ESTIMATING TREE CAVITY DISTRIBUTIONS FROM HISTORICAL FIA DATA

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Abstract.—Tree cavities provide important habitat features for a variety of wildlife species. We describe an approach for using historical FIA data to estimate the number of trees containing cavities during the 1990s in seven states of the Upper Midwest. We estimated a total of 280 million cavity-containing trees. Iowa and Missouri had the highest percentages of cavity-containing trees; Michigan and Minnesota had the lowest. The percentage of trees containing cavities was higher for the hard hardwood species group and dead trees, and it generally increased with increasing diameter at breast height. Abundance of cavities decreased with increasing cavity entrance diameter and increasing aboveground cavity height.

INTRODUCTION

Forest Inventory and Analysis (FIA) data (Woudenberg et al. 2010) span several decades and are easily queried to estimate status and trends of coarse-scale habitat characteristics, such as area of young hardwood forest or old softwood forest. These data also include attributes of tree species and tree size (and, for some state inventories, cavity entrance diameters, and cavity heights above ground), which can provide finer scale habitat information for many forest-associated vertebrate species.

Cavity availability is thought to limit populations of many secondary cavity nesters. Although primary cavity nesters excavate their own cavities (e.g., woodpeckers, nuthatches, flickers, and chickadees), secondary cavity users depend upon existing cavities formed from tree injury or through excavation by primary cavity nesters. Secondary cavity users include wood duck (*Aix sponsa*), hooded merganser (*Lophodytes cucullatus*), common goldeneye (*Bucephala clangula*), American kestrel (*Falco sparverius*), eastern bluebird (*Sialia sialis*), prothonotary warbler (*Protonotaria citrea*), tree swallow (*Tachycineta bicolor*), great crested flycatcher (*Myiarchus crinitus*), boreal owl (*Aegolius funereus*), barred owl (*Strix varia*), house wren (*Troglodytes aedon*), flying squirrels (*Glaucomys* spp.), American deer mouse (*Peromyscus maniculatus*), weasels (*Mustela* spp.), fisher (*Martes pennant*), American marten (*Martes Americana*), and raccoon (*Procyon lotor*). The size and location of tree cavities determine their suitability for each wildlife species.

Cavity formation and presence is related to tree species, size (diameter at breast height-d.b.h., height), and status (live, dead). Such relationships have been used with FIA data to estimate tree cavity abundance for mature second-growth timberland in Missouri (Fan et al. 2003) and to develop models for cavity-nesting waterfowl in hardwood forests of the north central United States (Denton et al. 2012). However, strategic estimates of tree cavities are lacking for the majority of cavity-dependent wildlife species, across most forests in the Midwest.

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Attributes of tree cavity diameter and cavity height above ground historically were recorded in some states in the northern FIA region. We analyzed cavity data from seven contiguous Midwestern States to produce estimates of historical numbers of cavity trees, by tree species group, tree diameter, cavity size, and cavity position.

DATA AND METHODS

Tree cavity data were queried from historical North Central FIA periodic field inventory plots from seven Midwestern States during 1989-1998. The inventory years were 1998 for Illinois and Indiana, 1990 for Iowa and Minnesota, 1993 for Michigan, 1989 for Missouri, and 1996 for Wisconsin. Tree cavity data no longer are collected in this FIA region.

The following text from the 1998 FIA field manual describes data collection protocols:

> At each sample point, examine all live and standing-dead trees, > 5.0" D.B.H., for cavities that could be used for nesting, resting or storage by birds or mammals. To qualify as a cavity, an entrance hole must be 1.0" or larger in the main stem, fork, or large limb. (A limb must be greater than 8.0" DOB.)
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> For the largest cavity record a two-digit code. [Only one cavity–the largest-was recorded for each cavity tree, regardless of the number of cavities present.] The first digit indicates the size of the cavity. Cavity size is the diameter of the largest ball that could fit through the entrance hole [by 1-inch categories, through 9+ inches (Table 1)]. The second digit indicates the location of the cavity on the tree [above-ground, in feet, aggregated into nine height categories (Table 1)].

We tabulated the total number of trees sampled and the number of those trees containing one or more cavities, by tree status (live, dead), tree d.b.h., and major species group: (1) pines; (2) other softwoods–spruce, fir, hemlock, etc.; (3) soft hardwoods-cottonwood, aspen, elm, basswood, soft maple, etc.; and (4) hard hardwoods–oak, hickory, beech, walnut, hard maple, etc. (Woudenberg et al. 2010: see Appendix F for complete list of species.). Tree records were omitted when status was absent or populated with unknown codes (n = 8,427; 1.1 percent), and when trees were down-dead (n = 10,915; 1.4 percent) or stumps (n = 39,772; 5.2 percent). For counts of trees with cavities, tree records were excluded when cavity codes did not reveal both cavity entrance diameter and cavity height above ground (n = 91; 0.01 percent).

Table 1.—Percentage of cavity-containing trees, by cavity entrance diameter and aboveground cavity height during the 1990s, Upper Midwest

Cavity Entrance Dia. (in.)	Aboveground cavity height (feet)									
	0-1	2-5	6-9	10-19	20-29	30-39	40-49	50-59	60+	Total
1	5.5	6.6	4.6	3.9	1.2	0.4	0.1	0.0	0.2	22.5
2	5.5	5.1	4.4	5.0	2.2	0.7	0.3	0.1	0.1	23.4
3	4.7	3.0	3.1	4.2	2.2	0.8	0.2	0.1	0.1	18.5
4	3.6	1.7	1.4	2.1	1.3	0.7	0.5	0.0	0.0	11.4
5	2.0	0.8	0.7	1.1	0.6	0.2	0.1	0.0	0.0	5.6
6	2.0	0.7	0.6	0.7	0.5	0.3	0.1	0.0	0.0	4.8
7	0.9	0.3	0.2	0.3	0.2	0.1	0.0	0.0	0.0	2.0
8	0.6	0.3	0.1	0.2	0.1	0.1	0.0	0.0	0.0	1.6
9+	4.5	1.6	1.2	1.5	0.9	0.3	0.1	0.0	0.1	10.2
Total	29.3	20.0	16.4	19.1	9.4	3.6	1.4	0.3	0.5	100.0

Numbers of all live and standing dead trees ≥ 5 inches d.b.h. on timberland were estimated using standard FIA estimators via FIA's online EVALIDator tool (http://apps.fs.fed.us/Evalidator/tmattribute.jsp). In brief, counts of trees on each sample plot, proportion of each plot in forest, and number of plots in each stratum were used in a stratified estimation procedure to produce estimates of total number of trees (Scott et al. 2005). Numbers of cavity trees were estimated by multiplying the estimates of numbers of live and standing dead trees times the proportion of sampled trees containing cavities, by combinations of tree diameter, major species group, and live/dead status. No estimates of uncertainty (e.g., standard errors) were computed for this preliminary study because population estimates of numbers of trees were weighted by the proportion of cavity trees in another database, with some mismatch in tree records.

RESULTS

A total of 709,638 trees were sampled in this study; one or more cavities were observed in 25,424 trees. Nearly half of all cavities were observed 0 to 5 feet above ground, one-third were 6 to 19 feet above ground, and the remainder were more than 20 feet above ground. Nearly two-thirds of cavities were 1 to 3 inches in diameter. Cavity abundance decreased with increasing cavity diameter (Table 1).

Percentage of cavity-containing trees varied by state, ranging from 1.7 percent and 2.8 percent in Michigan and Minnesota, respectively, to 6.5 percent and 7.8 percent in Missouri and Iowa, respectively. Standing dead trees made up 11 percent of all trees and 15 percent of cavity trees. The proportion of total trees containing cavities was 3.4 percent for live, 5.0 percent for dead, and 3.6 percent for live and dead trees combined. The largest absolute numbers of cavities in live trees were recorded in soft and hard hardwood tree species and in trees of 9.0 to 16.9 inches d.b.h. The hard hardwood major species group also contained the largest percentages of cavities relative to total number of live trees recorded for that group (4.9 percent). One or more tree cavities were recorded in more than 29 percent of the largest diameter live trees (41.0+ inches d.b.h.) (Fig. 1). Relative to the total number of trees by diameter class, cavity-containing trees were less abundant in small-diameter trees (<11 inches d.b.h.), similar in abundance for trees of 11 to 12.9 inches d.b.h., and more abundant for larger trees (13.0+ inches d.b.h.) (Fig. 1).

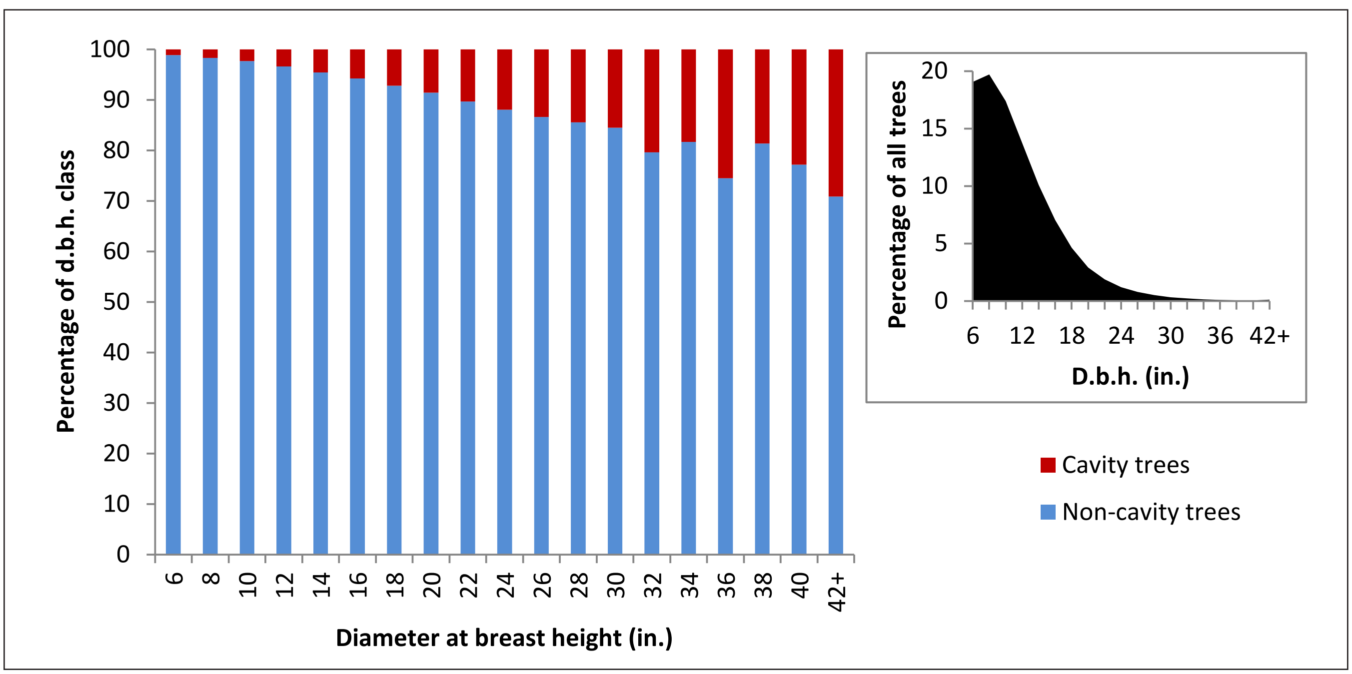

Figure 1.—Distribution of non-cavity and cavity-containing trees within each tree d.b.h. class during the 1990s, Upper Midwest.

Based on the sample, we estimated a total of 11.3 billion live trees and 1.6 billion dead trees ≥ 5 inches d.b.h. for the seven states during the 1990s, of which 225 million live trees (2.0 percent) and 55 million dead trees (3.4 percent) were estimated to contain one or more cavities.

DISCUSSION AND CONCLUSIONS

Using historical FIA data, we estimated a total of 280 million cavity-containing trees in the seven-state region during the 1990s. The number of cavity trees as a percentage of all trees generally increased with increasing d.b.h. Dead trees and live trees in the hard hardwood species group both contained higher percentages of cavities relative to total tree abundance of hard hardwoods, which may explain variability among states. The two states with the highest percentages of cavity-containing trees, Iowa and Missouri, both have <1 percent of all trees in softwoods; the two states with the lowest percentages of cavity-containing trees, Michigan and Minnesota, both have >20 percent of all trees in softwoods.

Almost half of all cavities had entrance diameters smaller than 3 inches; about half of all cavities were located less than 6 feet above ground. These characteristics are unsuitable for many wildlife species. We acknowledge that some entrances deemed cavities from the ground may not have been actual cavities (just knots or scars), and some cavities may not have been observed from the ground, despite their presence, especially at greater heights above ground: tree cavities on FIA plots in the Pacific Northwest are frequently missed by field crews (Tara Barrett, personal communication).

This study expands the geographic extent addressed in Fan et al. (2003) and introduces potential enhancements to the approach described in Denton et al. (2012): cavity probabilities were expanded to include both softwood and hardwood trees, both live and dead, for a wider range of tree diameters, and from a larger sample of trees.

Work is underway to estimate standard errors for historical tree cavity data and to refine models of tree cavity probabilities that can be applied to current and future FIA data for which cavity observations are no longer recorded. Ongoing collection of FIA tree cavity data could detect changes in cavity probabilities. Additional studies are being conducted to estimate abundance of cavities meeting species-specific wildlife habitat requirements.

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