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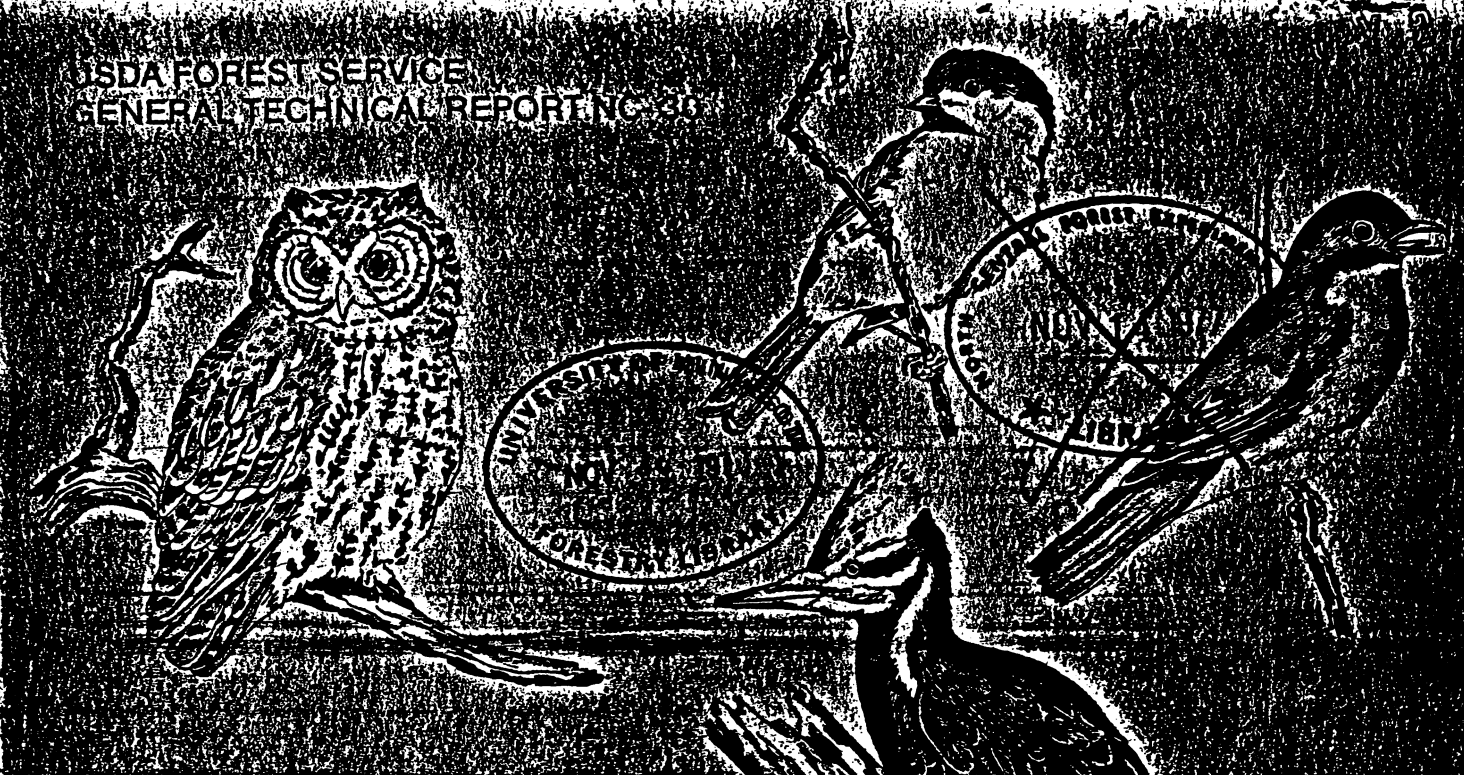
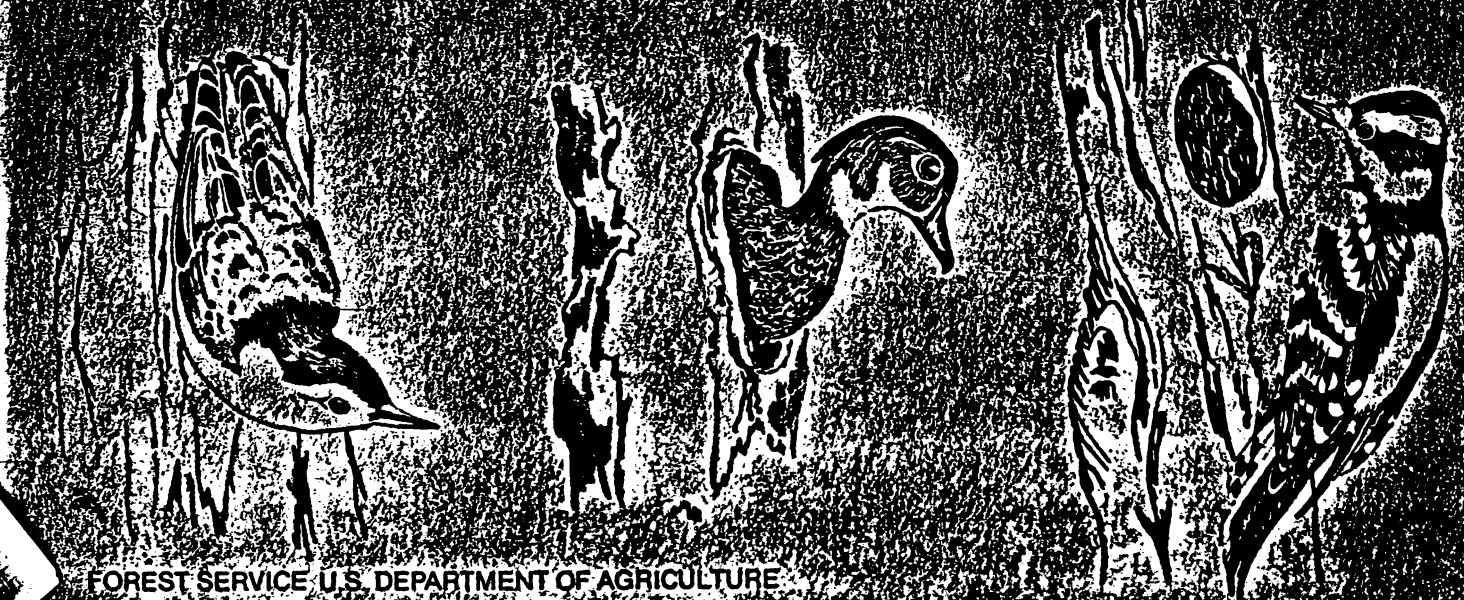


CAVITY NESTING BIRD HABITAT

in the oak-hickory forest...a review

BY KIMBERLY L. HARDIN AND KEITH E. EVANS



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CAVITY NESTING BIRD HABITAT IN THE OAK-HICKORY FORESTS--A REVIEW

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The group of bird species referred to as cavity nesters receive both praise and wrath from forest managers. The cavity "users" rarely cause any conflict with other forest activities. But cavity "makers" are often blamed for reduced economic output from a forest by their excavation activities in trees marked for harvest. The criticism is largely unwarranted, however, because woodpeckers in the oak-hickory forest usually make cavities in trees that previously have been damaged by insects, disease, fire, or storm.

The 47-million hectare oak-hickory forest is the most extensive timber type in the United States. It extends from the prairie border in Oklahoma northeast through the Appalachian Mountains into the Piedmont and southern New England. The oak-hickory forest is best developed and most continuous in the Ozark and Ouachita Highlands (Watt *et al.* 1973). High-grading, burning, and grazing practices in the past have created stands with a cull volume that ranges from 40 to 60 percent of the total volume (Gingrich 1970). Stands with a cull tree overstory or a high frequency of cull trees create a unique habitat with abundant natural cavities and many hollow trees suitable for cavity excavation. With more intensive forestry practices and removal of cull trees by thinning operations or harvest cuts, natural cavities may become limited. Currently, some cavity-nesting populations are declining, and one, the Ivory-billed Woodpecker (*Campephilus principalis*) of North America is believed to be extinct. Most forest management plans do not include steps to improve cavity nesters habitat. One reason for this is that forest managers are unaware of the type of habitat used by these birds.

The diversity of the 28 cavity-nesting bird species recognized by the USDA Forest Service (1973) enhances their value to the forest ecosystem. One aspect of this diversity is their size range; from the Turkey Vulture, which has a 180-cm wingspan, to the Carolina Chickadee, which has an 11.5-cm wingspan. Although most cavity nesters are predators, they are highly diversified in the size of their food and the method they obtain it: the American Kestrel feeds on small mammals, large insects, and some birds; the owls feed on small nocturnal mammals; the wrens gleen insects from the foliage; and the woodpeckers drill for insects; etc.

Cavity nesters are an important component of the oak-hickory ecosystem. Nine years of breeding bird survey data in Missouri indicate that cavity nesters make up 22 percent (30) of the 139 species of birds recorded (Evans and Dawson 1976). Frequency data (unpublished, preliminary) showed cavity nesters in the top 10 bird species in all of the 7 vegetation types sampled in Missouri's Ozarks. Forest and forest edge types each included 3 cavity nesters in the top 10 species. Aerial-sprayed areas had 4 cavity nesting species in the top 10. Fescue fields and clearcuts each included one species; these areas were used for feeding.

The purpose of this article is to review, analyze, and integrate the published information on habitat selection and utilization of cavity-nesting birds and relate this information to forest management situations. The report is divided into two major subject areas. First, the known aspects of the habitat selection and utilization are covered. This information can be gleened directly from the literature. Second, managment implications are discussed. This information must be interpreted and adapted from the published information to forest management situations. Some of the potential impacts of managment alternatives are speculative, which are noted with comments on future research needs. One concept appearing, both directly and indirectly, throughout the paper is the concept of species tolerance to habitat variability. The species with inherently narrow tolerances to habitat variability are more vulnerable to forest managment options. Cavity-nesting birds, because

they require cavities to complete their life cycle, are somewhat specific in their habitat selection.

HABITAT SELECTION AND USE

Turkey Vulture--*Cathartes aura*[1]

Turkey Vulture nesting sites are often at a premium because of the large size of the vulture and the shortage of large snags. Because both young and adults eat carrion, the smell around the nest attracts predators. Therefore, a fairly well protected site is required. The birds do not construct their own nests but rely on available sites and will return to the same nesting site year after year unless the site is badly disturbed (Jackson 1903, Kempton 1927). They lay two eggs, usually on whatever litter is present (Bent 1937, Kempton 1927). Inclubating time is approximately 30 days (Jackson 1903).

Turkey Vulture nesting records are fairly numerous. There have been reports of them nesting on cliffs, in caves, in hollow stumps, or in the midst of dense shrubbery with a narrow, easily defendable entrance. The site is almost always near the ground but one was reported to be 6.1 m up in a deep stump and one other 1.8 m below ground level in the hollow of a rotten stump (Bent 1937).

The most frequently reported nesting sites are those located in hollow trees and in hollow logs lying on the ground (Gingrich 1914, Townsend 1914). One nest in a hollow snag had an entrance 4.3 m up but the eggs were laid at ground level (Pearson 1919). Another was found in a live hollow soft maple, which had an inside diameter of 71 cm, was 102 cm above ground, and the opening was 107 cm above the eggs (Kempton 1927). The birds have been reported nesting in caves or dry sink holes in Florida and New York (Howes 1926, Pearson 1919). One nest site in Maryland was on the ground under the overturned bifurcated root stump of a large dead chestnut tree (Williams 1924). There is also a record of a pair nesting on a pig sty (Jackson 1903). Platt (1971) reported that vultures in Curlew Valley, Utah, nested on cliffs for lack of a better place.

[1]*Bird Nomenclature from American Ornithologists' Union (1957, 1973, 1976).*

Black Vulture--*Coragyps atratus*

Black Vultures have some of the same nest site requirements as their close relatives the Turkey Vultures, including the use of available sites that do not require additional construction (Hoxie 1886, Bent 1937). Court (1924) found a Black Vulture nest in Maryland, .6 m below ground level in a large white oak stump. The birds used it for two consecutive years. Another report is a nest with two eggs in an old tobacco shed on an abandoned farmstead in Virginia (Stewart 1974). Hollow stumps or standing trees are favorite nesting sites for Black Vultures. However, the eggs are occasionally merely laid on the ground, often in dense thickets of palmetto, yucca, tall sawgrass, or sometimes in the open, exposed to full daylight (Bent 1937).

The Black Vulture is uncommon throughout most of the oak-hickory type. It is primarily a southern scavenger. The Turkey Vulture inhabits the scavenger niche throughout the northern portions of the oak-hickory forests.

American Kestrel--*Falco sparverius*

Most hawks either build true nests or lay their eggs on open ledges or bare cliffs. However, the American Kestrel (Sparrow Hawk) prefers to lay its eggs in holes, either natural cavities, holes made by other birds, or man-made boxes. In the West, they will occasionally nest in abandoned Black-billed Magpie (*Pica pica*) nests (Richards 1970). Also, in common with other birds of prey, Kestrels require large breeding territories so their nests are widely spaced (Bent 1938).

Smith *et al.* (1972) observed 41 Kestrel nests in Utah. Of these, 28 were located in trees (19 in old flicker holes, 2 in old magpie nests, and 7 in natural cavities). The type and numbers of trees used were: 18 cottonwood, 3 poplar, 3 willow, 2 maple, 1 elm, and 1 apple. Two of the remaining nests were located in the rocky cliffs of abandoned quarries and the last 11 were found on building tops. Nest height ranged from 1.22 m to 19.8 m above the ground. The average height of eggs on buildings was 10 m and the average of the rest of the sites was 6.7 m. There was no observed attempt at nest construction--the eggs were laid either on debris in the cavity or on nest materials of previous occupants. Twelve pair used the same nest site for two consecutive years and eight of these used

the same site again the third year. Twenty-six pair used the same territory for 2 years and 21 returned to the same area the third year (Smith *et al.* 1972).

Roest (1957) found the favorite nesting sites of American Kestrels to be either abandoned Common Flicker holes or natural cavities located 2 to 10.7 m above the ground level (tables 1 and 2). Willoughbey and Cade (1964) reported that Kestrels prefer an 8 cm hole in man-made boxes. Usually four or five eggs are laid and require approximately 30 days for incubation. Kestrel eggs are pigmented unlike those of most cavity nesters which are white. This suggests that Kestrels have only recently, on the evolutionary time scale, become cavity nesters (Richards 1970).

Table 1.--*Nest sites used by American Kestrel (Roest 1957)*
(In number of nests)

	Natural cavity	Flicker hole	Woodpecker hole	Magpie nest	Hole in cliff	Building	Total
Oregon	2	6			1	3	12
Virginia	1	1					2
New York	1						1
California	12	15	3	2			32
Canada	1	13	3				17
Other	2	2					4
Total	19	37	6	2	1	3	68

Table 2.--*Height of American Kestrel nests above the ground (Roest 1957)*
(In number of nests)

Height (m)	Oregon	Virginia	New York	California	Canada	Totals
1.2-2.7	1				1	2
3-4.25	4			1	8	13
4.55-5.55	1		1	2	1	5
6.1-7.3	2	1		1	3	7
7.6-8.8	1			2	3	6
9.2-10.4	2			4		6
10.7-11.9				4	1	5
12.2-15				4	1	5
15.2+		1		2		3

Kestrels will often be found on high, exposed perches where they can look out over wide stretches of grassland or pasture to watch for prey. Common prey includes insects, birds, mammals, reptiles, and amphibians. Amounts of each vary with the season and the locality. They have also been observed catching and eating bats (Twente 1954). During the winter in northern latitudes, prey is restricted to birds and small mammals. However, when and where insects are abundant, they comprise the hawk's principal food. Kestrels are able to overcome birds that are nearly their own size such as starlings. They prefer to hunt in open areas, therefore, natural cavities or nest boxes should be along the edge or ecotone between the forest and an opening (Bent 1938).

Owls

The owls, Order Strigiformes, differ widely in their habitat requirements. Eighteen species of owls live in North America (American Ornithologists' Union 1957), but we will only discuss the habits of the four common cavity nesting, eastern forest owls. They are nocturnal hunters and are rarely seen. Techniques for inventorying the Strigiforme resource have not been developed so the impact management plans have had on owls is not known. Angell (1974), Burton (1973), Hamerstrom (1972), and Sparks and Soper (1970) have all expressed concern for the loss of owl habitat when overmature forests are cut and snags and cull trees removed.

Birds that nest in cavities may accept nest boxes, especially if the box is located near good hunting territory. Owls do not add nest material to their nest site, therefore, it is desirable to put sawdust, hay, or other material in the box so the parent can incubate the eggs without them rolling away. Owls are not known for their architectural selectivity, so nest box design can esthetically and economically please the builder (Hamerstrom 1972). However, different size boxes will attract different species of birds (table 3 and fig. 1).

Table 3.--*Recommended nest box sizes for eastern deciduous forest owls (Hamerstrom 1972)*

Owl species	Floor size	Cavity depth	Entrance diameter	Habitat
	- - - - Centimeters - - - -			
Saw-whet	15x15	20-25	6	Woods and swamps
Screech	20x20	20-25	7.5	Orchards and suburbs
Barred	33x38	38-43	20	Near streams, woods
Barn	33x38	38-43	13	Cities and farmland

Saw-whet Owl--Aegolius acadicus

Saw-whet Owls are small (18 cm), nocturnal hunters of the deep north woods. They do nest as far south as central Missouri, but only rarely. They do winter in Missouri. These small owls prefer to nest in old woodpecker or flicker holes as shown in the following summary of nesting sites used by owls (Bent 1938):

Species	*Height above ground (m)*	*Description*
Saw-whet Owl	----	Flicker hole--dead pine stub
	5.5	Flicker hole--dead pine stub
	6.7	Dead maple stump
	12.2	Dead stub
	6.1	Dead stub
	15.2	Dead stub
	19.2	Dead top of maple tree
	7.6	Woodpecker hole--pine stub
Screech Owl	6.1	Flicker hole--dead pine stub
	1.5	Natural cavity--apple tree
	3.0	Natural cavity--apple tree
	----	Flicker hole--dead poplar
	10.7	Natural cavity--large oak
Barred Owl	----	18 times used old hawk nest
	----	15 times used hollow tree
	----	5 times used squirrel nest

Nesting habitat may be improving in areas where Dutch elm disease has infected many elms and woodpeckers have drilled nest holes (Hamerstrom 1972). Pearson (1936) reported they will also use squirrel dens for nesting sites. The mature forest composed of a mixture of trees, living and dead, young and old, is the preferred nesting habitat of Saw-whet Owls (Angell 1974). Their three to six white eggs are deposited on whatever material is found in the cavity.

Saw-whet Owls feed primarily on beetles, grasshoppers, other insects, mice (Hamerstrom 1972), bats, frogs, and small birds (Burton 1973). Winter foods of Saw-whet Owls in Illinois and Iowa consisted of 97 percent mice and shrews of the genera *Peromyscus, Microtus, Cryptotis, Blarina,* and *Mus.* A few birds, mainly Fringillids, were also included (Scott 1938, Graber 1962). Summer foods consist of a high proportion of large insects.

Screech Owl--Otus asio

The male Screech Owl defends a nesting and feeding territory, as do other owls. Territory size varies and there is usually a neutral zone between individual territories (Burton 1973). Maples, apples, and sycamores with natural cavities or pines with woodpecker holes are preferred nesting sites. Old apple orchards seem to provide a good combination of cavities and open hunting areas (Hamerstrom 1972, Bent 1938). Screech Owls lay 5 to 8 nearly spherical, white eggs.

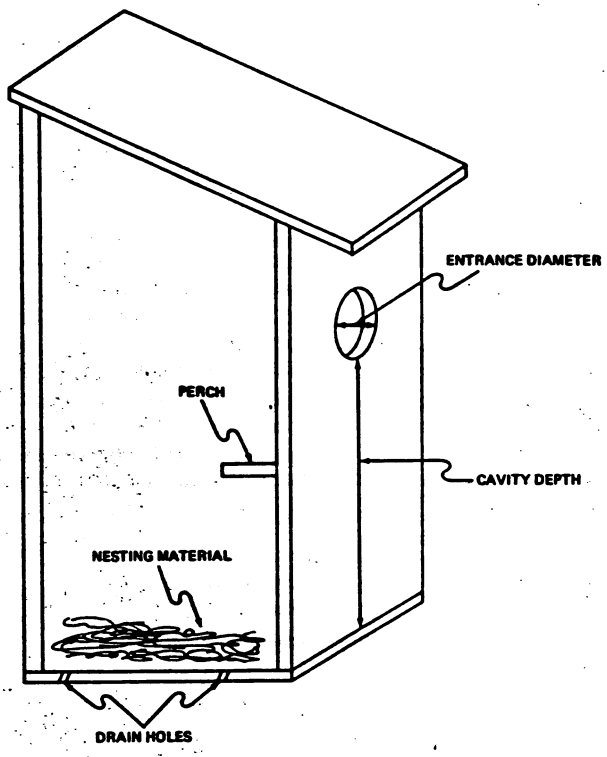

Figure 1.--*Components of an owl nest box.*

Screech Owls are one of the most nocturnal owls. They do not eat or even hunt until twilight is past. The birds hunt over low-land meadows and fields or catch insects over the tops of trees. Food depends largely on the environment and the most readily available prey. The owl is evidently satisfied with what animal food it can most easily obtain. Foods eaten by Screech Owls in western Missouri based on 419 pellets analyzed from 1957 to 1967 (Korschgen and Stuart 1972) were as follows:

Food	*Occurrence* (Percent)	*Volume* (Percent)
Meadow mouse	56.6	52.1
White-footed mouse	25.8	18.8
Cotton rat	14.8	14.8
Rabbit	4.8	5.6

Songbirds	8.4	4.1
Short-tailed shrew	3.1	1.8
Least shrew	3.6	1.2
Norway rat	0.5	0.5
Bog lemming	0.2	0.1
House mouse	0.2	0.1
Crayfish	0.2	0.1
June beetles	0.2	Trace
Frog, unidentified	0.2	Trace

In addition to these foods, the owls eat fish, lizards, spiders, earthworms, and birds as large as domestic pigeons, quail, and ruffed grouse. Van Camp and Henry (1975) found that Screech Owls on a northern Ohio study area captured 53 species of birds (65 percent of their diet) during the nesting season. They also feed extensively on insects which they grab off the leaves with their talons or catch on-the-wing in their beaks. Beetles, cutworms, grasshoppers, locusts, crickets, cicadas, katydids, and noctuid moths are only a few of the many insects that this owl eats (Bent 1938).

Barred Owls--Strix varia

Barred Owls select suitable cavities for nesting if available. If natural cavities are scarce, they will nest in abandoned raptor and squirrel nests. Both the male and female are efficient territorial hunters. Their ears are as well developed as their eyes. Barred Owls can capture a live mouse in complete darkness on a bare floor by audible detection. Woodland owls are commonly more vocal than open-country owls. Barred Owls have a unique call that has been described as "Who cooks for you, who cooks for you-all" (Burton 1973, Sparks and Soper 1970).

Barred Owls seem to be diverse in their eating habits and like the Saw-whet and the Screech Owls, prey is highly dependent on the season. Foods of Barred Owls in western Missouri based on 700 pellets analyzed from 1949 to 1968 (Korschgen and Stuart 1972) were as follows:

Food	*Occurrence* (Percent)	*Volume* (Percent)
Meadow mouse	26.1	20.2
Cottontail rabbit	20.1	19.6
Cotton rat	17.9	17.7
White-footed mouse	32.1	14.4
Songbirds	27.0	13.8
Crayfish	13.6	3.4
Fish, unidentified	9.1	2.4
Mole	1.9	1.7
House mouse	2.9	1.1
Short-tailed shrew	2.3	0.8
Harvest mouse	1.4	0.7
Birds, unidentified	1.3	0.7
Grey squirrel	0.6	0.6
Least shrew	3.6	0.6
Frogs, unidentified	4.4	0.5
Snakes, unidentified	1.3	0.4
Grasshoppers	1.0	0.4
Salamander, unidentified	0.6	0.3
Opossum	0.3	0.3
Norway rat	0.1	0.2
Bog lemming	0.3	0.2
June beetles	1.1	0.1
Pine mouse	0.1	0.1
Mourning dove	0.1	0.1

In southern Massachusetts, Barred Owls generally nest in white pine woods (Bent 1938), oak woods, or mixed hardwood-confier types (Nicholls and Warner 1972). The Barred Owl prefers a sparse understory, which facilitates clear flying and attacking prey. Oak woods with many dead or dying trees are preferred because they provide cavities as well as habitat for prey species such as mice and squirrels. Hollow trees also provide perches with good visibility for the owls to hunt from. Because they are nocturnal hunters, owls greatly depend on their hearing to find prey. Perches, which allow the bird to hear rustles in the leaves or scurrying rodents and squirrels, are very important.

Barn Owl--Tyto alba

Barn Owls use a wide variety of nesting sites for their 5 to 7 white eggs (Bent 1938). The sites include natural hollows in trees, holes and cavities in cave banks or cliffs, burrows under ground, sides of old wells, abandoned mining shafts, dovecotes, barns, and church steeples. Several pair have been found roosting in separate cavities of the same tree (Reed 1897).

Barn Owls are distinctly birds of the open country and are less inclined than other owls to shun areas occupied by man. They find their best food supplies in open fields, meadows, and around barns, granaries, and other buildings. In the wild state, birds will hunt as far as 2.4 to 3.7 km from nest site or roost buildings. Adults are almost wholly nocturnal. However, there are a few reports of them leaving roosts and nests before twilight--especially when feeding young (Marti 1974). Territoriality, centered primarily around the nest

site structure, is evident during the breeding season. Overlap of home ranges of adjacent pairs or of a pair and single bird is common (Smith *et al.* 1974).

Studies in Colorado and Pennsylvania found the Meadow Vole (*Microtus pennsylvanicus*) to be the primary food item of the Barn Owl (Smith *et al.* 1974, Reed 1897, Marti 1974). Another study showed House Mice (*Mus musculus*) to be the major item of consumption (Evans and Emlen 1947). Other prey includes members of the genera *Peromyscus, Sorex, Cryptotis, Sylvilagus, Microtus,* and *Rattus* as well as other rodents. Bats are occasionally eaten (Twente 1954, Marti 1974) and birds are also eaten sometimes. Birds such as House Sparrows and Red-winged Blackbirds, which have communal roosts, can become easy targets for Barn Owls. Barn Owls are versatile in their prey habits (Marti 1974).

Pileated Woodpecker--*Dryocopus pileatus*

Forests of dense timber and secondary growth consisting of mixed deciduous trees and conifers are the preferred year around habitat of the pileated woodpecker. Although there are reports of excavating and nesting in live trees, these birds prefer dead trees or dead limbs on live trees. One tree may be used for several years but a previous nest hole is rarely reused. This behavior provides cavities for other wildlife such as ducks, flying squirrels, and owls (Hoyt 1957).

Nests have been found in beech, poplar, birch, oak, hickory, maple, hemlock, pine, ash, elm, and basswood. Height ranged from 5 to 21 m and there was no reported preference of direction for entrance holes (Hoyt 1957). Tall dead trees with bonelike surfaces and few limbs are favored. Nest holes may be up to 10 cm in diameter and as deep as 76 cm (Hoyt 1941). In California, Carringer and Wells (1919) reported several nests in live aspen trees when plenty of dead trees were available. Most of the nests were in trees whose roots were under water. Unlike many birds, Pileated Woodpeckers retain close pair bonds throughout the years. Although the male and female roost in separate cavities, there is usually not much distance between them (Kilham 1974).

Pileated Woodpeckers lead all other woodpeckers in their ability to prey upon certain insects. Ants, especially Carpenter Ants (*Camponotus herculeanus* L.), and beetles are the major insects that comprise 72 percent of their food. Trees with heart rot provide suitable habitat for initial invasion by Carpenter Ants (Sanders 1964). Hence, silvicultural thinnings that remove infected trees could have a critical impact on the Pileated Woodpecker by removing one of its major food items. In the fall, dogwood berries, cherries, beechnuts, acorns, and other wild fruit are included in the bird's diet. Pileated Woodpeckers rely entirely on forests and brushy areas along the forest edge for food (Bent 1939). They are a highly beneficial bird because they stay with one tree until it is rid of insects, which prevents further infection of trees in the vicinity and gives the infected tree a chance to live. People point to dead trees, riddled with woodpecker holes, and blame the death of the tree on the woodpecker. However, the tree probably died from the insect infestation (Hoyt 1957).

During the regeneration stage of even-aged timber management systems, stands have little potential for Pileated Woodpecker nesting. These woodpeckers prefer older-aged stands that offer trees large enough for nesting cavities (table 4). Timber stands with medium size sawtimber (38 to 46 cm d.b.h.) would provide adequate Pileated Woodpecker nesting habitat if some of the trees were decayed (Conner *et al.* 1975).

Red-Headed Woodpecker--*Melanerpes erythrocephalus*

As with the other woodpeckers, cavities are important to Red-headed Woodpeckers all year, not just during the nesting season. Trunks of dead trees are the favored location for nesting cavities (table 5). Entrances of excavated holes usually face to the south or west (Reller 1972).

Red-headed Woodpeckers eat a wide variety of food depending on availability. Insects, including ants, wasps, beetles, bugs, grasshoppers, crickets, moths, and caterpillars, are the main year-around food. Fruit provides a supplement to their diet and they have been observed eating corn, dogwood berries, huckleberries, strawberries, blackberries, elderberries, wild black cherries, wild grapes, apples, pears, various seeds, acorns, and beechnuts.

Table 4.--*Average measurements of woodpecker nest trees in forest habitats in Virginia (Conner et al. 1975) (ranges are given in parentheses)*

Measurement	Species			
	Downy	Hairy	Flicker	Pileated
Male bird length (cm)	14.5	19.0	26.5	38.0
Nests (No.)	15	10	6	14
Nest tree dbh (cm)	31.8 (15-66)	40.6 (20-64)	36.8 (30-46)	54.6 (33-91)
Nest tree cavity diameter (cm)	20.8 (13-41)	25.2 (20-46)	27.9 (23-36)	37.9 (30-51)
Nest tree height (m)	8.3 (1.5-19.8)	13.0 (4.0-26.5)	12.4 (9.1-15.8)	20.3 (10.7-36.6)
Nest height (m)	4.7 (1.0-11.6)	8.8 (2.4-19.8)	8.5 (6.1-11.9)	13.6 (9.1-19.2)

Table 5.--*Nest site preference of Red-bellied and Red-headed Woodpeckers (Reller 1972)*

Species	Height (m)	Entrance hole direction	Tree type	Portion
Red-headed	12	SW	Dead	Trunk
	10	NW	do	do
	7	WSW	do	do
	7	NE	do	do
	15	WSW	do	do
	12	SE	do	do
	12	SW	do	do
	12	SE	do	do
	20	S	do	do
	17	SW	do	do
Red-bellied	13	SW	*Quercus rubra*	Limb
	13	W	Dead maple	Trunk
	10	S	*Quercus velutina*	Dead limb
	22	NW	*Plantanus occidentalis*	do
	20	WSW	*Quercus velutina*	do
	10	S	*Tilia americana*	do
	12	E	*T. americana*	do

Occasionally, this woodpecker eats eggs of small birds or kills and eats young birds and rodents (Bent 1939).

In the winter, Red-headed Woodpeckers roost and live in small well-defined territories (Kilham 1958a, 1958c). Pin Oak (*Quercus palustris*) acorns comprise a large portion of the winter food. The woodpecker stores the nuts whole or in pieces in cracks and crevices in bark and also in cavities that are sealed with bits of bark when filled. These birds also store insects in sealed hollows of trees (Kilham 1958b).

Red-headed Woodpeckers prefer to nest and roost near open areas. Fields, edges, and sprayed timber with little or no high leaf canopy are highly favored habitats. Few of their activities--feeding, nesting, or roosting--are carried out in mature timber stands. They are attracted to forest areas that have been sprayed with herbicide and contain many dead snags and lush herbaceous ground cover. Concentration of Red-headed Woodpeckers in sprayed areas is often spectacular.

Red-Bellied Woodpecker--*Melanerpes carolinus*

Red-bellied Woodpeckers often excavate their cavities in dead limbs of live trees (Reller 1972), unlike the Red-headed Woodpecker which prefers to nest in dead trees. Reported nesting sites for Red-bellied Woodpeckers include one 6 m above ground in the dead stub of a living ash, one 18 m up on a dead elm, and another 6 m up in the dead top of a living willow (Kilham 1961) (table 5). From September to January the male and female roost in separate cavities. One of the roost cavities becomes the nest site (Kilham 1958a). Cavities are usually excavated in mature timber stands where the bird's activities are centered. Loveless (1975) found Red-bellied Woodpeckers commonly using the forest edges of central Missouri. The Red-bellied Woodpecker ranked 12th on the list of 49 bird species using edge plots.

Red-bellied Woodpeckers consume more vegetable matter than do most woodpeckers. Vegetation eaten includes corn, acorns, beechnuts, pine seeds, juniper seeds, wild grapes, blackberries, strawberries, pokeberries, cherries, apples, mulberries, elderberries, blueberries, and fruit from Virginia creeper, holly, dogwood, and poison ivy. Seeds from ragweed, wild sarsaparilla, hazelnuts, and pecans are also eaten. These birds cause some economic damage by sucking pulp from oranges in the South (Bent 1939). But the insects eaten--including ants, adult and larval beetles, and caterpillars--more than atone for the damage (Bent 1939).

Red-bellied Woodpeckers store food in the fall by hammering acorns of various kinds into pieces and storing them in cavities. Berries are stored in rootlets of vines as well as in cavities. Knowledge of the presence of these stores is retained and reinforced by the bird's habit of occasionally restoring his supplies (Kilham 1963). In the winter, these woodpeckers are easily attracted to artificial feeding stations, especially those offering suet, nuts, or breadcrumbs.

Common Flicker--*Colaptes auratus*

Lawrence (1967) reported that Flickers prefer to nest close to the top of dead stubs. When excavating their own nest sites, Flickers seem to prefer trunks with smooth, open surfaces (table 6). Entrance direction shows a preference for the south and east, perhaps to ensure the access of light and warmth into the cavity when nesting (table 7). Flickers often excavate in the same tree year after year. They may also use excavations of other birds such as Pileated Woodpeckers (Lawrence 1967). Lawrence (1967) measured the height of 25 Flicker nests and found a range of 2.5 to 14 m with an average of 7 m. Observations reported by others support Lawrence's statements. One Flicker nest was found 3 m above the ground in a rotten maple stump which also had a Downy Woodpecker and a Bluebird nest (Brewster 1893). In New Hampshire, Kilham (1959) reported two nests in dead pine stubs, one of which was 15 m above ground. Concentrations of 19 breeding pairs per 40 ha of white pine forest have been observed in Massachusetts (Dennis 1969).

Table 6.--*Woodpeckers' selection of tree species for nest sites (Lawrence 1967)*

Tree	Flicker		Hairy		Downy	
	No.	*Percent*	*No.*	*Percent*	*No.*	*Percent*
In live trees	6	24	10	91	0	0
In dead trees	19	76	1	9	11	100
In trees used before	15	60	2	18	5	45
In *Populus tremuloides*	19	76	11	100	11	100
In *P. grandidentata*	2	8	0	0	0	0
In other trees	4	16	0	0	0	0
Total nests	[1]25		11		11	

[1]Totals do not add up as categories are not mutually exclusive.

Table 7.--*Orientation of the nest openings (Lawrence 1967)*

Species:	N	NE	E	SE	S	SW	W	NW	Total
Flicker	2	1	5	8	8	0	0	1	25
Hairy	0	1	4	1	2	0	2	1	11
Downy	0	0	2	2	2	2	3	0	11
Total	4	2	19	17	27	4	13	3	89

Flickers seem to prefer open country or lightly wooded areas although occasional nestings in deep woods have been reported. They nest in suburban areas where trees and parklike areas are plentiful as well as in rural districts. In fall and winter, Flickers live in open woodlands, fields, or meadows, and occasionally coniferous woods or swamps (Bent 1939).

Sixty percent of a Flicker's food intake is animal matter. Of this portion, 75 percent is ants (they eat more ants than any other bird). The rest of their insect intake includes beetles, wasps, grasshoppers, crickets, mole crickets, cinch bugs, wood lice, caterpillars, grubs, and various flying insects. The vegetable portion of their diet is similar to the vegetable portion of the diets of the Red-headed and Red-bellied Woodpecker except that no mast and few cultivated crops are consumed (Bent 1939).

Conner *et al.* (1975) reported most Flicker nest trees were in edge habitats such as woodlots and suburban areas, and the only nest trees found in forest areas were in clearcuts. Flickers frequently feed on or near the ground in open habitats. Selecting a nest tree with open ground availability appears to be equally important to selecting a suitable tree. The parklike habitat selection is illustrated by Loveless (1975) who reported a significantly high frequency of Flickers on forest-grazed pasture edges compared to forest-old field edges. Livestock grazing apparently eliminates some of the lush herbaceous cover and makes the area more suitable for ground feeding.

Hairy Woodpecker--*Picoides villosus*

Hard-centered live trees located in open woodlands were the most commonly used nesting site of Hairy Woodpeckers observed by Lawrence (1967) (table 6). Kilham (1968a), however, found many birds nesting in living trees with rotten centers. Lawrence (1967) measured the height of 11 nests and found a range of 4.5 to 14 m with an average of 10.5 m. D.b.h. of 7 of the trees used for nesting ranged between 25.5 to 35 cm with an average of 28 cm. The size of a Hairy Woodpecker's nest entrance is very convenient for starlings and flying squirrels (Kilham 1968a). Often Hairies will excavate their cavity with the entrance camouflaged or hidden, such as on the underside of a limb (Lawrence 1967). Nests have been reported

4 m up in the rotten center of an aspen, within the rotten center of a living butternut located between two fields, and 7 m up in a living white birch in an open forest composed of red oak, birch, and hornbeam (Kilham 1968a). Common Flickers and Downy Woodpeckers nest primarily in dead trees, but Hairy Woodpeckers use living trees. If the woodland where the woodpeckers nest have few suitable nest trees, the birds may be forced to excavate holes in nest trees that are below optimum size (table 4) or too rotten to be safe.

Hairy Woodpeckers make an effort to prevent competition for food as shown by the following general differences in the foraging behavior of males and females (Kilham 1968a):

	Male	*Female*
Area	Away from nest	Close to nest
Foraging Location	Mostly in trees	Trees, bushes, ground
of prey	Deep in wood	Superficial
Size of prey	Large	Small
Hunting technique	Deliberate	Keeps moving
Visits to young	Few	3 to 4 x no. of male
Care of young	Less concern	More attentive

Male Hairies were observed excavating dead trunks or limbs of aspens, black cherries, red oaks, and maples. These trees occurred mainly either along stone walls and dirt roadways, which had protected them from lumbering, or in fairly mature woods. When both members of a pair were feeding together, the female would usually feed on insects in dying elms by the roadway or on white and yellow birches in the woods (Kilham 1965). Both sexes supplement their primarily insect diet with fruit, some corn, and mast consisting of acorns, hazelnuts, and beechnuts. They will also eat suet and fat from carcasses in the winter. Hairies have been accused of sucking sap, however, this is not substantiated. Any sap or cambium taken is probably incidental to searching for insects (Bent 1939).

Downy Woodpecker--*Picoides pubescens*

Downy Woodpeckers resemble Flickers in many of their nesting habits (tables 4 and 6). Like Flickers, Downies prefer to excavate near the top of dead trees in fairly open timber stands. They will often make new excavations year after year in the same tree. They do not use cavities of other birds because they prefer to make a hole to suit their own tastes (Lawrence 1967). In the fall, each bird excavates a fresh hole to use as a winter roost (Kilham 1962). Lawrence (1967) measured the height of Downy Woodpeckers' nests and found a range of 4 to 15 m with an average of 9 m. D.b.h. of four trees used for nesting ranged from 21 to 30 cm with an average of 26 cm.

Insects comprise the main portion of the summer diet of Downy Woodpeckers. In Lyme, New Hampshire, *Xylococculus betulae*, an insect found in large numbers on paper birches and sometimes on yellow birches and beech, is an important food most of the year. The birds probably are responsible for keeping the insect population under control (Kilham 1970). Elsewhere, beetles, weevils, ants, and caterpillars comprise more than 60 percent of their diet. Other insects and wild fruit make up the remainder of their food (Bent 1939).

Downy Woodpeckers often feed on low vegetation. The distribution of Downies in one study was highly correlated with sapling density. Therefore, sustained brush clearance in the forest would decrease the amount of Downy Woodpecker habitat (Shugart *et al.* 1974).

Red-breasted Nuthatch--*Sitta canadensis*

Red-breasted Nuthatches will excavate their own cavity if a suitable cavity is not available. The female chooses the nesting site and does most of the excavating. After excavation, a true nest is built in the hole. Nuthatch nests have been found in old poplar and yellow birch snags (de Kiriline 1952, Kilham 1973).

Red-breasted Nuthatches breed in Canada and northern Minnesota, Michigan, and northern New England where they prefer evergreen forests (Peterson 1964). The bird is only a winter resident of Missouri. Nothing specific was found about the winter habitat but this Nuthatch probably roosts in natural or previously made cavities during the winter. Seeds of pine, spruce, and fir are its main winter diet with insects included when they are available. Nuthatches will use bird feeders offering suet (Bent 1948).

White-breasted Nuthatch--
Sitta carolinensis

White-breasted Nuthatches nest almost exclusively in natural cavities within living trees of mature forests (Kilham 1968b). When there are absolutely none to be found, they may use an abandoned woodpecker hole (Pearson 1936). No reports in the literature were found of any White-breasted Nuthatches excavating their own nest hole. However, E. L. Bull observed a pair nesting in a cavity they had excavated in a grand fir (*Abies grandis*).[2]

Because they are natural cavity nesters, these nuthatches compete fiercely with tree squirrels for cavities. Kilham (1968b) found that squirrels are attracted to two sizes of entrance holes in old sugar maples, holes of 3 to 4 cm in diameter attract red squirrels (*Tamiasciurus hudsonicus*) and holes of 7 to 10 cm in diameter attract grey squirrels (*Sciurus carolinensis*). Two reports of red squirrels occupying cavities used the previous year by White-breasted Nuthatches were discovered. Kilham (1968b) found that flying squirrels (*Glaucomys* spp.) do not compete with nuthatches for cavities because they seem to prefer woodpecker holes rather than the natural cavities used by White-breasted Nuthatches (Kilham 1968b).

Like Kestrels, White-breasted Nuthatches lay spotted eggs. This indicates, according to Haartman's (1957) classification, that the birds are secondary hole nesters and have acquired cavity-nesting habits much more recently than such species as woodpeckers, which lay white eggs (Kilham 1968b).

A myriad of insects, including larvae of the gypsy moth and the forest tent caterpillar, beetles, spiders, caterpillars, and ants comprise the main diet of White-breasted Nuthatches throughout the spring and summer. The winter diet is composed of beechnuts, acorns, hickory nuts, maize, and sunflower seeds. They can be attracted to feeders offering suet and sunflower seeds (Bent 1948).

Carolina Wren--*Thryothorus ludovicianus*

Carolina Wrens are versatile in their nesting site choices. Their nests have sides, a roof, and a side entrance, and are made predominantly from dry leaves, stems, and leaf skeletons. They prefer to build on a ledge or some kind of receptacle to give their nest support. They are well adapted to the habitats of man but also nest in the woods there they prefer tangles and brushy undergrowth (Laskey 1948, Peterson 1964).

Animal food, which is nearly all insects, makes up 94 percent of the Carolina Wren's diet. Of this, beetles, caterpillars, moths, and various Hemiptera and Orthoptera comprise the largest portion. The 6 percent vegetable matter is consumed during the winter when insects are unavailable. The chief component of the vegetable part is seeds including those of bayberry, sweet gum, poison ivy, sumac, pine, and acorns. Carolina Wrens come freely to feeding stations placed near brush piles, thickets, or other shelter to feed on ground peanuts, suet, bone marrow, or hamburger (Bent 1948).

Laskey (1948) reported that of the 37 Carolina Wren nests found; 17 were in bird boxes, either stationary or swinging; 9 were on shelves or various ledges inside a building; 4 were among growing plants in window boxes; 2 were in sacks of old clothes in a hen coop; and the remainder were in various other places such as a tin newspaper cylinder and a mail box. There are other reports of different locations for Carolina Wren nest sites. Among these are two accounts of the bird nesting in old hornet nests (Brooks 1932), and a pair that nested in a grape basket covered with a shingle (Nice and Thomas 1948). From the literature, it seems Carolina Wrens prefer a fairly well enclosed nesting site. However, they are not totally dependent upon cavities.

Bewick's Wren--*Thryomanes bewickii*

Nests of the Bewick's Wren can be found in a multitude of places. They are usually located in cavities in or within a few feet of the ground. Most nests are cup-shaped and open above, but occasionally the wren will build a dome over the nest if there is not enough cover present. Nests have been found in rock walls, piles of boxes, under tile on a roof, and in man-made nesting boxes when secluded enough. Two nests were found in natural cavities in fallen trees in the forest and one was found in a rotted-out cavity 3 m above ground in a live oak. Another interesting nesting site was a hole 15 cm wide and 10 cm deep

[2]*Bull, Evelyn L. 1976. Personal communication.*

that extended horizontally back 45 cm into a hillside (Miller 1941). There is also a report of a pair of wrens nesting in the glove compartment of a truck in an open garage (Beemer 1947).

Here again is a case of high adaptability in choosing a nesting site. From the literature, it would seem Bewick's Wrens are capable of adjusting themselves to suit their environment much better than some birds.

Bewick's Wrens, like other wrens, can be useful to have around because of their large consumption of insects; insects make up 97 percent of their diet. In the South, Bewick's Wrens eat boll weevils and in Nebraska they consume locusts (Bent 1948).

House Wren--*Troglodytes aedon*

Like the Bewick's Wren and the Carolina Wren, the House Wren is generally catholic in its choice of a nesting site. Odum and Johnston (1951) found three House Wren nests in pipes less that 5 cm in diameter that were used as slanting braces for a fence. When it can find them, the House Wren prefers cavities in trees or nesting boxes. Carolina Wrens and House Wrens are aggressive in their nesting habits and will drive other birds from cavities. They will nest in the vicinity of each other but the more timid Bewick's Wren does not nest very successfully in the presence of Carolina or House Wrens (Sutton 1930).

House Wrens eat large quantities of insects and arthropods. Their diet is similar to that of the wrens already mentioned (Bent 1948).

Great Crested Flycatcher--*Myiarchus crinitus*

The Great Crested Flycatcher is unable to excavate a cavity, so it must use natural cavities or excavations made by other birds. Nests have been found in oak, ash, maple, birch, pine, cedar, chestnut, tulip, pear, tupelo, sycamore, and locust trees. Most nests occur below 6 m, but they have been found from 1 to 21 m above the ground. The bird prefers a large cavity, which averages 45 to 76 cm deep, for its bulky nest and likes a hole large enough for easy access. They seem to prefer natural cavities--even deep ones that they fill with trash to within 30 to 45 cm of the top before constructing a nest (Bent 1942).

Great Crested Flycatchers' food consists of 94 percent animal and 6 percent vegetable material. Members of the family Lepidoptera were eaten most frequently, followed by various Coleoptera, Orthoptera (mainly grasshoppers, crickets, and katydids), then Hymenoptera (including many sawflies). Although the bird is called a flycatcher, very few true Diptera are eaten. Most food is taken on wing in the usual flycatcher fashion. However, in the early spring, much food is taken on or near the ground or from crevices in tree bark. Vegetables eaten are mainly wild fruits--including mulberries, pokeberries, sassafras, spicebush, raspberries, chokecherries, Virginia creeper, wild grapes, huckleberries, blueberries, and elderberries (Bent 1942).

Great Crested Flycatchers were originally a deep forest bird. However, with clearing on much forest land and thinning being carried out on a lot of the remaining forest, flycatchers find fewer cavities in which to build nests. They have learned to adapt to living in more open situations, such as old orchards, isolated trees in open lots, and around human habitations. Nesting in forests is still done when cavities can be found, but flycatchers now inhabitat the less extensively and less densely forested areas, becoming more of a forest edge species (Bent 1942, Loveless 1975). Hespenheide (1971) found the birds breeding in a wide range of habitats and coexisting with never more than one species of smaller flycatcher. Aspects of habitat utilization by coexisting flycatchers to avoid competition are not known.

Tree Swallow--*Iridoprocne bicolor*

Before North America was settled, Tree Swallows built nests in hollow trees or deserted woodpecker cavities. Occasional nests are located in old apple orchards and in holes of trees in or near meadows (Bent 1942). They can also be found nesting in old woodpecker holes if many dead trees are standing close to or in water (Whittle 1926). Houses erected for Purple Martins serve as nesting sites if old trees are felled and woodpecker holes are usurped by other cavity nesters.

Some authors consider Tree Swallows to be colonial and others with similar data say they are not. They are not as colonial as Purple Martins and are jealously watchful and pugnacious toward all birds of similar

nesting habits, including other Tree Swallows (Norton 1917). Reports have been made of many pairs of Tree Swallows nesting in multi-compartmented Martin houses. However, most of these have been discounted as incorrect observations. Multi-compartmented houses may be filled before the June breeding season but as soon as the nesting urge is felt, one pair takes over the entire house and allows no other bird to nest there (Whittle 1926). Whittle (1926) considers them to be colonial because of nesting densities which can be attained. By posting houses at least 2 m apart, birds can be concentrated in numbers of up to 150 pair per 0.3 ha. Factors that limit this density are the amount of open area for nesting boxes and adequate feeding areas such as meadows, marshes, or water.

Low (1933) gives dimensions of two boxes used commonly for Tree Swallows. The first is the Packard Bluebird box which is 12.7 by 12.7 cm on the bottom, 23 by 12.7 cm on the back, 19 by 12.7 on the front, and 19 cm square on the top. The Higgins box is 23 cm deep, 15.2 cm long, 14 cm wide, and has a flat top that overhangs the front by 5 cm. Both boxes have entrance holes 3.8 cm in diameter. It is recommended they be mounted on 1.7 m posts in open fields.

The Tree Swallow is the first of its tribe to arrive in the North in the spring and the last to depart in the fall. They can subsist on seeds and berries and therefore, are not so closely confined to insect abundance as are other swallows. Tree Swallows are partial to waxmyrtle and bayberry in the limited zones where they grow. Proportions of plants in their diet were 30 percent in the winter, 1 percent in the spring, 21 percent in the summer, and 29 percent in the fall (Martin *et al.* 1951, Forbush 1955).

Purple Martin--*Progne subis*

Before white man settled North America, Purple Martins built nests in natural cavities or in cliffs (Bent 1942), or in abandoned woodpecker holes in trees (Allen and Nice 1952). A few also nested in bird houses built by the Indians out of gourds. Purple Martins probably never did inhabit the great forests of the East but were found mostly on open grassy valleys, along rivers, around lake shores, and by seacoast marshes (Forbush and May 1955). Today, houses are set up for these colonial birds on poles in open areas with separate apartments that house from 1 to 200 birds (Bent 1942).

A Purple Martin house can be built to any size, but each apartment in it should be 15 by 19 by 13 cm high. The entrance hole is 6 cm in diameter. The house, painted white so as not to disturb the birds and provide a cooler nesting area (Sawyer 1955), is placed on a pole or roof 4 to 6 m from the ground.

Purple Martins are one of the first birds to arrive in the spring. The males arrive before the females and establish themselves at the nesting boxes. The Purple Martin has a strong homing instinct and will remember where old nesting boxes were the year before even if the boxes have not been put up for that year yet. The Martin house should not be erected or the entrances should be closed off until the birds arrive. Otherwise English Sparrows and Starlings will take over and the Purple Martins probably won't nest successfully (Bent 1942).

The Purple Martins' diet consists solely of insects. These are procurred mostly on-the-wing in the typical swallow fashion by darting, swooping, and skimming pond surfaces. The Purple Martin normally flys at a moderate speed but its favorite food, the fast flying dragonfly, is easily caught. The Purple Martins' diet is made up primarily of ants, wasps, flies, dragonflies, and a few bees. This bird is beneficial to man because it consumes millions of mosquitoes and houseflies (Allen and Nice 1952). Some birds will feed on the ground especially in severe weather when they can pick up dead or stunned insects (Forbush and May 1955).

The Purple Martin is an early fall migrant. They gather in large numbers to migrate (Bent 1942) to their winter home in Brazil (Pearson 1936).

Black-capped and Carolina Chickadees--*Parus atricapillus* and *Parus carolinensis*

Carolina and Black-capped Chickadees have similar nesting habits and are both found in Missouri. The Wildlife Habitat Management Guide for the National Forests in Missouri (1973) mentions only the Carolina Chickadee, which is the common nester south of the Missouri River on the National Forest lands. Black-capped Chickadees nest north of the Missouri River.

Until the breeding season, Chickadees roost anywhere it is convenient and generally not in cavities (Odum 1942). When the nesting season approaches, several nest sites are searched out and inspected. Often a pair nesting for the second year will nest in the cavity they used the previous year after making some alterations (Brewer 1961). The birds are found nesting in comparatively open situations such as young forests, hedgerows, or field borders. However, these sites are near deeper woods where Chickadees generally feed and rest (Odum 1941a).

Brewer (1961), working in Illinois with a population of Carolina Chickadees, a population of Black-capped Chickadees, and a population of the two species that had interbred (called the Vandalia population), found common likes as far as nesting stubs were concerned (table 8). Nests were found in cavities of stubs usually 1.6 to 2 m tall and 11 to 13 cm in diameter. Trees with partially decayed cores and firm shells were preferred. The particular tree species favored depends on the region. The 18 nests observed by Odum (1941b) were found in the following tree species: 4 in pin cherry (*Prunus penslyvanica*), 3 in paper birch (*Betula papyrifera*), 3 in beech (*Fagus grandifolia*), 2 in yellow birch (*Betula lutea*), 2 in willow (*Salix bebbiana*), 1 in basswood (*Tilia americana*), 1 in sugar maple (*Acer saccharum*), 1 in white ash (*Fraxinus americana*), and 1 in an apple tree.

The most suitable nesting sites are soft trees such as birch and pin cherry. These trees occur as living trees in the early seral stages but are short-lived and persist in the intermediate seral stages as decayed snags. By the time the mature forest develops, all are gone and the dead timber is mostly harder wood, less suitable for excavation. Occupancy of cavities other than these excavated by themselves is rare among Chickadees. If they do use an existing cavity, they almost always do some excavating in it. They will nest in boxes where some excavation is possible. This would mean partially filling boxes with peat and sawdust to entice Chickadees to use them (Brewer 1961).

Food of both Chickadee species are similar; approximately 70 percent animal matter and 30 percent vegetable matter. Vegetable intake is mostly wild fruits such as bayberries, blackberries, blueberries, poison ivy berries, and a little mast. Caterpillars, eggs, and full-grown moths are the insect items most often ingested. Spiders come next, then beetles, true bugs, ants, and various Hymenoptera and Orthoptera. Even in the winter, insects comprise more than half of their food; largely eggs of moths, katydids, and spiders. Bud and bud scales, which are ingested while eating plant lice, comprise less than 25 percent of the winter diet. Birds can be lured into feeders that offer bones with bits of raw meat and gristle attached, cheese, suet, sunflower seeds, and breadcrumbs (Bent 1946, Martin *et al.* 1951).

Tufted Titmouse--*Parus bicolor*

These active birds are generally found in groups of two to six in thick growth and often near water. They are essentially nonmigratory and although they are conspicuous in late fall and winter, they tend to disappear in late spring in order to nest and molt (Gillespie 1930). Many authors state Tufted Titmice nests are difficult to locate. Brackbill (1970) and Middleton (1949) both have reported observing titmice nests but these were in nesting boxes. Laskey (1957) observed nests in natural cavities that averaged from 1.5 to 2 m above ground--extremes were one that was 0.45 m above ground in a gum tree and one that was 6 m above ground in a hackberry. The female constructs a nest made of green moss, grass, leaves, vegetal matter, an occasional snake skin and lined with soft fiber or hair in which to lay her 5 to 7 eggs (Laskey 1957).

Table 8.--*Dimensions of nesting cavities of Black-capped and Carolina Chickadees and Chickadees of the Vandalia population (Brewer 1961)*

Measurement	Carolina Chickadee		Blk-capped Chickadee		Vandalia Pop.	
	No.	Mean ± S.E.	No.	Mean ± S.E.	No.	Mean ± S.E.
		mm		*mm*		*mm*
Entrance hole diameter						
Vertical	3	40.2±0.1	3	47.3±.4	5	42.0±1.4
Horizontal	3	44.7±5.4	3	41.4±2.7	6	36.7±1.6
Cavity diameter	2	65.2	4	64.8±3.4	2	81.8
Cavity depth	3	179.0±18.0	4	199.0±9.0	4	221.0±20.2

In the fall, Tufted Titmice abandon carefully guarded breeding territories and form small groups. There is some argument as to whether they have definite, more expanded winter territories or whether they are rovers (Condee 1970). Van Tyne (1948) offers a solution in her observation that in Michigan there seem to be titmice with restricted home ranges (assumed to be full adults) and those that wander (assumed to be birds in first winter).

The diet of Tufted Titmice also changes from season to season. In spring and summer it is mainly an animal diet (89 percent and 82 percent, respectively). Caterpillars often make up more than 50 percent of animal material (Martin *et al.* 1951) so the birds spend most of their time in the treetops. During late fall and winter, their diet is mainly vegetable (78 percent). Common winter foods consist of beechnuts, acorns, dogwood, Virginia creeper berries, alder seeds, Japanese honeysuckle, and seeds of tulip-tree pods so during the winter the birds spend more time on or near the ground (Gillespie 1930).

Eastern Bluebird--*Sialia sialis*

Bluebirds prefer to nest in natural cavities in savanna-like habitats consisting of pasture areas with scattered small trees and bushes near lakes (Rustad 1972). Nests are neatly made of dry grass or other plant material. The female lays from 3 to 6 eggs, which are most often blue but occasionally are white. In a good season, the female can raise three broods (Zeleny 1973).

Presently, Eastern Bluebird populations are low throughout most of their range because of a serious shortage of acceptable nesting sites, and because of competition from other, more aggressive birds. The birds refuse to nest in dense woods. In the more open areas, which they prefer, people often remove dead trees and limbs because they are unsightly or inconvenient when cultivating. Wooden fence posts are slowly being replaced by metal ones. Thus, these potential nest sites are disappearing (Pinkowski 1976, Zeleny 1973). Competition for nest sites has always been present but now is more intense because the number of suitable sites is diminishing. Tree Swallows, House Sparrows, and House Wrens all compete, usually successfully, with Bluebirds for nest sites (Rustad 1972, Musselman 1935).

Competition for nest sites has forced the Eastern Bluebird away from human population centers where Starling and House Sparrow densities are high. Clearcuts in mature oak-hickory forests create a suitable nesting habitat for Bluebirds--seven of 10 clearcuts searched contained an active Bluebird nest. All seven nests were in standing dead snags, and often were constructed in abandoned Common Flicker excavations. Entrances to the nest cavity ranged from 4 to 12 cm in diameter. If dead snags are left standing, clearcutting can create an acceptable nesting habitat for Bluebirds for at least 12 years afterward. Starlings and House Sparrows are usually absent from clearcuts (Conner and Adkisson 1974).

Pinkowski (1976), reporting on 98 cavities used by Bluebirds, found that 78 percent of the nests were in abandoned woodpecker holes, 17 percent were in natural cavities, and 5 percent were in fire-produced cavities. A wide range of cavity heights and dimensions are acceptable to Bluebirds for nesting (Pinkowski 1976) as shown by the following cavity measurements of Eastern Bluebirds in two areas in Michigan:

	Mean	*Range*
Cavity height (m)	3.6	0.5 to 16.8
Entrance diameter (cm)	6.1	3.7 to 13.3
Cavity depth (cm)	19.8	7.6 to 48.3
Interior diameter (cm)	9.2	5.7 to 15.9

One way to combat the shortage of natural cavities and the competition from other birds is to provide nesting houses (fig. 2). Both Rustad (1972) and Zeleny (1973) agree the diameter of the entrance hole should be exactly 3.8 cm in order to exclude Starlings and the hole should be 15 cm from the bottom of the box. Inside floor dimensions should be between 10 by 10 cm and 13 by 13 cm. Zeleny (1973) states that the smaller floor size is more advantageous because it tends to discourage House Sparrows, which like to build bulky nests. Boxes are most effective when placed in open areas. If mounted away from bushes, House Wrens are not likely to compete. The openings should be placed toward an open field; the compass direction is not important (Rustad 1972).

Bluebirds have been known to nest year after year within a few yards of Carolina Chickadees, Tufted Titmice, Bewick's and Carolina Wrens, Great Crested Flycatchers,

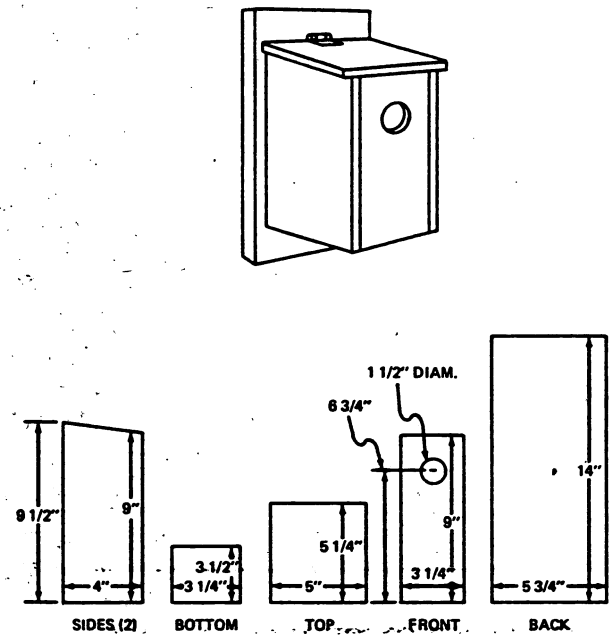

Figure 2.--*Design of a bluebird box (Missouri Conservation Commission, n.d.). The top is hinged to facilitate cleaning. Place bird box 2-5 m from ground in a sunny place along a roadside.*

and Flickers. This peaceful coexistence can be achieved by the following careful placement of nest boxes: place boxes for Bluebirds and Flycatchers in the open; hang Tufted Titmice boxes in trees; place Chickadee boxes, which are very small, on low posts under oak trees; place Wren boxes, which are shallow, under the eaves of low buildings, inside sheds or barns, or on a porch; and place Flicker boxes, which are deeper than Bluebird boxes in the open (Thomas 1946). Flickers adjust well to nesting in boxes. Hopefully with increased awareness of the Bluebirds' present low numbers, more boxes of suitable dimensions will be constructed and placed in convenient areas for them to raise successful broods. In this way, the population of these birds will perhaps be boosted to former levels.

On a yearly basis Bluebirds consume 68 to 70 percent animal matter and 30 to 32 percent vegetable matter. Vegetable intake increases to more than 50 percent in December and January and decreases to 0 in May. Animal matter consumed includes grasshoppers, crickets, katydids, various Coleoptera, moths and caterpillars, some Hymenoptera and Hemiptera, as well as various other invertebrates and an occasional lizard or tree frog. Vegetable matter is mostly wild fruit and a few cherries, raspberries, and blackberries when available (Bent 1949). Bluebirds perch in an exposed place and fly to the ground to catch prey. In the early spring and again in summer, they catch flies on the wing and return directly to their perch to eat (Thomas 1946).

Prothonotary Warbler--*Protonotaria citrea*

The border between water and thick deciduous woods seems to be the required habitat for Prothonotary Warblers. Nests are almost always in stumps and snags that are shaded most of the day and either standing in water or within 6 m of it (Simpson 1969). Downy Woodpecker and Chickadee holes from 0.6 to 4 m from the ground are used most often (Pearson 1936). However, the warblers reportedly have a wide tolerance of the type of cavities they will use for nesting. Walkinshaw (1953) found that when nesting houses were provided, the birds preferred sites between 1 and 2 m above the water. He also reported that 82 of 84 nests located in natural sites were from 0.5 to 4.5 m above ground or water. One writer also mentioned that in Mississippi birds frequently excavate their own cavities in soft cottonwood stumps (Chapman 1907). Females build nests within the cavity in which they lay five to seven eggs. Usually the foundation is made of straw or grass, next a layer of grape vine bark is put down, and finally a thick cover of moss is added (Chapman 1907).

Prothonotary Warblers are usually absent from waterways if the woody border is less than 30 m wide. However, they do tolerate one bare bank if the opposite one has enough woody vegetation. Chapman (1907) found them to range all along the bottom lands of the Mississippi River and its tributaries as far north as southern Minnesota. During the breeding season, singing males make their territories in a linear fashion, each one covering 240 to 300 m of woody vegetation along the water's edge (Simpson 1969). Unlike many cavity nesters, Prothonotary Warblers do not winter in their breeding area but migrate as far south as Venezuela and Nicaragua in the fall (Chapman 1907).

Prothonotary Warblers are mainly insectivores. They eat ants and other insects and their larvae as well as spiders, beetles, mayflies, caterpillars, and larvae of water

insects. They usually feed low on the vegetation (trunks and branches of trees, shrubs, and fallen logs) and near water. They will also eat small mollusks which they catch from perches on rank grasses and water plants (Bent 1953).

PREDATOR-PREY RELATIONS

Insects are an abundant form of life in the forest. They exert a continuous influence through all stages of forest development. Craighead (1950) estimated an economic loss of $200 million annually to forest insects. Half of this loss is insect damage to ornamental trees. Zeedyk and Evans (1975) discuss some of the complications in assessing the value of insectivorous birds (many of which are cavity nesters) in controlling insect populations. Conclusions from searching the literature are that birds do not control epidemic insect populations, but do reduce the threat of an insect outbreak.

Observations in Arkansas and Mississippi for the past 10 years indicated woodpeckers are among the most important natural control agents of trunk-boring insects in hardwoods. The greatest service rendered by woodpeckers is the constant pressure they exert upon endemic borer populations to keep them from becoming epidemic. Predation on borers was greatest during mid and late winter (Solomon and Morris 1970).

Massey and Wygant (1973) reported woodpecker nesting increased as spruce beetle populations increased. Beetle density was associated with the woodpeckers' efficiency as predators. When beetle populations were low (1,000 to 2,500 per ha), woodpecker feeding accounted for 28 percent mortality. When beetle populations were high (400,000 per ha), woodpeckers accounted for 84 percent mortality. However, when beetle populations reached epidemic proportions (4,000,000 per ha), woodpeckers only accounted for 53 percent mortality (Massey and Wygant 1973).

Many of the trade-offs between timber management practices and habitat management practices for cavity nesters are still speculative. Literature could not be found that reported on quantified changes of timber income by leaving some dead and dying trees in the stand. It has been reported that local insect outbreaks can be checked by insectivorous birds and more than 75 percent of the broods of eastern spruce bark beetles and southern pine beetles have been destroyed in patches of bark worked over by woodpeckers (Craighead 1950). Hall (1942) reported woodpeckers were the most important single factor in the control of locust borers.

Timber-woodpecker-wood borer interrelations are further complicated by the fact that wood borers commonly attack trees with low vigor. If timber stand improvement operations leave dead and dying trees to provide cavities, these low-vigor trees may encourage an insect outbreak if other environment factors become optimum for a certain insect species.

Only limited information has been published on the influence bird populations have on insect outbreaks (Dowden *et al.* 1953, George and Mitchell 1948). When looking at the oak-hickory ecosystem, we are observing the effects of a long sequence of evolutionary processes--the result is a diverse insect population and a diverse bird population in a changing and diverse plant community. Tree species that appear to be insect resistant in a mixed hardwood stand often become vulnerable in a monoculture. A mixture of plant and animal species and age diversity adds to the stability of a community.

Similar complexities exist when attempting to quantify the forest regeneration-rodent-owl interrelations. We can state a generalization that owls consume large numbers of rodents, and rodents occasionally cause economic loss to forest regeneration attempts, but we don't have any specifics. We found no information on what limits owl populations. If owls are limited by nest sites (cavities), then an increase in abundance of cavities (or nest boxes) could increase owl populations, therefore increase predation on rodents. Much research remains to be done to answer basic predator-prey questions.

MANAGEMENT IMPLICATIONS

We found no literature that reported the results of studies designed specifically to determine the impacts of silvicultural practices on the nesting habitat of cavity-nesting birds. The suggestions for management listed here are derived from synthesizing data on cavity-selection behavior. The suggestions have not been tested for

their effect or potential effect on population levels. Much research is needed before adequate and tested habitat models can be designed.

Timber Stand Improvement

The most obvious and potentially detrimental impact of timber stand improvement (TSI) is the removal of culls and snags from the forest stand. These trees are important for providing cavities, potential cavities, and future cavities. On the National Forests, cutting either by felling or shearing has essentially replaced herbicides in site preparation. As a result, few, if any, stems remain standing to become roost, perch, or den trees unless they are intentionally reserved (Zeedyk and Evans 1975).

Conner *et al.* (1975) studied the nesting habitat of Downy, Hairy, and Pileated Woodpeckers, and Common Flickers. All four species benefit by leaving dead snags and trees with heart rot standing during regeneration cuts and subsequent thinnings. The ideal practice on medium sites, where upland oaks grow 12 to 17 m in 50 years, would be to kill unwanted trees with a silvicide and leave them standing. On better sites, where upland oaks grow more than 23 m in 50 years, natural tree mortality provides the best habitat and thinnings may conflict with woodpecker management. Leaving uncut filter strips along streams and roadsides is recommended (Conner *et al.* 1975).

Stand development in upland hardwoods is a dynamic process. The first 10 to 15 years after a clearcut are referred to as the "brush stage" when there can be as many as 25,000 stems per ha. By age 20, most of the nontimber species are dead or are relegated to a subdominant position in the stand and there are from 3,400 to 6,200 trees per ha present. Without thinning, 90 percent of these trees will die during the next 60 years (Gingrich 1970). When thinning a forest stand, subdominant, low-vigor, silviculturally defective, and low-quality (economic) trees are normally removed. Therefore, silvicultural thinning could potentially reduce the value of the cavity nesters' habitat throughout the forest cycle because these are the type of tree most of them prefer (Zeedyk and Evans 1975). Recent research (Shugart *et al.* 1974, Perkins 1974) has considered the impact of silvicultural practices on nongame bird species. However, these studies fail to discuss the availability or potential availability of cavities.

Harvest Alternatives

Most foresters recommend managing the eastern deciduous forests with an even-age silvicultural plan. The creation of cull-free, young, fast-growing timber stands greatly reduces the cavities or the potential for cavities in a stand. Several options are available to the forester. Clearcuts should be kept small and planned so that each management unit (compartment) contains diverse stand age classes. Another alternative would be to leave 10 or 12 cull trees standing per hectare of regeneration cut. These trees could be killed by herbicide or girdling if they would conflict or compete with regeneration goals. Even when all culls and snags are felled, regeneration cuts provide several years of good feeding habitat for woodpeckers (table 9). These birds, except for Common Flickers, rely on adjacent areas for nesting cavities (table 10). Slash should not be diced, chopped, or burned unless it is absolutely necessary to accomplish regeneration goals. This extra site preparation effort is seldom

Table 9.--*Time spent by woodpeckers in four habitat types, based on a 60-hour sampling period (Conner and Crawford 1974)*

(In percent)

Species	1-year-old clearcut	5-year-old clearcut	12-year-old clearcut	Mature area
Downy	21	1	4	11
Hairy	31	5	1	6
Pileated	1	7	3	10
Flicker	2	30	1	0
Total	55	43	9	27

Table 10.--*Average vegetation characteristics of nesting sites of four species of woodpeckers (Conner and Adkisson 1976)*

Species	Nests	Basal area	Stem density	Canopy height	Age
	No.	*m^2/ha*	*stems/ha*	*m*	*years*
Downy woodpecker	17	10.1	361.8	16.3	63.6
Hairy woodpecker	10	17.2	401.3	17.8	91.2
Pileated woodpecker	15	27.1	475.3	24.2	143.5
Common Flicker	11	1.5	49.3	2.1	92.7

required in the oak-hickory forest if advanced regeneration is present (Connor and Crawford 1974).

Rotation age has a major influence on many of the cavity nesting bird species. These birds generally require mature forests for at least part of their life cycle. Short rotation cycles (pulpwood) create young, vigorous, fast-growing timber stands with very few natural cavities and dead trees. At least part of each management unit should be scheduled for a long rotation period--in excess of 100 years throughout the oak-hickory type. The Pileated and Red-bellied Woodpeckers are two examples of birds that require extensive mature forest stands. Barred Owls' preferred habitat is an oak woods that has many dead or dying trees and that is relatively free from understory brush. These conditions often exist in over-mature stands.

Guidelines

1. The literature indicated that an abundance of snags are needed in each timber stand. The exact number needed by cavity nesters will vary with the stand condition, site quality, and species of cavity nesters present. Snags are defined as completely or partially dead trees still standing and at least 3 m tall. It is generally assumed that if the snag requirements are met for the sound wood excavators (woodpeckers), they are also met for the secondary cavity users. Thomas *et al.* (1976) determined snag requirements to be approximately 45 snags per pair per species. Their model further subdivided the species into groups with similar requirements for snag size (>6 in. d.b.h., >10 in. d.b.h., >12 in. d.b.h., and >20 in. d.b.h.). Their models were developed for each timber type in the Blue Mountains of Oregon and Washington and further assumed that when the snag requirements were met for the species requiring the most snags in each d.b.h. class, then it satisfied the requirements of all other species within that d.b.h. group, and that snags present in the larger d.b.h. classes could be substituted for requirements in the smaller ones. Their model (if applied to the oak-hickory forests) indicates that 683 snags per 40 ha are required for potential maximum population of 6 species of woodpeckers nesting in the oak-hickory vegetation type. These numbers are highly speculative for the oak-hickory forests, as we do not have information on Red-headed and Red-bellied Woodpeckers (table 11) and we do not have sufficient information to test the model developed in the Northwest against oak-hickory ecosystem conditions.

Although the number of snags needed for potential maximum populations sounds high, it may not be unreasonable. An unmanaged oak-hickory stand will naturally progress from up to 25,000 stems per ha in the brush stage after clearcutting to approximately 740 stems per ha at age 80 (SI = 60). This indicates that a large number of trees die throughout the development of each mature timber stand and each dead and dying tree is normally suitable for cavities for several years before falling.

2. For generalized nongame-bird management, the land manager should strive to maintain a mixture of successional stages and forest age class categories in different size stands. This management goal is incorporated into the management guidelines of the Mark Twain National Forest in Missouri (USDA Forest Service 1973). These guidelines recommend that 10 percent of each compartment be in old growth and approximately 10 percent in permanent forage. For a 100-year rotation cycle the remaining 80 percent would be distributed as follows: 40 percent in saw logs, 30 percent in pole timber, 20 percent in sapling, and 10 percent in regenerated stands (less than 10 years old). This guideline combined with a program of leaving snags and potential snags (guideline #1) would also benefit the cavity nesting species.

3. Because some cavity-nesting species will utilize regeneration areas for feeding and 60 to 75 percent of many intensively managed forests are too young to provide adequate natural cavities (especially in the larger d.b.h. classes), Zeedyk and Evans (1975) discussed an alternative of leaving a 0.1 ha clump of trees (approximately 75) within each 2 ha of regeneration cut. This would be a 5 percent tradeoff in growing space, but, depending on placement may not be a 5 percent loss of timber production. These small clumps of older trees would provide mini-old-growth areas throughout most of the next rotation cycle. This alternative along with guideline #2 and a policy of leaving snags during TSI and harvest operations (when possible) should greatly enhance the habitat for cavity nesters.

Table 11.--*A summary of nest site characteristics of cavity nesting species*

Species	Body weight	Territory size	Max. pairs	Nest site			Comments
				Min. d.b.h.	Height min.	Nest type[1]	
	gm	*ha*	*No./40 ha*	*cm*	*m*		
Turkey vulture	1508				0	N	
Black vulture	2008				0	N	
Am. Kestrel	112	142	0.28	30	3	N	Primarily in natural cavity or Flicker hole
Saw-whet owl	89.6	40	1	30	5	N	
Screech owl	178			30	2	N	Natural cavities in apple trees, poplars
Barred owl	808			50	9	N	
Barn owl	505			50	5	N	Often nests in old buildings
Pileated woodpecker		43.0	1	30	9	H	
Red-headed woodpecker	66				7	HS	Prefer dead trunk
Red-bellied woodpecker	61.73				10	HS	Prefer dead limb
Common flicker	134.3	16.0	2	20	2	H	Will nest in clearcuts
Hairy woodpecker	43.57	3.0	13	20	3	H	Prefers live trees
Downy woodpecker	27.2	3.0	13	13	1	HS	Prefers dead trees
Red-breasted nuthatch	9.9					SN	
White-breasted nuthatch	20.7	0.8	50	30	5	SN	
Carolina wren	18.5	0.1	400			N	
Bewick's wren	11.0	0.5	80		0	N	
House wren	11.2	0.5	80	25	2	N	
Great crested flycatcher	34.4					N	
Tree swallow	19.5			25	5	N	
Purple martin	43	3.0	13			N	Will readily utilize colonial nest house
Black-capped chickadee	11.0	1.5	27	10	2	SN	
Carolina chickadee	10.1	1.5	27	10	2	SN	
Tufted titmouse	22.5				.5	N	
Eastern bluebird	30.8	1.0	40			N	Will readily utilize nest box
Prothonotary warbler	16.2	1.5	27	13	.6	N	One-half natural cavity; one-half Downy Woodpecker

[1]H = Excavator in hard snag; S = Excavator in soft snag; N = Secondary cavity user.

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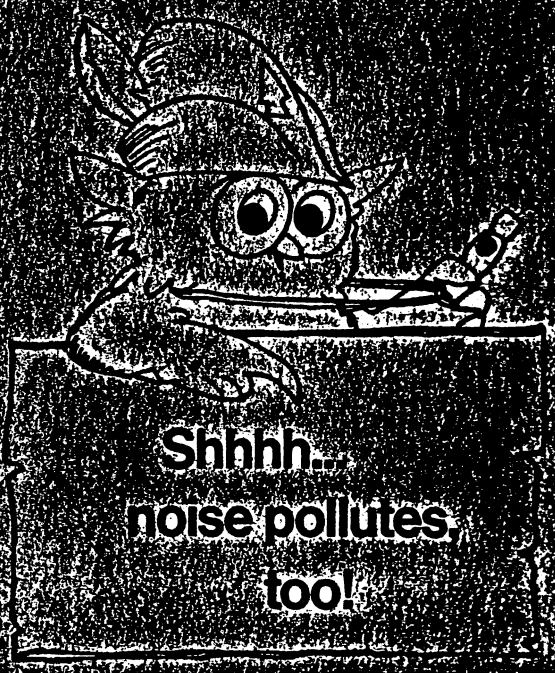
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noise pollutes
too!