Management and Conservation Article

Waterbird Response to Wetlands Restored Through the Conservation Reserve Enhancement Program

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ABSTRACT Conservation programs that facilitate restoration of natural areas on private land are one of the best strategies for recovery of valuable wetland acreage in critical ecoregions of the United States. Wetlands enrolled in the Conservation Reserve Enhancement Program (CREP) provide many ecological functions but may be particularly important as habitat for migrant and resident waterbirds; however, use of, and factors associated with use of, CREP wetlands as stopover and breeding sites have not been evaluated. We surveyed a random sample of CREP wetlands in the Illinois River watershed in 2004 and 2005 to quantify use of restored wetlands by spring migrating and breeding waterbirds. Waterbirds used 75% of wetlands during spring migration. Total use-day abundance for the entire spring migration ranged from 0 to 49,633 per wetland and averaged 6,437 ± 1,887 (SE). Semipermanent wetlands supported the greatest total number of use-days and the greatest number of use-days relative to wetland area. Species richness ranged from 0 to 42 ($\bar{x} = 10.0 \pm 1.5$ [SE]), and 5 of these species were classified as endangered in Illinois. Density of waterfowl breeding pairs ranged from 0.0 pairs/ha to 16.6 pairs/ha ($\bar{x} = 1.9 \pm 0.5$ [SE] pairs/ha), and 16 species of wetland birds were identified as local breeders. Density of waterfowl broods ranged from 0.0 broods/ha to 3.6 broods/ha and averaged 0.5 ± 0.1 (SE) broods/ha. We also modeled spring stopover use, waterbird species richness, and waterfowl reproduction in relation to spatial, physical, and floristic characteristics of CREP wetlands. The best approximating models to explain variation in all 3 dependent variables included only the covariate accounting for level of hydrologic management (i.e., none, passive, or active). Active management was associated with 858% greater use-days during spring than sites with only passive water management. Sites where hydrology was passively managed also averaged 402% greater species richness than sites where no hydrologic management was possible. Density of waterfowl broods was 120% greater on passively managed sites than on sites without water management but was 29% less on sites with active compared to passive hydrologic management. Densities of waterfowl broods also were greatest when ratios of open water to cover were 70:30. Models that accounted for vegetation quality and landscape variables ranked lower than models based solely on hydrologic management or vegetation cover in all candidate sets. Although placement and clustering of sites may be critical for maintaining populations of some wetland bird species, these factors appeared to be less important for attracting migrant waterbirds in our study area. In the context of restored CREP wetlands, we suggest the greatest gains in waterbird use and reproduction may be accomplished by emphasizing site-specific restoration efforts related to hydrology and floristic structure. (JOURNAL OF WILDLIFE MANAGEMENT 72(3):654–664; 2008)

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Although much of the original wetland area in the lower 48 states of the United States has been lost, progress has been made in recent decades to reduce additional loss and restore wetlands in watersheds throughout the Midwest. Conservation provisions of the 1985 Food Security Act (Public Law 99–198) and its amendments of 1990, 1996, and 2002 (i.e., the Farm Bill) have provided the impetus for much of this restoration, particularly on private lands (Gray and Teels 2006). For example, the Wetland Reserve Program (WRP), established under the Food, Agriculture, Conservation, and Trade Act of 1990, has led to the protection of >720,000 ha (Rewa 2005). The Conservation Reserve Enhancement Program (CREP) is another valuable tool for wetland conservation, focusing the enrollment of wetland acreage in regions of priority determined by each state. The United States Department of Agriculture introduced CREP in 1998, forming partnerships with state and nongovernmental organizations in an effort to address specific regional conservation priorities.

In many midwestern states, conservation priorities include protection and restoration of wetland habitat within environmentally and economically important watersheds (Allen 2005). Since the inception of CREP, >37,000 ha of land have been enrolled in wetland practices nationwide (Allen 2005). Examples of wetland-related conservation under CREP include efforts to protect and buffer the Chesapeake Bay in Pennsylvania and wetland restorations in the Minnesota River Basin of Minnesota, the Saginaw Bay Watershed of Michigan, and the Lake Erie ecosystem of Ohio. The Illinois River watershed is an especially noteworthy region that has benefited from CREP wetland restorations. The funding partnership between the Commodity Credit Corporation and the State of Illinois has facilitated enrollment of 14,000 ha in wetland practices ranging from discrete seeps to large marshes (State of Illinois 2004).

Wetlands restored through CREP have great potential to provide many ecological benefits but may be specifically valuable as habitat for millions of birds that migrate through the Midwest annually. Migration stopovers provide a vital link between wintering and breeding grounds by providing forage to enhance nutritional reserves essential for migration and reproduction (Farmer and Parent 1997). The Illinois River valley is one of the vital regions providing stopover habitat for substantial numbers of waterfowl, shorebirds, and wading birds in the Mississippi Flyway (Havera 1999). Indeed, availability of nonbreeding habitat is considered a critical factor limiting many wetland bird populations

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(Drent and Daan 1980, Reid et al. 1983). Illinois CREP wetlands have potential to contribute to conservation of wetland bird populations by providing stopover habitats during spring migration and suitable brood-rearing habitat for local production (Heitmeyer 1985). Additionally, these wetland sites may contribute to achieving regional conservation objectives for waterbirds, as detailed in the Upper Mississippi River and Great Lakes Region Joint Venture strategic implementation plan (Upper Mississippi River and Great Lakes Region Joint Venture Management Board 1998).

For CREP to contribute to regional goals it must first succeed at the local, farm level. Many local managers and landowners are motivated in their restoration efforts by tangible responses by wildlife. Previous studies have documented response of waterbirds to wetland restorations in general. However, few quantitative investigations have been conducted with the aim of providing local stewards with information to improve decision-making relevant to restoration and management of wetland habitats in the context of Farm Bill land conservation programs. Evaluation of the impact of restorations specifically carried out through CREP has been primarily limited to effects on hydrology and flora (O'Neal 2003, Richards and Grabow 2003, Wanhong et al. 2005, O'Neal and Heske 2007).

Restored wetlands in agricultural settings are used extensively by both migrant and resident waterbirds (LaGrange and Dinsmore 1989). However, variation in abundance and species richness of breeding and migrant birds at restored wetlands varies substantially with respect to characteristics such as wetland area (Brown and Dinsmore 1986, Hemesath and Dinsmore 1993), water regime (Harris 2001), vegetation (Ruwaldt et al. 1979), and surrounding land use (Wilson and Mitsch 1996, Naugle et al. 2000, Fairbairn and Dinsmore 2001). Substantial variation exists among CREP wetlands for all of these habitat characteristics and their individual and combined effects on use by waterbird are not well known (O'Neal 2003).

We are unaware of previous research evaluating responses of wildlife to restored CREP wetlands. To address this research need, we monitored CREP wetlands in the Illinois River watershed for 2 years to estimate use as stopover habitat by migrating waterbirds and reproduction by waterfowl. We developed generalized linear mixed models to evaluate relationships between avian use, richness, and reproduction and habitat characteristics and to parameterize relationships between restoration practices and use of wetlands by waterbirds and waterfowl. Finally, we endeavored to estimate and interpret key model parameters to guide resource professionals and stakeholders in making decisions about planning, restoration, and maintenance of these wetlands with respect to improving habitat for migrating and breeding waterbirds.

STUDY AREA

Brown and Phillips (2004) used a random number generator to select 100 CREP contracts from 657 contracts included in the Illinois Department of Natural Resources' Conservation Practices Tracking System in 2003. Each contract represented an individual enrollment in CREP and described the legal and financial agreement between the United States Department of Agriculture and landowner. These contracts also described the conservation practice (CP) applied to the particular tract, which included physical geographic boundaries but may not have coincided with natural boundaries. Wetland habitat suitable for waterbirds can develop as a product of any CP, such as planting of grass cover (CP 1 and 2) and hardwoods (CP 3) and establishment of filter strips and buffers (CP 13, 21, 22, 30). However, explicit wetland practices (CP 9, 23, and 31) are the typical avenues for intentional restoration of wetland habitat. Of these, CP 9 and 31 intend to provide shallow water areas for wildlife and bottomland hardwoods, respectively. Of the 3, CP 23 is the most common, and encompasses general practices of wetland restoration, targeting emergent marshes and wet meadows (Allen 2005).

The database sampled included contracts from Sangamon, Christian, Schuyler, Fulton, and Knox counties in central Illinois. In 2004, we revisited the sample of 100 wetland and riparian contracts from the Brown and Phillips (2004) study to determine the number of discrete CP 23 wetlands within their 100 contracts. We identified 28 wetland restoration sites that constituted independent and entire CP 23 wetlands. This sample was small relative to the total number of sites in the watershed, but we believed they were representative of all the sites in our area of inference. Sites were dispersed throughout the watersheds of the Illinois, LaMoine, Spoon, and Sangamon rivers (Fig. 1) and fell within the Western Forest-Prairie, Illinois River Bottomlands, and Grand Prairie natural divisions (Schwegman 1973).

METHODS

All wetland sites were classified as palustrine habitats following Cowardin et al. (1979) and ranged in age from 3 years to 6 years, with histories of either row crop production or pasturing prior to restoration. Using National Agriculture Imagery Program color-infrared digital orthoimagery (U.S. Department of Agriculture 2005), we delineated wetland boundaries based on hydrologic indicators and presence of hydrophytic vegetation (Reed 1988).

We classified these 28 selected wetlands as emergent, scrub-shrub, or forested wetland habitats as defined by Cowardin et al. (1979). Emergent wetlands were characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. Scrub-shrub wetlands included areas dominated by woody vegetation <6 m in height. Forested wetlands were characterized by woody vegetation ≥ 6 m tall (Cowardin et al. 1979).

We surveyed the flora of these wetlands using standard transect sampling techniques. We used a plant-species list from each site to estimate the average coefficient of conservatism (Mean C) for each wetland. A coefficient of conservatism is an integer, ranging from 0 to 10, assigned a

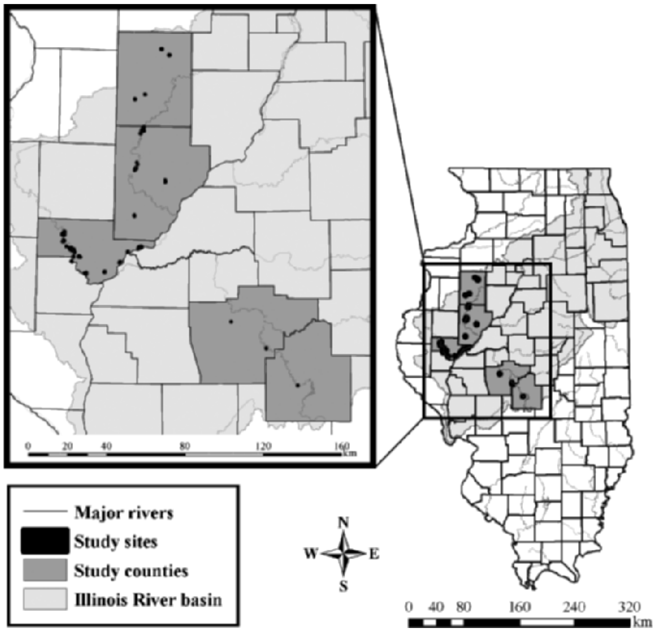

Figure 1. Conservation Reserve Enhancement Program wetland study sites, 2004–2005, Illinois River Basin, Illinois, USA. Black areas are enlarged for visibility and do not represent size of tracts.

priori to each taxon in a regional flora that represents the fidelity of a species to natural areas (Swink and Wilhelm 1979, 1994; Taft et al. 1997). Species with very low tolerances to disturbance and high fidelity to habitat integrity are assigned coefficients near 10, whereas non-native and ruderal species that tolerate almost any disturbance and may be found in almost any type of habitat are assigned zero or low values (Taft et al. 1997). Weighted indices, such as the Floristic Quality Index (FQI) and its component, Mean C, have been deemed reliable indicators of the integrity of wetland plant communities (Swink and Wilhelm 1979, 1994; Taft et al. 1997; Lopez and Fennessy 2002). We also surveyed each wetland in 2004 and 2005 to visually estimate areal coverage of hydrophytic vegetation (O'Neal and Heske 2007).

We visited sites weekly during the 2004 and 2005 growing seasons to monitor fluctuations in hydrology and determine duration of inundation as an indicator of wetland status and hydrology modifier class (Cowardin et al. 1979, Natural Resources Conservation Service 1997). We considered semipermanent wetlands as those having surface water throughout the growing season. We defined seasonal wetlands as those having surface water for extended periods in the growing season but not at the end of the growing season, and temporary wetlands as those with surface water for only brief periods during the growing season (Cowardin et al. 1979).

We also evaluated degree of hydrologic management present in each wetland. We assigned a score of 0 to passively restored and managed sites with no initial or ongoing physical manipulation of the hydrology; a score of 1 if it was actively restored through hydrologic engineering at the time of construction (i.e., excavated basin, a dozier valve, stoplog, berm, or levee) but passively managed; or a score of 2 if it was actively restored and managed. We used National Wetlands Inventory data in ArcGIS 9.0 to estimate the degree of wetland isolation (U.S. Fish and Wildlife Service 1996) by quantifying the proportion of the area within a 3-km buffer around each study wetland occupied by aquatic habitat.

Estimation of Bird Use

We conducted complete coverage counts of waterbirds weekly during springs 2004 and 2005. We defined waterbirds as any species of waterfowl, shorebird, wading bird, marsh bird, gull, tern, pelican, crane, or cormorant. We monitored migrant species beginning 1 March through the end of May and counted resident species until the first observation of territorial pair behavior. Observation points were located to enable unrestricted, discrete observations of the entire wetland, and the number of points varied with wetland size from 1 to 6 (Hemesath and Dinsmore 1993). We surveyed sites beginning at sunrise and varied the order of visits among weeks to distribute potential intraday temporal variation among sampled wetlands. We did not conduct counts during inclement weather (Dzubin 1969). We characterized stopover use by migratory species as use-days, which we calculated by multiplying mean number of individuals of a species observed on 2 consecutive censuses by number of days between those counts (Rundle and Fredrickson 1981).

Secretive species are often undersampled by standard visual censuses, so we also conducted 3 call–response surveys of secretive marsh birds in 2005 according to the Standardized North American Marshbird Monitoring Protocol (Conway 2003). We spaced fixed, permanent survey points every 400 m along marsh–upland interfaces. We used a portable compact disc player and amplified speakers to broadcast recorded vocalizations at 80 decibels. These surveys took place during the presumed peak breeding season for primary marsh birds in the area, which included least bittern (*Ixobrychus exilis*), sora (*Porzana carolina*), Virginia rail (*Rallus limicola*), king rail (*R. elegans*), American bittern (*Botaurus lentiginosus*), and pied-billed grebe (*Podilymbus podiceps*). We conducted each survey within 3-hour periods after sunrise and before sunset corresponding with the most vocal periods for the birds. We surveyed all wetlands within 10 days and waited 7 days between surveys. At each survey point we recorded all marsh bird species detected during a 5-minute passive period prior to broadcasting recorded calls and during a period in which we broadcast prerecorded vocalizations. The calling series included 30 seconds of calls followed by 30 seconds of silence for each species. We ordered calls from the least to most intrusive species (*I. exilis*, *P. carolina*, *R. limicola*, *R. elegans*, *B. lentiginosus*, *P. podiceps*). Because marsh birds tend to approach call-broadcasts, we estimated distance from each individual bird to the survey point to avoid double counting (Erwin et al. 2002). We did not conduct surveys during rain, fog, or high wind. Because we desired a complete list of species using each wetland, we combined all surveys to create a cumulative estimate of species richness.

Breeding pairs of dabbling ducks localize activities to one or 2 wetlands; thus we counted breeding pairs on each wetland repeatedly, from pair bonding until incubation, for use as an index of local reproduction (Eng 1986). Additionally, we conducted brood surveys to provide an estimate of an area's capability to support waterfowl production (Gillespie and Wetmore 1974). We conducted weekly counts of breeding pairs and broods at each wetland, lasting 10 minutes each, during 2.5-hour periods after sunrise and before sunset, coinciding with the time when pairs and broods are most active (Ringelman and Flake 1980). We timed breeding pair counts to include prenesting, laying, and early incubation stages of the species of interest and extended counts for 4 weeks to include early- and late-nesting ducks. Because sex ratios were not available to develop a correction factor for unpaired males, we calculated number of breeding pairs according to Dzubin (1969), which included lone males as pairs. By recording age-class and size of brood, we were able to reliably estimate total number of unique broods reared in each wetland (Gollop and Marshall 1954). We analyzed broods and breeding pairs relative to wetland area to assess intensity of use during this period and perhaps attractiveness of wetlands to breeding females (Stacier et al. 1994).

Analytical Approach

We used an information-theoretic approach to investigate factors associated with 1) waterbird use-days (UD), 2) species richness (SPECIES), and 3) waterfowl brood density (BROODS; Burnham and Anderson 1998). Specifically, we used combinations of the following hydrologic, physical, floristic, and faunal characteristics (i.e., covariates) to compile biologically justifiable candidate sets of models a priori intended to explain variation in the dependent variables.

1. Hydrologic management (HYDRO). Water depth and area are strong determinants of the distribution of migrant wetland birds across the landscape (Fredrickson and Reid 1986, Weller and Weller 2000). Hydrologic management at CREP sites in our study ranged from those that were simply retired from production to those that included engineered water control (e.g., excavation or control structures). We categorized wetlands as passively restored and managed (0), actively restored but passively managed (1), or actively restored and managed (2) and included this variable in some candidate models.

2. Distance to Illinois River (DIST). Waterbirds are believed to migrate in explicit geographic corridors that often follow major rivers (Bellrose 1980) and waterfowl species richness in restored wetlands may correlate positively with proximity to a river (Stevens et al. 2003). Therefore, we included distance (km) of wetlands from the Illinois River in some models of migratory use and species richness of waterbirds.

3. Wetland isolation (ISOL). The amount of aquatic habitat near wetlands may influence composition and distribution of waterbirds, including breeding waterfowl and waterfowl broods (Kantrud and Stewart 1977, Brown and Dinsmore 1986, Rotella and Ratti 1992, Fairbairn and Dinsmore 2001). Thus, we included proportion of aquatic habitat within 3 km of individual wetlands in some models of migratory use-days, richness of waterbirds, and density of waterfowl broods.

4. Vegetation cover (VEGCOV). Vegetation of a wetland influences distribution of most wetland bird guilds (Weller and Fredrickson 1973, Fredrickson and Reid 1986), and wetlands with interspersed emergent vegetation (i.e., 50:50 cover:water; Weller and Fredrickson 1974, Kaminski and Prince 1981) may provide quality foraging habitat and escape cover for waterfowl broods (Mack and Flake 1980, Ringelman et al. 1982). Therefore, we assigned wetlands a value of 0–5 based on proximity to the assumed ideal 50% areal coverage (e.g., wetlands with 0% or 100% cover scored 0; 30% or 70% cover scored 3; 50% cover scored 5) and included this categorical variable in some models.

5. Mean C (MEANC). The Modified FQI provides an index of habitat degradation based on plant quality (Rooney and Rogers 2002, Matthews et al. 2005). Further, presence of highly conserved plant species may reflect nondegraded wetland conditions (Swink and Wilhelm 1994, VanRees-Siewart and Dinsmore 1996, Taft et al. 1997). Therefore, we included this index of floristic quality in some models of migratory use-days, species richness of waterbirds, and density of waterfowl broods.

6. Nesting Cover (NESTCOV). Upland nesting ducks settle in wetlands based largely on characteristics of surrounding nesting cover (Clark et al. 1991), and larger upland areas may reduce predation and increase nest success (Naugle et al. 2000, Reynolds et al. 2001, Horn et al. 2005, Stephens et al. 2005). Thus, we included abundance of upland cover within 300 m of the wetland edge in models of density of waterfowl broods.

7. Breeding pair density (BP). Brood surveys provide an estimate of a wetland's reproductive output by waterbirds but typically require intense field work, whereas counting the number of breeding pairs on wetlands may be a more efficient technique to estimate reproductive potential for waterbirds (Eng 1986). Therefore, we included breeding pair density as a covariate in some models of brood density to evaluate if breeding pair counts were a practical alternative to brood surveys.

Selection of Candidate Model Sets

Candidate models of UD included all individual habitat variables: hydrologic management (HYDRO), distance to main stem (DIST), wetland isolation (ISOL), floristic quality (MEANC), and areal vegetation cover (VEGCOV). We also included a model based solely on spatial variables (DIST+ISOL), a rapid assessment model (HYDRO-VEGCOV), a floristic model (MEANC+VEGCOV), and a global model. The spatial model evaluated the contribution of location of the wetland and assessed whether selection of location for a CREP restoration site was important relative to quality of the wetland at the site level.

Table 1. Number, percentage of total area of surveyed conservation practice 23 Conservation Reserve Enhancement Program wetlands, and percentage of total, average per hectare, and standard error of estimated waterbirds use days (Use-days) and observed waterfowl broods (Broods), by water regime (Cowardin et al. 1979), in the Illinois River Valley, Illinois, USA, during springs 2004 and 2005.

			Use-days			Broods		
Water regime	***n***	**% area**	**%**	**$\bar{x}$/ha**	**SE**	**%**	**$\bar{x}$/ha**	**SE**
Semipermanent	6	76	56	1,500	369	65	1.1	0.4
Seasonal	16	17	37	373	151	35	0.2	0.2
Temporary	6	7	7	183	167	0	0.0	0.0

The rapid assessment model evaluated predictive power of relatively easy-to-quantify variables that could be estimated during one site visit. The floristic model evaluated the contribution of vegetation at the site, as an index of habitat quality, independent of spatial influences on the site.

Competing models for SPECIES included all the aforementioned individual habitat variables. We also included a model based solely on spatial variables (DIST+ISOL), a rapid assessment model (HYDRO+VEGCOV), a floristic model (MEANC+VEGCOV), and a global model.

Competing models for BROODS included all the aforementioned individual variables as well as nesting cover (NESTCOV) and waterfowl breeding pair density (BP). We also included a rapid assessment model (HYDRO+VEGCOV), an on-site evaluation model (HYDRO+VEGCOV+BP), a floristic model (MEANC+VEGCOV+COV+NESTCOV), and a global model.

Statistical Analyses

We modeled waterbird use-days, species richness, and waterfowl brood density using generalized linear mixed models in the GLIMMIX procedure, SAS v9.1 (SAS Institute 2004). We included study YEAR as a random effect in models to account for possible correlation of observations within sites and among years, and we specified a first-order autoregressive covariance structure (AR1). We also included wetland area as a random effect in models of UD and SPECIES to account for wetland size-specific effects. We fit models with a Poisson distribution and log-link function because count data are commonly Poisson distributed (Zar 1999). We evaluated our candidate sets of models via second-order pseudo Akaike's Information Criterion (pAIC_c) to determine best approximating and competing models (Burnham and Anderson 1998). We considered models competitive within candidate sets if they were within approximately 2 pAIC_c units of the best approximating model (Burnham and Anderson 1998). We examined parameter estimates and their confidence intervals for best and competing models to evaluate effect size of covariates. We interpreted importance of covariates by calculating 95% confidence intervals about parameter estimates or odds ratios (i.e., computed from back-transformed parameter estimates).

RESULTS

Of the 28 wetlands we delineated, 25 were <5 ha in size, and 17 of those 25 were <1 ha. Dominant wetland cover was emergent vegetation (91%), followed by forested (9%) and scrub-shrub (<0.1%) habitats. Plant species richness ranged from 11 to 41 ($\bar{x} = 26 \pm 1$ species [SE]) and Mean C ranged from 3.5 to 4.8 ($\bar{x} = 4.1 \pm 0.1$ [SE]). Areal coverage of hydrophytic vegetation within functional wetlands ranged from 0% to 100% and averaged 46 ± 6% (SE).

We identified 6 wetlands as semipermanent (76% of area), 16 as seasonal (17% of area), and 6 as temporary (7% of area). In terms of hydrologic management, 3 were actively restored and actively managed to manipulate water depths throughout the year by opening and closing water structures according to season and river stage. Twelve were actively restored but passively managed; thus, 15 of 28 functional wetlands had some type of hydrologic management. The remaining 13 wetlands lacked any hydrologic engineering or construction and were passively restored and passively managed, with water levels determined by rainfall and river flooding (O'Neal and Heske 2007). Amount of aquatic habitat within the 3-km buffers around each wetland ranged from 27 ha to 1,719 ha ($\bar{x} = 328 \pm 83$ ha [SE]; O'Neal and Heske 2007).

Waterbirds used 75% of wetlands during spring migration. Weekly abundance of all migratory waterbirds ranged from 0 to 4,585 per wetland. Total use-days for the entire spring migration ranged from 0 to 49,633 per wetland, ($\bar{x} = 6{,}437 \pm 1{,}887$ use-days/wetland [SE]).

Semipermanent wetlands supported the greatest total use-days as well as the greatest number of use-days relative to wetland area ($\bar{x} = 1{,}500 \pm 369$ use-days/ha [SE]; Table 1). Seasonal wetlands supported substantial use by migrant waterbirds, but use was low relative to wetland area ($\bar{x} = 373 \pm 151$ use-days/ha [SE]; Table 1). Temporary wetlands supported the fewest migrant use-days per unit area ($\bar{x} = 183 \pm 167$ use-days/ha [SE]; Table 1), but comprised a small percent of the total area of wetland in the sample.

Species richness ranged from 0 to 42 ($\bar{x} = 10.0 \pm 1.5$ species [SE]). Many of our sampled CREP wetlands (57%) were used as stopover habitat by migrant shorebirds and we recorded 16 species during our study (Table 2). Sixty-one percent of sites were used by ≥1 species of wading bird, with 4 species detected during the study (Table 2). Of the wetland-bird species we observed, 5 were classified as endangered in Illinois and one was considered threatened (Table 2). We recorded 3 species of waterfowl on CREP wetlands that were considered federal species of concern (Table 2; U.S. Fish and Wildlife Service 2004). Dabbling ducks were the most abundant guild of waterbird (69% of

Table 2. Species occurrence among 19 conservation practice 23 Conservation Reserve Enhancement Program wetlands with >1 species during 2005, ranked by species prevalence among sites and sites according to species richness.

Common name	Species	Sites																			Total
Mallard[a]	*Anas platyrhynchos*	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		18
Blue-winged teal[a]	*Anas discors*	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x		17
Greatblue heron[a]	*Ardea herodias*	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		17
Canada goose[a]	*Branta canadensis*	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x			16
Wood duck[a]	*Aix sponsa*	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x		16
Killdeer[a]	*Charadrius vociferus*	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x				16
Lesser yellowlegs	*Tringa flavipes*	x	x	x	x	x	x	x	x	x	x	x		x	x						13
Greater yellowlegs	*Tringa melanoleuca*	x	x	x	x	x	x	x	x	x	x			x						x	12
Wilson's snipe	*Gallinago delicata*	x			x				x	x	x	x		x	x		x			x	11
Northern pintail[b]	*Anas acuta*	x	x	x	x	x	x	x		x			x								9
Semipalmated sandpiper	*Calidris pusilla*		x	x	x	x	x					x	x		x		x				9
Green-winged teal	*Anas crecca*	x	x	x	x	x		x		x	x										8
Northern shoveler	*Anas clypeata*	x	x	x	x	x	x		x				x								8
Solitary sandpiper	*Tringa solitaria*	x	x	x	x		x	x	x	x											8
Least sandpiper	*Calidris minutilla*	x	x	x	x	x	x						x				x				8
Hooded merganser[a]	*Lophodytes cucullatus*	x	x	x					x		x			x				x			7
Spotted sandpiper[a]	*Actitis macularius*	x	x		x	x	x					x			x						7
American wigeon	*Anas americana*	x	x	x	x			x								x					6
Sora[a]	*Porzana carolina*	x			x			x					x			x					6
Ring-necked duck	*Aythya collaris*	x	x	x		x										x					5
Pied-billed grebe[a]	*Podilymbus podiceps*	x	x	x	x	x															5
Great egret [a]	*Ardea alba*	x	x	x		x		x													5
Gadwall	*Anas strepera*	x	x	x				x													4
American coot	*Fulica americana*	x	x		x											x					4
Semipalmated plover	*Charadrius semipalmatus*	x	x	x			x														4
Long-billed dowitcher	*Limnodromus scolopaceus*	x	x		x		x														4
Ring-billed gull	*Larus delawarensis*		x		x	x		x													4
Greater white-fronted goose	*Anser albifrons*	x				x		x													3
Lesser scaup[b]	*Aythya affinis*	x	x	x																	3
Pectoral sandpiper	*Calidris melanotos*	x		x	x																3
Black-crowned night heron[ac]	*Nycticorax nycticorax*	x		x		x															3
American white pelican	*Pelecanus erythrorhynchos*	x	x	x																	3
Redhead	*Aythya americana*	x	x																		2
Common goldeneye	*Bucephala clangula*	x	x																		2
Ruddy duck	*Oxyura jamaicensis*	x	x																		2
Common merganser	*Mergus merganser*	x	x																		2
Willet	*Catoptrophorus semipalmatus*		x	x																	2
Dunlin	*Calidris alpina*		x		x																2
Sandhill crane[d]	*Grus canadensis*		x		x																2
Green heron[a]	*Butorides virescens*			x		x															2
Lesser snow goose	*Chen caerulescens*	x																			1
Americanblack duck[c]	*Anas rubripes*		x																		1
Canvasback	*Aythya valisineria*	x																			1
Bufflehead	*Bucephala albeola*	x																			1
King rail[ac]	*Rallus elegans*	x																			1
Virginia rail[a]	*Rallus limicola*		x																		1
Ruddy turnstone	*Arenaria interpres*	x																			1
Short-billed dowitcher	*Limnodromus griseus*	x																			1
Black-necked stilt	*Himantopus mexicanus*						x														1
Black tern[c]	*Chlidonias niger*		x																		1
Common tern[c]	*Sterna hirundo*	x																			1
Littleblue heron[c]	*Egretta caerulea*																	x			1
Double-crested cormorant[a]	*Phalacrocorax auritus*	x																			1
	Total	42	37	27	25	21	17	17	12	11	11	10	9	9	9	9	8	7	4	2	

[a] Local breeder.
[b] Species of concern.
[c] IL endangered species (Illinois Endangered Species Protection Board 2004).
[d] IL threatened species.

individuals recorded), followed by diving ducks (9%), shorebirds (5%), rails and coots (5%), and geese (5%)

Density of waterfowl breeding pairs ranged from 0.0 pairs/ha to 16.6 pairs/ha and averaged 1.9 ± 0.5 pairs/ha (SE). Additionally, we documented 16 species of wetland birds that we considered local breeders (Table 2). Density of waterfowl broods ranged from 0.0 broods/ha to 3.6 broods/ha ($\bar{x}$ = 0.5 ± 0.1 broods/ha [SE]), most of which were wood ducks (*Aix sponsa*; 39%), Canada geese (*Branta canadensis*; 32%), and mallards (*Anas platyrhynchos*; 22%).

Table 3. Candidate models explaining variation in waterbird use-days on Illinois, USA, Conservation Reserve Enhancement Program wetlands, 2004–2005, ranked by second-order pseudo Akaike's Information Criterion (pAIC$_c$). Also included are the number of estimable parameters (K), model weight (w_i), and proportion of variance accounted for (R^2).

Model[a]	K	pAIC$_c$	ΔpAIC$_c$	w_i	R^2
HYDRO	6	140.8	0.0	0.999	0.74
MEANC	4	154.3	13.5	0.001	0.26
HYDRO+VEGCOV	11	163.1	22.4	0.000	0.47
DIST	4	163.1	22.4	0.000	0.26
ISOL	4	191.8	51.1	0.000	0.13
DIST+ISOL	5	203.8	63.1	0.000	0.13
HYDRO+VEGCOV+DIST+ISOL+MEANC	14	206.4	65.6	0.000	0.40
VEGCOV	8	272.9	132.1	0.000	0.30
MEANC+VEGCOV	9	277.3	136.5	0.000	0.30

[a] HYDRO = hydrologic management; MEANC = mean coefficient of conservatism; VEGCOV = vegetation cover; DIST = distance to main river stem; ISOL = wetland isolation.

We observed ≥1 Anatid brood on 67% of wetlands in 2004, but only 29% had >1 brood in 2005.

We documented most waterfowl broods on semipermanent wetlands (65%). Seasonal wetlands comprised only 17% of total wetland area surveyed; however, they supported 79% of waterfowl breeding pairs and 35% of waterfowl broods (Table 1). We observed no broods at sites with temporary water regimes.

The best approximating model of migrant waterbird use-days included only HYDRO (Akaike wt [w_i] = 0.999; Table 3) and indicated actively restored, passively managed wetlands averaged 124% more migratory use-days than entirely passive wetlands (95% CI: 54–225%). Correspondingly, the model predicted 858% more migratory use-days for sites with active restoration and management compared with sites that had active restorations but passive management strategies (95% CI: 483–1,477%), and 2,043% more migratory use-days than passively restored and managed wetlands (95% CI: 797–5,020%). No other covariates (VEGCOV, MEANC, DIST, or ISOL), either alone or in combination with other variables, appeared in competing models of migratory use-days.

Of 10 candidate models formulated to explain variation in species richness, the hydrology model was the best approximating model (w_i = 0.982; Table 4). Based on this model, actively restored, passively managed wetlands had, on average, 402% greater richness than those with passive restoration and management (95% CI: 271–580%). Wetlands with active restorations and active management averaged 146% greater species richness than actively restored sites with passive management (95% CI: 119–175%) and 1,136% greater richness than sites with entirely passive hydrologic management (95% CI: 716–1,771%). Although other models in the candidate set were not competitive based on information-criteria, it is noteworthy that the second best model, containing only the main effect of VEGCOV (ΔpAIC$_c$ = 8.6), explained 61% of variation in the dependent variable (Table 4).

The best of 10 candidate models to explain variation in brood density again included only the main effect of HYDRO (w_i = 0.704; Table 5), which predicted 120% more broods per hectare at actively restored passively managed sites compared to projects with no hydrologic management (95% CI: 105–135%). However, parameter estimates indicated only 55% more broods per hectare, on average, at actively managed and restored sites than at sites with no management at all (95% CI: 38–74%) and 29% fewer than on wetlands with passive management following active restoration (95% CI: −33 to −26%).

The model of BROODS that included the main effect of VEGCOV was 1.9 pAIC$_c$ units from the best model, captured 27.8% of model weight, and explained more variation in the dependent variable (R^2 = 0.34; Table 5). Parameterizing this model indicated that average broods per

Table 4. Candidate models formulated to explain variation in species richness on Illinois, USA, Conservation Reserve Enhancement Program wetlands, 2004–2005, ranked by second-order pseudo Akaike's Information Criterion (pAIC$_c$). Also included are the number of estimable parameters (K), model weight (w_i), and proportion of variance accounted for (R^2).

Model[a]	K	pAIC$_c$	ΔpAIC$_c$	w_i	R^2
HYDRO	6	99.84	0.0	0.982	0.61
VEGCOV	8	108.47	8.63	0.013	0.61
MEANC+VEGCOV	9	112.64	12.80	0.002	0.61
MEANC	4	112.71	12.87	0.002	0.38
HYDRO+VEGCOV	11	113.41	13.57	0.001	0.63
ISOL	4	114.57	14.73	0.001	0.33
DIST	4	120.65	20.81	0.000	0.36
DIST+ISOL	5	125.24	25.40	0.000	0.33
HYDRO+VEGCOV+DIST+ISOL+MEANC	14	145.91	46.07	0.000	0.60

[a] HYDRO = hydrologic management; VEGCOV = vegetation cover; MEANC = mean coefficient of conservatism; ISOL = wetland isolation; DIST = distance to main river stem.

Table 5. Candidate models formulated to explain variation in waterfowl brood density on Illinois, USA, Conservation Reserve Enhancement Program wetlands, 2004–2005, ranked by second-order pseudo Akaike's Information Criterion (pAIC$_c$). Also included are the number of estimable parameters (K), model weight (w_i), and proportion of variance accounted for (R^2).

Model[a]	K	pAIC$_c$	ΔpAIC$_c$	w_i	R^2
HYDRO	6	88.14	0.0	0.704	0.24
VEGCOV	8	90.00	1.9	0.278	0.34
BP	4	96.86	8.7	0.009	0.16
HYDRO+VEGCOV	11	97.46	9.3	0.007	0.36
HYDRO+VEGCOV+BP	12	100.27	12.1	0.002	0.41
MEANC	4	104.17	16.0	0.000	<0.01
ISOL	4	106.70	18.6	0.000	0.04
MEANC+VEGCOV+NESTCOV	10	107.27	19.1	0.000	0.33
NESTCOV	4	112.83	24.7	0.000	<0.01
HYDRO+ISOL+MEANC+VEGCOV+NESTCOV+BP	15	135.03	46.9	0.000	0.42

[a] HYDRO = hydrologic management; VEGCOV = vegetation cover; BP = breeding pair density; MEANC = mean coeff. of conservatism; ISOL = wetland isolation; NESTCOV = upland nesting cover.

hectare increased 7% (95% CI: 6–8%), 14% (95% CI: 9–20%), and 117% (95% CI: 98–138%) for each unit increase in VEGCOV score from 0 to 3. However, the model predicted decreases in brood density of 3% (95% CI: –8% to –1%) and 28% (95% CI: –34% to –20%) as VEGCOV score increased from 3 to 4 and from 4 to 5, respectively. No other covariates (BP, MEANC, NESTCOV, or ISOL), either alone or in combination with other variables, appeared in competing models of BROODS.

DISCUSSION

Wetlands restored through CREP generally were used by waterbirds during spring migration, nesting, and brood rearing; thus, CREP clearly provided additional habitat for wildlife. However, use by waterbirds varied considerably among CREP sites. Of the many spatial, physical, and floristic habitat parameters that may have been associated with use, site-level characteristics related to hydrology and vegetation cover were the best predictors of use by migrants, species richness, and waterfowl brood density. It is obvious that wetland restorations must contain water to attract and support waterbirds. However, when considering investments in CREP that most benefit waterbirds, our results indicated active restoration through initial engineering intended to establish and sustain a functional hydrology outweighed other factors, such as location and landscape context of restoration sites.

In our study, CP23 CREP sites with intentionally designed water regimes were considerably more likely to result in quality habitat for waterbirds throughout seasonal fluctuations in precipitation and river stage than were sites that lacked any hydrologic engineering or management. Although restored wetlands often benefit from hydrologic regimes that mimic natural systems, which typically include dry periods, they must be capable of retaining water during natural wet periods to allow wetland flora and fauna to colonize naturally (Keddy 2000). Our results indicate response by waterbirds to investment in hydrologic infrastructure, particularly during migration, may be substantial. A similar study of restored WRP sites in Indiana reported that wetlands with hydrologic engineering, in the form of excavated basins, were used more by migratory shorebirds and waterfowl than were areas without (Ehrenberger 2003).

Although migrant use-days on actively restored sites were greater when hydrologic management was active rather than passive, the effect of hydrologic management on species richness was not as pronounced. Kaminski et al. (2006) reported 1.4–2.3 times more taxa on actively restored and managed WRP wetlands in New York than on actively restored but passively managed wetlands. However, Kaminski et al. (2006) did not include passively restored (and, therefore, passively managed) sites in the sample of wetlands. By investigating 2 classes of restoration intensity and 3 classes of hydrologic management intensity, we were able to identify that greatest species richness on our study wetlands was associated with intensity of restoration, rather than management, activities.

The increase in intensity from passive to active management also had a limited effect on waterfowl brood density compared to the increase from passive to active restoration. The lower densities of waterfowl broods we observed on actively managed compared to passively managed sites was likely due to the greater extent of standing water that limited germination of wetland vegetation and associated cover and invertebrates that young waterfowl require. Our finding of lower brood densities on actively managed sites is consistent with another study of restored wetlands in Illinois that indicated increases in avian use resulting from investment in active water management did not outweigh the associated cost (A. K. McLeese, Southern Illinois University, Carbondale, unpublished data). Similar to species richness, the greatest increase in waterfowl brood density resulted from the increase from passive to active restoration.

Use by waterbirds relative to wetland area was clearly greatest for semipermanent wetlands. We suspect this relationship existed because semipermanent wetlands in our study were shallow enough to support productive wetland vegetation but were also engineered such that water levels were stable enough to promote conditions selected by many waterbird species for foraging and brood rearing (Weller 1999). Few wetlands with passive restoration and management strategies experienced both seasonal draw downs (e.g., to expose foraging substrate and promote moist-soil plant growth) and standing water needed to sustain submerged or robust hydrophytes. We found that passively restored, temporary wetlands were characterized by unpredictable water regimes that provided sparse habitat for waterbirds during either portion of the annual cycle.

Vegetation cover of wetlands was the second best predictor of waterfowl brood density. The effect of different categories of cover on brood density was only partially consistent with our hypothesis that brood density would increase as cover-water ratios approached 50:50, likely through mechanisms involving provision of escape and thermal cover and quality foraging sites (Weller 1978, Kaminski and Prince 1981, Murkin et al. 1982, Smith et al. 2004). Brood density was indeed least in wetlands with very high or low amounts of cover. However, instead of observing greater densities of broods as VEGCOV scores approached 5 (50% coverage), we observed a decrease in densities after our intermediate values. Sites with VEGCOV scores of 3 and 4 were most often covered by 30% and 40% wetland vegetation and less often by 70% and 60%. Thus, we suggest the relationship between increasing brood densities and VEGCOV index was likely due to suitability of wetlands as cover:water ratios increased to 50:50. In many situations increased vegetation would increase use by birds, but restored wetlands in our sample were often dominated by lower quality plants, possibly due to intense disturbance prior to restoration. Therefore, the increase in vegetation cover may actually have decreased the amount of suitable brood-rearing habitat in a given wetland and resulted in the observed decrease in brood density as VEGCOV increased from 3 to 4 and from 4 to 5. Regardless, we suggest management efforts for CREP wetlands endeavor to control hydrology to promote interspersed wetland vegetation and avoid extensive open water (e.g., lake-marsh; van der Valk and Davis 1976) or dense monotypic stands.

Models including the covariate accounting for vegetation quality (MEANC) ranked lower than models based solely on hydrology or vegetation cover. Although Mean C may be a valuable indicator of other biological parameters, it appeared to be a poor predictor of waterbird habitat quality in our study. Similarly, amount of adjacent upland nesting cover (NESTCOV) did not apparently influence waterfowl brood density at our sites, but all sites we surveyed contained considerable areas of upland (O'Neal and Heske 2007); thus, nesting habitat may not have been a limiting factor, or nesting cover at our sites did not vary sufficiently to detect trends if they were present. Although the model ranked poorly, number of waterfowl breeding pairs was associated with brood density, as predicted. Thus, we suggest counts of breeding pairs may serve as an index of reproduction by waterbirds when resources to conduct brood surveys are limited. Nonetheless, the variable nature of the relationship implies that brood density is still best estimated directly.

Landscape models including covariates of isolation, distance to main stem, and adjacent nesting cover were not supported in our hierarchies of waterbird models. At every enrollment period, funding for CREP acres in Illinois and other program states is allocated on a first-come, first-served basis, and many potential projects do not receive funding (State of Illinois 2004). Although lands proposed for enrollment must meet specific program criteria, sites are selected according to a simple queue system. Some agricultural conservationists have suggested that site selection could be improved through landscape-level analysis of the spatial context of candidate parcels. Such considerations would likely improve the regional enrollment process. Nonetheless, our results support the notion that basic, site-level conditions essential to wetland function and persistence should be the priority when restoring waterbird habitat through CREP (Stevens et al. 2003). Investing in hydrologic planning and infrastructure to facilitate effective restoration and management, combined with monitoring compliance and development of site-specific restoration goals, should take precedence over concerns about location and landscape context.

MANAGEMENT IMPLICATIONS

Wetlands we monitored that were restored through CREP in the Illinois River watershed provided quality habitat for many waterbird species during the important life-history events of migration and brood rearing. We believe the most important actions for conservation of waterbirds through CREP restorations are to actively restore hydrology to develop and sustain desired habitat conditions and support interspersed wetland vegetation. Landscape location of sites should not be dismissed, but it is secondary to securing local site conditions. When on-site conditions of hydrology and flora are achieved, CREP wetlands can provide high quality habitat that meets the needs of wetland-dependent wildlife and satisfies landowners.

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