Chapter 12

Breeding Bird Communities

Vanessa L. Artman[1] and Randy Dettmers[2]

[1]Department of Biology, DePauw University, Greencastle, Indiana
[2]U.S. Fish and Wildlife Service, Hadley, Massachusetts

Abstract

Prescribed burning is being applied on an experimental basis to restore and maintain mixed-oak communities in southern Ohio. This chapter describes baseline conditions for the breeding bird community prior to prescribed burning. We surveyed breeding bird populations at four study areas using the territory-mapping method. We observed 35 bird species during the surveys. The red-eyed vireo (*Vireo olivaceus*), ovenbird (*Seiurus aurocapillus*), wood thrush (*Hylocichla mustelina*), Acadian flycatcher (*Empidonax virescens*), and scarlet tanager (*Piranga olivacea*) were the most abundant, followed by the eastern wood-pewee (*Contopus virens*), hooded warbler (*Wilsonia citrina*), worm-eating warbler (*Helmitheros vermivorus*), and cerulean warbler (*Dendroica cerulea*). Densities of three bird species, the cerulean warbler, great crested flycatcher (*Myiarchus crinitus*), and eastern phoebe (*Sayornis phoebe*), varied among study areas. We compared our results to other surveys conducted in the Eastern United States and found that the composition of breeding bird communities was similar between mixed-oak and beech-maple forest types. We monitored 239 nests of 14 bird species to establish baseline levels of breeding productivity and to describe nest site selection. Predation of nest contents was the primary cause of nesting failure for most of the bird species monitored. Nest predation rates were highest for the ovenbird and wood thrush and lowest for the worm-eating warbler and Acadian flycatcher. Parasitism by brown-headed cowbirds (*Molothrus ater*) was a second factor limiting breeding productivity. Cowbird parasitism rates varied among host species but were comparable to rates reported from other studies. The overall nesting success rate for the wood thrush was lower than observed in other continuously forested landscapes in the Eastern United States, but this low rate was offset by the absence of cowbird parasitism for this bird species.

Introduction

Many species of forest birds in the eastern United States have declined in population (Sauer et al. 1997). The reasons for the declines are unclear, but possible explanations include loss of habitat, changes in habitat conditions, and increased fragmentation of remaining habitat (Finch 1991; Rappole and DeGraaf 1996). These changes underscore the need to monitor forest bird populations, document population trends, assess how these trends may be related to forest management activities, and identify habitat features that are important for maintaining population levels.

This chapter provides a general description of the breeding bird community inhabiting oak (*Quercus*)-dominated forests in southern Ohio. Oak-dominated forests are the most extensive forest type in the eastern United States (Powell et al. 1993), but forest inventories indicate that the proportion of forests dominated by oaks is declining (Griffith et al. 1993), as oaks are gradually being replaced by maples (*Acer* spp.) and beech (*Fagus grandifolia*). Prescribed burning is being applied on an experimental basis to assess its effectiveness in restoring and maintaining oak-dominated forests in the region. Effects of prescribed burning on various ecosystem components, including the breeding bird community, are being assessed by a long-term interdisciplinary research project (Chapter 1).

Many studies have shown changes in species composition or abundance of breeding bird communities in response to forest management practices (Thompson et al. 1996), including prescribed burning (Wilson et al. 1995; Salveter et al. 1996). Different bird species require specific structural features within the forest, such as large trees, dense understory vegetation, or thick leaf litter. These features provide critical nest sites or suitable foraging

areas. Forest management practices, such as prescribed burning, are likely to change the availability of these features and thus affect the community of forest birds.

Surveying bird populations is a standard procedure for describing and monitoring bird communities. Monitoring nesting productivity has become an additional standard approach to supplement surveys (Martin et al. 1997). Observations of active nests provide an indication of population health by assessing whether breeding productivity is sufficient to maintain existing populations or is so low that populations can be maintained only by immigration of individuals from surrounding areas (Van Horne 1983; Pulliam 1988). Nest predation is one of the primary factors affecting breeding productivity of forest birds. Selection of nest sites is likely to be nonrandom, based in part on the vulnerability of different sites to nest predators (Martin 1992). Identifying specific habitat features that directly affect reproductive success and assessing how the availability of these habitat features may change have become critical aspects of management plans that address conservation of breeding bird populations (Martin 1992). Thus, our goals in describing the baseline forest bird community were to: (1) estimate breeding bird population levels, (2) monitor nests of different bird species to estimate breeding productivity levels, (3) describe nest site selection and identify factors potentially influencing the likelihood of nesting success, and (4) compare our results to other published surveys to identify potential factors influencing the composition and breeding productivity of forest bird communities on a regional basis.

Methods

Study Areas and Experimental Design

The study areas and experimental design are described in detail in Chapter 1. Here a brief overview is provided. The four 75-90 ha study areas are located in Vinton County (Arch Rock and Watch Rock) and Lawrence County (Young's Branch and Bluegrass Ridge). The study areas are within in the Southern Unglaciated Allegheny Plateau, which is characterized by high hills, sharp ridges, and narrow valleys. Sandstones and shales are principle bedrocks. Forests are oak-dominated and the current overstory originated in the late-1800s, after the cessation of clearcutting for the charcoal iron industry. In each study area, three prescribed fire treatments were established, a control unit (CONT), an infrequent burn unit (INFR), and a frequent burn unit (FREQ).

Breeding Bird Populations

We used the territory-mapping method to estimate bird population densities (Robbins 1970). Each treatment unit was visited at least six times between mid-May and late June 1995. During each survey, locations of birds seen or heard were recorded on topographic maps. These observations were transferred to composite maps for each bird species and territories were delineated based on clusters of observations. To estimate bird densities, we counted the number of territories or bird pairs within each treatment unit and extrapolated to the number of territories per 40 ha. Densities were estimated only for bird species that occurred in discrete nonoverlapping territories smaller than the treatment units. Bird species were categorized by nest site and foraging site based on Ehrlich et al. (1988). Nest sites included ground, low shrub (less than 1 m), midstory (1 to 10 m), canopy (greater than 10 m), and rock. Foraging sites included ground, low shrub (less than 1 m), midstory (1 to 10 m), canopy (greater than 10 m), bole, and aerial. A one-way analysis of variance (ANOVA) was used to test for differences in bird densities (by species, nest site, foraging site, and total) among treatment units (Zar 1984).

We used IMI categories to describe the association of different bird species with moisture gradients. The IMI is based on solar radiation exposure, flow accumulation, soil water-holding capacity, and landscape curvature (Chapter 3). Three IMI categories are defined based on a continuum of values: xeric (IMI score less than 35), intermediate (35-50), and mesic (greater than 50). We assigned IMI categories to individual bird territories, and ran chi-square tests to compare observed and expected distributions of bird territories among IMI categories (Zar 1984). Expected distributions were calculated according to the existing composition of the four study areas combined (31 percent xeric, 40 percent intermediate, 29 percent mesic; Chapter 3).

To assess how typical the forest bird community observed at our study areas was relative to the general region, we compared our results with surveys conducted in deciduous forest habitat at 34 other sites in the Eastern United States. These survey results were compiled from primary literature and from a database of Breeding Bird Censuses compiled by the USGS Biological Resources Division (http://www.mp1-pwrc.usgs.gov/birds/ bbc.html). These surveys were conducted in mature forest habitat dominated by oak-hickory, beech-maple, or oak-pine (*Pinus* spp.). We converted survey results from densities or detection rates to percent composition by bird species within each site. We used detrended correspondence analysis (DCA) to compare the composition of the bird communities among the various sites (PC-ORD Version 3.05; McCune and Mefford 1997). DCA is an ordination technique that is appropriate for analyzing a sample-by-species abundance matrix (Gauch 1982). The result is a series of two-dimensional scores for each sample,

indicating similarities in overall species composition (Gauch 1982).

Nesting Success and Nest Site Selection

To assess levels of breeding productivity, we searched for and monitored active nests in each treatment unit between mid-May and late-July following standard protocol (Martin et al. 1997). Each treatment unit was marked with a 50-m grid of flagging to help relocate nests. Active nests were checked every 3 to 5 days to monitor their contents and determine their fate. We recorded fate as successful (nests that fledged at least one host young) or failed (nests that fledged no host young). We classified failed nests as depredated (nest, eggs, or nestlings disappeared), abandoned (eggs or nestlings left unattended in nest), or parasitized by brown-headed cowbirds (nest abandoned by host parents due to parasitism, or only cowbirds fledged successfully from nest).

Nesting success rates were estimated using the Mayfield method (Mayfield 1975), which calculates the daily nest survival rate (DSR), as follows:

$$DSR = 1 - \frac{\#\text{ of failed nests}}{\#\text{ of observation days}}$$

Observation days represent the pooled number of days that all active nests were observed, beginning with the first day of egg laying or the day an active nest was found, and ending with the estimated day of fledging or failure. The DSR estimates the probability that a given nest will survive on any given day during the breeding season, and is assumed to be constant throughout the nesting cycle. The overall nesting success rate for each bird species was calculated as DSR^x where x = total number of days of a complete nesting cycle based on estimates reported by Ehrlich et al. (1988). The overall nesting success rate estimates the probability that a given nest will survive an entire nesting cycle, from egg laying to fledging. The Mayfield method is preferred for estimating nesting success rates because it corrects for the potential bias associated with the greater likelihood of finding successful nests because they are active for longer periods than unsuccessful nests.

Nest site characteristics were measured at each nest following standard protocol (Martin et al. 1997). We measured nest height, nest substrate height, and nest substrate d.b.h. (diameter at breast height, 1.37 m above the ground). For ground-nesting birds, the nest substrate was defined as the closest plant stem within 30 cm of the nest; if no stems were within 30 cm, the nest was designated as "in open." The nest substrate d.b.h. was recorded as zero if the nest substrate was less than 1.37 m in height or if the substrate was rock. "Side cover" was estimated as the average percentage concealment of each nest at nest-height level from a height of 1 m from four cardinal directions (N, E, S, W). "Overhead cover" was estimated as the percentage concealment from 1 m above the nest.

Because the nest site variables were likely to be intercorrelated, we ran a principal components analysis (PCA) to reduce the dimensionality of the data set to a smaller set of uncorrelated variables that accounted for a large proportion of the variation in the original data set. Percentage variables were arcsine square-root transformed and other variables were square-root transformed prior to analysis to approximate a normal distribution (Zar 1984). The PCA was run on the transformed variables using the factor analysis procedure in SPSS (SPSS 9.0), and factor matrices were rotated with the varimax option. Differences in principal components scores among bird species and among nest fates (successful versus depredated and parasitized versus unparasitized) were assessed using one-way ANOVAs with post-hoc Tukey multiple comparisons (Zar 1984).

Results

Breeding Bird Densities

Densities of 29 breeding bird species were estimated based on the territory-mapping surveys (Table 1). The total population density per unit averaged 201.4 ± 9.0 pairs per 40 ha. Ovenbirds and red-eyed vireos were the most abundant species, with densities approaching 40 pairs per 40 ha (Table 1). Acadian flycatchers, scarlet tanagers, and wood thrushes were also common, with densities ranging from 12 to 26 pairs per 40 ha. Cerulean warblers, eastern wood-pewees, hooded warblers, and worm-eating warblers were less common, with densities of 6 to 9 pairs per 40 ha. Uncommon species included the indigo bunting, Kentucky warbler, and northern cardinal, each with densities of less than 1 pair per 40 ha.

Midstory-nesting birds were the most abundant of the nest site groups (Fig. 1a), represented primarily by the Acadian flycatcher, red-eyed vireo, and wood thrush. Ground-foraging birds were the most abundant of the foraging site groups (Fig. 1b), represented primarily by the ovenbird and wood thrush.

There were no significant differences in densities of individual bird species, densities of nest site groups or foraging site groups, or total densities among the three treatment units ($F_{2,9} < 5.7$, $p > 0.05$). Densities of several bird species varied by study area. The cerulean warbler was more common at AR and WR (12 and 15 pairs

Table 1.—Population densities (pairs per 40 ha), distributions of bird territories by integrated moisture index (IMI), and status of breeding bird species in mixed-oak forests, southern Ohio, 1995.

Species by nest site	Foraging site[a]	Mean Density (SE)	Proportion of territories by IMI[b] xeric	inter-mediate	mesic		Trends[c] Ohio	US	Area sensitive
Ground									
Black-and-white warbler (*Mniotilta varia*)	B	3.3 (0.8)	0.37	0.31	0.31		0	-	yes
Kentucky warbler (*Oporornis formosus*)	LS	0.4 (0.2)	0.24	0.07	0.69		0	-	yes
Louisiana waterthrush (*Seiurus motacilla*)	G	0.4 (0.3)	0	0	1.00	**	0	0	yes
Ovenbird (*Seiurus aurocapillus*)	G	38.9 (0.9)	0.34	0.39	0.27		0	+	yes
Wild turkey (*Meleagris gallopavo*)	G	+[e]	-	-	-		-	0	
Worm-eating warbler (*Helmitheros vermivorus*)	LS	8.0 (1.0)	0.16	0.35	0.27	***	0	0	yes
Low shrub									
Hooded warbler (*Wilsonia citrina)*	LS	7.2 (0.8)	0.40	0.44	0.17		0	0	
Indigo bunting (*Passerina cyanea*)	LS	0.1 (0.1)	0	0.50	0.50		-	-	
Midstory									
Acadian flycatcher (*Empidonax virescens*)	A	12.4 (1.4)	0.04	0.26	0.70	***	0	0	yes
American redstart (*Setophaga ruticilla*)	M	1.3 (0.7)	0.00	0.06	0.94	***	0	0	
American robin (*Turdus migratorius*)	G	0.0 (0.0)[f]	1.00	0	0		+	+	
Northern cardinal (*Cardinalis cardinalis*)	M	0.9 (0.4)	0.39	0.22	0.39		0	0	
Red-eyed vireo (*Vireo olivaceus*)	M	39.1 (2.0)	0.32	0.41	0.28		0	+	yes
Wood thrush (*Hylocichla mustelina*)	G	26.2 (2.0)	0.28	0.40	0.32		0	-	yes
Yellow-billed cuckoo (*Coccyzus americanus*)	M	2.4 (0.3)	0.26	0.50	0.24		-	-	yes
Canopy									
American crow (*Corvus brachyrhynchos*)	C	+	-	-	-		0	+	yes
Blue jay (*Cyanocitta cristata*)	C	+	-	-	-		+	-	
Blue-gray gnatcatcher (*Polioptila caerulea*)	C	3.6 (0.4)	0.39	0.35	0.26		0	0	yes
Cerulean warbler (*Dendroica cerulea*)	C	8.9 (2.2)	0.24	0.37	0.38		-	-	yes
Eastern wood-pewee (*Dendroica cerulea*)	A	6.0 (0.8)	0.50	0.31	0.19	*	-	-	yes

Table 1. cont.

Species by nest site	Foraging site[a]	Mean Density (SE)	Proportion of territories by IMI[b] xeric	inter-mediate	mesic		Trends[c] Ohio	US	Area sensitive
Ruby-throated hummingbird (*Archilochus colubris*)	C	+	-	-	-		+	+	
Scarlet tanager (*Piranga olivacea*)	C	12.2 (0.6)	0.31	0.38	0.31		0	0	yes
Summer tanager (*Piranga flava*)	C	0.5 (0.3)	0.76	0.24	0		0	0	yes
Yellow-throated vireo (*Vireo flavifrons*)	C	3.9 (0.6)	0.39	0.38	0.23		0	+	yes
Cavity									
Carolina chickadee (*Poecile carolinensis*)	C	1.4 (0.4)	0.24	0.44	0.32		0	-	
Downy woodpecker (*Picoides pubescens*)	B	1.8 (0.3)	0.34	0.36	0.30		0	-	
Great crested flycatcher (*Myiarchus crinitus*)	A	1.0 (0.4)	0.32	0.32	0.36		-	0	yes
Hairy woodpecker (*Picoides villosus*)	B	1.1 (0.3)	0.33	0.39	0.28		-	0	yes
Northern flicker (*Colaptes auratus*)	B	0.5 (0.3)	0.25	0.50	0.25		-	-	
Pileated woodpecker (*Dryocopus pileatus*)	B	+	-	-	-		0	+	yes
Red-bellied woodpecker (*Melanerpes erythrocephalus)*	B	4.4 (0.4)	0.34	0.47	0.19		0	+	yes
Tufted titmouse (*Baeolophus bicolor*)	C	5.9 (0.6)	0.27	0.39	0.34		0	+	yes
White-breasted nuthatch (*Sitta carolinensis*)	B	6.9 (0.7)	0.30	0.40	0.30		0	+	yes
Rock									
Eastern phoebe (*Sayornis phoebe*)	A	2.5 (0.7)	0.15	0.24	0.62	**	-	+	
Other									
Brown-headed cowbird (*Molothrus ater*)	G	+	-	-	-		-	-	

[a] Foraging sites: A = aerial; B = bole; C =canopy; G = ground; LS = low shrub; M = midstory.

[b] Chi-square tests used to compare observed and expected distributions of territories among IMI categories. Expected values calculated based on composition of four combined study areas: 31 percent xeric, 40 percent intermediate, 29 percent mesic. Asterisks represent significant differences between observed and expected values: * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

[c] Population trends from Breeding Bird Surveys, 1966-1996 from Sauer *et al.* (1997). + = population significantly increased during time period ($p < 0.05$); - = population significantly declined during time period ($p < 0.05$); 0 = no significant change in population detected during time period.

[d] Area-sensitive = abundance of bird species increases as size of forest tract increases; designations from Robbins *et al.* (1989).

[e] + = bird species present in study area but densities not estimated because species was rarely observed (e.g. wild turkey), did not occur in well-defined territories (e.g. blue jay), or territory size was larger than treatment unit (e.g. pileated woodpecker).

[f] Baseline densities of American robins = 0.04 (0.03).

Table 2.—Relative abundance of forest bird species by geographic location. 0 = bird species not present; 1 = bird species comprised less than 1 percent of total breeding bird population; 2 = 1-4 percent of population; 3 = 5-9 percent of population; 4 = 10-19 percent of population. "Southern Ohio" includes data from Table 1 and data from other study areas (see footnote). Additional bird species are listed here but not in Table 1 to show differences in community composition by geographic location.

Bird species by nest site	Southeast U.S.	southern Ohio	northern Ohio	Northeast U.S.
Ground				
Black-and-white warbler	2	2	0	2
Kentucky warbler	1	2	1	1
Louisiana waterthrush	1	2	2	1
Ovenbird	3	3	4	4
Veery	0	0	1	2
Worm-eating warbler	2	2	0	2
Low shrub				
Hooded warbler	2	2	2	1
Indigo bunting	2	2	1	1
Rufous-sided towhee (*Pipilo erythrophthalmus*)	2	2	1	1
Midstory				
Acadian flycatcher	2	3	3	1
American redstart	1	1	4	3
American robin	1	1	1	1
northern cardinal	2	2	2	1
red-eyed vireo	4	4	4	4
wood thrush	3	3	3	2
Canopy				
Black-throated green warbler (*Dendroica virens*)	1	1	1	2
Blue-gray gnatcatcher	2	2	1	2
Cerulean warbler	1	3	3	0
Eastern wood-pewee	2	2	3	2
Pine warbler	4	1	0	0
Scarlet tanager	2	2	2	3
Summer tanager	2	2	0	0
Yellow-throated vireo	2	2	2	2
Cavity				
Black-capped chickadee	1	0	2	2
Carolina chickadee	3	2	0	0
Great crested flycatcher	2	2	2	2
Red-bellied woodpecker	1	2	1	0
Tufted titmouse	2	2	3	2
White-breasted nuthatch	2	2	2	2

References:

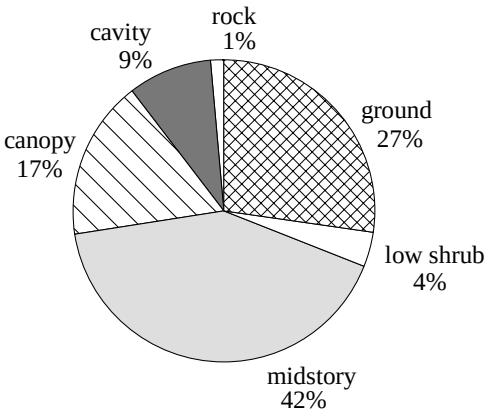
Southeast (Arkansas, Georgia, Tennessee, Virginia, West Virginia): Kendeigh 1944, Johnston and Odum 1956, Shugart and James 1973, Kendeigh and Fawver 1981, Cooper *et al.* 1990, Wilson *et al.* 1995, Salveter *et al.* 1996, Rodewald and Smith 1998.

Southern Ohio: this study, Breeding Bird Census database (surveys conducted in Adams, Hamilton, Hocking, Preble, and Scioto counties).

Northern Ohio: Williams 1936, Kendeigh 1944, Horn and Benninger-Truax 1997, Breeding Bird Census database (surveys conducted in Cuyahoga and Mahoning counties).

Northeast (Massachusetts, New York, Pennsylvania): Kendeigh 1944, Kendeigh 1946, Webb *et al.* 1977, Holmes *et al.* 1986, Rollfinke and Yahner 1990, DeGraaf *et al.* 1991, Yahner 1993.

a.) By nest site



b.) By foraging site

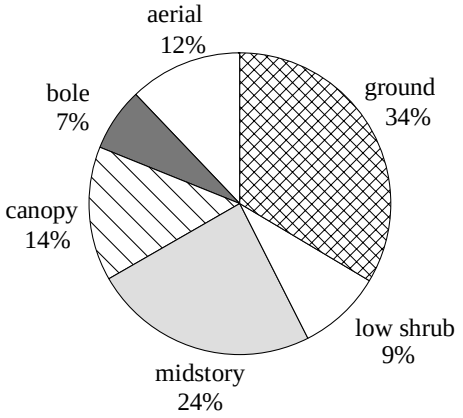


Figure 1.—Composition of breeding bird communities (percent of total density) in southern Ohio mixed-oak forests by nest site and foraging site.

respectively, per 40 ha), less common at YB (7 pairs per 40 ha), and uncommon at BR (1 pair per 40 ha). Eastern phoebes were more common at AR and YB (4 and 5 pairs respectively, per 40 ha) than at WR and BR (1 pair per 40 ha). The great crested flycatcher was observed more frequently at WR (4 pairs per 40 ha) than the other study areas (less than 1 pair per 40 ha).

Territories of six bird species were nonrandomly distributed with respect to IMI class (Table 1). The Louisiana waterthrush, worm-eating warbler, Acadian flycatcher, American redstart, and eastern phoebe occurred more frequently in mesic than xeric areas. The eastern wood-pewee occurred more frequently in xeric than mesic areas.

The breeding bird communities observed at our study areas were similar to those observed in eastern deciduous forests at other sites. Ovenbirds, red-eyed vireos, and wood thrushes were consistently the most abundant species, regardless of location (Table 2). Other common species present at most sites included the Acadian flycatcher, eastern wood-pewee, hooded warbler, scarlet tanager, and yellow-throated vireo. Cerulean warblers were observed most frequently in Ohio, in both mixed-oak and beech-maple forest types.

The DCA separated the sites primarily along a first axis which accounted for 61.3 percent of the summed eigenvalues of the ordination. The second axis accounted for an additional 28.0 percent of the summed eigenvalues. The bird communities in all but one oak-pine site were clearly separated, compositionally, from sites dominated by oak-hickory or beech-maple (Fig. 2a). By contrast, composition was similar among sites dominated by oak-hickory and beech-maple, as shown by the central overlap of sites in Fig. 2a. Also, DCA indicated that the composition of bird communities in southern Ohio differed from communities in northern Ohio (Fig. 2b). Bird communities in southern Ohio were more similar to communities in the Southeastern United States because of the presence of species with more southern distributions, including the Carolina chickadee and summer tanager (Table 2). Conversely, bird communities in northern Ohio were more similar to communities in the Northeastern United States because of the presence or higher abundance of species with more northern distributions, including the American redstart, black-capped chickadee, and veery.

Nesting Success

We monitored 239 active nests of 14 bird species, resulting in 2,768 observation days. Daily nest mortality due to predation accounted for the majority of nest failures for most species. Predation rates were highest for the ovenbird and wood thrush and lowest for the worm-eating warbler and Acadian flycatcher (Table 3).

Brown-headed cowbirds parasitized 23 nests. Nest failures due to parasitism occurred most frequently for the hooded warbler and worm-eating warbler (Table 3). These failures occurred either because the host parents abandoned the parasitized nest or because only cowbirds fledged from the nest. Parasitism rates varied among host species with highest rates observed for the hooded warbler and scarlet tanager, and intermediate rates for the worm-eating warbler, red-eyed vireo, and ovenbird. Only one Acadian flycatcher nest was parasitized and no eastern phoebe or wood thrush nests were parasitized.

Table 3.—Fate of active nests in 1995.

Bird species by nest site	Number of nests	Daily nest mortality rates by cause of failure			Daily survival rate (SE)	Overall survival rate	Cowbird parasitism rate[c]
		Predation	Other[a]	Parasitism[b]			
Ground							
Ovenbird	27	0.053	0.004	0	0.944 (0.01)	24.8	14.8
Worm-eating warbler	12	0.023	0	0.023	0.954 (0.02)	31.9	33.3
Low shrub							
Hooded warbler	9	0.032	0	0.021	0.947 (0.02)	28.4	66.7
Midstory							
Acadian flycatcher	52	0.027	0.001	0	0.972 (0.01)	44.5	1.9
Red-eyed vireo	19	0.047	0.047	0.005	0.949 (0.02)	26.8	15.8
Wood thrush	89	0.052	0	0	0.948 (0.01)	22.6	0
Other							
Eastern phoebe	15	0.030	0	0	0.970 (0.01)	33.4	0
Scarlet tanager	6	0.048	0.012	0	0.940 (0.03)	20.1	50.0
other[d]	10	-	-	-	-	-	20.0

[a] Other = nest failure due to abandonment (after eggs laid), adult mortality, or weather.
[b] Parasitism = nest failure due to brown-headed cowbird parasitism, either because host parents abandoned nest after parasitism or because only cowbirds fledged from nest and host's offspring did not survive.
[c] Cowbird parasitism rate = percentage of all nests parasitized by cowbirds, regardless of fate.
[d]Other = species with less than 5 monitored nests: American redstart (1 nest), eastern wood-pewee (1 nest), Kentucky warbler (1 nest), northern cardinal (2 nests), ruby-throated hummingbird (1 nest), yellow-billed cuckoo (4 nests).

Nest Site Selection

The principal components analysis produced two factors, PC1 and PC2, that accounted for 84 percent of the variation in the five original nest site variables (Table 4). PC1 was positively correlated with nest height, nest substrate height, and nest substrate d.b.h. PC2 was positively correlated with overhead cover and side cover.

PC1 and PC2 scores differed significantly among bird species (PC1: $F_{6, 165} = 102.3$, $p < 0.001$; PC2: $F_{6, 165} = 10.1$, $p < 0.001$). PC1 scores were arrayed along a continuum of nest heights and nest substrate sizes, from the ground-nesting ovenbirds and worm-eating warblers to the upper midstory-nesting Acadian flycatcher (Fig. 3). Acadian flycatchers consistently placed their nests higher off the ground, and in taller and larger diameter trees than other bird species, including the red-eyed vireo and wood thrush (Table 5). PC1 scores differed among species as follows: Acadian flycatcher > (red-eyed vireo = wood thrush) > hooded warbler > (ovenbird = worm-eating warbler) (Tukey $p < 0.05$). PC1 scores for eastern phoebe nests were intermediate, similar to PC1 scores for red-eyed vireo, wood thrush, and hooded warbler nests.

The eastern phoebe had higher PC2 scores than all other bird species except the ovenbird (Tukey $p < 0.05$; Figure 3). Overhead cover estimates were higher for the eastern phoebe than other bird species (Table 5); their nests, placed on cave-like rock faces, were concealed from above and from three of four sides by rounded rock walls. Side cover estimates were higher for the ovenbird, worm-eating warbler, and eastern phoebe than other bird species (Table 5).

PC scores did not differ between successful and depredated nests for the Acadian flycatcher, eastern phoebe, hooded warbler, ovenbird, red-eyed vireo, wood thrush, or worm-eating warbler (Table 6). PC1 scores were lower at parasitized than unparasitized nests for the hooded warbler, red-eyed vireo, and worm-eating warbler (Table 7), indicating that parasitized nests were placed at lower heights, in smaller diameter substrates, or in more open areas. PC2 scores were lower at parasitized than unparasitized nests for the red-eyed vireo, indicating that parasitized nests were less concealed by surrounding vegetation than unparasitized nests.

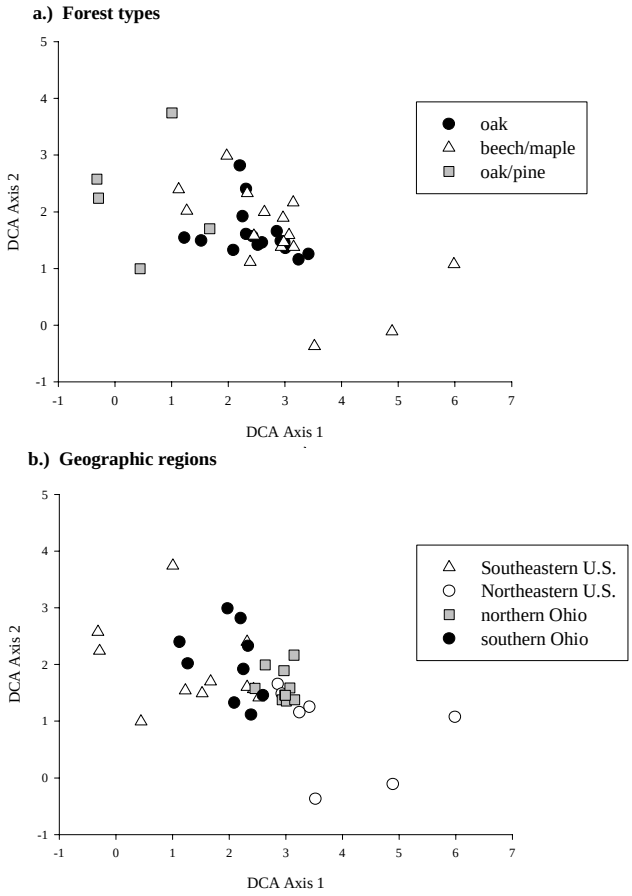


Figure 2.—Detrended correspondence analysis of breeding bird communities by forest type and geographic region.

Table 4.—results of principal components analysis nest site characteristics for the ovenbird, worm-eating warbler, hooded warbler, Acadian flycatcher, red-eyed vireo, wood thrush, and eastern phoebe.

	PC1	PC2
Total variance accounted for	56.4 %	27.4 %
Eigenvalue	2.823	1.374
Eigenvectors		
Nest height	0.937	-0.132
Nest substrate height	0.947	-0.041
Nest substrate DBH	0.884	-0.272
Overhead cover	-0.006	0.941
Side cover	-0.516	0.629

Discussion

Breeding Bird Community

Our surveys show that mixed-oak forests in southern Ohio provide habitat for at least 35 species of breeding birds. Species composition did not differ among the treatment units prior to the re-introduction of fire. Densities of three bird species, the cerulean warbler, eastern phoebe, and great crested flycatcher, varied among the four study areas. The cerulean warbler was more common at the Vinton County study areas (AR and WR) than the Lawrence County study areas (YB and BR). Cerulean warblers require mature forests of broadleaved deciduous trees, but they may occur in wet bottomlands, along mesic slopes, or upland ridges. Densities vary locally because individual territories are often clustered within suitable habitat; this clustering may facilitate social interactions between neighboring pairs, and is apparently unrelated to fine-scale variation in habitat conditions (Vanderah and Robinson 1995). By contrast, eastern phoebes require vertical rock faces for nesting, and densities of this species are likely to vary depending on the availability of these nest substrates. Great crested flycatchers nest in cavities. Densities of other cavity-nesting birds did not differ among the study areas, so availability of cavities probably was not a limiting factor; other factors potentially affecting population densities of the great crested flycatcher are unknown.

As described by Dettmers and Bart (1999), the abundance of some bird species varies across topographic gradients. Ovenbirds, red-eyed vireos, and wood thrushes were widely distributed throughout the treatment units, occurring on hillsides, ridgetops, and along streams. Eastern wood-pewees tended to occur primarily on dry hillsides and ridgetops. Acadian flycatchers, American redstarts, eastern phoebes, Louisiana waterthrushes, and worm-eating warblers were restricted primarily to stream bottoms and ravines.

Regional Status of Breeding Bird Species

Many of the species occurring at our study areas are declining in abundance nationwide. Twelve bird species, including 7 neotropical migrants, have experienced significant population declines in the United States during the last 30 years, as indicated by Breeding Bird Survey results (Sauer et al. 1997). Six of these twelve species (black-and-white warbler, blue jay, Carolina chickadee, downy woodpecker, Kentucky warbler, wood thrush) are declining in most of their range but are stable or increasing in Ohio. However, populations of the other six species (brown-headed cowbird, cerulean warbler, eastern wood-pewee, indigo bunting, northern flicker, and yellow-billed cuckoo) are declining both in Ohio and in other portions of their range in the United States.

Many bird species inhabiting our study areas are designated as area-sensitive, indicating a dependence on

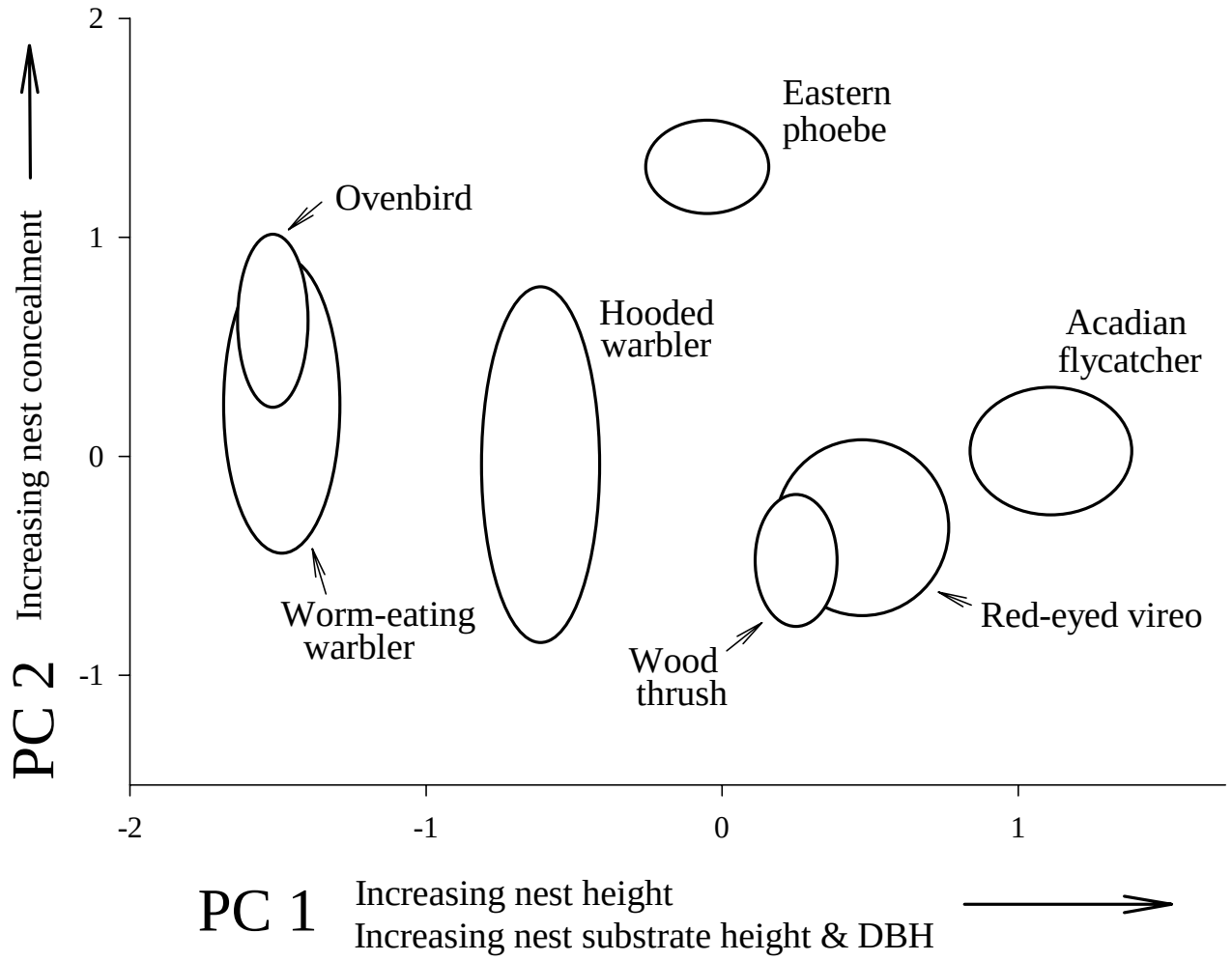


Figure 3.—Principal component analysis scores for nests in mixed-oak forests, southern Ohio.

large forest tracts and/or a sensitivity to forest fragmentation (Robbins et al. 1989). The extensive forest land in the Unglaciated Allegheny Plateau has been identified as an important area for providing large blocks of habitat that are likely to maintain populations of area-sensitive and declining species (Rosenberg and Wells 1995). Landscapes that are predominantly forested, such as those encompassing our study areas, appear to provide important habitat for three bird species in particular: the cerulean warbler, eastern wood-pewee, and wood thrush. These three species are common at our study areas, require mature forest habitat, and have shown population declines at both the regional and national level.

Importance of Oaks

Although forested landscapes are important for a number of bird species, the forest composition may be less critical. We found no difference in the species composition of breeding bird communities between mixed-oak and beech-maple forest types. Our analysis did not address differences in population levels because there was substantial variation in density estimates among the reported survey results. However, other studies have shown that bird population densities (for all species combined) were lower in mixed-oak forests than in mesic hardwood or beech-maple forests (Udvardy 1957, Probst 1979), although the reasons for these differences have not been investigated.

Mixed-oak forests are frequently identified as important wildlife habitat because acorns represent a valuable and energy-rich food resource, particularly during the non-breeding season (Healy et al. 1997). Our research focused specifically on the breeding bird community; only one-third of the species in this community are present during the non-breeding season and only two species (wild turkey and blue jay) regularly consume acorns. Bird species have developed a high degree of habitat selectivity, but the selectivity of birds inhabiting eastern deciduous forests may be based more on the structure of the vegetation, as illustrated by the different nest and foraging site requirements, than on the composition of the vegetation.

Table 5.—Mean nest site characteristics (SE) for the ovenbird, worm-eating warbler, hooded warbler, Acadian flycatcher, red-eyed vireo, wood thrush, and eastern phoebe.

Bird species by nest site	Nest height	Nest substrate height[a]	Nest substrate d.b.h.[b]	Side cover[c]	Overhead cover	Number of nests
Ground	—meters—		-cm-	—percent—		
Ovenbird	0 (0)	0.2 (0.04)	0 (0)	72 (5.2)	87 (4.6)	24
Worm-eating warbler	0 (0)	0.4 (0.09)	0 (0)	64 (4.2)	76 (9.4)	12
Low shrub						
Hooded warbler	0.6 (0.10)	1.4 (0.16)	0.4 (0.18)	21 (5.3)	78 (12.6)	9
Midstory						
Acadian flycatcher	3.8 (0.33)	10.0 (1.17)	7.7 (0.80)	22 (2.2)	70 (4.8)	35
Red-eyed vireo	2.6 (0.28)	5.3 (0.58)	4.1 (0.61)	19 (4.7)	64 (6.3)	17
Wood thrush	2.3 (0.11)	3.7 (0.27)	4.3 (0.28)	24 (2.3)	57 (4.7)	63
Rock						
Eastern phoebe	2.0 (0.24)	4.1 (0.47)	0 (0)	56 (4.3)	100 (0.0)	12

[a] Substrate for ground nests was the closest plant stem within 50 cm of the nest. If no stems were within 50 cm, the nest was designated as having no substrate.
[b] d.b.h. = 0 if substrate was less than 1.4 m in height or if substrate was rock.
[c] Side cover = mean of four values from each of four cardinal directions surrounding nest.

However, the presence of oaks does influence the composition of bird communities in other regions because oaks provide unique nesting or foraging substrates or because associated bird species are uniquely adapted to oaks. In northern Arizona, for example, pine-oak forests support more species of breeding birds than pine forests, in part because the low foliage of Gambel oaks (*Quercus gambelii*) provides more suitable cover for ground-nesting birds (Rosenstock 1998). In California, the acorn woodpecker (*Melanerpes formicivorus*) is one of the few bird species that is entirely dependent on oaks. Acorns are the primary food source of this species, but populations can be maintained only if multiple species of oaks are present to provide a reliable food supply (Bock and Bock 1974). Perhaps part of the reason more species of birds are not dependent on oaks is because acorn production tends to be irregular and unpredictable. Most species of oaks produce large acorn crops every 2 to 6 years, with low production or total failure in intervening years (Sork et al. 1993).

Other characteristics of oaks, such as the foliage and the associated arthropod community, are worth considering in terms of their value to breeding bird communities. Canopy-foraging birds may prefer some types of foliage over others because different arrangements of leaves may provide more accessible foraging surfaces or different types of hiding places for insects. For example, Holmes and Robinson (1981) found that canopy-foraging birds in New Hampshire preferred yellow birch (*Betula allegheniensis*) but avoided beech and sugar maple. These preferences were associated with higher densities and increased accessibility of insects on yellow birch foliage. Such comparisons have not been made among oaks, beech, and maple, though arthropod communities are likely to vary, particularly in response to differences in secondary compounds in the foliage. Oak foliage is high in tannin content, whereas red maple and yellow-poplar (*Liriodendron tulipifera*) foliage contains high concentrations of alkaloids. Gypsy moths (*Lymantria dispar*) consume tannin-laden oak leaves but avoid foliage containing alkaloids (Barbosa and Krischik 1987). Such preferences have not been identified for other species of foliage-consuming insects, though the implications of such preferences are substantial in terms of potential differences in food availability for canopy-foraging bird species.

Breeding Productivity

Assessing nesting success rates of different bird species is important in monitoring bird populations. Populations in an area may be high, but if breeding productivity and/or survival is not sufficient to sustain a local population, population stability will depend on immigration of dispersing individuals from surrounding areas. In the absence of immigration, such populations may become locally extinct (Van Horne 1983; Pulliam 1988). Monitoring breeding productivity thus provides an assessment of the health of local populations and provides

Table 6.—Mean principal component scores (SE) for successful and depredated nests.

Species		PC scores by nest fate: successful		PC scores by nest fate: depredated		*F*-value [a]	*N* [b]
Ovenbird	PC1	-1.46	(0.044)	-1.52	(0.044)	1.0	10, 13
	PC2	0.82	(0.164)	0.67	(0.182)	0.3	
Worm-eating warbler	PC1	-1.49	(0.114)	-1.55	(0.158)	0.1	8, 2
	PC2	0.18	(0.413)	0.21	(0.854)	0.0	
Hooded warbler	PC1	-0.71	(0.033)	-0.40	(0.183)	2.9	3, 3
	PC2	-0.08	(0.890)	-0.41	(0.556)	0.1	
Acadian flycatcher	PC1	0.99	(0.173)	1.14	(0.188)	0.4	16, 15
	PC2	-0.02	(0.161)	-0.03	(0.161)	0.0	
Red-eyed vireo	PC1	0.45	(0.262)	0.62	(0.156)	0.3	5, 9
	PC2	-0.44	(0.327)	-0.20	(0.263)	0.3	
Wood thrush	PC1	0.16	(0.129)	0.29	(0.057)	1.2	20, 39
	PC2	-0.61	(0.235)	-0.37	(0.164)	0.7	
Eastern phoebe	PC1	-0.07	(0.054)	-0.03	(0.177)	0.1	7, 5
	PC2	1.26	(0.084)	1.41	(0.125)	1.3	

[a] *F*-values from one-way ANOVAs testing for differences between successful and depredated nests.
[b] First number = number of successful nests; second number = number of depredated nests.

opportunities to identify different landscape or habitat features that directly influence reproduction (Martin 1992).

The primary factor affecting breeding productivity for many forest bird species is predation of nest contents (Martin 1992). Several studies have shown that nest predation rates for the wood thrush and other bird species were correlated with the extent of forest fragmentation (Donovan et al. 1995; Hoover et al. 1995; Robinson et al. 1995). As the extent of forest fragmentation increases, nesting success rates decline, apparently because nests become more accessible to predators associated with edge and open habitats surrounding smaller forest patches. Nesting success rates for wood thrushes at our study areas were lower than in other predominantly-forested landscapes (Donovan et al. 1995; Hoover et al. 1995; Robinson et al. 1995). Variation in nesting success rates may depend more on the local community of nest predators than on the extent of forest fragmentation (Yahner 1996). Eastern chipmunks (*Tamias striatus*) are common at our study areas and may be responsible for a high proportion of nest failures, but may be less common or absent in highly fragmented forests. Conversely, blue jays and American crows are among the primary nest predators in other regions and are present at our study areas, but are uncommon and do not appear to be responsible for a substantial proportion of wood thrush nest failures. Few studies have been conducted on variation in abundance, or differences in search behavior, diet, and activity patterns of potential nest predators. Future studies focusing on the behavior and abundance of nest predators may provide more precise identification of factors limiting productivity of wood thrushes and other bird species in different regions and landscape types.

A second factor affecting breeding productivity is parasitism by brown-headed cowbirds. For the wood thrush, cowbird parasitism rates vary regionally and with extent of forest fragmentation, with highest rates observed in highly fragmented landscapes in the Midwest, closer to the historic range of cowbirds (Hoover and Brittingham 1993; Donovan et al. 1995; Brawn and Robinson 1996). The absence of parasitism of wood thrush nests at our study areas was consistent with low rates observed in other predominately-forested landscapes (Donovan et al. 1995; Hoover et al. 1995). However, in our study areas, parasitism rates for nests of hooded warblers, ovenbirds, and worm-eating warblers were higher than in other studies, regardless of the extent of forest fragmentation (Hahn and Hatfield 1995; Winslow et al. 2000). Brown-headed cowbirds appear to be shifting their host preferences from the wood thrush to wood warblers as they expand their range eastward. Why is this apparent shift in host preference occurring? Perhaps cowbird nestlings are more successful in wood warbler nests than in wood thrush nests because they are more effective competitors against smaller nestmates. These cowbird nestlings then may become imprinted on their host

Table 7.—Mean principal component scores (SE) for unparasitized vs. parasitized nests. Results shown only for individual bird species with sample sizes of 2 or more parasitized nests.

Species		PC scores by nest fate				*F*-value [a]	*N* [b]
		successful		depredated			
Ovenbird	PC1	-1.51	(0.039)	-1.52	(0.033)	0.0	21, 3
	PC2	0.55	(0.187)	1.11	(0.129)	1.2	
Worm-eating warbler	PC1	-1.59	(0.092)	-1.27	(0.073)	5.1*	8, 4
	PC2	-0.06	(0.389)	0.83	(0.208)	2.4	
Hooded warbler	PC1	-0.41	(0.189)	-0.72	(0.027)	5.8*	3, 6
	PC2	0.40	(0.387)	-0.26	(0.458)	0.8	
Red-eyed vireo	PC1	0.61	(0.134)	-0.04	(0.159)	6.4*	13, 4
	PC2	-0.13	(0.184)	-0.95	(0.203)	5.4*	

[a] *F*-values from one-way ANOVAs testing for differences between unparasitized and parasitized nests. * = $p < 0.05$.
[b] First number = number of unparasitized nests; second number = number of parasitized nests.

parents and prefer to parasitize the same host species as adults, thus potentially leading to increased preferences for particular host species over multiple generations (Marchetti et al. 1998; Freeberg et al. 1999). Alternatively, cowbirds may be expanding their preferences as the rate at which they encounter more naive hosts increases in eastern regions (Lanyon 1992). Regardless of the explanation, cowbirds are likely to have a substantial impact on wood warblers if these high rates of parasitism are widespread. Fortunately, some potentially naive hosts are developing effective defenses against cowbirds. For example, hooded warblers have been sympatric with cowbirds for less than 200 years, and appear to be chosen preferentially as hosts. However, hooded warblers recognize cowbirds near their nests as threats (Mark and Stutchbury 1994) and frequently abandon parasitized nests, thus potentially reducing costs associated with high parasitism rates.

Population Sustainability

Are breeding productivity rates at our study areas high enough to sustain local populations? Populations are considered self-sustaining if daily nest survival rates are greater than 96 percent and brown-headed cowbird parasitism rates are less than 25 percent (Robinson 1996). Our results show that the eastern phoebe and Acadian flycatcher meet both these specifications, but other bird species listed in Table 3 do not, with daily nest survival rates less than 96 percent and/or cowbird parasitism rates over 25 percent. However, the upper portions of the 95 percent confidence intervals of the daily nest survival rates [DSR + (SE ´ 1.96)] for all bird species listed in Table 3 include 96 percent, suggesting that their populations may be self-sustaining in some situations.

An additional parameter that must be considered in assessing population health is seasonal fecundity, estimated as the number of fledglings produced per female per year. Daily nest survival rates were low for the wood thrush at our study areas, suggesting that productivity may be too low to sustain local populations. However, these low rates were offset by low cowbird parasitism rates and short renesting intervals. Wood thrushes renest soon after both failed and successful nesting attempts, with individual females nesting up to four times during a breeding season (Simons et al. 2000). Multiple nesting attempts increases the likelihood that any one attempt will be successful, thus enhancing a population's productivity and increasing the likelihood that populations are self-sustaining.

Acadian flycatchers, eastern phoebes, and hooded warblers also have multiple nesting attempts per year (usually two) even if the first attempt is successful (Walkinshaw 1966; Evans et al. 1994; Martin 1995), thus increasing the likelihood that populations are self-sustaining. This strategy is particularly beneficial for the hooded warbler because second nesting attempts are less likely to be parasitized by cowbirds than first nesting attempts (Artman and Dettmers, unpublished data). By contrast, the ovenbird and worm-eating warbler often have only one nesting attempt per year and may not renest if their first attempt is unsuccessful (Hann 1937; Hanners and Patton 1998). These two bird species thus may be more susceptible to reduced fecundity, potentially affecting the likelihood of populations being self-sustainable. Indeed, the daily nest survival rate for the ovenbird was one of the lowest of the species monitored. However, our sample sizes for ovenbirds and worm-eating warblers were relatively low, especially for the ovenbird,

considering it was one of the most abundant species at the study areas. These small sample sizes limit the precision of the daily survival rate estimates. In addition, monitoring these ground nests may have increased the likelihood of nest failure, thus biasing the daily nest survival estimates. To assess the extent of potential bias and obtain an additional measure of nesting productivity levels, future monitoring of ovenbirds and worm-eating warblers should include searches for fledglings in territories where nest contents are not directly monitored.

Nest Site Selection and Nesting Success

Though we found differences in nest site characteristics between parasitized and unparasitized nests for several bird species, we found no differences between successful and depredated nests. The conventional argument is that birds should respond to high rates of nest predation by selecting less vulnerable nest sites (Martin 1992). Selection of more concealed nest sites should reduce the search efficiency of predators and selection of higher nest sites should reduce accessibility of nests to predators (Martin 1993). However, support for these hypotheses has been variable. Concealment reduced the probability of nest predation for the hermit thrush (*Catharus guttatus*; Martin and Roper 1988) but not for the hooded warbler (Howlett and Stutchbury 1996; Kilgo et al. 1996), northern cardinal (Filliater et al. 1994), or wood thrush (Johnson 1997). Increasing nest height reduced the probability of nest predation for the Acadian flycatcher (Wilson and Cooper 1998) and American robin (Schmidt and Whelan 1999) but not for the wood thrush (Hoover and Brittingham 1998).

Why are these results so variable? In general, the effectiveness of strategies to avoid predation depends on the types of predators in the community and the search tactics they use to find prey (nests). Potential nest predators at our study areas include chipmunks, squirrels (*Sciurus* spp.), raccoons (*Procyon lotor*), black rat snakes (*Elaphe obsoleta*), and blue jays, each of which uses different types of foraging cues (visual, olfactory, auditory, chemosensory) and forages in different zones (ground, shrub, midcanopy). Increased nest concealment or increased nest height thus may reduce exposure to one type of predator while increasing exposure to another type of predator. In addition, the relative abundance or activity levels of different predators in the community may change as the nesting season progresses or from year to year (Schmidt 1997; McShea 2000), thus influencing the effectiveness of different strategies. Future monitoring should include identification of potential nest predators and assessment of their abundance and activity levels in the community. Such monitoring would increase our understanding of the factors potentially affecting breeding bird productivity.

Conclusions

The baseline data presented here will be used in assessing the effects of prescribed burning on the breeding bird community. The composition and abundance of breeding birds did not differ among the treatment units, prior to prescribed fire treatments. At a regional scale, populations of many bird species in the community are declining. These declines emphasize the need to continue to document trends in population levels and to assess potential changes in response to different management activities, including prescribed fire.

Acknowledgments

We thank Ron Beatty, Sandy Bloomfield, Shay Garriock, and Kristine Hill for their efforts in conducting the field work for this project. Jeff Brawn, Therese Donovan, Tom Grubb, Elaine Kennedy Sutherland, and Todd Hutchinson provided helpful comments on earlier drafts of this chapter. We are indebted to Jon Bart for providing the opportunity to work on this project and advice on establishing sampling protocols.

Literature Cited

Barbosa, P.; Krischik, V. A. 1987. **Influence of alkaloids on feeding preference of eastern deciduous forest trees by the gypsy moth *Lymantria dispar*.** American Naturalist. 130: 53-69.

Bock, C. E.; Bock, J. H. 1974. **Geographical ecology of the acorn woodpecker: diversity versus abundance of resources.** American Naturalist. 108: 694-698.

Brawn, J. D.; Robinson, S. K. 1996. **Source-sink population dynamics may complicate the interpretation of long-term census data.** Ecology. 77: 3-12.

Cooper, R. J.; Dodge, K. M.; Martinat, P. J.; Donahoe, S. B.; Whitmore, R. C. 1990. **Effect of diflubenzuron application on eastern deciduous forest birds.** Journal of Wildlife Management. 54: 486-493.

DeGraaf, R. M.; Healy, W. M.; Brooks, R. T. 1991. **Effects of thinning and deer browsing on breeding birds in New England oak woodlands.** Forest Ecology and Management. 41: 179-191.

Dettmers, R.; Bart, J. 1999. **A GIS modeling method applied to predicting forest songbird habitat.** Ecological Applications. 9: 152-163.

Donovan, T. M.; Thompson, F. R.; Faaborg, J.; Probst, J. R. 1995. **Reproductive success of migratory birds in**

habitat sources and sinks. Conservation Biology. 9: 1380-1395.

Ehrlich, P. R.; Dobkin, D. S.; Wheye, D. 1988. **The birder's handbook: a field guide to the natural history of North American birds.** New York: Simon & Schuster Inc. 785 p.

Evans Ogden, L. J.; Stutchbury, B. J. 1994. **Hooded warbler (*Wilsonia citrina*).** In: Poole, A.; Gill, F., eds. The birds of North America, No. 110. Philadelphia, PA: The Academy of Natural Sciences; and Washington, DC: The American Ornithologists' Union. 20 p.

Filliater, T. S.; Breitwisch, R.; Nealen, P. M. 1994. **Predation on northern cardinal nests: does choice of nest site matter?** Condor. 96: 761-768.

Finch, D. M. 1991. **Population ecology, habitat requirements, and conservation of neotropical migratory birds.** Gen.Tech. Rep. RM-205. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 26 p.

Freeberg, T. M.; Duncan, S. D.; Kast, T. L.; Enstrom, D. A. 1999. **Cultural influences on female mate choice: an experimental test in cowbirds, *Molothrusater*.** Animal Behaviour. 57: 421-426.

Gauch, H. G., Jr. 1982. **Multivariate analysis in community ecology.** Cambridge, UK: Cambridge University Press. 298 p.

Griffith, D. M.; DiGiovanni, D. M.; Witzel, T. L.; Wharton E. H. 1993. **Forest statistics for Ohio, 1991.** Resour. Bull. NE-128. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 169 p.

Hahn, D. C.; Hatfield, J. S. 1995. **Parasitism at the landscape scale: cowbirds prefer forests.** Conservation Biology. 9: 1415-1424.

Hann, H. W. 1937. **Life history of the ovenbird in southern Michigan.** Wilson Bulletin. 44: 146-235.

Hanners, L. A.; Patton, S. R. 1998. **Worm-eating warbler (*Helmitheros vermivorus*).** In Poole, A.; Gill, F., eds. The birds of North America, No. 367. Philadelphia, PA: Academy of Natural Sciences; and Washington, DC: American Ornithologists' Union. 19 p.

Healy, W. M.; Gottschalk; K. W.; Long, R. P.; Wargo, P. M. 1997. **Changes in eastern forests: chestnut is gone, are the oaks far behind?** Transactions of the North American Wildlife and Natural Resources Conference. 62: 249-263.

Holmes, R. T.; Robinson, S. K. 1981. **Tree species preferences of foraging insectivorous birds in a northern hardwoods forest.** Oecologia. 48: 31-35.

Holmes, R. T.; Sherry, T. W.; Sturges, F. W. 1986. **Bird community dynamics in a temperate deciduous forest: long-term trends at Hubbard Brook.** Ecological Monographs. 56: 201-220.

Hoover, J. P.; Brittingham, M. C. 1993. **Regional variation in brood parasitism of wood thrushes.** Wilson Bulletin. 105: 228-238.

Hoover, J. P.; Brittingham, M. C. 1998. **Nest-site selection and nesting success of wood thrushes.** Wilson Bulletin. 110: 375-383.

Hoover, J. P.; Brittingham, M. C.; Goodrich, L. J. 1995. **Effects of forest patch size on nesting success of wood thrushes.** Auk. 112: 146-155.

Horn, D. J.; Benninger-Truax, M. 1997. **The summer bird community in a late-successional beech-maple forest in Ohio.** Ohio Journal of Science. 97: 14-16.

Howlett, J. S.; Stutchbury, B. J. 1996. **Nest concealment and predation in hooded warblers: experimental removal of nest cover.** Auk. 113: 1-9.

Iverson, L. R.; Dale, M. E.; Scott, C. T.; Prasad, A. 1997. **A GIS-derived integrated moisture index to predict forest composition and productivity of Ohio forests.** Landscape Ecology. 12: 331-348.

Johnson, M. S. 1997. **The effect of age on nest concealment and its complimentary effect on production of wood thrushes.** Wilson Bulletin. 109: 68-73.

Johnston, D. W.; Odum, E. P. 1956. **Breeding bird populations in relation to plant succession on the Piedmont of Georgia.** Ecology. 37: 50-62.

Kendeigh, S. C. 1944. **Measurement of bird populations.** Ecological Monographs. 14: 67-106.

Kendeigh, S. C. 1946. **Breeding birds of the beech-maple-hemlock community.** Ecology. 27: 226-245.

Kendeigh, S. C.; Fawver, B. J. 1981. **Breeding bird populations in the Great Smoky Mountains, Tennessee and North Carolina.** Wilson Bulletin. 93: 218-242.

Kilgo, J. C.; Sargent, R. A.; Chapman, B. R.; Miller, K. V. 1996. **Nest-site selection by hooded warblers in bottomland hardwoods of South Carolina.** Wilson Bulletin. 108: 53-60.

Lanyon, S. M. 1992. **Interspecific brood parasitism in blackbirds (Icterinae): a phylogenetic perspective.** Science. 255: 77-79.

Marchetti, K.; Nakamura, H.; Gibbs, H. L. 1998. **Host-race formation in the common cuckoo.** Science. 282: 471-472.

Mark, D.; Stutchbury, B. J. 1994. **Response of a forest-interior songbird to the threat of cowbird parasitism.** Animal Behaviour. 47: 275-280.

Martin, T. E. 1992. **Breeding productivity considerations: what are the appropriate habitat features for management?** In: Hagan, J.M.; Johnston, D.W., eds. Ecology and conservation of neotropical migrant landbirds. Washington, DC: Smithsonian Institution Press. 455-473.

Martin, T. E. 1993. **Nest predation and nest sites: new perspectives on old patterns.** BioScience. 43: 523-532.

Martin, T. E. 1995. **Avian life history evolution in relation to nest sites, nest predation, and food.** Ecological Monographs. 65: 101-127.

Martin, T. E.; Roper, J. J. 1988. **Nest predation and nest-site selection of a western population of the hermit thrush.** Condor. 90: 51-57.

Martin, T. E.; Paine, C.; Conway, C. J.; [et al.]. 1997. **BBIRD (Breeding Biology Research and Monitoring Database) field protocol.** Missoula, MT: University of Montana, Montana Cooperative Wildlife Research Unit. 64 p.

Mayfield, H. F. 1975. **Suggestions for calculating nest success.** Wilson Bulletin. 87: 456-466.

McCune, B. L.; Mefford, M. J. 1997. **PC-ORD for Windows. Multivariate analysis of ecological data. Version 3.05.** Gleneden Beach, OR: MjM Software. 47 p.

McShea, W. J. 2000. **The influence of acorn crops on annual variation in rodent and bird populations.** Ecology. 81: 228-238.

Powell, D. S.; Faulkner, J. L.; Darr, D. R.; [et al.]. 1993. **Forest resources of the United States, 1992.** Gen. Tech. Rep. RM-234. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 133 p.

Probst, J. R. 1979. **Oak forest bird communities.** In: DeGraaf, R. M.; Evans, K. E., eds. Management of north-central and northeastern forests for nongame birds. Gen. Tech. Rep. NC-51. St. Paul, MN: U.S. Department of Agriculture, Forest Service North Central Forest Experiment Station: 80-88.

Pulliam, H. R. 1988. **Sources, sinks, and population regulation.** American Naturalist. 132: 652-661.

Rappole, J. H.; DeGraaf, R. M. 1996. **Research and effective management of neotropical migrant birds.** Transactions of the North American Wildlife and Natural Resource Conference. 61: 450-462.

Robbins, C. S. 1970. **Recommendations for an international standard for a mapping method in bird census work.** Audubon Field Notes. 24: 723-726.

Robbins, C. S.; Dawson, D. K.; Dowell, B. A. 1989. **Habitat area requirements of breeding forest birds of the Middle Atlantic States.** Wildlife Monographs. 103: 1-34.

Robinson, S. K. 1996. **Threats to breeding neotropical migratory birds in the Midwest.** In: Thompson, F. R., ed. Management of midwestern landscapes for the conservation of neotropical migratory birds. Gen. Tech. Rep. NC-187. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 1-21.

Robinson, S. K.; Thompson F.R.; Donovan, T.M.; [et al.] 1995. **Regional forest fragmentation and the nesting success of migratory birds.** Science. 267: 1987-1990.

Rodewald, P. G.; Smith, K. G. 1998. **Short-term effects of understory and overstory management on breeding birds in Arkansas oak-hickory forests.** Journal of Wildlife Management. 62: 1411-1417.

Rollfinke, B. F.; Yahner, R. H. 1990. **Community structure and composition of breeding and wintering birds in a wastewater-irrigated oak forest.** Journal of Wildlife Management. 54: 493-500.

Rosenberg, K. V.; Wells, J. V. 1995. **Conservation priorities for neotropical migratory birds in the Northeast.** In: American Ornithologists' Union, 113th stated meeting, 1995 August 15-19, Cincinnati, OH. Washington, DC: American Ornithologists Union. Abstract.

Rosenstock, S. S. 1998. **Influence of Gambel oak on breeding birds in ponderosa pine forests of northern Arizona.** Condor. 100: 485-492.

Salveter, A. L.; James, D. A.; Smith, K. G. 1996. **Responses of avian populations and vegetation to prescribed burning in pine forests of the Arkansas Ozarks.** Transactions of the North American Wildlife and Natural Resource Conference. 61: 237-245.

Sauer, J. R.; Hines, J. E.; Gough, G.; [et al.]. 1997. **The North American Breeding Bird Survey Results and Analysis. Version 96.4** Laurel, MD: U.S. Geological Survey, Patuxent Wildlife Research Center. htttp:\www.mbr-pwrc.usgs.gov/bbs/bbs.html.

Schmidt, K. A. 1997. **Foraging theory as a conceptual framework for studying nest predation in a forest bird community.** Chicago, IL: University of Illinois. 155 p. Ph. D. Dissertation.

Schmidt, K. A.; Whelan, C. J. 1999. **Effects of exotic *Lonicera* and *Rhamnus* on songbird nest predation.** Conservation Biology. 13: 1502-1506.

Shugart, H. H., Jr.; James, D. 1973. **Ecological succession of breeding bird populations in northwestern Arkansas.** Auk. 90: 62-77.

Simons, T.; Farnsworth, G. L.; Shriner, S. A. 2000. **Evaluating Great Smoky Mountains National Park as a population source for wood thrush.** Conservation Biology. 14(4): 1133-1144.

Sork, V. L.; Bramble, J.; Sexton, O. 1993. **Ecology of mast-fruiting in three species of North American oaks.** Ecology. 74: 528-541.

Thompson, F. R.; Robinson, S. K.; Whitehead, D. R.; Brawn, J. D. 1996. **Management of central hardwood landscapes for the conservation of migratory birds.** Gen. Tech. Rep. NC-187. St. Paul, MN: U.S. Department of Agriculture, North Central Forest Experiment Station: 117-143.

Udvardy, M. D. F. 1957. **An evaluation of quantitative studies in birds.** In: Proceedings of Cold Spring Harbor Symposium in Quantitative Biology. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory. 22: 301-311.

Van Horne, B. 1983. **Density as a misleading indicator of habitat quality.** Journal of Wildlife Management. 47: 893-901.

Vanderah, G. C.; Robinson, S. K. 1995. **Habitat selection of cerulean warblers in Illinois.** In: American Ornithologists' Union, 113th stated meeting, 1995 August 15-19; Cincinnati, OH. Washington, DC: American Ornithologists Union: Abstract 211.

Walkinshaw, L. H. 1966. **Studies of the Acadian flycatcher in Michigan.** Bird-Banding. 37: 227-257.

Webb, W. L.; Behrend, D. F.; Saisorn, B. 1977. **Effect of logging on songbird populations in a northern hardwood forest.** Wildlife Monographs. 55: 1-35.

Williams, A. B. 1936. **The composition and dynamics of a beech/maple climax community.** Ecological Monographs. 6: 317-408.

Wilson, C. W.; Masters, R. E.; Bukenhofer, G. A. 1995. **Breeding bird response to pine-grassland community restoration for red-cockaded woodpeckers.** Journal of Wildlife Management. 59: 56-67.

Wilson, R. R.; Cooper, R. J. 1998. **Acadian flycatcher nest placement: does placement influence reproductive success?** Condor. 100: 673-679.

Winslow, D. E.; Whitehead, D. R.; Whyte, C. F.; [et al.]. 2000. **Within-landscape variation in patterns of cowbird parasitism in the forests of south-central Indiana.** In: Smith, J. N. M.; Cook, T. L.; Rothstein, S. I.; [et al.], eds. Ecology and management of cowbirds and their hosts. Austin, TX: University of Texas Press: 298-310.

Yahner, R. H. 1993. **Effects of long-term forest clearcutting on wintering and breeding birds.** Wilson Bulletin. 105: 239-255.

Yahner, R. H. 1996. **Forest fragmentation, artificial nest studies, and predator abundance.** Conservation Biology. 10: 672-673.

Zar, J. H. 1984. **Biostatistical analysis.** Second edition. Englewood Cliffs, NJ: Prentice-Hall. 718 p.