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Ecological Conservation Through Aesthetic Landscape Planning: A Case Study of the Lower Wisconsin State Riverway

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ABSTRACT / A consequence of expanding residential development into rural areas is the potential alteration of ecological communities. Certain novel land-use policies seek practical solutions by accommodating social needs for housing while conserving biodiversity. This study investigates whether regulations designed to protect the aesthetic characteristics of a river corridor simultaneously mitigate negative effects of development on avian biodiversity, despite the absence of explicit conservation objectives. Using housing data from the US Census (1990 and 2000) and the Audubon Christmas Bird Count (1987–2000), we examined changes in housing density, avian communities, and the relationship between these two variables in a location that has adopted aesthetic landscape planning, the Lower Wisconsin State Riverway. We found that overall species diversity increased in the Riverway, but remained constant in reference areas, although the relative increase in housing density in the two areas did not differ. We also found that omnivore populations decreased in the Riverway and increased in reference sites. On the whole, our study provides preliminary evidence that aesthetic landscape planning, such as employed in the Lower Wisconsin State Riverway, might constitute a politically viable approach to conserve ecological resources.

Exurbanization, the migration of people from cities to rural and forested areas, has increased in the past two decades (Harper and others 1990; Klase and Guries 1999; Egan and Luloff 2000; Theobald 2001). As a result, formerly undeveloped areas are changing into developed residential sites (Harper and others 1990; Klase and Guries 1999; Maestas and others 2001). Although the ecological consequences of this landscape/land-use change are largely unknown (Maestas and others 2003), recent studies indicate that exurban development can affect biodiversity (Maestas and others 2003; Miller and others 2003). Thus, managing the impact of exurbanization is an important conservation issue (Miller and Hobbs 2002), particularly becase many of our nation's most ecologically intact areas are those that are most attractive to development.

Land-use planning can be a valuable policy tool to resolve the growth-conservation dilemma. A number of communities are striving to accommodate development pressures while protecting key habitat patches and ecological communities by developing novel approaches to land-use planning (Batisse 1997; Lathrop and Bognar 1998; Beatley 2000; Maestas and others 2001). These approaches often include partnerships between government and private organizations. They differ from reactive conservation laws of previous decades (e.g., the Endangered Species Act), which promoted piecemeal, fragmented conservation strategies that were inadequate to protect threatened populations (Beatley 2000). These approaches also increas-

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ingly take place at the landscape-scale, reflecting the call among conservationists for land-use policies at multiple scales (Franklin 1993; Batisse 1997; Knight and Landres 1998; Beatley 2000). This is important, as ecological needs and human uses of the landscape often occur at different scales and only policies at the landscape level can fully encompass these different scales.

Landscape-scale planning to promote conservation in response to exurban development is a highly politically charged process. Several communities that have attempted to implement conservation-oriented land-use policies have experienced heated conflict and irresolvable impasses (e.g., Lathrop and Bognar 1998 Walker and Fortmann 2003). Often, these debates divide along the lines of long-time local residents and newcomers (e.g., Walker and Fortmann 2003). Divergent, visceral attitudes about property rights and desired landscape and environmental characteristics can present intractable roadblocks to landscape-scale planning.

One kind of land-use policy that has the potential to accommodate both development and conservation is *aesthetic landscape planning*. Under this policy approach, scenery constitutes a valuable resource, so planners aim to preserve specified qualities of the landscape's appearance (Porteous 1996). Typically, these characteristics are ecological or cultural features, such as riparian communities or farm fields and pastures (Nassauer 1989, 1997; Porteous 1996; Van Mansvelt 1997). By restricting alterations to the *appearance* of the landscape, aesthetic management policies could simultaneously impact its *ecological function*.

Aesthetic landscape planning can be politically viable. In the mid and late 1980s, communities along the lower Wisconsin River, scientists and government officials successfully negotiated, adopted, and implemented an aesthetically based management plan. The result of this process was the establishment the Lower Wisconsin State Riverway (hereafter referred to as the Riverway). The Lower Wisconsin State Riverway Board (LWSRB) is charged with the difficult task of managing land uses in the Riverway to protect scenic beauty (Lower Wisconsin State Riverway Board 1993).

Using the Lower Wisconsin State Riverway as a case study, this research investigates the hypothesis that aesthetic landscape planning simultaneously promotes ecological conservation, despite the absence of explicit conservation goals. We propose that aesthetic regulations to protect Riverway scenery, such as restrictions on vegetative removal and timber harvests, mitigate the alterations to ecological communities typically associated with development. We examine this hypothesis through a study of changes in development (measured by housing density), changes in ecological characteristics (measured by avian species diversity), and interactions between these two variables. To better characterize changes in species diversity, we also analyze changes in specific guilds that previous studies have identified as potential indicators. Three primary questions structure this study:

1. Have development trends changed since the establishment of the Riverway?
2. Has avian community diversity changed in the Riverway since its establishment?
3. Building on the answers to the previous two questions, does the implementation of aesthetic landscape planning in the Riverway affect the interaction between housing density and avian community diversity?

We do not expect that aesthetic management will modify housing density trends, because the Riverway does not strive to limit residential construction. Rather, we predict that alterations to avian diversity indices associated with development will be modified, because of the restrictions on alterations to vegetation and, thus, on some avian habitats in the Riverway.

Given the short time since the Riverway's implementation, the data necessary for a long-term analysis of the impacts of establishment of the Riverway do not exist. Consequently, we designed our study to compare changes in a group of sites within the Riverway to a group of similar reference sites in southern Wisconsin. This study compares data across these two groupings from 1990 (considered early-Riverway) with data from 2000 (post-Riverway, approximately 10 years after the Riverway's implementation).

Materials and Methods

Site Description

The Lower Wisconsin State Riverway measures ~32,000 ha, stretching west 147 km from near Sauk City, Wisconsin to the confluence of the Wisconsin with the Mississippi (see Figure 1). Southern Wisconsin possesses a cool-temperate continental climate. Mean monthly temperatures range from −6°C in January to 20°C in July. The mean annual precipitation is 825 mm. The average river discharge at Muscoda (located in the center of the Riverway) is 247 m^3/s. Annual floods typically occur in the spring. Floodplain forests dominate the lowlands along the Lower Wisconsin

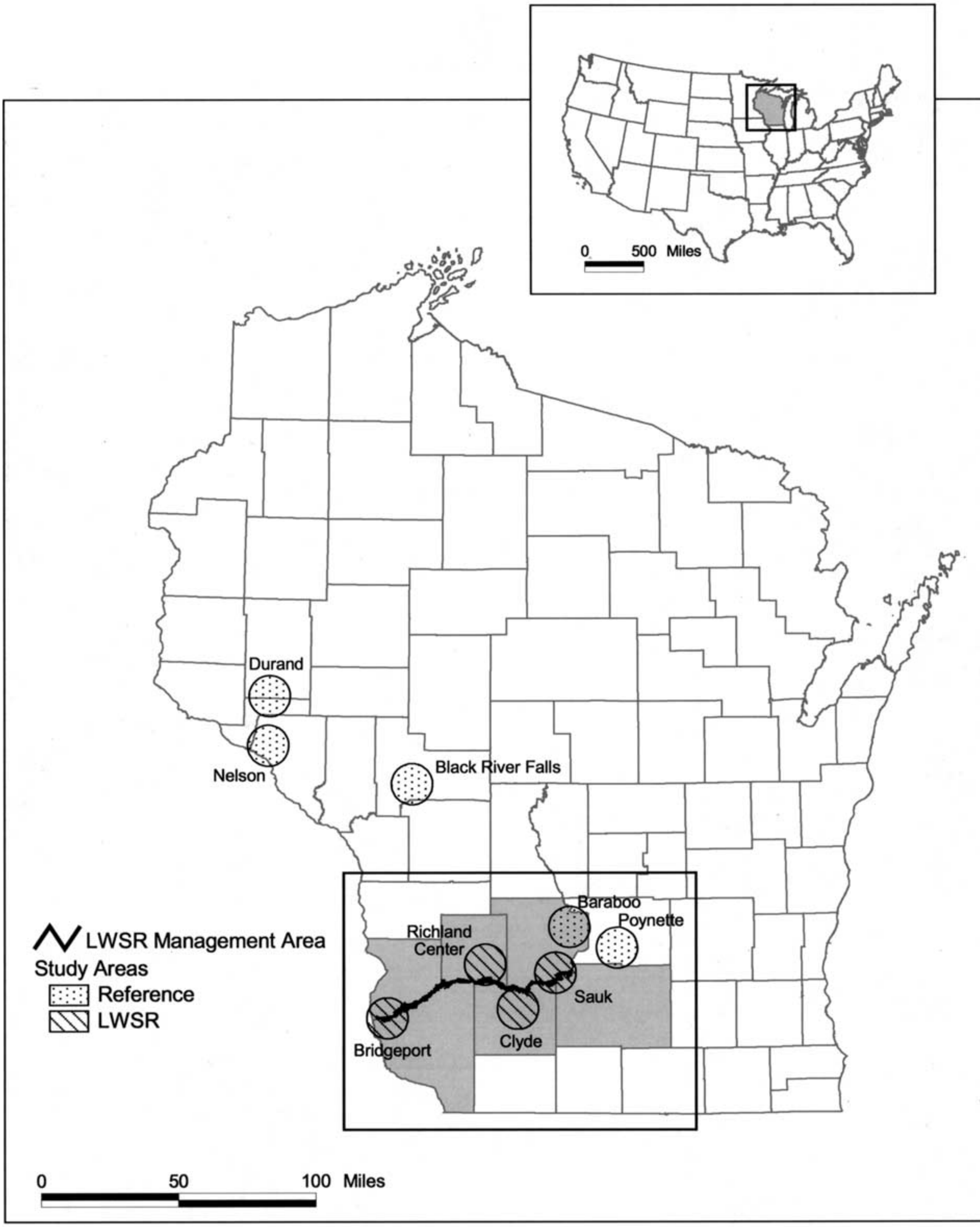

Figure 1. Study sites for the Lower Wisconsin State Riverway and reference areas.

River (Freeman and others 2003). Typical canopy species of the forest include silver maple, swamp white oak, green ash, and bitternut hickory (Hale 2004).

The LWSRB oversees the Riverway and enforces a set of regulations designed to conserve the aesthetic character of the both public and private land within the Riverway while allowing for development. These regulations fall under two types of legal code: those that regulate the removal of vegetation (including timber harvests) and those that regulate the construction and maintenance of structures. The level of control varies with visibility from the river, with more visible sites possessing stronger controls. Appendix A provides more detailed information on Riverway policy.

The Riverway functions as an excellent site to study the interactions between development and conservation. Large river floodplains provide habitat for a high diversity of flora and fauna (Naiman and others 1993), but they experience human activities, such as development, which pose a potential threat to this diversity (Machtans and others 1996). Even in areas where forest cover remains, increased building density can alter landscape characteristics (Wear and Bolstad 1998). Avian species represent a suitable development indicator, as they are sensitive to land-use change and development (Lindsay and others 2002).

Site Selection

Within the Riverway, we selected sites that intersect with Audubon Christmas Bird Count (CBC) survey areas. Typically, volunteers conduct these annual counts during a single day between mid-December and early January (National Audubon Society 2003). The volunteers count all birds that are present within a 12-km radius of a fixed point. To ensure a complete dataset, we stipulated that each of the avian survey sites had been surveyed consistently since 1980. All of the four survey sites within the Riverway met this criterion. One site (Clyde) was not surveyed during one of the 6 survey years, however. Specifically, the survey areas are centered at Bridgeport, Clyde, Richland Center, and Sauk City (Figure 1).

We also selected a group of sites to function as a reference. These sites are located outside of the Riverway within similar river systems. We applied four criteria to determine our reference sites: (1) the sites must be located within a CBC survey area; (2) they must be located in a river–floodplain system of relatively similar size; (3) they must be located in a non-urban area; and (4) they must be located south of the tension zone (*sensu* Curtis 1959), which runs from northwest to southeast through the state of Wisconsin. This zone divides the flora into predominately southern and northern groups; the Lower Wisconsin lies south of the tension zone. Five sites met these criteria: Black River Falls (Black River), Baraboo (Baraboo and Wisconsin rivers), Durand (Chippewa River), Nelson (Chippewa River), and Poynette (Wisconsin River). These stringent criteria allow us to develop a quality reference group for this analysis. Because these stipulations limit the number of potential sites, they also limit the statistical power of the analysis.

Table 1. Land-cover classifications in the Riverway and reference sites (as percentages of total) in the early 1990's

Land cover	Riverway	Reference
Urban/developed	0.7%	0.4%
Agriculture	18.1%	17.7%
Grassland	6.0%	6.6%
Forest	20.2%	19.3%
Coniferous	4.8%	1.4%
Deciduous	15.3%	17.1%
Mixed deciduous/coniferous	0.0%	0.9%
Open water	1.1%	1.3%
Wetland	2.0%	2.2%
Emergent/wet meadow	1.7%	0.9%
Floating aquatic herbaceous vegetation	0.0%	0.3%
Lowland shrub	0.3%	1.0%
Forested wetland	1.9%	2.2%
Broad-leaved deciduous	1.9%	2.0%
Coniferous	0.002%	0.2%
Mixed deciduous/coniferous	0.0%	0.1%
Barren	0.4%	0.5%
Shrubland	0.0%	0.05%

Source: Wisconsin Department of Natural Resources 1998.

The Riverway and reference sites possess similar land covers (Table 1), based on a comparison of WISCLAND data, which consists of satellite imagery (30-m^2 raster cells) collected for the state of Wisconsin between August 1991 and May 1993 (Wisconsin Department of Natural Resources 1998). For both the Riverway and reference sites, there is a comparable proportion of the three primary land-cover classes, specifically forest (20.2% and 19.3% of total area, respectively), agriculture (18.1% and 17.7%, respectively), and grassland (6.0% and 6.6%, respectively). There is also a comparable proportion of urban/developed land in the two areas: 0.7% and 0.4%, respectively.

Housing Density

Conservation researchers have employed several different socio-economic indicators of development (Theobald 2003), including road density (Mladenoff and others 1995; Gelbard and Belknap 2003) and population density (Chown and others 2003; Luck and others 2004; McKee and others 2004). This study employs housing density, which other researchers have used to investigate the influence of development on biodiversity of avian populations (Miller and others 2003) and avian nest predation (Thorington and Bowman 2003).

For this study, there are two primary advantages of employing housing density as a development indicator. First, it safeguards against underestimating human presence in zones populated by second homeowners, because the US Census population data derive from primary place of residence (Theobald 2003). Second, housing density, as compared to population density, more directly reflects the physical modifications of the landscape, which is of particular interest in this study.

To develop estimates for housing density in both of our study groups, we developed a Geographic Information System (GIS). The GIS contains three layers: (1) the US Census TIGER (Topologically Integrated Geographic Encoding and Referencing system) block data from either 1990 or 2000, as appropriate (ESRI 2002); (2) the CBC survey area (see below); and (3) the boundary of either the Riverway or the reference area. We established a boundary for the reference areas using a buffer that possessed the same general characteristics of the Riverway, set at 2.4 km (1.5 miles) from the waterway center. For both groups of sites, we overlaid the three layers to identify the US Census blocks that fell within both the CBC survey area and the Riverway/reference boundary zone, enabling us to focus the housing density calculation on either the area subject to Riverway policy or the comparable area in the reference sites (Figure 2).

We then used the GIS to calculate the average housing density for the nine study sites in 1990 (at the beginning of the Riverway's establishment) and in 2000 (10 years after its establishment). To calculate housing density, we divided the sum of the housing units at a given site by the sum of that area's census blocks. For blocks that were bisected by the Riverway/reference boundary, the perimeter of the Audubon inventory zones, or both, we calculated the proportion of the block within the study area and used it to adjust the housing density estimate from that block. In keeping with the methods employed by other researchers (Radeloff and others 2001), we deleted US Census blocks that fell entirely within water areas from our study area. Because housing units are restricted to land (i.e., not water) zones, retention of these blocks would have underestimated housing density.

Avian Species Diversity

Scientists have used various ecological indicators to investigate ecological responses to development. In this study, we employ avian species diversity. Studies in the Midwest have shown that vegetation can affect the composition of avian communities, in particular shaping insectivore populations (Temple and others 1979), controlling the presence of forest-interior, forest-edge, and generalist species (Ambuel and Temple 1983), and controlling nest predation (Knutson and others 2000). We focus our analysis on winter avian communities, as these communities should be most responsive to changes in the study areas. In contrast, migratory species populations, such as neotropical migrants, are influenced by the multiple habitats they use throughout the year and, thus, would not function as well as direct indicators of change in the Riverway and reference areas.

We chose to use CBC data, which we acquired from *Passenger Pigeon*, the Wisconsin Audubon Society's quarterly publication. We used CBC data for two reasons: They generally provide good data on winter bird population (Kammermeier and Hochachka 1999) and they represented the largest and most complete dataset available for the Riverway and reference areas. This seems like a reasonable choice, as CBC data have been used successfully in many scientific studies to analyze changes in avian communities throughout the United States. A bibliography of these studies is available on the Audubon Society's website (http://www.audubon.org/bird/cbc/bb.html).

The CBC data possess several weaknesses and any analysis of these data must address these issues. One weakness lies in the variation in sampling effort. Similar to other bird surveys, CBC data are collected by volunteers and are, thus, a function of participant effort. To adjust for effort across years and avian survey areas, we followed previous studies (Stapanian and others 1994; Root and McDaniel 1995; Sauer and others 1996) and divided bird count data by sampling effort for a given year and survey area. In our dataset, there were also inconsistencies in the owl species counts. As such, we chose to remove these species from our dataset and, consequently, from our analysis. Finally, there can be large variations in the weather conditions. CBC data are collected 1 day from mid-December through mid-January; as such weather conditions can vary drastically across sites and years. To minimize sampling variation due to weather, we chose to average data from 3 years for each study period. We also employed a set of criteria to select appropriate years. For each study period, we selected 3 years of data

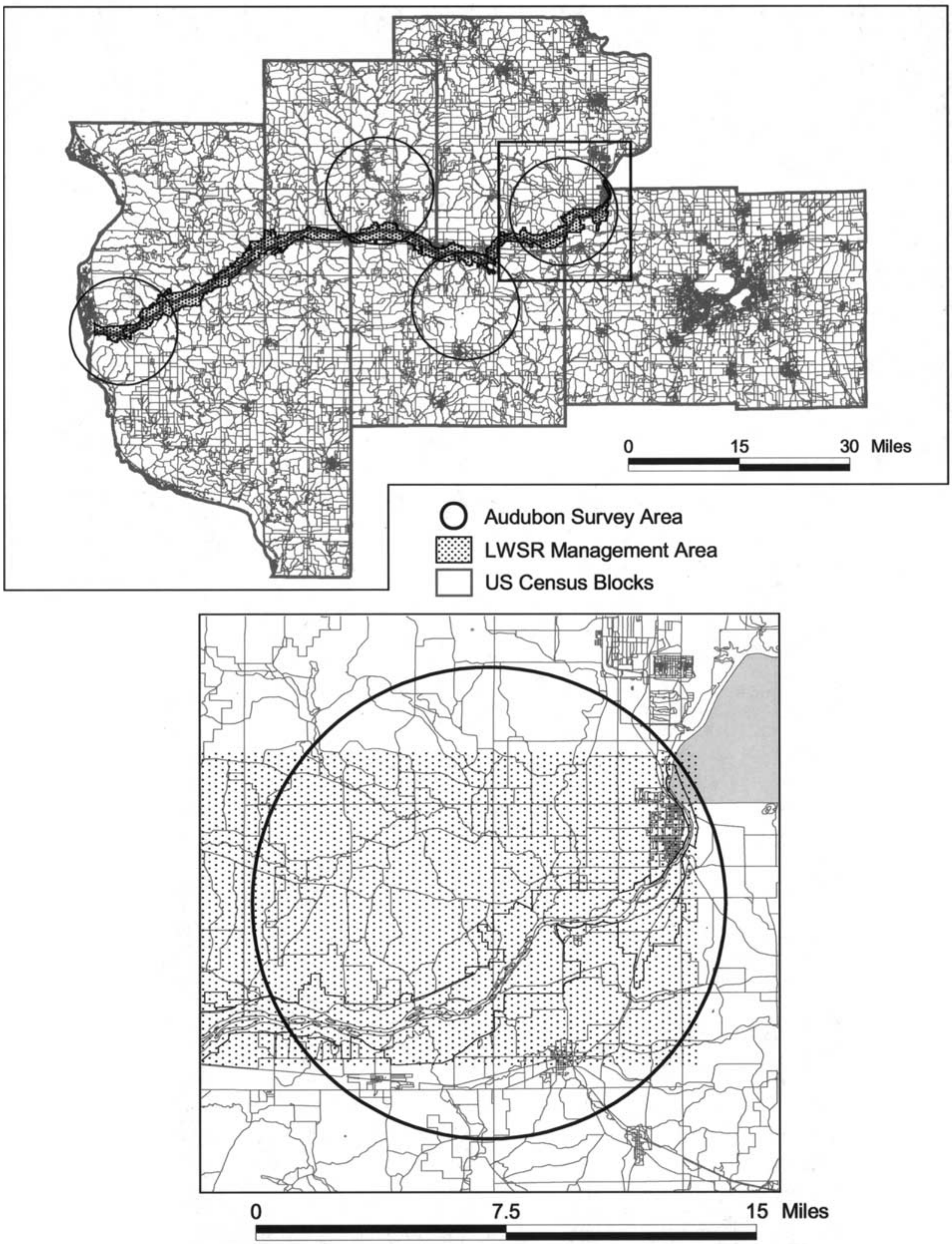

Figure 2. Determination of study areas using a GIS by overlaying US Census blocks, Riverway boundaries, and Audubon bird survey areas.

Table 2. Mean observer effort, housing density, species richness, evenness, and Shannon's diversity index for Riverway and reference sites (± 1 SE)

Site	*n*	CBC hours	Housing density	Shannon's (H′)	Richness (S)	Evenness (E)
Reference 2000	5	34.8 ± 8.9	19.3 ± 4.4	2.62 ± 0.05	55 ± 5.5	0.66 ± 0.02
Reference 1990	5	38.5 ± 11.4	15.8 ± 3.9	2.64 ± 0.09	54 ± 6.9	0.67 ± 0.02
Riverway 2000	4	64.7 ± 15.9	2.6 ± 0.6	2.74 ± 0.08	61 ± 7.5	0.67 ± 0.01
Riverway 1990	4	69.5 ± 17.2	2.3 ± 0.5	2.68 ± 0.11	59 ± 12.2	0.68 ± 0.03

that had been collected under fair to good weather conditions, which we define as being warmer than −10°C and having no precipitation. The resulting selections were: early-Riverway (1987, 1991, 1992) and post-Riverway (1997–99). Due to missing data for the Clyde site, our estimates derive from 1997 and 1999 data, as 1998 data were unavailable. No more recent data for Clyde were available, as no CBC surveys were completed there between 2000 and 2002. This situation reduces the potential species richness of the Riverway sample and biases the dataset against detecting changes in the direction predicted by our hypotheses.

To estimate avian species diversity at each site, we calculated the Shannon Diversity index (H′) (Ludwig and Reynolds 1988). We also calculated the richness (S), and evenness (J) for each site. Because species diversity provides limited information on the actual composition of a community, we supplement our diversity indicator with three other avian indicators that relate to development (percent omnivores and percent species in a group of brood parasites, nest predators, and exotics) or to this ecological system (percent wetland species). Previous studies have shown that omnivores as well as brood parasites, nest predators, and non-native species tend to be positively influenced by human development (Ambuel and Temple 1983; Allen and O'Connor 2000; Lindsay and others 2002). We used data from Ehrlich (1988) to determine omnivore species and data from both Ehrlich (1988) and the previously mentioned studies to identify a grouping of brood parasites, nest predators, and non-natives. Analyzing changes in wetland species provides a means to focus on a group of species that are particularly sensitive to changes in river–floodplain systems. To classify wetland species, we used data from Robbins (1991). Appendix B lists the species used in this study and their membership in these three groupings.

Data Analysis

We analyzed each of variables for both absolute and relative changes across time (early-LWSR versus post-LWSR establishment) and across space (Riverway sites versus reference sites) using a Wilcoxon rank-sum test, a nonparametric test for differences in central tendency. To compare the diversity index across the Riverway and reference groups, we used a *t*-statistic developed by Hutcheson (1970).

To examine the relationship among housing density, the Riverway, and the avian variables, we performed an analysis of covariance (ANCOVA). We used avian species diversity as the response variable and tested for relationships among housing density, the presence of the Riverway, and interactions between the housing density and Riverway variables. We also used each of the three avian groupings as response variables. To better approximate a Normal distribution for the housing density data, we used a natural logarithmic transformation. For all statistical tests, we set $\alpha = 0.05$. Although not statistically significant, we also present results that yielded *P*-values between 0.05 and 0.1, as they might be indicative of possible responses that might become stronger with time.

Results

Housing Density

Our analysis of basic site characteristics revealed that the change in overall housing densities (Table 2) was higher in the reference areas ($Z = 2.20$; $n = 9$; $P = 0.03$), where housing densities were also much greater. Examining relative changes over time did not reveal any significant differences between the reference and Riverway sites ($Z = 0.24$; $n = 9$; $P = 0.81$).

Avian Community Change

The CBC observer effort was visibly, but not significantly larger in the Riverway. In both study areas, the CBC effort was lower in the post-Riverway period. In all cases, observer effort showed substantial variation across sites (Table 2).

Our results indicate a significant change in the avian communities within the Riverway compared to the reference areas (Figure 3). We found that the species diversity in the Riverway showed a significant increase with time ($t = -3.49$; $df = 173$; $P = 0.0003$), whereas the reference sites showed no significant change

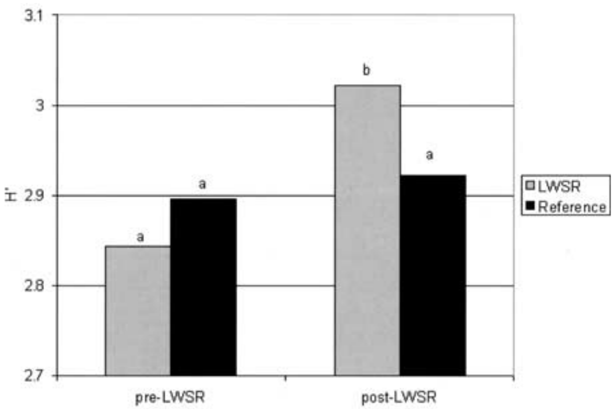

Figure 3. Change in Shannon diversity index over time across Riverway and reference groups. Bars with different letters are significantly different ($P < 0.05$).

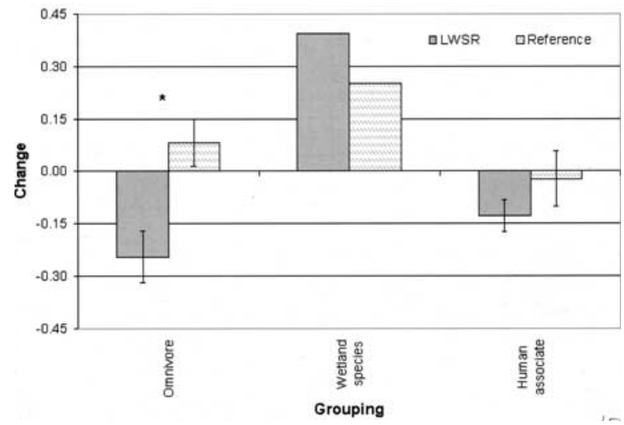

Figure 4. Relative abundance changes in avian variable across management treatments since Riverway establishment (Note: The change in wetland dweller guild has been divided by 10 for display purposes and error bars were thus not included). An asterisk (*) indicates significant difference between treatments at the 0.05 level.

Table 3. Models demonstrating significant ($P < 0.05$) or almost significant ($P < 0.1$) coefficients; residual $df = 5$ for all models

Response variable	Model variable	Coefficient	F-Value	P-Value
Omnivore (absolute change)	Riverway	−0.10	7.19	0.04
	Housing density	−0.03	0.73	0.43
	Interaction	0.03	0.50	0.51
Omnivore (relative change)	Riverway	−0.47	15.39	0.01
	Housing density	−0.68	1.60	0.26
	Interaction	0.81	3.22	0.13
Wetland spp. (relative change)	Riverway	−2.9	0.30	0.60
	Housing density	−7.3	0.96	0.37
	Interaction	29.5	4.28	0.09

($t = -0.50$; $df = 168$; $P = 0.31$). Comparing indices across management groupings, we found no significant differences between species diversity in Riverway and reference sites before the establishment of the LWSR ($t = -1.00$; $df = 165$; $P = 0.16$). In contrast, species diversity was significantly greater in the Riverway sites in the post-LWSR law period ($t = 2.00$; $df = 179$; $P = 0.02$).

We also found that both the absolute and relative proportions of the omnivore guild showed significant changes across treatments ($Z = 2.20$; $n = 9$; $P = 0.03$ for both analyses), decreasing in the Riverway area and increasing in the reference area (Figure 4). Neither wetland species nor human-associated species showed significant differences between the reference and the Riverway at the 0.05 level (Figure 4).

Interactions Among Variables

We found no significant results from our ANCOVA model using species diversity and housing density. An ANCOVA model using absolute change in the omnivore guild mirrored the results of the t-test, with a significant coefficient for the Riverway variable (−0.10; $F = 7.19$, $df = 5$, $P = 0.04$). This result indicates that the presence of the Riverway correlates with a decrease in the omnivore guild (Table 3). An ANCOVA model using relative change in the omnivore proportion revealed a yet stronger interaction (−0.47), yielding a highly significant coefficient for the Riverway ($F = 15.39$, $df = 5$, $P = 0.01$). A model based on relative change in wetland species yielded an interaction coefficient (29.5) that approached significance ($F = 4.28$, $df = 5$, $P = 0.09$), suggesting a possible interaction between the riverway and housing density that benefits wetland species.

Discussion

This case study investigated whether aesthetic landscape planning, as implemented in the Lower

Wisconsin State Riverway, moderated alterations to avian communities that typically occur in association with exurban development. Despite the small sample size and limited statistical power, our results indicate that the land-use policies introduced by the Riverway's establishment correspond with an ecological effect, which is beneficial to conservation. This study's findings correspond with conclusions of Miller and others (2003) and Miller and Hobbs (2002) that argue that landscape-scale land-use policies that maintain or restore vegetation in settled areas can mitigate alterations to biodiversity, specifically to avian communities. When combined with previous studies, our results suggest that land-use policies that preserve the scenic characteristics of the landscape might simultaneously promote biodiversity, even when conservation goals are not an explicit management objective.

Housing density was much greater in our reference areas and certainly could influence local biodiversity, although species diversity did not differ significantly in the pre-LWSR period. The rate of change in housing density did not differ across these two groups. Because the rate of development in the Riverway resembles the reference areas, which are not subject to the Riverway regulations, the Riverway appears to achieve its goal not to limit development, but, rather, guide it in a way that maintains scenic beauty. The question that follows and that was the focus of this study is how might interactions between the regulations of the Riverway interact with the management and use of this area to alter the effect of the increase in housing density on local ecological communities, specifically on the avian community.

In light of our finding that the relative increase in housing density did not differ significantly between the Riverway and reference sites, differences in avian metrics are especially interesting. Studies in the US Midwest, Northeast, and the Rocky Mountains have found that human development patterns tend to have a negative effect on native avian communities (Ambuel and Temple 1983; Allen and O'Connor 2000; Miller and others 2003). In our study, avian species diversity became significantly greater in the Riverway compared to the reference areas. Although the larger observer effort might explain the larger overall species diversity in the Riverway sites, it does not explain the increase in diversity seen with time, as observer effort was not significantly different across time periods and showed a nonsignificant decrease with time. This suggests that the Riverway might be moderating the influence of human presence on this population. The lack of data at Clyde (a Riverway site) adds strength to this finding, as we would expect lower species diversity in the Riverway sites, simply due to the smaller sample size caused by this lack of data. Moreover, the increase in diversity in the Riverway does not appear to reflect an increase in species typically associated with development, as we found a statistically significant decrease in the proportion of omnivores in the avian communities of the Riverway and no difference in our grouping of species generally associated with development. We also found a potential, albeit not quite significant ($P = 0.09$) interaction between the presence of the Riverway and housing density in our model using wetland species as a response variable. The positive value of the coefficient implies that the presence of the Riverway interacts with housing density to increase wetland species in Riverway sites.

One possible mechanism to explain the divergent changes in the Riverway and reference sites is the Riverway regulations (or ''performance standards'' as they are called). They have moderated vegetation changes that would have normally occurred in the process of human development, both on a landscape level and a local level. In turn, this moderation has reduced the level of impact to the avian community in the Riverway, despite similarities in land-cover types (Table 1) and a similar rates of development. Existing studies document a relationship between bird populations and landscape factors, specifically fragmentation (Burdick and others 1989), size of forest habitat area (Ambuel and Temple 1983), and width of the riparian zone (Stauffer and Best 1980; Keller and others 1993; Kilgo and others 1998). The nature of the timber harvest regulations of the Riverway in comparison to the reference sites might result in plausible differences in landscape characteristics. In the Riverway, harvest restrictions on much of the gradient from the river's edge to the bluff likely conserve larger forest habitat areas than in the reference sites, where harvest regulations are limited to a narrow riparian strip. Second, silvicultural practices that exclude clear-cuts in three of the four Riverway management zones and limit harvests to selection cuts in two of four zones might function as a check against the fragmentation that can occur in the reference sites. Management practices in the immediate riparian corridor, the Riverway, and reference sites should not bring about significant differences, because similar regulations apply to both riparian areas.

Another possible landscape-level factor behind this change is a possible conversion of the Riverway area to a landscape with less agriculture. Rodewald and Yahner (2001) found populations of less desirable species to be lower in forested landscapes that contain timber operations than in forested landscape that also contain agriculture. The Riverway is indirectly reducing the amount of agriculture in the Riverway (while allowing for continued timber harvests), due to the state's active acquisition of land in Riverway, where state holdings have increased from 25% to 50% in the Riverway's first 10 years (Wisconsin Department of Natural Resources 2002).

Local (stand-level) effects might also contribute to observed differences in the bird community indices between the Riverway and the reference sites. Research has shown that certain factors influence avifauna, including (1) the presence of snags, dead limbs, and mature trees, (2) a multistoried canopy, and (3) a heterogeneous shrub layer (Temple and others 1979; Hansen and Hounihan 1996, Knutson and Klaas 1998, Miller and others 2003). Just as differing regulations between the Riverway and reference sites might lead to differences in landscape characteristics, they might also promote variation in local characteristics between the Riverway and the reference sites. In the Riverway, harvest restrictions apply to two areas that are not subject to harvest limitations in the reference sites. Two of the three types of harvests allowed in these zones (selection and small regeneration cuts) are uneven-age management techniques and, thus, promote the maintenance of multistory canopy structure; tall canopy layers provide feeding and breeding habitat for some Midwestern bird species (Knutson and Klaas 1998). In addition, checks on clear-cut harvests can help to maintain standing snags. The significant changes seen in the omnivore guild could well be a result of these types of vegetation change.

Caveats

There are several limitations to this case study that readers should recognize. Because our study took advantage of the natural experiment to answer a set of applied research questions relating to the implementation of the Riverway, we were limited in the number of suitable sites (which thus limited our statistical power) as well as in type of data we could use for our ecological indicator. The most complete dataset available for the desired time period was the winter bird data collected during Audubon Christmas Bird Counts. Data from the National Breeding Bird survey did not overlap well with our study areas and lacked data on winter birds. Winter birds should be a robust indicator for local landscape changes, as they do not depend strongly on habitats across multiple regions, such as species that migrate south during the winter. Nonetheless, species such as neotropical migrants have proven to be very sensitive to land development in other studies (Ehrlich and others 1988; Friesen and others 1995, Allen and O'Connor 2000). Should the study design of future investigations allow, we would recommend the use of both winter and summer resident bird species.

We were also limited in the choice of suitable reference areas. Data were not available for a long-term time series analysis solely within the Riverway, so a comparison with reference areas was the next logical choice. The reference areas were limited by the same criteria that limited our number of Riverway sites. One consequence of our design was that our reference areas had significantly higher housing densities compared to the Riverway sites, which alone could explain some of the differences seen in the avian communities. Nonetheless, the fact that housing density was not a significant explanatory variable in our modeling would seem to speak to the contrary.

Given the small number of sites in our study and consequently low statistical power, as well as the recent establishment of the Riverway, the difference in species diversity and omnivore populations across study groups indicate a solid response. As the Riverway has been in place for only a decade, this is a short time in which to elicit an ecological response. With the multiple social–ecological interactions involved, we anticipate that other changes might become more significant with time; the interaction seen in the model using wetland species represents one possible example. Generating a larger sample size, either by including more study sites (a difficult option, given the criteria for site selection) or encompassing more years, might help to determine whether these interactions are indeed significant.

Finally, we urge caution when interpreting the omnivore finding. On the one hand, generalist species such as omnivores are species that often succeed in a human-altered landscape because they are not dependent on a single resource. As such, they serve as good indicators of human development; an increase in their relative abundance suggests an increase in human impact to the landscape and ecosystem. Conversely, several omnivore species in this study are species that are generally desirable for ecologists, bird enthusiasts and/or hunters, including coots, grouse, red-headed woodpeckers, and sandhill cranes. This demonstrates the complexity of using indicators in the analysis of conservation policies as well as the importance of examining the components of any indicator before making policy decisions.

In conclusion, this case study revealed that in an area subject to the aesthetic landscape planning policies of the Lower Wisconsin State Riverway, species diversity increased and omnivore guild diversity decreased relative to a group of reference sites, despite similar housing density trends. We expect that these effects will become more pronounced in the future, especially as development outside the Riverway continues in the absence of Riverway-like guidelines. As development increases outside the Riverway, the avian population of the Riverway might even act as a source population for surrounding habitat. With development trends unlikely to subside, land-use policies that accommodate development while mitigating alterations to natural systems are critically important to conserve biodiversity. This study suggests that even lacking explicit conservation goals, aesthetic landscape planning, such as implemented in the Riverway, can simultaneously preserve ecological resources.

Appendix A: Regulations in the Lower Wisconsin State Riverway

Wisconsin State law stipulates timber harvest regulations in the Lower Wisconsin State Riverway (Lower Wisconsin State Riverway Board 2002a). For the purpose of conserving the visual integrity of the Riverway from the vantage point of a person in the river channel, harvest regulations have been divided among four Riverway zones, based on the visibility of each zone from the river:

1. River Edge: 23 m (75 ft) from the place where river-edge tree growth begins
2. Resource Management: those lands not visible from the river channel
3. River View: those lands visible from river channel and below Bluff zone
4. Bluff: 30.5 m (100 ft) down slope from each side of the bluff ridge, 61 m in total

With the exception of the Resource Management zone, where harvest restrictions do not apply, harvests must retain at least 13.8 m^2 of basal area per hectare. Riverway law specifies allowable silvicultural practices. In the highly visible River Edge and Bluff zones, only selection cuts are permitted. In the River View Zone, which is less visible from the river channel, shelterwood and small regeneration cuts (less than 2.4 ha) are also allowed. On the whole, these harvest regulations promote uneven-aged forest management, except for the regeneration cuts, which are still limited in size (Lower Wisconsin State Riverway Board 2002a).

In addition to the restrictions on timber harvests, restrictions also apply to the construction of structures and to the removal of vegetation. As with harvest codes, the strictest regulations apply to those zones that are visible from the river, where structures ''must be visually inconspicuous during leaf-on conditions'' (Lower Wisconsin State Riverway Board 2002b) and where construction must be limited to sites with a slope less than 20%. To make structures visually inconspicuous during the leaf-on period, landowners must use woody vegetation or trees as screening. If landowners plant vegetation, species must be perennial and adapted to the local climate; Riverway policy encourages the selection of native species.

State forest management policies apply in the LWSR and to this study's reference sites. Both the reference area and the LWSR are subject to regulations for riparian zones developed to attain the water quality goals of Section 208 of the 1977 Clean Water Act (Wisconsin Department of Natural Resources 1999). In the reference areas, recommendations apply to the Riparian Management Zone (RMZ), which is defined as the strip of land between the high-water mark and at least 100 ft from the river edge. In the RMZ, best management practices (BMPs) direct harvests to leave at least 13.8 m^2 of basal area per hectare, evenly distributed through the site. Cuts should take the form of a selective harvest. Although these practices are not mandatory, they have had a compliance rate of 85% (Filbert and others 1997). In contrast to the LWSR, there is no additional aesthetic management scheme for the reference sites.

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Appendix B: Bird Species and Respective Groupings

Common name	Scientific name	OM	WL	BP, NP, or EX
Cooper's hawk	*Accipiter cooperii* Vieillot			
Northern goshawk	*Accipiter gentiles* L.			
Sharp-skinned hawk	*Accipter striatus* Vieillot			
Red-winged blackbird	*Agelaius phoeniceus* L.			
Wood duck	*Aix sponsa* L.		Y	
Northern pintail	*Anas acuta* L.		Y	
American widgeon	*Anas americana* Gmelin		Y	
Northern shoveler	*Anas clypeata* L.		Y	
Green-winged teal	*Anas crecca* L.		Y	
Mallard	*Anas platyrhynchos* L.		Y	
American black duck	*Anas rubripes* Brewster		Y	
Gadwall	*Anas strepera* L.		Y	
Golden eagle	*Aquila chrysaetos* L.			
Great blue heron	*Ardea herodias* L.		Y	
Lesser scaup	*Aythya affinis* Eyton		Y	
Canvasback	*Aythya valisineria* Wilson		Y	
Cedar waxwing	*Bombycilla cedrorum* Vieillot			
Bohemian waxwing	*Bombycilla garrrulus* L.			Y
Ruffed grouse	*Bonasa umbellus* L.	Y		
Canada goose	*Branta canadensis* L.		Y	
Bufflehead	*Bucephala albeola* L.		Y	
Common goldeneye	*Bucephala clangula* L.		Y	
Red-tailed hawk	*Buteo jamaicensis* Gmelin			
Rough legged hawk	*Buteo lagopus* Pontoppidan			
Red-shouldered hawk	*Buteo lineatus* Gmelin			
Lapland longspur	*Calcarius lapponicus* L.			
Northern cardinal	*Cardinalis cardinalis* L.			
Common redpoll	*Carduelis flammea* L.			
Pine siskin	*Carduelis pinus* Wilson			
American goldfinch	*Carduelis psaltria* Say			
House finch	*Carpodacus mexicanus* Mueller			
Purple finch	*Carpodacus purpureus* Gmelin			
Hermit thrush	*Catharus guttatus* Pallas			
Brown creeper	*Certhia americana* Bonaparte		Y	
Belted kingfisher	*Ceryle alycon* L.		Y	
Killdeer	*Charadrius vociferous* L.		Y	
Snow goose	*Chen caerulescens* L.		Y	
Northern harrier	*Circus cyaneus* L.		Y	
Marsh wren	*Cistothorus palustris* Wilson		Y	
Oldsquaw	*Clangula hyemala* L.		Y	
Evening grosbeak	*Coccothraustes vespertinus* Cooper			
Northern flicker	*Colaptus auratus* L.			
Northern bobwhite	*Colinus virginianus* L.			
Rock dove	*Columba livia* Gmelin			
American crow	*Corvus brachyrhynchos* Brehm	Y		Y
Common raven	*Corvus corax* L.	Y		Y
Blue jay	*Cyanocitta cristata* L.	Y		Y
Trumpeter swan	*Cygnus buccinator* Richardson		Y	
Tundra swan	*Cygnus columbianus* Ord		Y	
Mute swan	*Cygnus olor* Gmelin		Y	Y
Yellow-rumped warbler	*Dendroica coronata* L.			
Pileated woodpecker	*Dryocopus pileatus* L.			
Horned lark	*Eremophila alpestris* L.			
Rusty blackbird	*Euphagus carolinus* Mueller			
Merlin	*Falco columbarius* L.			
Peregrine falcon	*Falco peregrinus* Tunstall		Y	
American kestrel	*Falco sparverius* L.			
American coot	*Fulica americana* Gmelin	Y	Y	
Common snipe	*Gallinago gallinago* L.		Y	

Common name	Scientific name	OM	WL	BP, NP, or EX
Sandhill crane	*Grus canadensis* L.	Y	Y	
Bald eagle	*Haliaeetus leucocephalus* L.		Y	
Dark-eyed junco	*Junco hyemalis* L.			
Northern shrike	*Lanius excubitor* L.			
Herring gull	*Larus argentatus* Pontoppidan	Y	Y	
Ring billed gull	*Larus delawarensis* Ord	Y	Y	
Glaucous gull	*Larus hyperboreus* Gunnerus	Y	Y	
Greater black-backed gull	*Larus marinus* L.	Y	Y	
Thayer's gull	*Larus thayeri* Brook	Y	Y	
Hooded merganser	*Lophodytes cucullatus* L.		Y	
Red crossbill	*Loxia curvirostra* L.			
White-winged crossbill	*Loxia leucptera* Gmelin			
Red-bellied woodpecker	*Melanerpes carolinus* L.			
Red-headed woodpecker	*Melanerpes erythrocephalus* L.	Y		
Wild turkey	*Meleagris gallopavo* L.	Y		
Swamp sparrow	*Melospiza georgiana* Latham		Y	
Lincoln's sparrow	*Melospiza lincolnii* Audubon		Y	
Song sparrow	*Melospiza melodia* Wilson			
Common merganser	*Mergus merganser* L.		Y	
Red-breasted merganser	*Mergus serrator* L.		Y	
Northern mockingbird	*Mimus polyglottus* L.			
Brown-headed cowbird	*Molothrus ater* Boddaert			Y
Ruddy duck	*Oxyura jamaicensis* Gmelin		Y	
Black-capped chickadee	*Parus atricapillus* L.			
Tufted titmouse	*Parus bicolor* L.			
Fox sparrow	*Passarella iliaca* Merrem		Y	
House sparrow	*Passer domesticus* L.			Y
Grey partridge	*Perdix perdix* L.			
Gray jay	*Perisoreus canadensis* L.	Y		
Double crested cormorant	*Phalacrocorax auritus* Lesson		Y	
Ring-necked pheasant	*Phasianus colchicus* L.	Y	Y	
Rose-breasted grosbeak	*Pheuctius ludovicianus* L.			
Downy woodpecker	*Picoides pubescens* L.			
Hairy woodpecker	*Picoides villosus* L.			
Pine grosbeak	*Pinicola enucleator* L.			
Eastern (rufous-sided) towhee	*Pipilo erythrophthalmus* L.			
Snow bunting	*Plectrophenax nivalis* L.			
Pied-billed grebe	*Podilymbus podiceps* L.		Y	
Common grackle	*Quiscalus quiscula* L.	Y		Y
King rail	*Rallus elegans* Audubon		Y	
Virginia rail	*Rallus limicola* Vieillot		Y	
Ruby-crowned kinglet	*Regulus calendula* L.			
Golden-crowned kinglet	*Regulus satrapa* Lichtenstein			
American woodcock	*Scolopax minor* Gmelin			
Eastern bluebird	*Sialia sialis* L.			
Red-breasted nuthatch	Sitta canadensis			
White-breasted nuthatch	*Sitta carolinensis* Latham			
Yellow-bellied sapsucker	*Sphyrapicus varius* L.			
American tree sparrow	*Spizella arborea* Wilson			
Field sparrow	*Spizella pusilla* Wilson			
European starling	*Sturnus vulgaris* L.			Y
Carolina wren	*Thryothorus ludovicianus* Latham			
Brown thrasher	*Toxostoma rufum* L.	Y		
Winter wren	*Troglodytes troglodytes* L.		Y	
American robin	*Turdus migratorius* L.			
Greater prarie chicken	*Tympanuchus cupido* L.		Y	
Mourning dove	*Zenaida macroura* L.			
White-throated sparrow	*Zonotrichia albicollis* Gmelin		Y	
White-crowned sparrow	*Zonotrichia leucophrys* Forster			
Harris's sparrow	*Zonotrichia querrula* Nuttall			

OM: omnivore; WL: wetland species; BP, NP, EX: Brood parasite, nest predator, exotic species, respectively.

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