Biological Conservation 144 (2011) 3117–3126

Contents lists available at SciVerse ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Effects of oak barrens habitat management for Karner blue butterfly (*Lycaeides samuelis*) on the avian community

Eric M. Wood [a,*], Anna M. Pidgeon [a], Claudio Gratton [b], Timothy T. Wilder [c]

[a] *Department of Forest and Wildlife Ecology, University of Wisconsin-Madison, 1630 Linden Drive, Madison, WI 53706, USA*
[b] *Department of Entomology, University of Wisconsin-Madison, 1630 Linden Drive, Madison, WI 53706, USA*
[c] *Fort McCoy Military Installation, WI 54656, USA*

ARTICLE INFO

Article history:
Received 5 May 2011
Received in revised form 3 October 2011
Accepted 11 October 2011
Available online 8 November 2011

Keywords:
Avian community
Habitat management
Karner blue butterfly
Adjacent habitat
Oak barren
Savanna

ABSTRACT

The federally endangered Karner blue butterfly (*Lycaeides samuelis*) is the focal species for a conservation plan designed to create and maintain barrens habitats. We investigated whether habitat management for Karner blue butterflies influences avian community structure at Fort McCoy Military Installation in Wisconsin, USA. From 2007 through 2009 breeding bird point count and habitat characteristic data were collected at 186 sample points in five habitat types including two remnant barrens types, barrens habitat restored from woodland and managed specifically for the Karner blue butterfly, and two woodland habitat types. Although the bird community of managed barrens was not identical to the communities of remnant barrens, the Field Sparrow (*Spizella pusilla*), a species of conservation concern, and sparse canopy associated bird species, such as the Baltimore Oriole (*Icterus galbula*) and Eastern Bluebird (*Sialia sialis*) were predicted to occupy managed barrens and remnant barrens in similar proportions. Adjacent habitat was the most influential factor in determining the community of bird species using the managed barrens. In Wisconsin, and likely throughout the range of the Karner blue butterfly, management for the butterfly creates habitat that attracts a bird community similar to that of remnant barrens, and benefits several avian species of conservation concern. Additionally, the landscape context surrounding the managed habitat influences avian community composition. Managed barrens that are adjacent to remnant barrens, rather than adjacent to woodland habitats, have the highest potential for conserving barrens breeding birds.

1. Introduction

In the United States, federal, state, and private agencies have established conservation plans for species recovery, which often involve restoring or maintaining habitat through active management. Managing habitat to promote populations of wildlife species is a science that has evolved from altering the structure of habitat for single game species (Leopold, 1933) to complex ‘active adaptive management’ approaches that optimize decision-making processes (Walters and Hilborn, 1978; Wilhere, 2002). Although habitat management planning that takes into account all species is a desired goal, practically there may be enough resources to address the needs of only the most vulnerable species. Vulnerability arises for many reasons, one of which is dependence on a specific habitat type that has declined in extent. The degree to which the vulnerable species functions as a surrogate for other species (i.e., a species for which management benefits other species, Caro and O’Doherty, 1999) is usually unknown (Simberloff, 1998; Loyola et al., 2007).

In the northeastern and central portions of the United States, conservation and recovery plans have been implemented for the federally endangered Karner blue butterfly (Lepidoptera: Lycaenidae, *Lycaeides samuelis*, hereafter Karner blue, US Fish and Wildlife Service, 2003). Across their range, which extends from Minnesota east to New York, Karner blue populations have severely declined, due primarily to the loss of barrens habitat (Nuzzo, 1986; Heikens and Robertson, 1994). Barrens are a type of savanna, classified by sparse tree canopies (5–50% cover), with a diverse forb and grass understory, typically found on poor soils (Curtis, 1959; Bray, 1960). Barrens were historically maintained by fire (Wolf, 2004) and large native grazers (Ritchie et al., 1998). However, following European settlement, anthropogenic modifications, such as plowing and clearing for agriculture as well as fire suppression reduced the extent of barrens to highly localized regions (Nuzzo, 1986; Anderson and Bowles, 1999; Leach and Givnish, 1999). The Karner blue needs barrens habitat because the host plant of Karner blue larvae, wild blue lupine (*Lupinus perennis*) along with ant species needed by larvae to reach pupation (Pierce et al., 2002) occur in these habitats (Grundel et al., 1998, 2000). Additionally, the spatially heterogeneous tree canopy cover and sandy soils of barrens

* Corresponding author. Tel.: +1 608 265 9219; fax: +1 608 262 992.
E-mail address: emwood@wisc.edu (E.M. Wood).

0006-3207/$ - see front matter
doi:10.1016/j.biocon.2011.10.010

provides a diverse suite of Karner blue nectar sources (Grundel et al., 2000; Grundel and Pavlovic, 2007b) as well as optimal ovipositing locations for females (Grundel et al., 1998). The federal conservation and recovery plan focuses on restoring and maintaining barrens habitat with the purpose of 'perpetuating viable metapopulations of the Karner blue' (US Fish and Wildlife Service, 1997).

Wisconsin is important for the conservation of the Karner blue (Wisconsin Department of Natural Resources, 2009) because it contains some of the largest patches of oak and pine barrens habitat in the upper Midwest (Anderson and Bowles, 1999). Various federal, state, and private landowners have restored barrens habitat for the Karner blue by thinning and burning successional barrens and oak woodlands, mowing, and direct seeding of wild blue lupine and other associated forbs (King, 2003; Kleintjes et al., 2003; Wisconsin Department of Natural Resources, 2009). Because of the extent of oak barrens habitats and management efforts, Wisconsin has some of the highest densities of Karner blue (US Fish and Wildlife Service, 2003). Although the primary objective of the federal and state habitat conservation plans is to restore populations of the Karner blue, a secondary objective is to conserve barrens habitat (US Fish and Wildlife Service, 2003; Wisconsin Department of Natural Resources, 2009).

Many animal species use barrens habitat in Wisconsin. These include rare species, such as the federally endangered Kirtland's Warbler (*Dendroica kirtlandii*, Probst et al., 2003), the state endangered Western Slender Glass Lizard (*Ophisaurus attenuatus*, McConkey, 1954), and Phlox Moth (*Schinia indiana*, Eckstein and Moss, 1995) as well as unique communities of arthropods (Siemann et al., 1997). In addition, a multitude of bird species are found in the sparse canopy habitat (Mossman et al., 1991; Davis et al., 2000; Grundel and Pavlovic, 2007a; Au et al., 2008; Mabry et al., 2010), including a nationally listed species of conservation concern, the Red-headed Woodpecker (*Melanerpes erythrocephalus*, Rich et al., 2004) and several species of conservation concern in the Prairie Hardwood Transition region including the Brown Thrasher (*Toxostoma rufum*), Clay-colored Sparrow (*Spizella pallida*), Field Sparrow (*Spizella pusilla*), and Vesper Sparrow (*Pooecetes gramineus*; Rich et al., 2004). Bird species found in savanna habitat types, such as oak barrens, are associated with habitat characteristics dependent on the disturbance history of the stand including structure of the tree canopy, (Brawn, 2006; Grundel and Pavlovic, 2007a), early successional stage (e.g., shrub cover and tree sprouts, Davis et al., 2000), and snags or dead limbs on live trees (King et al., 2007). Bird populations have declined in savanna and barrens habitats primarily because of loss of these key habitat characteristics (Brawn et al., 2001). Reports point out the need for regular management to maintain this habitat type (Henderson, 1995; Minnesota Department of Natural Resources, 2006; Benton et al., 2008) and yet, while these habitats are clearly important for several declining species, there is no unified management plan for the state or the region that directly address oak barrens or savanna habitat (Wisconsin Bird Conservation Initiative, 2011). Thus understanding how oak barrens habitat management affects bird communities has important conservation benefits.

Butterflies function as umbrella taxa for invertebrate conservation (New, 1997; Kerr et al., 2000). Butterfly diversity may also be a useful surrogate for bird diversity (Blair, 1999; Swengel and Swengel, 1999; Fleishman et al., 2003; Thomson et al., 2007). But to our knowledge, the influence of habitat management for a butterfly species on the avian community has not been assessed. We investigated how habitat characteristics and the bird community in habitat managed for the Karner blue differs from unmanaged remnant barrens habitat (i.e., habitat that has remained in a similar state for at least 20 years) in order to better understand how factors relating to the habitat management influence the bird community. Our study was conducted at Fort McCoy Military Installation, Wisconsin, USA, in five habitats including sparse canopy remnant barrens habitats, barrens managed for Karner blue and dense canopy woodland habitats. We had three objectives. Our first objective was to evaluate the similarity of bird species composition in remnant oak barrens, oak barrens managed for Karner blue and oak woodland habitats. We hypothesized that bird community composition of oak barrens managed for Karner blue would be similar to remnant oak barrens habitats and different from oak woodland habitats. Our second objective was to determine if individual bird species, particularly species of conservation concern, in remnant oak barrens and oak woodland habitats have similar predicted site-occupancy patterns to the bird community in oak barrens managed for Karner blue. We hypothesized that the occupancy patterns of sparse canopy associated bird species would be similar in the oak and restored barrens habitats and different from the oak woodland habitats. Our third objective was to determine whether management method, time since restoration, type of adjacent habitat, or management area patch size influence the avian community in oak barrens managed for the Karner blue.

2. Materials and methods

2.1. Study area

We studied bird and habitat characteristics at the 24,281 ha Fort McCoy Military Installation, in southwestern Wisconsin, USA (Fig. 1). Fort McCoy has been an operational military installation since 1909. The study area is characterized by varying topography with well-drained sandy soils (Curtis, 1959). The dominant habitats at Fort McCoy range from open sand prairie, to dry oak barrens, to woodlands and dense forests that are representative of southwestern Wisconsin. Oak barrens are a type of savanna habitat typically situated on xeric (sandy) soils and are dominated by black oak (*Quercus velutina*), northern pin oak (*Quercus ellipsoidalis*), and jack pine (*Pinus banksiana*). Adaptation to this edaphic niche is in contrast to other oak savanna habitats in the upper Midwestern US, which are located on mesic soils and are typically associated with tall grass prairie and dominated by bur oak (*Quercus macrocarpa*, Curtis, 1959). In oak barrens, the herbaceous layer is distinct because of the xeric soils, and wild blue lupine, the host plant of the Karner blue, is especially common (Curtis, 1959). Fire, which has occurred either accidentally (e.g., military training), or naturally at Fort McCoy for the past century, has maintained some of the largest tracts of remnant oak barrens habitats in southern Wisconsin. Additional trees, shrubs and grasses in the upland study habitats include black cherry (*Prunus serotina*), red oak (*Quercus rubra*), white oak (*Quercus alba*), red maple (*Acer rubrum*), big-tooth aspen (*Populus gradidentata*), quaking aspen (*Populus tremuloides*), red pine (*Pinus resinosa*), white pine (*Pinus strobus*), blueberry (*Vaccinium angustifolium*), American hazelnut (*Corylus americana*), little bluestem (*Schizachyrium scoparium*), and Pennsylvania sedge (*Carex pensylvanica*).

2.2. Karner blue management and conservation areas

Fort McCoy has an approved Karner blue management plan that guides survey and habitat management activities for this species (Wilder, 2006). The primary objective is to maintain two large viable populations of Karner blues. To achieve this objective, the installation established 17 Karner blue management areas (Fig. 1). These areas were selected for their potential to support high Karner blue populations, were located in areas used minimally for military training, and often contained other rare or sensitive species such as Phlox Moth and Western Slender Glass

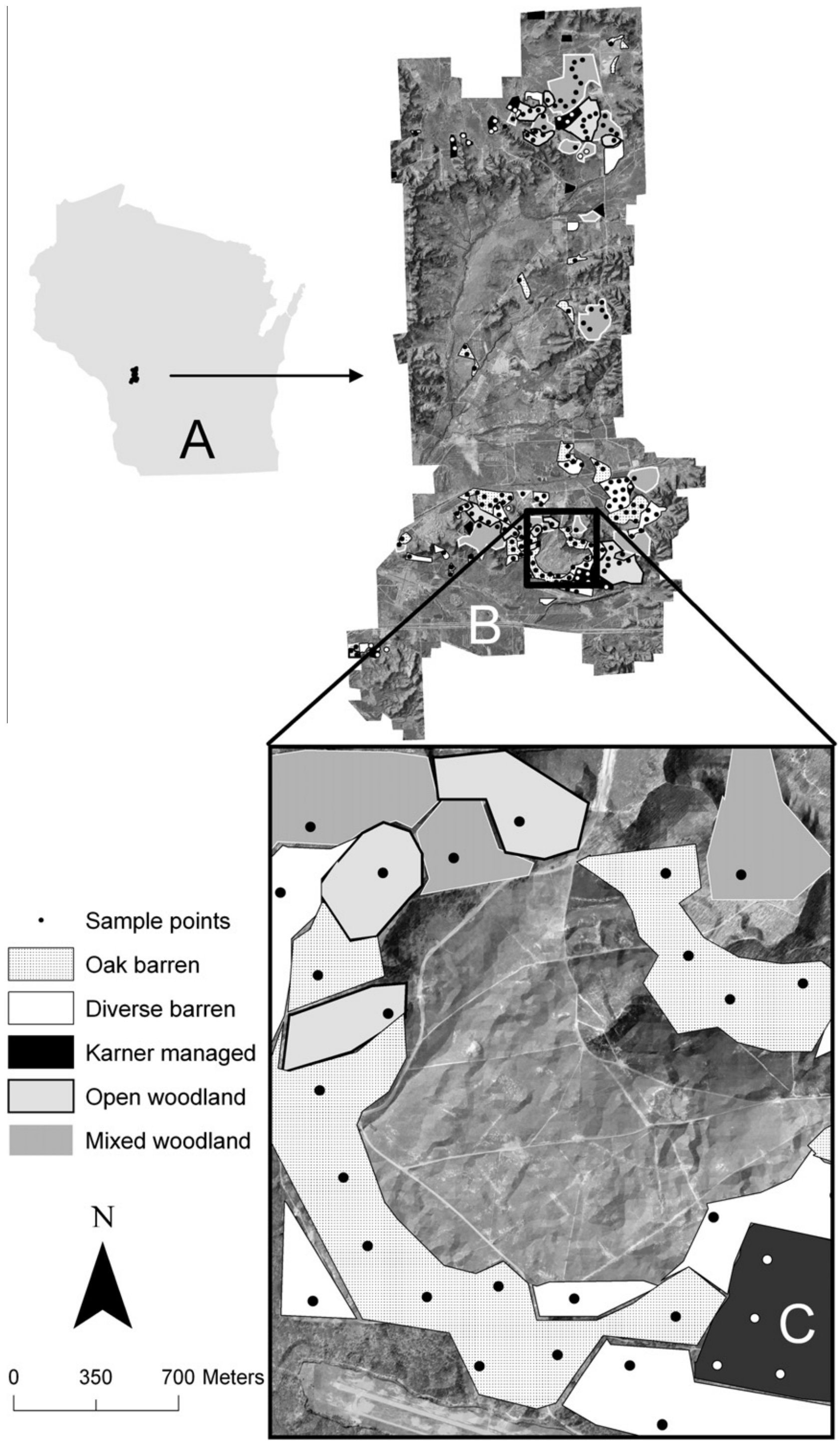

Fig. 1. (A) Location of Fort McCoy Military Installation, Wisconsin, USA, (B) Fort McCoy, (C) subset of five habitats and sample points where bird and vegetation surveys were completed during the 2007–2009 breeding season.

Lizard. Management actions utilized as part of the plan to maintain these open areas include commercial timber sales (i.e., thinning), mowing, removal of small trees and brush with chainsaws, and prescribed burning (Wilder, 2006). It is estimated that to maintain high quality barrens habitat, burning or thinning treatment is needed at least every 15 years (US Fish and Wildlife Service, 2003). On occasion, the objective of Fort McCoy managers has been to increase the abundance of wild blue lupine and forbs that adult Karner blues use as nectar sources. Normally this is achieved through the management actions listed above, though occasionally wild blue lupine and other native forbs have been planted.

2.3. Sample points

One hundred and eighty-six sample points were selected within five upland habitats using a stratified random sampling design. The habitats included oak barrens, diverse barrens, oak barrens managed for Karner blue (hereafter called Karner barren), open woodland, and mixed woodland, classes that were adopted and modified from Curtis (1959) and Sample and Mossman (1997). Four of the habitats, oak barrens, diverse barrens, open woodland, and mixed woodland occur naturally without intentional management. These four habitats have experienced natural burns and, on occasion, accidental fires associated with military training activities. The fifth habitat, Karner barren, is actively managed. Random sample points within the extent of the five habitats were generated using Hawth's Tools (Beyer, 2004) in ArcGIS 9.1 (ESRI, Redlands, California, USA, 2008). Sample points were separated by at least 300 m and were located at least 110 m from roads or manmade structures.

At each sample point, habitat characteristics were quantified using BBIRD protocols (Martin et al., 1997). To determine if there were differences in habitat characteristics among habitats, we used the Kruskal–Wallis test because the data were not distributed normally and thus a non-parametric test was appropriate (Table 1, Zar, 1999). Following significant Kruskal–Wallis tests, we used the Dunn's test for multiple comparisons to discover which pairs of habitat characteristics differed from each other (Dunn, 1964; Hintze, 2004). Ten comparisons among habitats were made, therefore we used a Bonferonni adjusted *z-test* value ($z_{\alpha/2}$) by dividing α by $k(k-1)/2$ where $k(k-1)/2$ are the number of possible pairs of k groups. The Kruskal–Wallis test and Dunn's test were computed using the NCSS statistical software package (Hintze, 2004).

Forty-five sample points were located in oak barrens, which are characterized by sparse tree canopy cover (5–50%), low vegetation structure (i.e., foliage–height diversity), and a low percentage of shrub and tree-sprout cover (i.e., <20%) and a diverse herbaceous layer (Table 1). Forty-three sample points were located in diverse barrens, which have greater shrub and tree sprout cover. Twenty-eight sample points were located in Karner barrens, where active management for the Karner blue is conducted (see Section 2.2). Tree canopy and vegetation structure are similar to barrens habitat and shrub and tree sprout cover are similar to diverse barrens habitat. There is high diversity of forbs due to management activities (Table 1). Of the 28 sample points, nine were located in managed barrens adjacent to remnant barrens, and 19 were located adjacent to woodlands. All adjacent habitat patches were at least 20 ha. Thirty-three sample points were located in open woodlands, which have greater canopy cover and vegetation structure than barrens and low shrub cover. These four habitats are found on sandy soils and have relatively low tree diversity. Thirty-seven sample points were located in mixed woodlands, which are located on more nutrient rich soils and have greater tree diversity and shrub cover (Table 1).

2.4. Avian point counts

At each of the 186 sample points, four, standardized five minute point counts were completed from 25 May to 4 July in 2007 and 2008 to characterize the avian community during the breeding season (Ralph et al., 1995). In 2009, sample points were visited on three occasions during the same time frame. Observations were limited to 100 m, and distance to each bird was estimated with a laser rangefinder and flagging placed at known distances. To distribute observer variability as equally as possible, four trained observers during 2007 and 2008 and three trained observers in 2009 performed one count at each sample point. Observers were extensively trained by the lead author on bird identification and sampling protocol prior to field sampling. The lead author was one of the observers each year.

2.5. Data analyses

2.5.1. Patterns of avian community diversity

To identify the degree of similarity of the avian communities in the five habitats, we performed nonmetric multidimensional scaling ordination (NMS) on the square-root transformed average abundance of bird species, grouped by sample point, over the three seasons (Carr, 1997). To explore group membership of bird species among habitats, we performed a hierarchical cluster analysis (Clarke and Gorley, 2006), using the Bray–Curtis dissimilarity measure (McCune et al., 2002).

In a second analysis of community similarity we conducted a one-way analysis of similarities test (ANOSIM, Carr, 1997), using the Bray–Curtis similarity of the square-root transformed average abundance of bird species, grouped by sample point. The ANOSIM test uses Monte Carlo randomization of observed data to assess whether rank similarities within habitats are more different than among habitats. We used 999 Monte Carlo permutations to generate the random test statistic, *R*, which generally ranges from 0 to 1. An *R* value near zero indicates that the avian community does not differ among habitats, while larger *R* values indicate increasing dissimilarity. Pairwise comparisons among habitats were evaluated using a Bonferroni adjusted alpha value (0.05/10 = 0.005).

2.5.2. Patterns of avian occupancy

To determine if individual bird species occupy habitats in similar proportions, we calculated the probability of site-occupancy, psi (Ψ), adjusted for detection probability, using program PRESENCE (Hines, 2006). A single-season, single-species model was used to estimate sample point-specific probabilities of occupancy using the history of detection and non-detection of birds that commonly used barrens and woodland habitats from our four visits in

Table 1
Mean summary (±SE) of habitat characteristics including foliage–height diversity (FHD), and percent cover of seven habitat elements among five habitats at Fort McCoy Military Installation, Wisconsin. Within rows, parameter estimates with same letter (A–C) do not differ significantly among habitats (Kruskal–Wallis test, Dunn's test with Bonferonni adjustment for multiple comparisons of *z*-score, $z > 2.80$).

	Oak barren[c]		Diverse barren[c]		Karner barren[c]		Open woodland[c]		Mixed woodland[c]	
Vegetation										
FHD	1.37^{A}	(0.07)	1.51^{A}	(0.07)	1.62^{A}	(0.12)	2.72^{B}	(0.10)	2.84^{B}	(0.08)
Tree[a]	18.29^{A}	(1.87)	24.49^{A}	(1.93)	24.21^{A}	(2.99)	86.02^{B}	(2.49)	81.13^{B}	(2.49)
Shrub	4.11^{A}	(1.31)	11.57^{B}	(1.36)	11.19^{B}	(2.10)	5.98^{A}	(1.75)	15.47^{B}	(1.47)
Tree sprout	8.75^{AB}	(1.62)	22.91^{C}	(1.67)	24.29^{C}	(2.58)	5.52^{A}	(2.15)	14.16^{AB}	(1.80)
Bare	21.87^{A}	(2.41)	13.19^{A}	(2.49)	10.69^{A}	(3.85)	3.03^{B}	(3.21)	1.17^{B}	(2.69)
Grass[b]	18.76^{A}	(1.76)	17.60^{A}	(1.82)	29.02^{A}	(2.82)	4.25^{B}	(2.34)	4.51^{B}	(1.96)
Forb	10.76^{A}	(0.99)	12.38^{A}	(1.02)	11.50^{A}	(1.58)	3.33^{B}	(1.31)	5.42^{B}	(1.10)
Leaf litter	14.15^{A}	(1.99)	24.39^{B}	(2.06)	18.21^{A}	(3.18)	56.20^{C}	(2.64)	44.22^{C}	(2.22)

[a] Tree – composite variable of hardwood cover and conifer cover combined.
[b] Grass – composite variable of percent cover of grass and sedge combined.
[c] Indicates remnant habitat that has remained in a similar state for at least 20 years.

2007 to 2008 and our three visits in 2009 (MacKenzie et al., 2006). The detection histories of individual bird species from all three seasons were included in one single-season, single-species design matrix. The null model, in which the probability of sample point occupancy and detection probability were held constant, [$\Psi(.)$, $p(.)$] was fitted for 25 bird species, which resulted in unique derived parameter estimates for probability of site-occupancy for each species at each sample point. Within each habitat type, the median of these sample point-specific parameter estimates was calculated. Patterns in median avian site-occupancy among the five habitats were analyzed using a Kruskal–Wallis and Dunn's test with a Bonferonni adjustment (Zar, 1999). Habitat type was used as the treatment.

2.5.3. Factors influencing the avian community in Karner blue managed habitat

To investigate whether the avian community in Karner barrens was affected by the Karner blue management plan, ANOSIM tests were performed following methods described in Section 2.5.1 (Carr, 1997). We hypothesized that four factors potentially influence avian community structure and we included these factors in ANOSIM tests. The first factor was management method which included thinning, burning, or no recent management. Of 28 sample points in our study, 14 were thinned, 11 were burned, and three were not treated during the previous twenty years, although they were designated as Karner management areas. We believed that bird species would not respond equally to different management treatments because habitat characteristics after treatment vary according to management method (Nielsen et al., 2003) and other studies in similar managed habitat found that management methods influenced bird use (Davis et al., 2000; Hartung and Brawn, 2005; Au et al., 2008). The second factor potentially influencing bird community structure was time, measured in years since the last Karner blue management treatment, and ranged from 1 to 20 years. This factor was categorized into three groups; 1–10 ($n = 17$), 10–20 ($n = 8$). The third group included the three untreated sample points (>20 years). We hypothesized bird species that prefer structurally simpler conditions would be more likely to occupy sites in the years immediately after treatment, and species preferring greater structural heterogeneity would be more evident with increasing time since treatment as oak sprouts and shrubs grew (Davis et al., 2000). The third management factor we considered was habitat adjacent to Karner management patches. We hypothesized that the vegetation structure of habitat patches adjacent to managed Karner barrens patches would influence the avian community within Karner barrens, because most species would not strictly limit their activity according to habitat type. Furthermore other studies in the region had found that landscape context, (i.e., what habitat is adjacent to oak savanna) influences the bird community within the savanna (Mabry et al., 2010). We classified the dominant habitat of adjacent patches working from high-resolution air-photos, as oak barrens or oak woodland. Nine Karner barrens were adjacent to large remnant patches of oak barrens and 19 were adjacent to large patches of oak woodland. The fourth factor was patch size of the Karner management areas. We hypothesized that larger patches would be colonized by bird species that require large expanses of barrens habitat. Patch size was calculated using ArcGIS 9.1 and grouped into three categories: nine sample points were located in 'small' patches (<9 ha), nine sample points were located in 'medium' patches (9–20 ha), and ten sample points were located in 'large' patches (20–80 ha). We used a Bonferroni adjustment for pairwise comparisons for management, treatment year, and patch size ($\alpha = 0.05/3 = 0.02$).

To assess which bird species were primarily responsible for an observed difference in the avian community among Karner barrens sample points, we conducted occupancy analyses for 21 common species, using methods described in Section 2.5.2. Sample points were grouped by the four management factors: management type, years since treatment, adjacent habitat type, and patch size.

3. Results

3.1. Patterns of avian community diversity

Fifty-four bird species were commonly detected during avian surveys and were used for the avian community analysis (Table A1). The hierarchical cluster analysis revealed two groupings at the 40% similarity level representing barrens and woodland avian communities (Fig. 2). Although the avian communities at the majority of Karner barrens points were similar to communities of

Table A1
Common name, scientific name, and American Ornithologists' Union four-letter code (AOU) for 54 common breeding bird species.

Common name	Scientific name	AOU
American Goldfinch	*Spinus tristis*	AMGO
American Redstart	*Setophaga ruticilla*	AMRE
Baltimore Oriole	*Icterus galbula*	BAOR
Black-and-white Warbler	*Mniotilta varia*	BAWW
Black-billed Cuckoo	*Coccyzus erythropthalmus*	BBCU
Black-capped Chickadee	*Poecile atricapillus*	BCCH
Blue Jay	*Cyanocitta cristata*	BLJA
Blue-gray Gnatcatcher	*Polioptila caerulea*	BGGN
Blue-winged Warbler	*Vermivora pinus*	BWWA
Brown Thrasher	*Toxostoma rufum*	BRTH
Brown-headed Cowbird	*Molothrus ater*	BHCO
Cedar Waxwing	*Bombycilla cedrorum*	CEDW
Chestnut-sided Warbler	*Dendroica pensylvanica*	CSWA
Chipping Sparrow	*Spizella passerina*	CHSP
Clay-colored Sparrow	*Spizella pallida*	CCSP
Common Yellowthroat	*Geothlypis trichas*	COYE
Dickcissel	*Spiza americana*	DICK
Downy Woodpecker	*Picoides pubescens*	DOWO
Eastern Bluebird	*Sialia sialis*	EABL
Eastern Kingbird	*Tyrannus tyrannus*	EAKI
Eastern Meadowlark	*Sturnella magna*	EAME
Eastern Towhee	*Pipilo erythrophthalmus*	EATO
Eastern Wood-Pewee	*Contopus virens*	EAWP
Field Sparrow	*Spizella pusilla*	FISP
Grasshopper Sparrow	*Ammodramus savannarum*	GRSP
Gray Catbird	*Dumetella carolinensis*	GRCA
Great-crested Flycatcher	*Myiarchus crinitus*	GCFL
Hairy Woodpecker	*Picoides villosus*	HAWO
Hermit Thrush	*Catharus guttatus*	HETH
Hooded Warbler	*Wilsonia citrina*	HOWA
House Wren	*Troglodytes aedon*	HOWR
Indigo Bunting	*Passerina cyanea*	INBU
Lark Sparrow	*Chondestes grammacus*	LASP
Least Flycatcher	*Empidonax minimus*	LEFL
Mourning Dove	*Zenaida macroura*	MODO
Mourning Warbler	*Oporornis philadelphia*	MOWA
Nashville Warbler	*Vermivora ruficapilla*	NAWA
Northern Flicker	*Colaptes auratus*	NOFL
Orchard Oriole	*Icterus spurius*	OROR
Ovenbird	*Seiurus aurocapillus*	OVEN
Red-bellied Woodpecker	*Melanerpes carolinus*	RBWO
Red-breasted Nuthatch	*Sitta canadensis*	RBNU
Red-eyed Vireo	*Vireo olivaceus*	REVI
Red-headed Woodpecker	*Melanerpes erythrocephalus*	RHWO
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	RBGR
Scarlet Tanager	*Piranga olivacea*	SCTA
Song Sparrow	*Melospiza melodia*	SOSP
Upland Sandpiper	*Bartramia longicauda*	UPSA
Veery	*Catharus fuscescens*	VEER
Vesper Sparrow	*Pooecetes gramineus*	VESP
White-breasted Nuthatch	*Sitta carolinensis*	WBNU
Wood Thrush	*Hylocichla mustelina*	WOTH
Yellow-billed Cuckoo	*Coccyzus americanus*	YBCU
Yellow-throated Vireo	*Vireo flavifrons*	YTVI

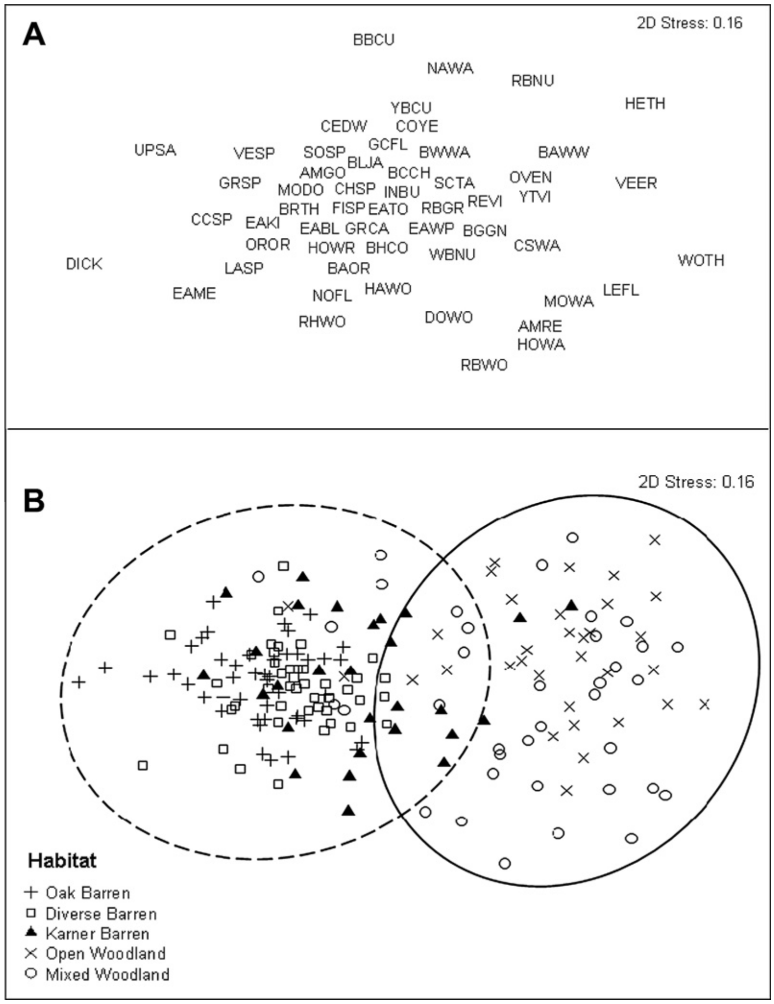

Fig. 2. NMS plots of resemblance matrix (Bray–Curtis, log-transformed average bird abundance) for (A) 54 common breeding bird species among barrens and woodland habitats, (B) and all sample points distributed among all five habitats. Stress indices were a measure of fit between the resemblance matrix and the two-dimensional representation of the similarity matrix (0.10–0.20 = good fit). Lines around points in (B) were groupings indicating avian community membership, independently determined by cluster analysis (group average, >40% similarity). Dotted circle indicates barrens avian communities. Solid circle represents woodland avian communities.

the other barrens habitats, seven Karner barrens communities fell in the area of intersection between barrens and woodland groups and three points fell within the woodland group. The avian communities in each of the five habitats were distinct ($R = 0.46$, $p < 0.001$). The Karner barrens avian community was most similar to the diverse barrens avian community ($R = 0.22$, $p < 0.001$), and was most different from the avian communities of mixed woodland ($R = 0.34$, $p < 0.001$), oak barren ($R = 0.36$, $p < 0.001$), and open woodland ($R = 0.53$, $p < 0.001$, Table 2). The avian communities of open woodland and mixed woodland ($R = 0.06$) and the oak barrens and diverse barrens ($R = 0.06$) were most similar.

3.2. Patterns of avian occupancy

We had expected that Karner barrens would be occupied by species in similar proportions as the other barrens habitats, and indeed, this was the case. Two groupings of birds emerged from the analysis of site occupancy. The first group consisted of barrens bird

Table 2
One-way analysis of similarities (ANOSIM) of avian communities among five habitats: oak barren, diverse barren, Karner managed barren (Karner barren), open woodland, and mixed woodland, from three breeding seasons, 2007–2009. Numbers below the diagonal are *R* values. Numbers above the diagonal are *p*-values. Pairwise comparisons among habitats were evaluated using a Bonferroni adjustment of the critical alpha value (0.05/10 = 0.005).

	Oak barren[a]	Diverse barren[a]	Karner barren	Open woodland[a]	Mixed woodland[a]
Oak barren[a]	–	0.002	<0.001	<0.001	<0.001
Diverse barren[a]	0.06	–	<0.001	<0.001	<0.001
Karner barren	0.36	0.22	–	<0.001	<0.001
Open woodland[a]	0.86	0.81	0.53	–	0.009[b]
Mixed woodland[a]	0.74	0.65	0.34	0.06	–

Global $R = 0.46$, $P < 0.001$
[a] Indicates remnant habitat that has remained in a similar state for at least 20 years.
[b] Not significant at the Bonferroni adjusted $\alpha = 0.005$.

species such as the Field Sparrow, Baltimore Oriole (*Icterus galbula*), Chipping Sparrow (*Spizella passerina*), Eastern Bluebird (*Sialia sialis*), and House Wren (*Troglodytes aedon*, Table 3). The second group consisted of bird species that use woodland habitats such as the Eastern Wood-Pewee (*Contopus virens*), Ovenbird (*Seiurus aurocapillus*), Rose-breasted Grosbeak (*Pheucticus ludovicianus*), and Scarlet Tanager (*Piranga olivacea*, Table 3).

3.3. Factors influencing the avian community found in Karner blue managed habitat

Of the four factors associated with Karner blue management areas that we tested, adjacent habitat (i.e., whether Karner barrens were adjacent to oak barrens or oak woodlands) had the greatest effect on the avian community ($R = 0.32$, $p < 0.001$). Size of the Karner-managed patch ($R = 0.22$, $p = 0.004$) and management method ($R = 0.21$, $p = 0.006$) also were associated with differences in the avian communities, though to a lesser degree. In contrast to our expectation, treatment year ($R = 0.15$, $p = 0.052$) did not have a strong influence on avian communities (Table 4).

Further supporting the hypothesis that adjacent habitat shapes the avian community in Karner barrens, restored barrens adjacent to oak barrens harbored bird species typical of sparse tree canopy cover habitats such as Brown Thrasher and Vesper Sparrow which are both species of conservation concern, as well as Baltimore Oriole, Eastern Kingbird (*Tyrannus tyrannus*), and Orchard Oriole (*Icterus spurius*, Table 4). Sample points in Karner barrens situated next to woodlands harbored bird species more typical of dense tree canopy habitats such as Eastern Wood-Pewee, Great Crested Flycatcher (*Myiarchus crinitus*), and Rose-breasted Grosbeak (Table 4). Neither management technique used to create Karner barrens, treatment year, nor the patch size of the management areas, were strongly related to patterns of expected bird species occupancy.

4. Discussion

Our results suggest that the management of oak barrens for the Karner blue in Wisconsin creates habitat that closely resembles remnant oak barrens, in terms of both habitat characteristics and avian community structure. Furthermore, the habitat adjacent to Karner management areas and, to a lesser extent, the method used for management, and patch size of the management areas affects the composition of birds using the Karner barrens. The Karner barrens included primarily avian species found in remnant barrens habitats as well as a lower numbers of species typical of woodlands.

The primary technique used for the conservation of the Karner blue is habitat management, and efficiencies can be gained if created barrens not only meet the needs of Karner blues, but also of other species of concern. We expected that habitat types with similar canopy cover would have similar bird communities (Brawn, 2006). However, we did not find perfect overlap among bird communities of Karner barrens and oak barrens and we speculate that, along with landscape context, the higher cover of shrub and tree sprouts in Karner barrens were the cause of differences, because we found that Karner barrens and diverse barrens were most similar to each other in both shrub cover and bird community structure. Tree sprouts respond rapidly following management in similar habitats (Peterson and Reich, 2001; Brudvig and Asbjornsen, 2007). In other systems such as African savanna and the savanna-like pinyon-juniper habitat of the Chihuahuan Desert, the

Table 3
Median derived parameter estimates of probability of sample point occupancy, psi (Ψ), for six bird species of conservation concern and 19 common species found in barrens and woodland habitats at Fort McCoy, Wisconsin, USA. Across rows, parameter estimates with same letter (A–C) do not differ significantly among habitats (Kruskal–Wallis test, Dunn's test with Bonferonni adjustment for multiple comparisons of *z*-score, $z > 2.80$).

	Oak barrens[d] ($n = 45$)	Diverse barren[d] ($n = 43$)	Karner barren ($n = 28$)	Open woodland[d] ($n = 33$)	Mixed woodland[d] ($n = 37$)
Species of conservation concern					
Brown Thrasher[a,b]	0.50^{A}	0.49^{A}	0.27^{AB}	0.24^{B}	0.27^{B}
Field Sparrow[a,b]	1^{A}	1^{A}	1^{A}	0.05^{B}	0.11^{B}
Grasshopper Sparrow[a,b]	0.72^{A}	0.34^{B}	0.34^{B}	0.02^{C}	0.07^{C}
Red-headed Woodpecker[a,b]	0.13^{AB}	0.13^{A}	0.16^{AB}	0.17^{B}	0.17^{AB}
Rose-breasted Grosbeak[c]	0.52^{A}	0.59^{A}	0.61^{AB}	0.72^{B}	0.75^{B}
Vesper Sparrow[a,b]	1^{A}	1^{A}	0.21^{B}	0.12^{B}	0.14^{B}
Species of least concern					
Baltimore Oriole	0.74^{A}	0.71^{A}	0.89^{A}	0.23^{B}	0.23^{B}
Blue-gray Gnatcatcher	0.18^{A}	0.18^{A}	0.48^{B}	0.41^{B}	0.24^{AB}
Brown-headed Cowbird	1	1	1	1	1
Chipping Sparrow	1^{A}	1^{A}	1^{A}	0.20^{B}	0.49^{B}
Eastern Bluebird	1^{A}	0.76^{A}	0.70^{A}	0.26^{B}	0.30^{B}
Eastern Kingbird	0.67^{A}	0.42^{B}	0.17^{BC}	0.19^{C}	0.19^{C}
Eastern Towhee	0.68^{A}	1^{B}	1^{B}	0.61^{A}	1^{AB}
Eastern Wood-Pewee	0.41^{A}	0.44^{A}	0.60^{A}	1^{B}	1^{B}
Great-crested Flycatcher	0.31^{A}	0.31^{A}	0.56^{B}	0.31^{A}	0.31^{A}
Gray Catbird	0.40^{A}	0.41^{A}	0.29^{AB}	0.11^{B}	0.14^{B}
House Wren	0.41^{A}	0.56^{A}	0.37^{A}	0.09^{B}	0.11^{B}
Indigo Bunting	0.72^{A}	1^{B}	1^{B}	0.67^{A}	1^{B}
Lark Sparrow	0.12^{A}	0.09^{B}	0.10^{AB}	0.08^{B}	0.09^{B}
Mourning Dove	0.84^{A}	0.84^{A}	0.64^{AB}	0.50^{B}	0.50^{B}
Orchard Oriole	0.41^{A}	0.10^{B}	0.11^{B}	0.12^{B}	0.12^{B}
Ovenbird	0.02^{A}	0.02^{A}	0.03^{A}	0.52^{B}	0.53^{B}
Red-eyed Vireo	0.08^{A}	0.08^{A}	0.45^{B}	1^{B}	1^{B}
Scarlet Tanager	0.31^{A}	0.51^{A}	0.63^{AB}	0.77^{B}	0.75^{B}
White-breasted Nuthatch	0.46^{A}	0.62^{AB}	0.63^{B}	0.71^{BC}	0.72^{C}

[a] Partner's in Flight priority species of continental and regional concern: Region 23 Prairie Hardwood Transition.
[b] Species of Greatest Conservation Need (SGCN) for Wisconsin's Comprehensive Wildlife Conservation Plan.
[c] Partner's in Flight species of regional stewardship. Region 23 Prairie Hardwood Transition.
[d] Indicates remnant habitat that has remained in a similar state for at least 20 years.

Table 4
Median derived parameter estimates of probability of sample point occupancy, psi (Ψ), for six bird species of conservation concern and 15 species of least concern at 28 sample points located within barrens managed for Karner blue butterfly. The analysis evaluated four independent factors related to the management and restoration of barrens for the Karner blue butterfly including management method, treatment year, adjacent habitat and patch size of management areas. *R* values represent results of randomization tests (ANOSIM) on the differences in bird communities of each of the factor groupings. Parameter estimates with same or no letter do not differ significantly among factor groupings based on a Kruskal–Wallis test. A Dunn's test for multiple comparisons with a Bonferonni adjustment of z-score, $z > 2.80$, was used for factor groupings with more than two comparisons.

	Management method			Treatment year			Adjacent habitat		Patch size		
	($R = 0.21$, $p < 0.01$)			($R = 0.15$, $p = 0.05$)			($R = 0.32$, $p < 0.01$)		($R = 0.22$, $p < 0.01$)		
	Thinned ($n = 14$)	Burned ($n = 11$)	Maintained ($n = 3$)	1 to 10 ($n = 17$)	10 to 20 ($n = 8$)	>20 ($n = 3$)	Barrens ($n = 9$)	Woodland ($n = 19$)	Small ($n = 9$)	Medium ($n = 9$)	Large ($n = 10$)
Species of conservation concern											
Brown Thrasher[a,b]	0.26	0.67	0.26	0.26	0.71	0.26	0.67^{A}	0.26^{B}	0.60^{A}	0.26^{B}	0.48^{A}
Field Sparrow[a,b]	1	1	1	1	1	1	1	1	1	1	1
Grasshopper Sparrow[a,b]	0.32	0.34	0.09	0.36	0.34	0.09	0.35	0.34	0.50	0.15	0.34
Red-headed Woodpecker[a,b]	0.17	0.14	0.41	0.16	0.14	0.41	0.18	0.14	0.17	0.18	0.14
Rose-breasted Grosbeak[c]	0.67	0.52	0.63	0.72	0.35	0.63	0.45^{A}	0.72^{B}	0.67	0.63	0.57
Vesper Sparrow[a,b]	0.16^{A}	0.70^{B}	0.16^{A}	0.16	0.85	0.16	0.75^{A}	0.16^{B}	0.17	0.17	0.64
Species of least concern											
Baltimore Oriole	0.81	1	0.51	0.61	1	0.51	1^{A}	0.61^{B}	1^{A}	0.22^{B}	1^{A}
Blue-gray Gnatcatcher	0.84^{A}	0.25^{B}	0.24^{B}	0.73^{A}	0.19^{B}	0.24^{A}	0.19^{A}	0.68^{B}	0.66	0.67	0.37
Brown-headed Cowbird	1	1	1	1	1	1	1	1	1	1	1
Chipping Sparrow	1	0.72	0.73	1	0.72	0.73	0.72^{A}	1^{B}	1^{A}	1^{A}	0.64^{B}
Eastern Bluebird	0.84	0.75	0.57	0.69	0.75	0.57	0.75	0.68	0.75	0.68	0.75
Eastern Kingbird	0.15	0.21	0.17	0.16	0.56	0.17	0.56^{A}	0.16^{B}	0.15	0.17	0.19
Eastern Towhee	1^{A}	1^{A}	0.79^{B}	1	1	0.79	1	1	1	1	1
Eastern Wood-Pewee	1	0.60	1	0.71	0.38	1	0.29^{A}	1^{B}	0.16	1	0.66
Gray Catbird	0.14	0.41	0.14	0.18	0.40	0.14	0.41	0.14	0.54	0.14	0.41
Great-crested Flycatcher	0.56	0.49	0.56	0.72	0.40	0.56	0.32^{A}	0.56^{B}	0.40	0.56	0.49
House Wren	0.53	0.39	0.10	0.37	0.60	0.10	0.53	0.12	0.53	0.10	0.39
Indigo Bunting	1	1	1	1	1	1	1	1	1	1	1
Lark Sparrow	0.10	0.10	0.09	0.09	0.11	0.09	0.13^{A}	0.09^{B}	0.11	0.10	0.10
Mourning Dove	0.53	0.82	0.50	0.59	0.78	0.50	0.84	0.53	0.68	0.51	0.83
Orchard Oriole	0.08^{A}	0.41^{B}	0.11^{A}	0.11^{A}	0.55^{B}	0.11^{A}	0.42^{A}	0.11^{B}	0.09	0.11	0.28

[a] Partner's in Flight priority species of continental and regional concern: Region 23 Prairie Hardwood Transition.
[b] Species of Greatest Conservation Need (SGCN) for Wisconsin's Comprehensive Wildlife Conservation Plan.
[c] Partner's in Flight species of regional stewardship. Region 23 Prairie Hardwood Transition.

amount of shrub cover, similar to successional tree sprouts, influences avian community structure (Pidgeon et al., 2001; Sirami et al., 2009).

Therefore, depending on management goals, treatment of tree-sprout and potentially shrub encroachment in recently treated (e.g., thinned) barrens may be warranted to provide optimal conditions for the Karner blue (e.g., appropriate wild blue lupine cover) and also for birds that use oak barrens habitats. Davis et al. (2000) and others (e.g., Grundel and Pavlovic, 2007a) found that a range of barrens conditions (e.g., shrub and tree cover) provided suitable habitat for multiple bird species. Supporting this, we learned that Karner blue management creates habitat for species of conservation concern, such as the Field and Grasshopper Sparrow (*Ammodramus savannarum*), and other sparse canopy associating bird species. This is important, because we found there are indeed carry-over effects of Karner blue management on individual bird species, and thus Karner blue managers can achieve multiple conservation objectives within the guidelines of the butterfly management plan.

We found greater support for the hypothesis that avian community structure within Karner barrens was influenced by the adjacent habitat than by either management technique used to restore or manage Karner barrens, time since major restoration treatment, or patch size. Temple (1998) postulated that a given barrens (savanna) avian community is composed of a mix of sparse canopy species and woodland species. Thus birds such as Baltimore Oriole and Eastern Bluebird would occupy niches provided by the patch-level structural heterogeneity (e.g., habitat characteristics) of barrens. However, additional species from neighboring open grasslands such as the Grasshopper Sparrow or woodlands such as the Rose-breasted Grosbeak would also be expected, highlighting the influence of the adjacent habitat (or landscape context) on avian communities in savanna type habitats. This appears to be true not only in Midwestern oak savannas (Mabry et al., 2010) but similar patterns are found in California oak savanna (Sisk et al., 1997) as well, where the composition of surrounding habitat strongly influences avian community composition. Karner blue occupancy (e.g., patch colonization) is also influenced by the quality of the surrounding landscape matrix (Grundel and Pavlovic, 2007b) thus highlighting the importance of this variable for both bird community and Karner blue conservation. However landscape level measures do not seem to affect all Lepidoptera. In Colorado grassland habitats butterfly diversity was not predicted by landscape context and was more strongly related to patch-size and site-level quality (e.g., nectar and host-plant sources, Collinge et al., 2003).

Management, treatment year, and patch size were not as influential as adjacent habitat possibly because, as long as barrens habitat exists, regardless of how it was created, how long since the major treatment (i.e., time lags of vegetation succession), or the general patch-size, bird species will use it as breeding habitat (Au et al., 2008; King et al., 2011). However, we found that the neighboring vegetation structure contributed greatest to expected species occupancy patterns and overall differences in avian community structure. This conclusion supports the general descriptions of Dunning et al. (1992) who highlight the composition and arrangement of habitat types in a landscape largely influences wildlife community structure.

5. Conclusions

We found that habitat management for the Karner blue at Fort McCoy provides habitat for oak barrens birds. Further, we found the composition and structure of habitat adjacent to sites selected for restoration and management, and to a lesser extent, the management method used to treat Karner barrens, and the restoration patch-size affects the bird species composition. The first priority of Karner blue management is of course to create suitable conditions for the Karner blue butterfly. But within this goal there is the opportunity to provide breeding habitat for sparse canopy associated bird species, including some species of conservation concern. This is important because there are currently no management plans for bird species using oak barrens habitats in Wisconsin or neighboring states where Karner blues reside. By careful consideration of patch context and selection of sites for restoration that are adjacent to existing remnant barrens, the highest habitat benefit is achieved for oak barrens breeding birds, with no compromise to Karner blue habitat and populations.

Acknowledgments

We thank our field assistants, C. Rockwell, A. Nolan, B. Summers, H. Llanas, S. Grover, P. Kearns, and A. Derose-Wilson, for their tireless help in collecting the bird and habitat data. S. Vos provided valuable logistical field support. We are grateful for support from the Strategic Environmental Research and Development Program (SERDP) and Prairie Biotic Research, Inc.

References

Anderson, R.C., Bowles, M.L., 1999. Deep-soil savannas and barrens of the Midwestern United States. In: Anderson, R.C., Fralish, J.S., Baskin, J.M. (Eds.), Savannas, Barrens, and Rock Outcrop Communities of North America. Cambridge University Press, Cambridge, UK, pp. 155–170.

Au, L., Andersen, D.E., Davis, M., 2008. Patterns in bird community structure related to restoration of Minnesota dry oak savannas and across a prairie to oak woodland ecological gradient. Natural Areas Journal 28, 330–341.

Benton, N., Ripley, J.D., Powledge, F., (Eds.), 2008. Conserving Biodiversity on Military Lands: A Guide for Natural Resources Managers, 2008 ed. Arlington, Virginia: NatureServe. <http://www.dodbiodiversity.org> (accessed 01.08.11).

Beyer, H.L., 2004. Hawth's Analysis Tools for ArcGIS.

Blair, R.B., 1999. Birds and butterflies along an urban gradient: surrogate taxa for assessing biodiversity? Ecological Applications 9, 164–170.

Brawn, J.D., 2006. Effects of restoring oak savannas on bird communities and populations. Conservation Biology 20, 460–469.

Brawn, J.D., Robinson, S.K., Thompson III, F.R., 2001. The role of disturbance in the ecology and conservation of birds. Annual Reviews in Ecology and Systematics 32, 251–276.

Bray, J.R., 1960. The composition of savanna vegetation in Wisconsin. Ecology 41, 721–732.

Brudvig, L.A., Asbjornsen, H., 2007. Stand structure, composition, and regeneration dynamics following removal of encroaching woody vegetation from Midwestern oak savannas. Forest Ecology and Management 244, 112–121.

Caro, T.M., O'Doherty, G., 1999. On the use of surrogate species in conservation biology. Conservation Biology 13, 805–814.

Carr, M.R., 1997. PRIMER User Manual (Plymouth Routines in Multivariate Ecological Research). Plymouth Marine Laboratory, Plymouth, United Kingdom.

Clarke, K.R., Gorley, R.N., 2006. PRIMER v6: User Manual/Tutorial PRIMER-E. Plymouth, United Kingdom.

Collinge, S.K., Prudic, K.L., Oliver, J.C., 2003. Effects of local habitat characteristics and landscape context on grassland butterfly diversity. Conservation Biology 17, 178–187.

Curtis, J.T., 1959. The Vegetation of Wisconsin: An Ordination of Plant Communities. University of Wisconsin Press, Madison, Wisconsin.

Davis, M.A., Peterson, D.W., Reich, P.B., Crozier, M., Query, T., Mitchell, E., Huntington, J., Bazakas, P., 2000. Restoring savanna using fire: impact on the breeding bird community. Restoration Ecology 8, 30–40.

Dunn, O.J., 1964. Multiple comparisons using rank sums. Technometrics 6, 241–252.

Dunning Jr., J.B., Danielson, B.J., Pulliam, H.R., 1992. Ecological processes that affect populations in complex landscapes. Oikos 65, 169–175.

Eckstein, R., Moss, B., 1995. Oak and pine barrens communities. In: Addis, J., Blesser, C. (Eds.), Wisconsin's Biodiversity as A Management Issue: A Report to Department of Natural Resource managers. Wisconsin Department of Natural Resources, Madison, Wisconsin, pp. 98–113.

ESRI, Redlands, California, USA (Ed.), 2008. ArcGIS 9.3, ESRI, Redlands, California.

Fleishman, E., Betrus, C.J., Blair, R.B., 2003. Effects of spatial scale and taxonomic group on partitioning of butterfly and bird diversity in the Great Basin, USA. Landscape Ecology 18, 675–685.

Grundel, R., Pavlovic, N.B., 2007a. Distinctiveness, use, and value of Midwestern oak savannas and woodlands as avian habitats. Auk 124, 969–985.

Grundel, R., Pavlovic, N.B., 2007b. Resource availability, matrix quality, microclimate, and spatial pattern as predictors of patch use by the Karner blue butterfly. Biological Conservation 135, 135–144.

Grundel, R., Pavlovic, N.B., Sulzman, C.L., 1998. The effect of canopy cover and seasonal change on host plant quality for the endangered Karner blue butterfly (*Lycaeides melissa samuelis*). Oecologia 114, 243–250.

Grundel, R., Pavlovic, N.B., Sulzman, C.L., 2000. Nectar plant selection by the Karner blue butterfly (Lycaeides melissa samuelis) at the Indiana Dunes National Lakeshore. American Midland Naturalist 144, 1–10.

Hartung, S.C., Brawn, J.D., 2005. Effects of savanna restoration on the foraging ecology of insectivorous songbirds. The Condor 107, 879–888.

Heikens, L.A., Robertson, P.A., 1994. Barrens of the Midwest: a review of the literature. Castanea 59, 184–194.

Henderson, R., 1995. Oak savanna communities. In: Addis, J., Blesser, C. (Eds.), Wisconsin's Biodiversity As A Management Issue: A Report to Department of Natural Resource Managers. PUB RS 91595. Wisconsin Department of Natural Resources, Madison, Wisconsin, pp. 88–96.

Hines, J.E., 2006. PRESENCE Version 2.3. United States Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland.

Hintze, J., 2004. NCSS and PASS Number cruncher statistical systems. Kaysville, Utah.

Kerr, J.T., Sugar, A., Packer, L., 2000. Indicator taxa, rapid biodiversity assessment, and nestedness in an endangered ecosystem. Conservation Biology 14, 1726–1734.

King, R.S., 2003. Habitat management for the Karner blue butterfly (*Lycaeides melissa samuelis*): evaluating the short-term consequences. Ecological Restoration 21, 101–106.

King, R.S., Brashear, K.E., Reiman, M., 2007. Red-headed woodpecker nest-habitat thresholds in restored savannas. Journal of Wildlife Management 71, 30–35.

King, D.I., Schlossberg, S., Brooks, R.T., Akresh, M.E., 2011. Effects of fuel reduction on birds in pitch pine–scrub oak barrens of the United States. Forest Ecology and Management 261, 10–18.

Kleintjes, P.K., Sporrong, J.M., Raebel, C.A., Thon, S.F., 2003. Habitat type conservation and restoration for the Karner Blue Butterfly: a case study from Wisconsin. Ecological Restoration 21, 107–115.

Leach, M.K., Givnish, T.J., 1999. Gradients in the composition, structure, and diversity of remnant oak savannas in southern Wisconsin. Ecological Monographs 69, 353–374.

Leopold, A., 1933. Game Management. Scribners, New York.

Loyola, R.D., Kubota, U., Lewinsohn, T.M., 2007. Endemic vertebrates are the most effective surrogates for identifying conservation priorities among Brazilian ecoregions. Diversity and Distributions 13, 389–396.

Mabry, C.M., Brudvig, L.A., Atwell, R.C., 2010. The confluence of landscape context and site-level management in determining Midwestern savanna and woodland breeding bird communities. Forest Ecology and Management 260, 42–51.

MacKenzie, D.I., Nichols, J.D., Pollock, K.H., Royle, J.A., Bailey, L.L., Hines, J.E., 2006. Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence. Academic Press, San Diego, California.

Martin, T.E., Paine, C.R., Conway, C.J., Hochachka, W.M., Jenkins, W., 1997. BBIRD Field Protocol. Montana Cooperative Wildlife Research Unit, University of Montana, Missoula. <http://pica.Wru.Umt.edu/BBIRD/protocol/Protocol.Htm> (accessed 05.04.07).

McConkey, E.H., 1954. A systematic study of the North American lizards of the genus *Ophisaurus*. American Midland Naturalist 51, 133–171.

McCune, B., Grace, J.B., Urban, D.L., 2002. Analysis of Ecological Communities. MJM Software Design, Gleneden Beach, Oregon.

Minnesota Department of Natural Resources, 2006. Tomorrow's Habitat for The Wild and Rare: An Action Plan for Minnesota Wildlife, Comprehensive Wildlife Conservation Strategy. Division of Ecological Services, Minnesota Department of Natural Resources. St. Paul, Minnesota.

Mossman, M.J., Epstein, E., Hoffman, R.M., 1991. Birds of Wisconsin pine and oak barrens. Passenger Pigeon 53, 137–163.

New, T.R., 1997. Are Lepidoptera an effective 'umbrella group 'for biodiversity conservation? Journal of Insect Conservation 1, 5–12.

Nielsen, S., Kirschbaum, C., Haney, A., 2003. Restoration of Midwest oak barrens: structural manipulation or process-only? Conservation Ecology 7, 10.
Nuzzo, V.A., 1986. Extent and status of Midwest oak savanna: presettlement and 1985. Natural Areas Journal 6, 6–36.
Peterson, D.W., Reich, P.B., 2001. Prescribed fire in oak savanna: fire frequency effects on stand structure and dynamics. Ecological Applications 11, 914–927.
Pidgeon, A.M., Mathews, N.E., Benoit, R., Nordheim, E.V., 2001. Response of avian communities to historic habitat change in the northern Chihuahuan Desert. Conservation Biology 15, 1772–1789.
Pierce, N.E., Braby, M.F., Heath, A., Lohman, D.J., Mathew, J., Rand, D.B., Travassos, M.A., 2002. The ecology and evolution of ant association in the Lycaenidae (*Lepidoptera*). Annual Review of Entomology 47, 733–771.
Probst, J.R., Donner, D.M., Bocetti, C.I., Sjogren, S., 2003. Population increase in Kirtland's warbler and summer range expansion to Wisconsin and Michigan's Upper Peninsula, USA. Oryx 37, 365–373.
Ralph, C.J., Droege, S., Sauer, J.R., 1995. Managing and Monitoring Birds Using Point Counts: Standards and Applications. Monitoring Bird Populations by Point Counts. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-149, pp. 161–168.
Rich, T.D., Beardmore, C.J., Berlanga, H., Blancher, P.J., Bradstreet, M.S.W., Butcher, G.S., Demarest, D.W., Dunn, E.H., Hunter, W.C., Inigo-Elias, E.E., Kennedy, A.M., Martell, A.O., Panajabi, D.N., Pashley, K.V., Rosenberg, C.M., Rustary, C.M., Wendt, J.S., Will, T.C., 2004. Partners in Flight North American Landbird Conservation Plan. Cornell Lab of Ornithology. Ithaca, NY. Partners in Flight. (VERSION: March 2005). Cornell Lab of Ornithology, Ithaca, New York <http://www.partnersinflight.org/cont_plan/> (accessed 15.02.11).
Ritchie, M.E., Tilman, D., Knops, J.M.H., 1998. Herbivore effects on plant and nitrogen dynamics in oak savanna. Ecology 79, 165–177.
Sample, D.W., Mossman, M.J., 1997. Managing Habitat for Grassland Birds, A Guide for Wisconsin. Wisconsin Department of Natural Resources, Madison, Wisconsin.
Siemann, E., Haarstad, J., Tilman, D., 1997. Short-term and long-term effects of burning on oak savanna arthropods. American Midland Naturalist 137, 349–361.
Simberloff, D., 1998. Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? Biological Conservation 83, 247–257.
Sirami, C., Seymour, C., Midgley, G., Barnard, P., 2009. The impact of shrub encroachment on savanna bird diversity from local to regional scale. Global Ecology and Biogeography 15, 948–957.
Sisk, T.D., Haddad, N.M., Ehrlich, P.R., 1997. Bird assemblages in patchy woodlands: modeling the effects of edge and matrix habitats. Ecological Applications 7, 1170–1180.
Swengel, S.R., Swengel, A.B., 1999. Correlations in abundance of grassland songbirds and prairie butterflies. Biological Conservation 90, 1–11.
Temple, S.A., 1998. Surviving where ecosystems meet: ecotonal animal communities of Midwestern oak savannas and woodlands. Transactions of the Wisconsin Academy of Science, Arts and Letters 86, 207–222.
Thomson, J.R., Fleishman, E., Nally, R.M., Dobkin, D.S., 2007. Comparison of predictor sets for species richness and the number of rare species of butterflies and birds. Journal of Biogeography 34, 90–101.
US Fish and Wildlife Service, 1997. Karner Blue Butterfly (*Lycaeides melissa samuelis*) Working Draft Recovery Plan. Fort Snelling, Minnesota.
US Fish and Wildlife Service, 2003. Final Recovery Plan for the Karner Blue Butterfly (*Lycaeides melissa samuelis*). Fort Snelling, Minnesota.
Walters, C.J., Hilborn, R., 1978. Ecological optimization and adaptive management. Annual Review of Ecology, Evolution, and Systematics 9, 157–188.
Wilder, T.T., 2006. Fort McCoy Karner blue butterfly endangered species management plan. Fort McCoy, Wisconsin.
Wilhere, G.F., 2002. Adaptive management in habitat conservation plans. Conservation Biology 16, 20–29.
Wisconsin Bird Conservation Initiative, 2011. <http://www.wisconsinbirds.org/> (accessed 13.02.11).
Wisconsin Department of Natural Resources, 2009. Karner Blue Butterfly Habitat Conservation Plan. Madison, Wisconsin.
Wolf, J., 2004. A 200-year fire history in a remnant oak savanna in southeastern Wisconsin. The American Midland Naturalist 152, 201–213.
Zar, J.H., 1999. Biostatistical Analysis, fourth ed. Prentice-Hall Englewood Cliffs, New Jersey.