THE ECOLOGY AND MANAGEMENT OF AVIAN COMMUNITIES IN MIXED HARDWOOD-CONIFEROUS FORESTS

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Abstract.--High horizontal diversity of vegetation in mixed hardwood-coniferous forests is identified as a key feature affecting avian communities. The extremely high bird species diversity of mixed forests is explained by patchiness of forest vegetation and selection of discrete habitat patches by birds that are typical of either more northerly or southerly forest types. Bird population densities, seasonality of avian communities, and impacts of succession on avian communities are interpreted in relation to forest ecology. Impacts of silviculture on avian communities are predicted, and modifications that favor diverse avian communities are suggested.

INTRODUCTION

In spite of their northerly distribution, the various types of mixed hardwood-coniferous forests in north central and northeastern United States support remarkedly rich avifaunas. The bird species diversities in these mixed forest types are among the highest of any of the forests in North America and the highest of any of the forest types in the north central and northeastern regions (Table 1). This conspicuously high bird species diversity provides the basis for our discussion of the bird communities of the mixed forests. We address ourselves to the following questions: What characteristics of the forest vegetation allow such diverse bird communities to develop? How do the geographic distributions and habitat preferences of bird species that occur in the mixed forests relate to the high species diversity? How are these diverse bird communities organized? What effects do modern forestry practices have on the diversity of bird communities in mixed forests? What types of management practices promote high bird species diversity in mixed forests?

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DESCRIPTION OF MIXED HARDWOOD-CONIFEROUS FOREST VEGETATION

The following description of the hardwood-coniferous forests of the north central and northeastern U.S. begins by considering the presettlement forest biome. This historical approach seems worthwhile because much of the research on the dynamics of both forest and bird communities has been conducted using historical records or studying virgin relics and unmanaged forests. The same biological and physical processes illustrated in these studies continue to shape the composition of our modern, mixed forest biome, albeit altered by man's actions. A prerequisite to the management of this modern forest biome for non-game birds is an understanding of the complete range of forest environments in which the bird community evolved, and this comes only from an historical perspective.

Distribution and Composition of Forest Types

The mixed forest biome of the north-central and northeastern United States is roughly synonymous with the hemlock-white pine-northern hardwood region of Braun (1950). It covers the northern Great Lakes region, southern Quebec, Nova Scotia, New Brunswick and New England, dipping south along the Appalachian Mountains (Fig. 1). At the western boundary in northern Minnesota the biome grades into parkland and prairie; to the north, it is replaced by

Table 1.--Comparisons of bird species diversity in various forest communities in the northeastern and north central United States[1/]

Community Type[2/]	Forest composition	Average No. of bird species per census route	Average species diversity index[3/] per census route
Spruce-Hardwood	mixed	60.3	3.377
Adirondack Mountain	mixed	61.3	3.457
Northern Hardwoods	mixed	63.3	3.508
Wisconsin Driftless Area	deciduous	58.1	3.123
Eastern Lake Section	deciduous	54.4	2.938
St. Lawrence Valley	deciduous	55.9	3.063
Allegany Plateau	deciduous	54.9	3.135
Closed Boreal Forest	coniferous	51.5	3.262

[1/]Data from an analysis of Breeding Bird Surveys (1968-1973) by Peterson (1975).

[2/]See map in Peterson (1975).

[3/]Calculations based on Shannon-Weaver function (Tramer 1969).

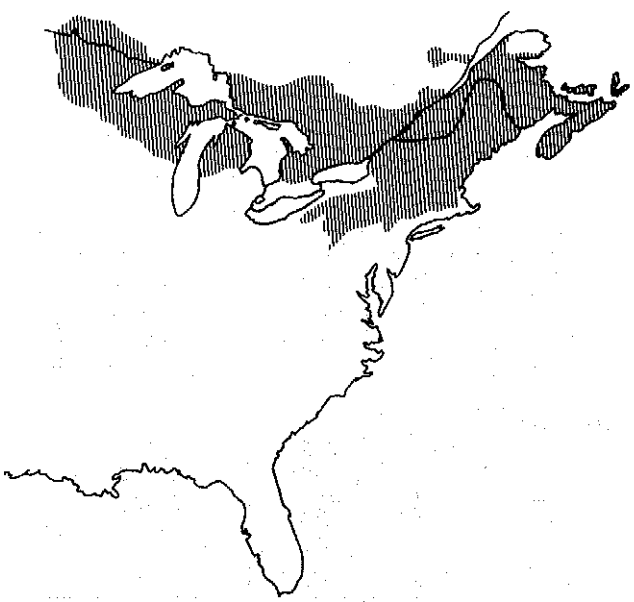

Figure 1.--The geographic distribution of mixed hardwood-coniferous forests in the north central and northeastern United States (adapted from Braun's (1950) map of the hemlock-white pine-northern hardwoods region). Forests within this region differ in their species composition, but all are mixed forests.

boreal forest and to the south by southern deciduous forest, savanna and mixed forest of the southern Appalachians. Various associations of hardwood-coniferous forest occur throughout this biome.

Curtis (1959) has given a most complete regional description of the presettlement hardwood-coniferous forest community. The major dominant tree species of the upland mixed forests of Wisconsin are, in order of increasing shade tolerance: jack pine, (*Pinus banksiana*); hill's oak, (*Quercus elipsoidales*); quaking aspen, (*Populus tremuloides*); red pine, (*P. resinosa*), white pine, (*P. strobus*); paper birch, (*Betula papyrifera*); red oak, (*Q. borealis*); red maple, (*Acer rubrum*); yellow birch, (*B. lutea*); basswood, (*Tilia americana*); hemlock (*Tsuga canadensis*); beech, (*Fagus grandifolia*); and sugar maple, (*A. saccharum*). Table 2 summarizes the composition and structure of typical stands of mixed forest in Wisconsin.

There are several geographic trends in the biome. In the extreme western portion of the biome, beech, hemlock and yellow birch successively disappear and white pine and basswood increase in importance. East of Wisconsin, red spruce (*Picea rubens*), sweet birch (*Betula lenta*) and gray birch (*B. populifolia*) join the forest and increase in importance along with hemlock and beech; jack pine, red pine and yellow birch decline. These compositional changes often involve the replacement of one species by an ecological equivalent with a similar life-form so that the physiognomy of the

Table 2.--Structure and composition of typical stands of hardwood-coniferous forest.[1/]

Locality and Species	Plants per acre Less than 1" d.b.h.		Plants per acre More than 1" d.b.h.				
	Less than 1"tall	More than 1"tall	1-4"	4-10"	10-20"	20-30"	30+"
a. Wet-mesic swamp of cedar and fir in Vilas County, Wisconsin							
Abies balsamea	3800	1000	56	200	0	0	0
Acer rubrum	3000	200	39	9	4	0	0
Betula lutea	1600	0	0	0	7	0	0
B. papyrifera	0	0	3	44	14	0	0
Fraxinus nigra	400	400	0	19	0	0	0
Picea mariana	0	0	0	3	0	0	0
Populus tremuloides	0	0	0	0	4	0	0
Sorbus americana	1000	0	9	6	0	0	0
Thuja occidentalis	10,400	0	76	31	14	0	0
Quercus borealis	400	0	0	0	0	0	0
b. Mesic forest in Vilas County, Wisconsin							
Abies balsamea	40	15	23	1	0	0	0
Acer saccharum	20,160	5680	72	36	16	2	0
Betula lutea	7100	7	6	3	20	3	0
Ostrya virginiana	80	100	18	6	0	0	0
Picea glauca	0	0	0	0	0	1	0
Pinus strobus	0	0	0	0	2	2	1
Tilia americana	130	65	15	6	7	0	0
Tsuga canadensis	260	2	17	18	18	4	0
Ulmus americana	65	90	5	8	4	3	0
c. Mesic forest in Door County, Wisconsin							
Acer saccharum	17,280	960	11	17	41	0	0
Betula papyrifera	0	0	1	12	0	0	0
Fagus grandifolia	0	0	1	12	0	0	0
Fraxinus americana	2560	480	0	0	0	0	0
Ostrya virginiana	640	1440	3	0	0	0	0
Pinus strobus	0	0	0	0	2	1	1
Prunus serotina	160	0	0	1	0	0	0
Quercus borealis	160	0	0	0	2	0	0
Tsuga canadensis	0	0	6	0	4	1	0
d. Dry-mesic red pine forest in Oneida County, Wisconsin							
Acer rubrum	3400	1000	80	25	0	0	0
Betula papyrifera	0	0	35	31	2	0	0
Pinus resinosa	0	0	5	7	67	0	0
P. strobus	2800	1400	27	5	3	4	0
Populus grandidentata	0	0	3	5	1	0	0
P. tremuloides	0	0	1	3	1	0	0
Quercus borealis	400	0	23	24	1	0	0
e. Dry jack pine forest in Burnett County, Wisconsin							
Acer rubrum	312	62	14	6	2	0	0
Betula papyrifera	0	0	0	9	0	0	0
Pinus banksiana	0	144	71	59	33	0	0
P. strobus	164	20	0	0	2	0	0
Populus tremuloides	0	0	0	7	0	0	0
Quercus ellipsoidalis	1568	865	68	43	11	0	0

[1/] After Curtis (1959).

forest, which is so important to the bird community, changes less than a list of tree species might indicate.

Topography also varies from west to east as the gentle, glacial landscape of the lake states gives way to the montane landscape of Pennsylvania, New York and New England. In the lake states, variation in forest composition is often associated with changes in the underlying glacial deposits and in the depth of the water table which varies with slight changes in topography. The eastern region was also glaciated, but montane topography has a dominant influence upon the vegetation which varies with changes in altitude, exposure and bedrock(Braun 1950).

Within the mixed hardwood-coniferous forest, boreal elements such as black and white spruce (*Picea mariana* and *P. glauca*) increase toward the north while deciduous species such as the maples and oaks increase towards the south. In a sense, the biome may be considered a broad zone of transition or an ecotone between the boreal forest and southern deciduous forests; however, it is largely composed of unique tree and shrub communities which include important tree species that are essentially limited to the mixed forest biome (Braun 1950).

The composition of the upland, mixed forest on any particular site is determined by a complex interplay of edaphic factors, climate, succession, gap phase (sensu Watt 1947) disturbances (such as windthrows, disease and insect damage), and catastrophic disturbances (such as blowdowns, fire and insect or disease epidemics). The interaction of these biotic and physical factors constantly alters the forest environment, shifting the competitive advantage in a given locale from one tree species to another and creating a mosaic of forest types.

In the absence of disturbance, the replacement of shade intolerant trees by tolerant species and changes in the soil would theoretically result in a homogeneous climax forest over much of the hardwood-coniferous forest biome. Throughout much of the lake states region, sugar maple would become the single dominant tree. Largely because of disturbance, the mixed forest has never been dominated by one or a few shade tolerant species. Relatively small gaps in the canopy create favorable conditions for the growth of yellow birch, basswood, elms (*Ulmus americana; U. rubra*), white ash (*Fraxinus americana*), red maple and, if the gap is sufficiently large, white pine. Windthrown trees provide ideal seed beds for hemlock which is shade tolerant once established as a seedling. Catastrophic events often create conditions favorable for shade-intolerant pioneer species such as the pines, quaking aspen, paper birch and pin cherry (*Prunus pensylvanica*). However, catastrophic disturbances, when not associated with fire, and small scale disturbances of mesic forest do not necessarily lead to the establishment and growth of pioneer or gap phase species, but may be followed instead by the immediate reestablishment of mesic species from sprouts, and existing seedlings and saplings. This interplay of succession and disturbance tends to favor mixed forests over homogeneous forests of coniferous or hardwood species. Studies throughout the hardwood biome indicate that the dominant, presettlement forests were mixed hardwood-coniferous forests at various successional stages (Lutz 1930; Bromley 1935: Nichols 1935; Hough 1936; Graham 1941; Curtis 1959; Marsh 1965; Carroll 1973).

Successional Patterns in Mixed Hardwood-Coniferous Forests

Figure 2 outlines the basic pathways that succession follows, the effects of disturbances, and the relationship of mixed hardwood-coniferous forests to the other forest communities of the north central and northeastern regions. Table 2 shows the tree composition of typical stands of mixed forest. The structure and composition of stands is determined by a complex of environmental factors that results in variations in composition that follow major environmental gradients.

Rather than disrupting the mixed forest biome, fire, windthrow and other disturbances have contributed to a rich plant community by maintaining a dynamic balance between tree species (Graham 1941; Stearns 1949; Loucks 1970). In the presettlement hardwood-coniferous forests, this interplay of succession and disturbance created a complex mosaic of forest types in which all successional stages of forest were represented by stands of varying age and species composition (Watt 1947; Braun 1950; Bray 1956; Curtis 1959; Carroll 1973). This complex physiognomy has been an important factor in the evolution and persistence of the diverse community of birds in the biome. The diverse life-forms, vertical patterns of vegetation, and successional types present in the hardwood-coniferous forest provide a rich variety of habitats and resources for birds, allowing many species to coexist. Furthermore, localized changes in the composition of the forest vegetation through succession and disturbance continually alter the competitive environment for

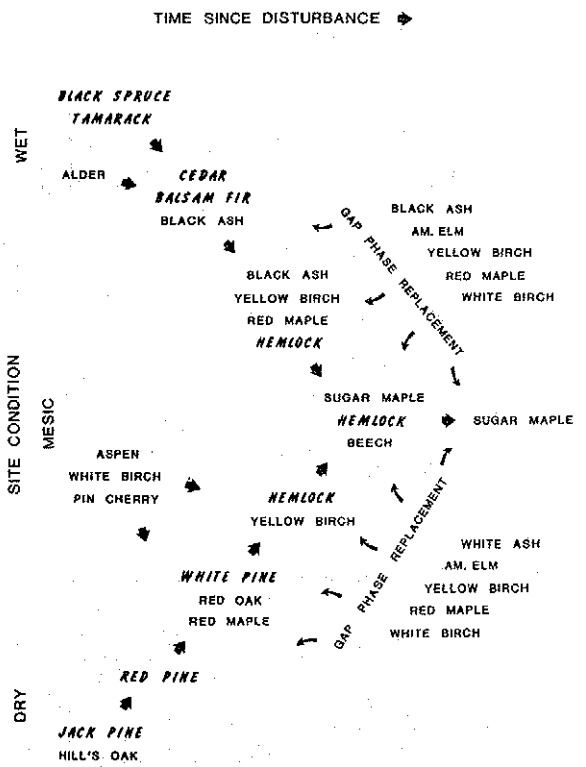

Figure 2.-- A generalized scheme of forest succession in the mixed hardwood-coniferous forests of northern Wisconsin. Succession follows the arrows from left to right. Coniferous trees are italicized.

the resident birds species, preventing a single species or group of species from dominating the entire forest bird community.

Alterations of the Mixed Forests in Historical Times

Beginning with European settlement, historical changes have altered the species composition and physiognomy of the hardwood-coniferous forests. Some of these changes are permanent. Although local economic conditions, technology and the motivation of the early settlers and those who followed varied from New England to the Midwest, the various accounts of settlement reveal a common chronology of change throughout the biome.

Beginning with the arrival of the first settlers, selective cutting of the most economically valuable trees eliminated white pine from large tracts of mixed forest (Marsh 1965; Carroll 1973). In Wisconsin, pine was removed from forests where it grew at a density of only 3 or 4 trees per acre (Curtis, 1959). Following this high grading, the forest was clear-cut for timber and/or to clear the land for agriculture. Clear-cutting increased soil erosion, disrupted the water cycle and dried out the remaining forests (Marsh 1973; Curtis 1959). Fueled by slash, the incidence of forest fires and intense crown fires increased, further limiting the distribution and reproductive potential of those species sensitive to fire, such as hemlock and white pine (Curtis 1959).

Land in many areas proved uneconomical for farming and was abandoned (Curtis 1959; Marsh 1973). This land succeeded to second growth forest of shade intolerant trees or was reforested with selected species. In areas where agricultural land-use continued, the forest persisted as isolated woodlots in a rural landscape (Curtis 1956). Chestnut blight and dutch elm disease virtually eliminated the chestnut (*Castanea dentata*) and American elm from the biome, and increased populations of herbivores such as white-tailed deer and porcupine also had some impact, especially on hemlock, white cedar and white pine.

These historical changes reduced the amount of mixed hardwood-coniferous forest by eliminating hemlock and pine from many areas of deciduous forest; favored early successional species; and created a younger, less diverse, second-growth forest with a simple vertical profile.

Modern forestry practices are leading to managed succession throughout much of the biome. The two principle management strategies are even-aged management by clear-cutting or shelterwood and uneven-aged management by selective cutting. The former has most frequently been used to perpetuate shade intolerant species while the latter can only be used to manage shade tolerant species. The physiognomy of the forest which results from either management practice depends upon the length of rotation in even-aged management, the minimum merchantable size-class in uneven-aged management, and the area and configuration of timber stands. In the past, these management decisions have been made without regard to the bird communities of the biome. Whereas uneven-aged management and selective cutting could closely simulate gap phase disturbance, it is generally used to encourage the most valuable species and to eliminate poorly shaped individuals and uneconomical species (Curtis 1959). Clear-cutting and shelterwood management could also simulate disturbances such as blowdowns and fire, but have been used most frequently to favor single, homogeneous

forest types on short rotations. The management practices continue the post-settlement pattern of: maintaining a forest of simple physiognomy by favoring conifer or hardwood forests over mixed forests; favoring early successional stages; and maintaining a young forest with a simple vertical profile.

The modern hardwood-coniferous forest is less complex and heterogeneous than the forest in which the birds of this biome evolved. In light of our current understanding of the effect that the spatial complexity of an environment has upon the distribution of birds species and the density and diversity of the bird communities, one would conclude that these differences have probably affected the bird community of the biome. The contrast between the presettlement and modern plant communities is a logical source of hypotheses related to the management of the biome for non-game birds.

SOURCES OF INFORMATION ON BIRD COMMUNITIES

The following discussion of bird communities of the mixed hardwood-coniferous forests is based on a combination of our own field work in the mixed forests of Wisconsin from 1976 to present and on the published accounts of other researchers. In Wisconsin, we have studied the bird communities of mixed forests primarily in two localities: the Apostle Islands in Lake Superior and the Baraboo Hills in central Wisconsin. The vegetation and general ecology of the Apostle Islands have been described by Beals and Cottam (1960) and the vegetation of the hardwood-coniferous forests in northern Wisconsin has been described by Brown and Curtis (1952). Lange (1976) describes the vegetation of the Baraboo Hills, a unique region slightly south of the normal range of mixed forests, which because of its topography supports typical hardwood-coniferous forest types. Less intensive field work has taken place in several other localities in northern Wisconsin, such as the Chequamegon National Forest and the Red Cliff Indian Reservation.

Within these study areas we have used a variety of techniques to study bird communities. We used the census procedures developed by Emlen (1971, 1977) to determine the species composition of the bird communities and the population densities of each species. We described the habitats occupied by breeding birds using the procedures described by James (1971) and James and Shugart (1970). In the Baraboo Hills we also used IPA mapping procedures (Ferry and Frochot 1970) to determine population densities.

BIRD COMMUNITIES OF HARDWOOD-CONIFEROUS FORESTS

Species Diversity

The high bird species diversity of the mixed hardwood-coniferous forests is one of the most important community characteristics that needs to be understood. Table 1 shows that the diversity of mixed forests exceeds the diversity of both the boreal coniferous forests, which are located to the north, and the deciduous forests to the south. There are two possible explanations for the biome's elevated species diversity. One possibility is that there are a large number of bird species restricted in geographic distribution to the mixed forests. Together these mixed-forest specialists might elevate the species diversity above that found to the north or south of the biome. Udvardy (1963) analyzed the distribution patterns of forest birds in North America. He found that mixed hardwood-coniferous forests contained only 5 species that had both the centers of their ranges and the majority of their ranges located in areas of mixed forest: the nashville warbler, black-throated blue warbler, blackburnian warbler, chestnut-sided warbler, and canada warbler. The overlap of these species' ranges with the distribution of mixed forests is not precise, and even within the mixed hardwood-coniferous forest biome, the specific habitat perferences of these species do not suggest that they are mixed forest specialists. Therefore, it does not seem likely that the high bird species diversity is the result of species being restricted to the mixed forests.

An alternative explanation is that there are a large number of bird species whose ranges lie primarily to the north or south of the mixed forests but overlap in the intervening areas. Thus, the bird communities of the hardwood-coniferous forests contain a mixture of bird species that are most typical of forest types to the north or south. In this respect, the avifauna of the mixed forests would be reacting to the mixed forests as an ecotone. It is well known that species diversity is often elevated in ecotones; this occurs apparently because species from each of the two adjoining biomes find suitable areas or patches of habitat, thus permitting coexistence within the ecotone and enriching its species diversity. Apparently this type of species enrichment occurs in the mixed forests; boreal forest and deciduous forest birds occur together in the mixed forests. Table 3 shows the north-south extent of the ranges of various mixed forest birds within Wisconsin, a state which has deciduous forests in its southern tier, mixed forests over the central regions, and coniferous forest in the far north. It is clear that the avifauna of these mixed forests is comprised of species that have extended their

Table 3.--Distributions of breeding forest birds of Wisconsin with respect to the distributions of deciduous, mixed hardwood-coniferous, and boreal coniferous forests[1/]

Breeding bird species	Deciduous forest	Mixed forest	Boreal forest
	S. Wisconsin ← (Extent of Species' Range) →		N. Wisconsin
Sharp-shinned Hawk		XXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Cooper's Hawk	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Goshawk		XXXXXXXXXX	XXXXXXXXXX
Red-shouldered Hawk	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Broad-winged Hawk	XXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Spruce Grouse		XXXX	XXXXXXXXXX
Ruffed Grouse	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Mourning Dove	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Yellow-billed Cuckoo	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Black-billed Cuckoo	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Long-eared owl		XXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Great Gray Owl		XXX	XXXXXXXXXX
Barred Owl	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Great Horned Owl	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Ruby-throated Hummingbird	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Red-headed woodpecker	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Red-bellied Woodpecker	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXX	
Flicker	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Pileated Woodpecker	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Downy Woodpecker	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Hairy Woodpecker	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Yellow-bellied Sapsucker	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Northern 3-toed Woodpecker		XXX	XXXXXXXXXX
Black-backed Woodpecker		XXXXXXXXXXXXXX	XXXXXXXXXX
Crested Flycatcher	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Olive-sided Flycatcher		XXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Least Flycatcher	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Alder Flycatcher	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Acadian Flycatcher	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	
Yellow-bellied Flycatcher		XXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Eastern Phoebe	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Wood Pewee	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Gray Jay		XXXXXXXXXX	XXXXXXXXXX
Blue Jay	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Crow	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Raven		XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Tufted Titmouse	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXX	
Black-capped Chickadee	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Boreal Chickadee		XXXXXXXXXX	XXXXXXXXXX
Brown Creeper		XXXXXXX	XXXXXXXXXX
White-breasted Nuthatch	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Red-breasted Nuthatch		XXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Bewick's Wren	XXXXXXXXXXXXXXXXXXXX		
House Wren	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Winter Wren		XXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Carolina Wren	XXXXXXXXXXXXXXXXXXXXXXXXXX		
Brown Thrasher	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Mockingbird	XXXXXXXXXXXXXXXXXXXXXXXXX		
Gray Catbird	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
American Robin	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Eastern Bluebird	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Olive-backed Thrush		XXXXXXXXXXXXXX	XXXXXXXXXX
Gray-cheeked Thrush		XXX	XXXXXXXXXX
Wood Thrush	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Hermit Thrush		XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX

Table 3.--Continued

Breeding bird species	(Extent of Species' Range) S. Wisconsin ← → N. Wisconsin: Deciduous forest	Mixed forest	Boreal forest
Veery	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Ruby-crowned Kinglet		XXXXXXXXXXXX	XXXXXXXXXX
Golden-crowned Kinglet		XXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Blue-gray Gnatcatcher	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXX	
Cedar Waxwing	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Bell's Vireo	XXXXXXXXXXXXXXXXXXXXXXXXXXXX		
Red-eyed Vireo	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Warbling Vireo	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Yellow-throated Vireo	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Solitary Vireo		XXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Black-and-White Warbler	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Prothonotary Warbler	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX		
Golden-winged Warbler	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Blue-winged Warbler	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXX	
Nashville Warbler	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Parula Warbler		XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Yellow Warbler	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Magnolia Warbler		XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Black-throated Blue Warbler		XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Yellow-rumped Warbler		XXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Black-throated Green Warbler		XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Cerulean Warbler	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX		
Blackburnian Warbler		XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Chestnut-sided Warbler	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Pine Warbler	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXX	
Palm Warbler		XXXXXXXXXXXX	XXXXXXXXXX
Ovenbird	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Northern Waterthrush	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Louisiana Waterthrush	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXX	
Connecticut Warbler		XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Mourning Warbler	XXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Common Yellowthroat	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Yellow-breasted Chat	XXXXXXXXXXXXXXXXXXXXXXXXXXXX		
Canada Warbler	XXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
American Redstart	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Orchard Oriole	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX		
Northern Oriole	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Brown-headed Cowbird	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Brewer's Blackbird	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Common Grackle	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Scarlet Tanager	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Cardinal	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Rose-breasted Grosbeak	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Purple Finch		XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Pine Siskin		XXXX	XXXXXXXXXX
Red Crossbill		XXXXXXXXXXXXXXXXXX	XXXXXXXXXX
White-winged Crossbill		XXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Rufous-sided Towhee	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Dark-eyed Junco		XXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
White-throated Sparrow	XXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Fox Sparrow		XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX
Song Sparrow	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXXXX

1/ Distributions of forest types taken from Curtis (1959); distributions of birds taken from Gromme (1963).

ranges into mixed forest from the north or south.

The key to the maintenance of this high bird species diversity is the spatial complexity of the forest. Both the vertical and horizontal complexity of the vegetation are known to affect bird species diversity (MacArthur and MacArthur 1961), and it seems likely that horizontal complexity is relatively more important than vertical complexity in promoting diversity in the mixed forests. As we mentioned in our discussion of the physiognomy of the forest, one important characteristic of the forest is its patchiness. Hardwoods and conifers rarely form a truely homogeneous mixture. Rather, the dispersion of tree-types is contagious or clumped: both coniferous and deciduous trees tend to be found in discrete patches or groves. This dispersion pattern allows birds that are primarily adapted for coniferous vegetation to select patches of conifers in which to establish breeding territories, whereas those birds that are primarily adapted for living on deciduous vegetation can select patches containing predominantly deciduous trees in which to establish territories.

To demonstrate this selection by birds of patches of vegetation that are either more northerly or southernly in their affinities, we analyzed the vegetation within the territories of several warbler species breeding in the mixed forests of the Baraboo Hills of Wisconsin. Figure 3 shows the strong correlation between the northern affinity of the vegetation within a bird's territory and the percentage of that particular species range (on a north-south basis) that lies to the north of the site. Clearly, the bird species that have the most northerly geographic distributions are selecting for their territories those patches of forest that include the most northerly types of vegetation. The converse is true for southern bird species.

It seems that most birds of the mixed forests are not responding to the mixed forests as a single type of vegetation. Rather they are responding to the mixed forest as a mosaic of vegetation patches with either northerly or southerly affinities. This may be one of the most important ecological characteristics of the birds that breed in mixed forests, and as we shall mention later, it is perhaps the most important characteristic with relevance to forest management.

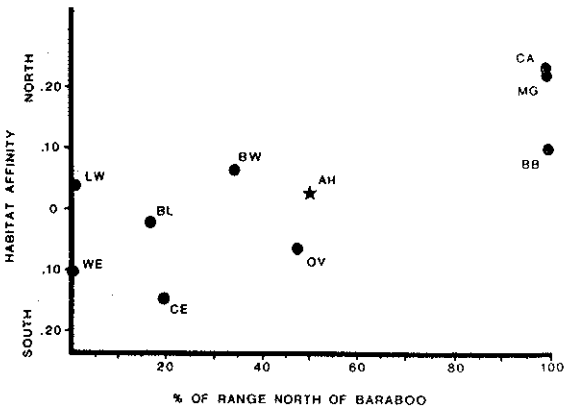

Figure 3.--The relationship between the geographic distribution of a species and the type of vegetation within its territory in the Baraboo Hills of central Wisconsin. The percent of range north of Baraboo was measured along the 90th meridean. Habitat affinity was calculated as N-S/N+S, where N is habitat similarity with Curtis' (1959) northern Wisconsin forest types and S is the similarity with southern Wisconsin forest types. Similarities were calculated as "coefficients of community" (Gleason 1920) using importance values for tree species. LW=Louisiana Waterthrush, WE=Worm-eating Warbler, BL=Blue-winged Warbler, CE=Cerulean Warbler, BW=Black-and-White Warbler, OV=Ovenbird, BB=Blackburnian Warbler, MG=Magnolia Warbler, CA=Canada Warbler, AH=available habitat.

Bird Population Densities In Hardwood-Coniferous Forests

Although mixed hardwood-coniferous forests are somewhat unique for their high bird species diversities, they are not very unusual in terms of the densities of birds that they support. From our own work and published accounts, we have assembled some representative breeding bird population densities for various types of mixed forest in the north central and northeastern U.S. (Table 4). These data suggest that most mixed-forest stands can be expected to support bird densities on the order of 150-300 territorial birds per 100 acres (40ha) during the breeding season. These figures are not very different from bird population densities reported for either boreal coniferous forests or northern hardwood forests.

Bird population densities are known to be affected by the productivity of the habitat that the birds are occupying. It seems reasonable, therefore, to expect that some, if not most, of the inter-stand variability in bird population densities in mixed forests can be accounted for by differences in productivity. In particular, for the majority of forest birds, which are primarily insectivorous

Table 4.--Population densities of breeding birds in various stands of mixed hardwood-coniferous forest in north central or northeastern United States.

Species	Sources of Data[1/]															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A. Percent composition of vegetation in study area[2/]																
White cedar	+	0		0	0		+	0	0	0		0	0		0	
Hemlock		4		0	0		+	0	0	20	+	20	6	+	74	+
Pine		69		0	0		0	0	20	60	+	7	0		0	
Spruce-fir		0	+	73	90	++	34	53	0	0		0	0		0	
Total coniferous		73		73	90		41	53	20	80		27	6		74	
Maple-beech				0	1		+	24	20		++	20	56	++	23	
Yellow birch				0	9		+	23	7		+	10				
Aspen-white birch	+	22	+	27	0		0	0	5			0				
Total deciduous		27		27	10	+	59	47	80	20		73	94		26	
B. Bird population densities (pairs/40ha)[3/]																
Mourning dove	3	+	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Yellow-billed Cuckoo	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0
Black-billed Cuckoo	0	0	0	0	0	0	0	0	0	0	1	0	0	+	0	0
Turkey Vulture	0	0	0	0	0	0	0	0	+	0	0	+	0	0	0	0
Goshawk	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0
Coopers Hawk	0	0	0	0	0	0	0	0	+	0	+	0	0	0	0	0
Sharp-shinned Hawk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red-tailed Hawk	0	0	0	0	0	0	0	0	+	0	0	+	0	0	0	0
Red-shouldered Hawk	0	0	0	0	+	0	0	+	+	0	0	+	0	0	0	0
Broad-winged Hawk	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	1
Peregrine Falcon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Merlin	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0
Ruffed Grouse	0	1	0	0	0	6	0	+	+	1	+	+	3	+	2	0
Great-horned Owl	0	0	0	0	0	0	0	0	0	+	0	0	+	0	+	0
Long-eared Owl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Barred Owl	0	0	0	0	0	0	0	0	2	0	1	2	0	1	0	1
Saw-whet Owl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Common Nighthawk	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Whip-poor-will	0	0	0	0	0	0	0	0	0	1	0	+	0	0	0	0
Chimney Swift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ruby-throated Hummingbird	+	0	3	0	0	0	0	0	1	0	+	4	0	0	0	0
Common Flicker	3	2	0	+	0	0	0	0	3	0	0	+	0	+	0	2
Pileated Woodpecker	0	0	0	+	0	0	0	+	2	+	+	+	+	+	+	1
Red-bellied Woodpecker	0	0	0	0	0	0	0	0	4	0	0	+	0	1	0	0
Red-headed Woodpecker	0	0	0	0	0	0	0	0	1	0	0	+	0	0	0	0
Yellow-bellied Sapsucker	3	0	6	0	0	3	3	0	0	2	0	0	0	0	0	0
Hairy Woodpecker	3	1	0	0	+	+	1	3	2	3	1	4	2	4	3	3
Downy Woodpecker	1	+	0	0	0	0	0	0	6	2	0	2	0	5	0	2
Eastern Kingbird	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Great-crested Flycatcher	3	2	0	0	0	0	0	0	6	1	1	+	3	3	1	0
Eastern Phoebe	0	0	0	0	0	0	0	0	3	0	0	6	0	2	0	0
Yellow-bellied Flycatcher	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0
Acadian Flycatcher	0	0	0	0	0	0	0	0	8	0	0	36	0	5	0	0
Least Flycatcher	0	0	0	4	0	0	0	0	0	0	6	36	0	0	0	0
Eastern Pewee	3	16	0	0	0	0	6	0	14	6	14	16	1	10	0	0
Olive-sided Flycatcher	0	0	0	+	0	0	0	0	0	2	0	0	0	0	0	0
Tree Swallow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bluejay	3	2	3	0	+	+	3	3	11	2	1	4	2	1	2	0

Table 4.--Continued.

Species	Sources of Data[1/]															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Gray Jay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+
Common Raven	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Common Crow	0	+	0	+	0	0	0	0	+	0	1	0	0	0	0	0
Black-Capped Chickadee	5	8	6	2	4	6	9	2	6	6	3	8	3	5	9	14
Carolina Chickadee	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0
Boreal Chickadee	0	0	0	5	0	0	+	0	0	0	0	0	0	0	0	0
Tufted Titmouse	0	0	0	0	0	0	0	0	0	0	0	+	0	9	0	0
White-breasted Nuthatch	0	0	0	0	0	0	0	0	6	1	2	6	2	5	5	0
Red-breasted Nuthatch	1	1	0	4	13	3	0	7	0	1	0	0	0	0	0	10
Brown Creeper	0	0	0	0	0	0	0	7	0	1	0	0	0	0	0	7
House Wren	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winter Wren	13	0	0	4	0	0	0	3	1	1	1	0	0	0	0	5
Carolina Wren	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0
Gray Catbird	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Brown Thrasher	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
American Robin	7	12	3	16	8	3	1	3	6	0	1	2	0	1	0	0
Wood Thrush	0	0	0	0	+	3	0	3	7	0	2	10	0	22	1	0
Hermit Thrush	0	8	6	+	8	0	1	3	0	10	0	0	5	0	6	5
Swainson's Thrush	0	0	0	21	4	1	14	13	0	0	0	0	0	0	0	3
Veery	0	+	9	0	+	18	0	7	8	5	8	6	4	0	5	0
Blue-gray Gnatcatcher	0	0	0	0	0	0	0	0	8	0	0	16	0	0	0	0
Golden-crowned Kinglet	0	0	7	0	33	0	0	32	0	0	1	0	0	0	0	2
Ruby-crowned Kinglet	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	+
Cedar Waxwing	0	4	0	0	0	0	0	0	1	0	1	+	0	0	0	0
Starling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solitary Vireo	3	0	0	2	17	0	3	26	0	4	0	0	0	0	1	2
White-eyed Vireo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow-throated Vireo	0	0	0	0	0	0	0	0	2	0	1	6	0	3	0	0
Red-eyed Vireo	3	1	17	14	0	20	54	10	14	10	32	36	25	14	1	17
Philadelphia Vireo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Warbling Vireo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black & White Warbler	13	0	8	+	0	17	0	0	2	8	1	0	3	0	2	5
Worm-eating Warbler	0	0	0	0	0	0	0	0	1	0	0	+	0	0	0	0
Golden-winged Warbler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue-winged Warbler	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Tennessee Warbler	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0
Nashville Warbler	10	0	6	19	0	9	0	0	0	0	0	0	0	0	0	3
Northern Parula Warbler	7	0	0	4	+	0	26	3	0	0	0	0	0	0	0	5
Yellow Warbler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Magnolia Warbler	0	0	17	32	42	31	10	45	0	4	0	8	2	0	25	9
Cape May Warbler	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Yellow-rumped Warbler	3	+	6	26	0	6	+	0	0	2	0	0	0	0	0	17
Black-throated Green Warbler	3	16	0	0	21	6	23	31	0	13	8	0	9	4	32	28
Black-throated Blue Warbler	5	0	0	0	21	3	29	16	0	6	2	0	6	0	9	0
Cerulean Warbler	0	0	0	0	0	0	0	0	+	0	0	4	0	3	0	0
Blackburnian Warbler	0	0	8	2	67	15	30	55	4	18	6	2	6	0	14	102
Chestnut-sided Warbler	0	0	+	0	0	14	+	0	0	0	0	0	0	0	0	0
Bay-breasted Warbler	0	0	0	95	0	0	0	0	0	0	0	0	0	0	0	1
Blackpoll Warbler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pine Warbler	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prairie Warbler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palm Warbler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ovenbird	10	20	25	2	0	33	23	3	1	9	19	14	28	28	32	2
Northern Waterthrush	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0
Louisiana Waterthrush	0	0	0	0	0	0	0	0	8	0	0	6	0	4	0	0
Common Yellowthroat	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0

Table 4.--Continued.

Species	Sources of Data[1/]															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Yellow-breasted Chat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mourning Warbler	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Connecticut Warbler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hooded Warbler	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
Wilson's Warbler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Canada Warbler	3	0	14	0	0	23	0	16	6	7	0	8	4	0	10	0
American Redstart	0	0	+	4	0	18	3	0	0	6	37	0	0	17	0	0
Common Grackle	0	0	+	0	0	0	0	0	+	0	0	0	0	0	0	0
Brown-headed Cowbird	+	+	0	0	0	0	0	0	9	0	+	16	0	2	0	0
Northern Oriole	2	0	0	0	0	0	0	0	5	0	0	+	0	0	0	0
Scarlet Tanager	10	0	0	0	4	3	3	7	15	3	3	20	3	9	5	0
Cardinal	0	0	0	0	0	0	0	0	3	0	0	8	0	5	0	0
Rose-breasted Grosbeak	+	0	0	0	8	+	0	3	17	0	0	18	0	3	0	0
Evening Grosbeak	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Indigo Bunting	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Purple Finch	3	+	+	7	8	3	+	3	0	0	1	0	0	0	0	3
Pine Grosbeak	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Common Redpoll	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pine Siskin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
American Goldfinch	0	0	0	0	+	0	0	0	2	0	0	6	0	0	0	0
Red Crossbill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
White-winged Crossbill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vesper Sparrow	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rufous-sided Towhee	0	4	0	0	4	0	0	0	0	0	0	0	0	1	0	0
Dark-eyed Junco	3	4	+	9	33	0	0	21	0	10	0	0	0	0	0	13
Tree Sparrow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chipping Sparrow	0	4	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Field Sparrow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
White-throated Sparrow	10	0	15	14	0	8	0	0	0	8	0	0	0	0	0	9
Song Sparrow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	139	112	159	318	295	258	241	325	207	158	155	310	111	215	165	274

1/ Sources of Data: Kendeigh, 1948 (1, 2, 11); Kendeigh, 1946 (13, 15); Martin, 1960 (3, 6, 16); Stewart and Aldrich, 1952 (4); Stewart and Aldrich, 1949 (5, 8); Mossman, unpubl. (9, 12); Smith, 1944 (10); Williams, 1947 (14); Cope and Hensley; 1951 (7).

2/ Tree composition is recorded, when available, as percent of total number of trees. + indicates presence, ++ dominance and 0 absence.

3/ + indicates presence, 0 absence, and numbers density of males or pairs.

during the breeding season, the abundance of forest insects can be an important factor in determining local bird population densities. It is well known for example, that bird populations show dramatic numerical responses to localized outbreaks of forest insects that temporarily increase the productivity of a stand (Buckner and Turnock 1965). Conversely, stands with low productivity of forest insects can be expected to have reduced bird population densities.

Relative Abundance of Bird Species

The internal composition of the bird communities of mixed hardwood-coniferous forests can be analyzed in terms of the relative abundances of the various species that are members of the communtiy. In Table 4, we have presented for various types of mixed forests the population densities of each bird species present. Comparision of these figures reveals that there is definitely a consistent group of species which can be considered dominant in most mixed forests. These include: the ovenbird, red-eyed vireo, black-throated green warbler, blackburnian warbler, black-throated blue warbler, veery, and white-throated sparrow. Each species is present at densities that are conspicuously higher than those of other species, and together these species usually comprise 20-40 percent of the total number of individuals in the community.

If we rank sequentially the relative abundances of the 15 most abundant bird species in each of several types of mixed forests, a general pattern emerges (Figure 4). Basically, there are very few really common species, a relatively small number of moderately abundant species, and a large number of fairly uncommon species within the mixed hardwood-coniferous forests, a pattern which is common to many, if not most, forest bird communities.

Habitat Affinities of Mixed Forest Birds

Several researchers have attempted to describe the specific habitat preferences of birds in mixed forests (Kendeigh 1946, 1948; Martin, 1960; Stewart and Aldrich, 1949, 1952). Beals (1960) used an ordination technique to reveal the vegetation characteristics to which birds are responding. We have also used ordinations but have followed the technique described by James (1971) which is based on the vegetation surrounding the singing perches used by territorial males and presumably, is a reflection of the vegetation in the bird's territory. We have

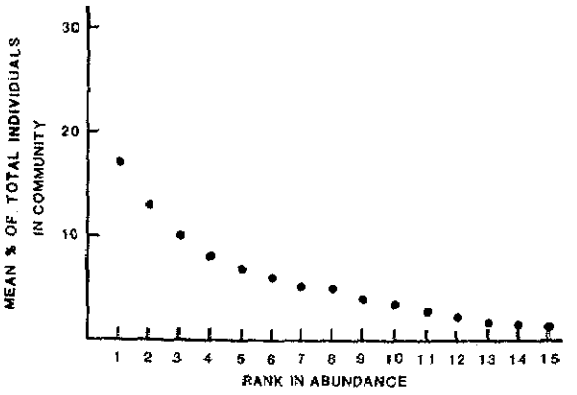

Figure 4.--The relative abundances of the fifteen most abundant bird species in various stands of mixed hardwood-coniferous forest. Data are taken from the same sources cited in Table 4.

interpreted our ordination results in terms of several characteristics of the vegetation within bird territories that are relevent to questions of forest management. These include: relative abundance of pines, relative abundance of hemlocks, relative abundance of spruce-fir, relative abundance of sugar maple, relative abundance of aspen, average basal area of trees, density of trees, relative density of understory. In Table 5, we have summarized some of our ordination results in terms of these vegetation characteristics.

Seasonality In Mixed Forest Bird Communities

So far we have restricted our discussion to the breeding bird communities of the mixed hardwood-coniferous forests. It is important to recognize, however, that the high bird species diversity and relatively high density of birds that characterize the mixed forests during the summer months do not prevail throughout the year. The contrast between the summer bird communities and the winter bird communities is striking. A comparison of the diversity and density of birds in two similar stands of mixed forests in northern Wisconsin, one in summer and the other in winter illustrates this. In June we detected an average of 39 species of birds per hour of censusing and an average density of 252 individuals per 100 acres (40 ha). In contrast, during our December censuses we detected an average of 5 species per hour of censusing and an average density of 16 individuals per 100 acres (40 ha).

From selected Christmas Bird Count records and our own experience, we can list the species of forest birds that regularly occur in the

Table 5.--An interpretation of habitat ordination results from breeding bird communities of mixed forests on the Apostle Islands, Wisconsin.

Alterations of vegetation within a stand	Bird species that are likely to become more abundant
1. Increasing abundance of pine	Sharp-shinned hawk, red-breasted nuthatch, hermit thrush, redstart, blackburnian warbler, Nashville warbler, pine warbler
2. Increasing abundance of hemlock	pileated woodpecker, yellow-bellied sapsucker, yellow-bellied flycatcher
3. Increasing abundance of spruce or fir	cedar waxwing, yellow-bellied flycatcher, swainson's thrush, redstart, parula warbler, blackburnian warbler
4. Increasing abundance of yellow birch and sugar maple	black-billed cuckoo, downy woodpecker, wood-pewee, least flycatcher, crow, brown creeper, veery, robin, warbling vireo, red-eyed vireo, Connecticut warbler, chestnut-sided warbler, black-throated green warbler, black and white warbler, Tennessee warbler, indigo bunting, rufous-sided towhee, rose-breasted grosbeak
5. Increasing abundance of aspen	yellow-shafted flicker, hairy woodpecker, house wren, veery, yellowthroat, mourning warbler, chestnut-sided warbler, song sparrow, white-throated sparrow
6. Increasing average basal area of trees	pileated woodpecker, solitary vireo
7. Increasing density of trees per unit area	scarlet tanager, ovenbird
8. Increasing density of understory	veery, black-throated blue warbler, Canada warbler

mixed forests of Wisconsin during winter; these include: goshawk, great horned owl, barred owl, ruffed grouse, downy woodpecker, hairy woodpecker, pileated woodpecker, blue-jay, gray jay, common raven, black-capped chickadee, red-breasted nuthatch, white-breasted nuthatch, brown creeper, evening grosbeak, cardinal, and purple finch. All these species are severely limited by the restricted supply of food available in the mixed forest during the winter. Many of the species, particularly the woodpeckers, chickadees, nuthatches, and creepers, are insectivorous and forage by probing in bark or dead wood. For these species, the presence in the forest of snags, dead limbs, and old mature trees is essential.

Successional Changes in Bird Communities

Although our main concern is with the bird communities of relatively mature stands of mixed hardwood-coniferous forests, it is important to summarize briefly the changes in the composition of the bird community as a stand progresses through successional stages of vegetation. Table 6 summarizes the bird communities associated with early, middle, and late seral stages leading to a beech-maple-hemlock forest in New York State. Bird species diversity increases progressively through these successional stages whereas bird densities tend to decrease slightly. In his analysis of Breeding Bird Surveys conducted by the U.S. Fish and Wildlife Service, Peterson (1975) found that in the ecological regions dominated by mixed hardwood-coniferous forests observers detected more species of birds in total than in any other ecological region of the U.S. Within the region characterized by "Spruce-hardwood forest" observers saw an average of 194.2 species per year for the period 1968-1973. The next highest species list was recorded in the "upper coastal plain" where an average of 169.8 species was observed each year. Although the mature mixed forests support a high species diversity, many of the birds

Table 6.--Bird species associated with seral stages leading to a mature beech-maple-hemlock forest on the Helderberg Plateau of central New York state (after Kendeigh 1946).

Bird Species	Seral Stage[1/]			
	Early →	Middle →	Late →	Mature
Common Yellowthroat	+			
Song Sparrow	+			
Field Sparrow	+			
Chestnut-sided Warbler		+		
Rufous-sided Towhee		+		
Gray Catbird		+		
Alder Flycatcher		+		
Swamp Sparrow		+		
Red-winged Blackbird		+		
Indigo Bunting		+		
Brown Thrasher		+		
Yellow-breasted Chat		+		
Golden-winged Warbler		+		
American Robin			+	
American Redstart			+	
Nashville Warbler			+	
American Goldfinch			+	
Cedar Waxwing			+	
House Wren			+	
Woodcock			+	
Northern Oriole			+	
Common Flicker			+	
Eastern Kingbird			+	
Chipping Sparrow			+	
Ruby-throated Hummingbird			+	
Black-billed Cuckoo			+	
Purple Finch			+	
Mourning Dove			+	
Eastern Phoebe			+	
Eastern Bluebird			+	
Rose-breasted Grosbeak			+	
Downy Woodpecker			+	
Red-eyed Vireo			+	+
Veery			+	+
Canada Warbler			+	+
Ovenbird			+	+
Magnolia Warbler			+	+
Black-and-White Warbler			+	+
Black-capped Chickadee			+	+
Black-throated Green Warbler				+
Blackburnian Warbler				+
Black-throated Blue Warbler				+
Hermit Thrush				+
White-breasted Nuthatch				+
Scarlet Tanager				+
Hairy Woodpecker				+
Ruffed Grouse				+
Wood Thrush				+
Solitary Vireo				+
Pileated Woodpecker				+
Crested Flycatcher				+
Great Horned Owl				+
Sharp-shinned Hawk				+

[1/] Early=scattered briars, herbs, and low shrubs; middle=mature shrubs and small trees; late=scattered stands of tall trees and shrubs; mature=well-developed forest dominated by beech, maple, and hemlock.

that account for the extremely high total species list are birds of early successional stages. These early seral stages are, therefore, important in contributing to the overall bird species diversity in the regions dominated by mixed forests.

FOREST MANAGEMENT AND BIRD COMMUNITIES

We have already summarized briefly the impact that man has had on the mixed hardwood-coniferous forests of the north central and northeastern U.S. Our intent now is to outline in a general way the types of forestry practices that would promote what we feel is the single most significant ecological trait of the mixed forests bird communities: their high species diversity. First, we will list the important characteristics of the bird communities that relate to high species diversity:

(1) most forest birds respond to the mixed forest as a mosaic of patches which are either dominated by conifers or hardwoods. Few birds are actually selecting habitats that are a homogeneous blend of conifers and deciduous trees.
(2) most of the breeding birds are insectivorous and depend on a well-stratified forest with good vertical diversity in order to segregate their feeding niches.
(3) most breeding birds are insectivorous and depend on rich and varied insect populations in order to maintain high population densities.

(4) there are a few common or moderately common bird species that are dominant in the mixed forests, but the high species diversity is, in large part, the result of the many relatively uncommon species occurring in the mixed forests.
(5) from habitat ordinations, we can predict which bird species will be favored or adversely affected by specific habitat alterations.
(6) bird species diversity in mixed forests is high only during the summer; during the winter the species diversity is extremely low, and the species present have readily identifiable and fairly similar requirements of the mixed forest.
(7) maintaining a mosaic of seral stages promotes an overall diversity of birds within the regions that are dominated by mixed forests.

These ecological characteristics of the mixed forest bird communities must be reconciled with potential silviculture options in order to develop a set of management procedures that will sustain the entire complement of bird species in the biome and favor high bird species diversity.

Potential Silviculture Options For Mixed Forests

There are few specific management guidelines available for mixed forests because in almost all cases the silviculturalist is interested in either hardwoods or conifers, not a mixture of types. Tubbs (1977) provides a recent set of recommendations for the management of northern hardwoods and he includes brief descriptions of mixed stands in his discussion. Nonetheless, it seems most useful to discuss management options from the viewpoint of northern hardwood silviculture.

We will consider the following options for managing northern hardwoods: even-age management, uneven-age management and preservation. Although the effects that each of these management options would have on bird communities in mixed forests are as yet undemonstrated, we can make reasonable predictions on the basis of our knowledge of what these practices will do to the vegetation and our knowledge of what bird communities require. Although only a few specific studies of the impact of silviculture have been carried out, the recent results of Webb et al. (1977) should serve to emphasize the potential that silviculture has for altering bird communities.

Even-Aged Management

Even-aged management can be used to regenerate shade tolerant or intolerant species, and has the advantage over uneven-aged management of increased efficiency (Tubbs, 1977). Shelterwood and clear-cutting, the two methods of even-aged management most widely used, allow succession to proceed in some modified way with infrequent interventions into the forest for thinning or harvesting. Clear-cutting is generally used where the ultimate goal is reproduction of intolerant trees for pulpwood on a 50-70 year rotation, while the ultimate goal of shelterwood management is the reproduction of more valuable, shade tolerant hardwoods on a cycle of 100-120 years (Tubbs 1977).

We can identify some of the general effects

that even-aged management has on mixed forest vegetation, and from these infer how bird communities are likely to respond. Shelterwood management encourages horizontal diversity of vegetation within a stand and will tend to favor a patchy distribution of tree species. This is particularly true if intermediate cuts favor moderately intolerant, as well as tolerant species, and a patchy distribution of conifers and hardwoods. Clear-cutting for pulpwood generally favors monotypic stands with a low horizontal diversity of vegetation, and the prescribed rotations of 50-70 years do not allow much diversity to develop due to natural disturbances. Both methods of even-aged management reduce the vertical diversity of vegetation within a stand by favoring single age-classes of trees, reducing the diversity of tree species, and opening the canopy. The opening of the canopy, in turn, tends to increase the development of the understory. Traditionally, the intermediate cuts reduce the density of dead and diseased trees.

In terms of the important ecological characteristics of the mixed forest bird communities, we can say that even-aged management has the following benefits and disadvantages for promoting high bird speices diversity.

(1) by promoting horizontal diversity in the forest vegetation shelterwood management can enhance bird species diversity, particularly if intermediate cuts can be made in such a way as to encourage a patchy distributuion of tree species.
(2) by reducing vertical diversity in the forest vegetation, even-aged management will tend to reduce the foraging opportunities available to birds and, hence, will reduce both the diversity and density of birds within specific patches of vegetation.
(3) by reducing the density of dead or diseased trees within a stand, even-aged management can reduce the productivity of insects in the forest and the availability of nesting cavities. This has a particularly important impact on the winter bird community which includes mostly bird species which probe in bark or wood to extract insects.
(4) from our understanding of the habitat requirements of individual bird species, we can predict some of the specific effect of even-aged management. Clear-cutting will create early seral stages and favor the bird species that prefer this type of habitat. Even-aged management will probably favor the more common members of the bird community, but may eliminate some of the less common species that contribute to high diversity.

Within the accepted guidelines for even-aged management of mixed forests there are several possibilities for minor modifications that would be beneficial to the mixed forest bird communities. We offer these as suggestions, but it should be realized that these are mostly unproven techniques:

(1) after clear-cutting or a shelterwood cut, an area is usually allowed to regenerate naturally through successional stages. The planting of small (3 ha) patches of conifers, particularly hemlocks and red or white pines, within the stand soon after cutting sould insure that conifer patches will develop. This would increase the horizontal diversity of vegetation in the stand, and would also increase vertical diversity of vegetation since conifers have a different vertical profile than hardwoods.
(2) when intermediate cuts are made to improve the quality of harvestable trees, several other objectives could simultaneously be achieved. These include allowing patches of conifers to persist within the hardwoods, preserving all snags or diseased trees that are not directly threatening valuable species, and creating snags by girdling species that are to be eliminated anyway and leaving them standing.
(3) within the constraints of silvicultural practices and economics, rotations should be as long as possible in clear-cut management, and cutting cycles should be as long as possible in shelterwood management.

Uneven-Aged Management

Uneven-aged management results in a different set of modifications of the mixed forest vegetation. Although current trends lean towards even-aged management, most of the management that has taken place in the past in mixed forests has been uneven-aged silviculture (Tubbs. 1977).

Under an uneven-aged management program, individual trees within the stand are selected for harvest or culling on the basis of species, age, diameter, and form. Maximum tree size in a stand depends upon whether

management is for pole lumber or saw logs. The periodic removal of highly desirable trees from the forest results in several changes in forest vegetation that can have an impact upon bird communities. Uneven-aged management favors shade tolerant species which can reproduce under the canopy. The development of shade tolerant seedlings and saplings along with the growth of shrubs in canopy openings created by selective cuts, creates a forest which is vertically diverse. This vertical diversity is enhanced where the maximum tree size is large, and is reduced where it is small. The elimination of intolerant trees reduces the horizontal diversity of the forest. As in uneven-aged management, diseased, poorly formed and uneconomical trees are culled. Conifers cannot be maintained in a stand by uneven-aged management.

We can make some predictions about the impact that uneven-aged management would have on bird communities in the mixed hardwood-coniferous forests, but again there has been almost no research that would clearly prove these predictions valid. The following, however, seem to be the likely outcomes:

(1) by enhancing vertical diversity in the forest vegetation, uneven-aged management will favor high densities of a few species of birds.
(2) by reducing horizontal diversity, uneven-aged management will tend to depress the overall species diversity within the stand.
(3) by reducing the density of snags and overmature trees, uneven-aged management reduces the availability of insects for certain birds, particularly those that overwinter in the forest.
(4) by maintaining the forest in a seral stage close to the climax, uneven-aged management reduces the overall bird species diversity of a region by eliminating the early seral-stage habitats that some birds require. However, this may provide habitat for bird species of the forest interior which may not find suitable habitat in younger stands.
(5) when compared with even-aged management, uneven-aged management results in more frequent disturbance of the forest for harvesting, but the disturbance is not as severe as in even-aged management. Various bird species may respond in different ways to the frequency and severity of disturbance.

We can again offer some unproven suggestions for modifying current uneven-age management procedures in such a way that bird communities will benefit; these include:

(1) increasing horizontal diversity within a stand by either planting small patches (about 3ha) of conifers or allowing patches of conifers to develop and persist.
(2) simulating gap phase replacement by periodically opening up small patches and allowing them to pass through normal succession
(3) allowing snags to persist, as was suggested under even-aged management.
(4) cutting trees only of the largest size class that is economically feasible, thus maximizing vertical diversity of the stand.

Preservation

Preservation as a management practice is less well defined than the two options previously discussed. It may range from a completely "hands-off" policy, to active management for maximum esthetic and recreational benefits. For this discussion we take preservation to mean minimal intervention with management for esthetics, scientific research and/or wilderness recreation. If enough land were managed by preservation (i.e., thousands of hectares), this would result in mixed forest vegetation similar to the presettlement forests in which succession and disturbance created a mosaic of vegetation types with high horizontal and vertical diversity. On smaller management units the results of preservaiton will be less predictable. Small areas are likely to be maintained as a single seral stage by succession or catastrophic disturbances, such as ice and wind storms or fire.

Management by preservation has the following benefits and disadvantages for promoting high bird species diversity:

(1) tracts of land which are sufficiently large can offer horizontal and vertical diversity of vegetation that supports a diverse avian community.
(2) smaller areas of land will have a more uniform vegetation type which may be suddenly changed by catastrophic disturbances. Their contribution to an area's bird diversity will depend entirely upon whether they supply a unique habitat.

Recommendations for managing these areas for birds follow directly from these and include:

(1) large tracts of wildlands should be managed so as to allow natural succession and disturbance to occur and, thus, create diverse habitats for birds.
(2) if managing for the diversity of bird species is the principle goal, it is inappropriate to manage small areas of mixed forest by preservation. If small tracts of land are not to be economically exploited, they would best be managed for a forest type which is unavailable in the area.

Our management recommendations are specifically aimed at increasing the vertical and horizontal diversity of forests which are managed for lumber, pulpwood and other uses, thereby simulating the mosaic pattern of vegetation characteristic of the primeval forest. As we currently understand the dynamics of bird communities, this strategy will help sustain the full complement of the bird species of the hardwood-coniferous forest and maintain the region's high species diveristy.

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APPENDIX I

Common and scientific names of bird species mentioned in the text

Turkey Vulture (*Cathartes aura*)
Goshawk (*Accipiter gentilis*)
Cooper's Hawk (*A. cooperii*)
Sharp-shinned Hawk (*A. striatus*)
Red-tailed Hawk (*Buteo jamaicensis*)
Red-shouldered Hawk (*B. lineatus*)
Broad-winged Hawk (*B. platypterus*)
Peregrine Falcon (*Falco peregrinus*)
Merlin (*F. columbarius*)
Spruce Grouse (*Canachites canadensis*)
Ruffed Grouse (*Bonasa umbellus*)
American Woodcock (*Philohela minor*)
Mourning Dove (*Zenaida macroura*)
Yellow-billed Cuckoo (*Coccyzus americanus*)
Black-billed Cuckoo (*C. erythropthalmus*)
Great Horned Owl (*Bubo virginianus*)
Long-eared Owl (*Asio otus*)
Barred Owl (*Strix varia*)
Saw-whet Owl (*Aegolius acadicus*)
Common Nighthawk (*Chordeiles minor*)
Whip-poor-will (*Caprimulgus vociferus*)
Chimney Swift (*Chaetura pelagica*)
Ruby-throated Hummingbird (*Archilochus colubris*)
Belted Kingfisher (*Megaceryle alcyon*)
Common Flicker (*Colaptes auratus*)
Pileated Woodpecker (*Dryocopus pileatus*)
Red-bellied Woodpecker (*Melanerpes carolinus*)
Red-headed Woodpecker (*M. erythrocephalus*)
Yellow-bellied Sapsucker (*Sphyrapicus varius*)
Hairy Woodpecker (*P. pubescens*)
Downy Woodpecker (*P. villosus*)
Black-backed 3-toed Woodpecker (*P. arcticus*)
Northern 3-toed Woodpecker (*P. tridactylus*)
Eastern Kingbird (*Tyrannus tyrannus*)
Great Crested Flycatcher (*Myiarchus crinitus*)
Eastern Phoebe (*Sayornis phoebe*)
Acadian Flycatcher (*Empidonax virescens*)
Yellow-bellied Flycatcher (*E. flaviventris*)
Alder Flycatcher (*E. trailli*)
Least Flycatcher (*E. minimus*)
Eastern Pewee (*Contopus virens*)
Olive-sided Flycatcher (*Nuttalornis borealis*)
Tree Swallow (*Iridoprocne bicolor*)
Blue Jay (*Cyanocitta cristata*)
Gray Jay (*Perisoreus canadensis*)
Common Raven (*Corvus corax*)
Common Crow (*C. brachyrhynchus*)
Black-capped Chickadee (*Parus atricapillus*)
Carolina Chickadee (*P. carolinensis*)
Boreal Chickadee (*P. hudsonicus*)
Tufted Titmouse (*P. bicolor*)
White-breasted Nuthatch (*Sitta carolinensis*)
Red-breasted Nuthatch (*S. canadensis*)
Brown Creeper (*Certhia familiaris*)
House Wren (*Troglodytes aedon*)
Winter Wren (*T. troglodytes*)
Bewick's Wren (*Thryomanes bewickii*)
Carolina Wren (*Thryothorus ludovicianus*)
Mockingbird (*Mimus polyglottus*)
Gray Catbird (*Dumetella carolinensis*)
Brown Thrasher (*Toxostoma rufum*)
American Robin (*Turdus migratorius*)
Wood Thrush (*Hylocichla mustelina*)
Hermit Thrush (*Catharus guttata*)
Swainson's Thrush (*C. ustulata*)
Gray-cheeked Thrush (*C. minima*)
Veery (*C. fuscescens*)
Eastern Bluebird (*Sialia sialis*)
Blue-gray Gnatcatcher (*Polioptila caerulea*)
Golden -crowned Kinglet (*Regulus satrapa*)
Ruby-crowned Kinglet (*R. calendula*)
Cedar Waxwing (*Bombycilla cedorum*)
Starling (*Sturnus vulgaris*)
Solitary Vireo (*Vireo solitarius*)
White-eyed Vireo (*V. griseus*)
Bell's Vireo (*V. belii*)
Yellow-throated Vireo (*V. flavifrons*)
Red-eyed Vireo (*V. olivaceus*)
Philadelphia Vireo (*V. philadelphicus*)
Warbling Vireo (*V. gilrus*)
Black-and-white Warbler (*Mniotilta varia*)
Prothonotary Warbler (*Protonotaria citrea*)
Worm-eating Warbler (*Helmitheros vermivorus*)
Golden-winged Warbler (*Vermivora chrysoptera*)
Blue-winged Warbler (*V. pinus*)
Tennessee Warbler (*V. peregrina*)
Nashville Warbler (*V. ruficapilla*)
Northern Parula Warbler (*Parula americana*)
Yellow Warbler (*Dendroica petechia*)
Magnolia Warbler (*D. magnolia*)
Cape May Warbler (*D. tigrina*)
Yellow-rumped Warbler (*D. coronata*)
Black-throated Green Warbler (*D. virens*)
Black-throated Blue Warbler (*D. caerulescens*)
Cerulean Warbler (*D. cerulea*)
Blackburnian Warbler (*D. fusca*)
Chestnut-sided Warbler (*D. pensylvanica*)
Bay-breasted Warbler (*D. castanea*)
Blackpoll Warbler (*D. striata*)
Pine Warbler (*D. pinus*)
Prairie Warbler (*D. discolor*)
Palm Warbler (*D. palmorum*)
Ovenbird (*Seiurus aurocapillus*)
Northern Waterthrush (*S. noveboracensis*)
Louisiana Waterthrush (*S. motacilla*)
Common Yellowthroat (*Geothlypis trichas*)
Yellow-breasted Chat (*Icteria virens*)
Mourning Warbler (*Oporornis philadelphia*)
Connecticut Warbler (*O. agilis*)
Hooded Warbler (*Wilsonia citina*)
Wilson's Warbler (*Wilsonia pusilla*)
Canada Warbler (*W. canadensis*)
American Redstart (*Setophaga ruticilla*)
Red-winged Blackbird (*Agelaius phoeniceus*)
Brewer's Blackbird (*Euphagus cyanocephalus*)
Common Grackle (*Quiscalus quiscala*)
Brown-headed Cowbird (*Molothrus ater*)
Orchard Oriole (*Icterus spurius*)
Northern Oriole (*I. galbula*)
Scarlet Tanager (*Piranga olivacea*)
Northern Cardinal (*Cardinalis cardinalis*)
Rose-breasted Grosbeak (*Pheuticus ludovicianus*)
Evening Grosbeak (*Hesperiphona vespertina*)
Indigo Bunting (*Passerina cyanea*)
Purple Finch (*Carpodacus purpureus*)

Pine Grosbeak (*Pinicola enucleator*)
Common Redpoll (*Carduelis flammea*)
Pine Siskin (*C. pinus*)
American Goldfinch (*C. tristis*)
Red Crossbill (*Loxia curvirostra*)
White-winged Crossbill (*L. leucoptera*)
Vesper Sparrow (*Pooecetes gramineus*)
Rufous-sided Towhee (*Pipilo erythropthalmus*)
Dark-eyed Junco (*Junco hyemalis*)
Tree Sparrow (*Spizella arborea*)
Chipping Sparrow (*S. passerina*)
Field Sparrow (*S. pusilla*)
White-throated Sparrow (*Zonotrichia albicollis*)
Fox Sparrow (*Passerella iliaca*)
Swamp Sparrow (*Melospiza georgiana*)
Song Sparrow (*M. melodia*)