove	WB 3	195	0.51604
		484.77	unsubsided cove	NP 23	15	0.03094
		174.02	unsubsided cove	NP 45	15	0.08620
		508.39	unsubsided cove	NP 6A	16	0.03147
		612.18	unsubsided cove	NP 4	157	0.25646
19 Feb	124.40	459.91	exposed shoreline	NP 2	2	0.00435
		189.25	exposed shoreline	WB 3 E	141	0.74505
		148.54	exposed shoreline	NP TOWER	203	1.36664
		243.32	subsided cove	WB 1	2	0.00822
		476.07	subsided cove	NP SUB	16	0.03361
		157.86	subsided cove	WB 2	110	0.69681
		377.87	subsided cove	WB 3	165	0.43665
		508.39	unsubsided cove	NP 6A	8	0.01574
		174.02	unsubsided cove	NP 45	196	1.12630
		612.18	unsubsided cove	NP 4	309	0.50475
		484.77	unsubsided cove	NP 23	560	1.15518
20 Feb	124.42	311.37	exposed shoreline	NP 5	3	0.00963
		459.91	exposed shoreline	NP 2	42	0.09132
		148.54	exposed shoreline	NP TOWER	49	0.32988
		189.25	exposed shoreline	WB 3 E	69	0.36460
		243.32	subsided cove	WB 1	9	0.03699
		377.87	subsided cove	WB 3	40	0.10586
		476.07	subsided cove	NP SUB	46	0.09662
		157.86	subsided cove	WB 2	59	0.37374

Appendix F. Continued.

Date	Water level (m)	Shoreline length (m)	Primary habitat	Location	Total dabbling ducks	Total dabbling ducks (m)
		508.39	unsubsided cove	NP 6A	33	0.06491
		484.77	unsubsided cove	NP 23	52	0.10727
		612.18	unsubsided cove	NP 4	170	0.27770
		174.02	unsubsided cove	NP 45	252	1.44810
21 Feb	124.44	189.25	exposed shoreline	WB 3 E	3	0.01585
		311.37	exposed shoreline	NP 5	4	0.01285
		148.54	exposed shoreline	NP TOWER	23	0.15484
		476.07	subsided cove	NP SUB	16	0.03361
		157.86	subsided cove	WB 2	29	0.18370
		612.18	unsubsided cove	NP 4	72	0.11761
22 Feb	124.45	459.91	exposed shoreline	NP 2	2	0.00435
		311.37	exposed shoreline	NP 5	7	0.02248
		148.54	exposed shoreline	NP TOWER	13	0.08752
		243.32	subsided cove	WB 1	2	0.00822
		476.07	subsided cove	NP SUB	14	0.02941
		157.86	subsided cove	WB 2	17	0.10769
		508.39	unsubsided cove	NP 6A	25	0.04917
24 Feb	124.44	459.91	exposed shoreline	NP 2	23	0.05001
		148.54	exposed shoreline	NP TOWER	40	0.26929
		157.86	subsided cove	WB 2	3	0.01900
		612.18	unsubsided cove	NP 4	80	0.13068
25 Feb	124.43	311.37	exposed shoreline	NP 5	2	0.00642
		148.54	exposed shoreline	NP TOWER	30	0.20197
		189.25	exposed shoreline	WB 3 E	33	0.17437
		459.91	exposed shoreline	NP 2	52	0.11306
		476.07	subsided cove	NP SUB	2	0.00420
		157.86	subsided cove	WB 2	13	0.08235
		484.77	unsubsided cove	NP 23	2	0.00413
		174.02	unsubsided cove	NP 45	2	0.01149
		508.39	unsubsided cove	NP 6A	6	0.01180
		612.18	unsubsided cove	NP 4	55	0.08984
26 Feb	124.47	148.54	exposed shoreline	NP TOWER	18	0.12118
		189.25	exposed shoreline	WB 3 E	19	0.10040
		459.91	exposed shoreline	NP 2	32	0.06958
		476.07	subsided cove	NP SUB	4	0.00840
		157.86	subsided cove	WB 2	9	0.05701
		612.18	unsubsided cove	NP 4	3	0.00490

Appendix F. Continued.

Date	Water level (m)	Shoreline length (m)	Primary habitat	Location	Total dabbling ducks	Total dabbling ducks (m)
27 Feb	124.44	311.37	exposed shoreline	NP 5	1	0.00321
		189.25	exposed shoreline	WB 3 E	27	0.14267
		476.07	subsided cove	NP SUB	2	0.00420
		243.32	subsided cove	WB 1	8	0.03288
		157.86	subsided cove	WB 2	8	0.05068
		174.02	unsubsided cove	NP 45	2	0.01149
1 Mar	124.43	189.25	exposed shoreline	WB 3 E	13	0.06869
		148.54	exposed shoreline	NP TOWER	38	0.25582
		459.91	exposed shoreline	NP 2	116	0.25222
		476.07	subsided cove	NP SUB	1	0.00210
		157.86	subsided cove	WB 2	17	0.10769
		612.18	unsubsided cove	NP 4	33	0.05391
4 Mar	124.44	189.25	exposed shoreline	WB 3 E	6	0.03170
		311.37	exposed shoreline	NP 5	34	0.10919
		243.32	subsided cove	WB 1	22	0.09042
6 Mar	124.40	189.25	exposed shoreline	WB 3 E	4	0.02114
		148.54	exposed shoreline	NP TOWER	28	0.18850
		459.91	exposed shoreline	NP 2	44	0.09567
		476.07	subsided cove	NP SUB	2	0.00420
		157.86	subsided cove	WB 2	6	0.03801
		612.18	unsubsided cove	NP 4	27	0.04410
8 Mar	124.41	189.25	exposed shoreline	WB 3 E	14	0.07398
		459.91	exposed shoreline	NP 2	29	0.06306
		148.54	exposed shoreline	NP TOWER	36	0.24236
		476.07	subsided cove	NP SUB	2	0.00420
		157.86	subsided cove	WB 2	3	0.01900
11 Mar	124.72	67.05	exposed shoreline	NP TOWER	4	0.05965
		293.20	exposed shoreline	NP 2	13	0.04434
		135.32	subsided cove	WB 1	2	0.01478
		419.99	subsided cove	WB 3	59	0.14048
		445.90	unsubsided cove	NP 4	2	0.00449
		545.57	unsubsided cove	NP 6A	4	0.00733
12 Mar	124.75	211.83	exposed shoreline	NP 5	8	0.03777
		218.53	subsided cove	WB 2	2	0.00915
		419.38	subsided cove	NP SUB	6	0.01431
		419.99	subsided cove	WB 3	126	0.30000

Appendix F. Continued.

Date	Water level (m)	Shoreline length (m)	Primary habitat	Location	Total dabbling ducks	Total dabbling ducks (m)
		445.90	unsubsided cove	NP 4	2	0.00449
		545.57	unsubsided cove	NP 6A	2	0.00367
19 Mar	124.86	69.20	exposed shoreline	WB 3 E	4	0.05780
		306.78	exposed shoreline	NP 5	9	0.02934
		27.81	exposed shoreline	NP TOWER	43	1.54621
		114.39	exposed shoreline	NP 2	143	1.25011
		522.18	subsided cove	WB 1	4	0.00766
		563.77	subsided cove	WB 2	47	0.08337
		840.95	subsided cove	WB 3	121	0.14388
		449.63	subsided cove	NP SUB	207	0.46038
		857.10	unsubsided cove	NP 4	16	0.01867
		1,107.84	unsubsided cove	NP 23	34	0.03069
		543.13	unsubsided cove	NP 45	216	0.39769
		803.39	unsubsided cove	NP 6A	740	0.92110
21 Mar	125.04	69.20	exposed shoreline	WB 3 E	2	0.02890
		27.81	exposed shoreline	NP TOWER	9	0.32362
		114.39	exposed shoreline	NP 2	18	0.15736
		563.77	subsided cove	WB 2	19	0.03370
		522.18	subsided cove	WB 1	111	0.21257
		840.95	subsided cove	WB 3	175	0.20810
		449.63	subsided cove	NP SUB	336	0.74728
		543.13	unsubsided cove	NP 45	122	0.22462
		1,107.84	unsubsided cove	NP 23	123	0.11103
		803.39	unsubsided cove	NP 6A	138	0.17177
		857.10	unsubsided cove	NP 4	170	0.19834
25 Mar	125.05	27.81	exposed shoreline	NP TOWER	31	1.11471
		114.39	exposed shoreline	NP 2	44	0.38465
		563.77	subsided cove	WB 2	83	0.14722
		522.18	subsided cove	WB 1	95	0.18193
		840.95	subsided cove	WB 3	167	0.19858
		449.63	subsided cove	NP SUB	217	0.48262
		857.10	unsubsided cove	NP 4	78	0.09100
		1,107.84	unsubsided cove	NP 23	241	0.21754
		803.39	unsubsided cove	NP 6A	411	0.51158
		543.13	unsubsided cove	NP 45	488	0.89850
28 Mar	125.12	114.39	exposed shoreline	NP 2	72	0.62943
		522.18	subsided cove	WB 1	2	0.00383
		449.63	subsided cove	NP SUB	20	0.04448
		563.77	subsided cove	WB 2	41	0.07272

Appendix F. Continued.

Date	Water level (m)	Shoreline length (m)	Primary habitat	Location	Total dabbling ducks	Total dabbling ducks (m)
		840.95	subsided cove	WB 3	90	0.10702
		857.10	unsubsided cove	NP 4	72	0.08400
		803.39	unsubsided cove	NP 6A	100	0.12447
		543.13	unsubsided cove	NP 45	219	0.40322
		1,107.84	unsubsided cove	NP 23	366	0.33037
1 Apr	125.06	69.20	exposed shoreline	WB 3 E	5	0.07225
		114.39	exposed shoreline	NP 2	43	0.37591
		563.77	subsided cove	WB 2	7	0.01242
		449.63	subsided cove	NP SUB	12	0.02669
		840.95	subsided cove	WB 3	25	0.02973
		522.18	subsided cove	WB 1	28	0.05362
		857.10	unsubsided cove	NP 4	34	0.03967
		803.39	unsubsided cove	NP 6A	40	0.04979
		1,107.84	unsubsided cove	NP 23	101	0.09117
		543.13	unsubsided cove	NP 45	205	0.37744
4 Apr	125.02	69.20	exposed shoreline	WB 3 E	6	0.08671
		114.39	exposed shoreline	NP 2	59	0.51578
		522.18	subsided cove	WB 1	11	0.02107
		449.63	subsided cove	NP SUB	42	0.09341
		563.77	subsided cove	WB 2	47	0.08337
		840.95	subsided cove	WB 3	97	0.11535
		543.13	unsubsided cove	NP 45	39	0.07181
		803.39	unsubsided cove	NP 6A	56	0.06970
		1,107.84	unsubsided cove	NP 23	69	0.06228
		857.10	unsubsided cove	NP 4	124	0.14467
9 Apr	124.95	27.81	exposed shoreline	NP TOWER	8	0.28767
		69.20	exposed shoreline	WB 3 E	9	0.13006
		114.39	exposed shoreline	NP 2	12	0.10490
		522.18	subsided cove	WB 1	20	0.03830
		449.63	subsided cove	NP SUB	42	0.09341
		840.95	subsided cove	WB 3	44	0.05232
		563.77	subsided cove	WB 2	76	0.13481
		803.39	unsubsided cove	NP 6A	10	0.01245
		857.10	unsubsided cove	NP 4	16	0.01867
		543.13	unsubsided cove	NP 45	45	0.08285
		1,107.84	unsubsided cove	NP 23	91	0.08214
12 Apr	124.90	69.20	exposed shoreline	WB 3 E	16	0.23121
		114.39	exposed shoreline	NP 2	18	0.15736
		522.18	subsided cove	WB 1	7	0.01341

Appendix F. Continued.

Date	Water level (m)	Shoreline length (m)	Primary habitat	Location	Total dabbling ducks	Total dabbling ducks (m)
		449.63	subsided cove	NP SUB	10	0.02224
		563.77	subsided cove	WB 2	53	0.09401
		840.95	subsided cove	WB 3	80	0.09513
		543.13	unsubsided cove	NP 45	8	0.01473
		803.39	unsubsided cove	NP 6A	30	0.03734
		857.10	unsubsided cove	NP 4	36	0.04200
		1,107.84	unsubsided cove	NP 23	69	0.06228
18 Apr	124.88	114.39	exposed shoreline	NP 2	2	0.01748
		27.81	exposed shoreline	NP TOWER	2	0.07192
		840.95	subsided cove	WB 3	1	0.00119
		522.18	subsided cove	WB 1	2	0.00383
		563.77	subsided cove	WB 2	8	0.01419
		803.39	unsubsided cove	NP 6A	2	0.00249
		857.10	unsubsided cove	NP 4	24	0.02800
		1,107.84	unsubsided cove	NP 23	33	0.02979
		543.13	unsubsided cove	NP 45	45	0.08285
25 Apr	124.84	840.95	subsided cove	WB 3	3	0.00357
		803.39	unsubsided cove	NP 6A	2	0.00249
		1,107.84	unsubsided cove	NP 23	4	0.00361
		543.13	unsubsided cove	NP 45	13	0.02394
		857.10	unsubsided cove	NP 4	14	0.01633

[a] see appendices A and B for locations; experimental units containing 0 dabbling ducks were excluded from this listing but were included in the analysis.

Appendix G. Total number of waterbird taxa and individuals observed during 16 weekly ground surveys conducted August-November 2000 at Ward Branch and Nason Point, Rend Lake, Illinois.

Date	Geese	Dabbling ducks	Diving ducks	Mergansers	Wading birds	Coots	Pelicans	Plovers	Avocets	Sandpipers	Grebes	Unidentified	Total
15 Aug	0	42	0	0	89	2	0	62	0	3	0	0	198
21 Aug	0	31	0	0	94	0	0	108	0	53	0	0	286
28 Aug	0	248	0	0	105	0	0	507	0	121	0	0	98
03 Sep	40	178	0	0	33	0	0	435	0	68	0	0	754
10 Sep	0	578	0	0	40	0	0	84	0	306	0	0	1,008
17 Sep	0	142	0	0	66	0	0	135	0	162	0	0	505
23 Sep	0	53	0	0	27	0	0	81	0	105	0	0	266
30 Sep	0	146	0	0	73	14	0	34	0	158	0	0	425
06 Oct	0	14	0	0	11	105	0	32	0	154	0	0	316
13 Oct	16	136	0	0	26	0	0	4	0	164	0	0	346
20 Oct	65	339	0	0	20	0	0	140	0	134	0	0	698
25 Oct	12	365	0	0	7	9	0	128	0	217	0	0	738
04 Nov	286	1,464	0	0	11	244	0	58	2	25	0	0	2,090
13 Nov	1,180	3,314	0	1	11	0	0	48	0	168	0	0	4,722
21 Nov	60	750	0	0	7	0	0	17	0	0	0	0	834
29 Nov	420	449	0	0	4	0	0	23	0	76	0	0	972
Total	2,079	8,249	0	1	624	374	0	1,896	2	1,914	0	0	15,139

Appendix H. Total number of waterbird taxa and individuals observed during 18 weekly ground surveys conducted July-October 2001 at Ward Branch and Nason Point, Rend Lake, Illinois.

Date	Geese	Dabbling ducks	Diving ducks	Mergansers	Wading birds	Coots	Pelicans	Plovers	Avocets	Sandpipers	Grebes	Unidentified	Total
03 Jul	0	4	0	0	27	0	0	176	0	22	0	0	229
10 Jul	0	27	0	0	45	0	0	205	0	178	0	0	455
17 Jul	0	60	0	0	74	0	0	80	0	49	0	0	263
24 Jul	2	65	0	0	44	0	0	61	0	65	0	0	237
31 Jul	2	77	0	0	65	0	0	144	0	187	0	0	475
08 Aug	100	122	0	0	52	0	0	263	0	523	0	0	1,060
14 Aug	15	97	0	0	61	0	0	443	0	1,270	0	0	1,886
20 Aug	0	84	0	0	30	0	0	76	0	542	0	0	732
26 Aug	0	37	0	0	99	0	0	41	1	932	0	0	1,110
02 Sep	0	80	0	0	27	0	1	37	0	139	1	0	285
09 Sep	0	471	0	0	51	0	0	28	0	134	0	0	684
16 Sep	0	15	0	0	34	0	0	69	0	38	0	0	156
22 Sep	6	183	0	0	76	0	0	68	0	144	0	0	477
29 Sep	0	43	0	0	25	0	0	44	0	18	0	0	130
06 Oct	121	318	0	0	17	0	0	9	0	4	0	0	469
12 Oct	507	510	0	0	18	56	4	29	0	155	0	0	1,279
19 Oct	188	275	0	0	4	213	0	2	0	84	0	0	766
26 Oct	1,420	726	0	0	3	178	38	7	0	115	0	0	2,487
Total	2,361	3,194	0	0	752	447	43	1,782	1	4,599	1	0	13,180

Appendix I. Number of shorebirds observed by species during 2000 and 2001 surveys at Nason Point and Ward Branch, Rend Lake, Illinois.

Species	Scientific Name	Nason Point		Ward Branch		Total
		2000	2001	2000	2001	
Spotted sandpiper	*Actitis macularia*	1	23	0	12	36
Ruddy turnstone	*Arenaria interpres*	0	0	1	1	2
Sanderling	*Calidris alba*	0	0	3	4	7
Dunlin	*Calidris alpina*	160	108	10	0	278
Baird's sandpiper	*Calidris bairdii*	0	2	1	3	6
White-rumped sandpiper	*Calidris fuscicollis*	0	4	1	0	5
Stilt sandpiper	*Calidris himantopus*	0	13	8	2	23
Western sandpiper	*Calidris mauri*	1	0	2	0	3
Pectoral sandpiper	*Calidris melanotos*	131	2,081	402	1,014	3,628
Least sandpiper	*Calidris minutilla*	320	336	225	256	1,137
Semipalmated sandpiper	*Calidris pusilla*	81	113	269	120	578
Piping plover	*Charadrius melodus*	0	0	1	0	1
Semipalmated plover	*Charadrius semipalmatus*	3	10	23	7	43
Killdeer	*Charadrius vociferus*	609	1,118	1,293	612	3,632
Common snipe	*Gallinago gallinago*	13	7	18	4	42
Dowitcher	*Limnodromus* (*sp.*)	7	14	38	32	91

Appendix I. Continued.

Species	Scientific Name	Nason Point		Ward Branch		Total
		2000	2001	2000	2001	
Lesser golden-plover	*Pluvialis dominica*	0	7	7	15	29
Black-bellied plover	*Pluvialis squatarola*	5	0	22	13	40
American avocet	*Recurvirostra americana*	0	0	2	1	3
Lesser yellowlegs	*Tringa flavipes*	22	146	55	91	314
Greater yellowlegs	*Tringa melanoleuca*	31	77	35	42	185
Solitary sandpiper	*Tringa solitaria*	0	1	1	0	2
Buff-breasted sandpiper	*Tryngites subruficollis*	0	0	7	1	8
Unknown (peep)	small *Calidris* (*sp.*)	4	13	0	79	96
Combined Total	all species	1,388	4,073	2,424	2,309	10,189

APPENDIX J

Pre- and post-subsidence prediction of habitat change for proposed Panel 2K, Nason Point (see attached paper copy and CD map files: Pre_subside2k.pdf and Post_subside2k.pdf).

Pre-subsidence topographic survey of proposed longwall Panel 2K, Nason Point, Rend Lake, Illinois. Survey completed 9 May 2002. (See attached CD - Map files: Rend.dwg - 2D , Rend1.dwg - 3D)

APPENDIX K

Pre- and post-subsidence assessment of Ward Branch study area (Owen 1992). (See attached CD - File: Owen92.pdf)

Appendix J. Pre- and post-subsidence prediction of habitat change for proposed Panel 2K, Nason Point[1].

Elevation (ft)	Pre-subsidence (ha)	Post-subsidence (ha)	Change (ha)
408 (± 2 ft)			
406.00-408.00	1.39	3.16	1.77
408.00-410.00	1.08	3.68	2.60
406-410			
406.00-406.25	0.23	0.30	0.07
406.25-406.50	0.17	0.18	0.01
406.50-406.75	0.15	0.17	0.02
406.75-407.00	0.15	0.19	0.04
407.00-407.25	0.14	0.19	0.05
407.25-407.50	0.15	0.23	0.08
407.50-407.75	0.18	0.37	0.19
407.75-408.00	0.24	1.52	1.28
408.00-408.25	0.16	1.53	1.37
408.25-408.50	0.12	0.30	0.18
408.50-408.75	0.11	0.27	0.16
408.75-409.00	0.10	0.26	0.16
409.00-409.25	0.11	0.26	0.15
409.25-409.50	0.12	0.26	0.14
409.50-409.75	0.14	0.28	0.14
409.75-410.00	0.22	0.53	0.31

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[1] From ArcView habitat model (maps attached)