The Effects of Forest Management on Cavity-Nesting Birds in Northwestern Washington
Author(s): Jill E. Zarnowitz and David A. Manuwal
Source: *The Journal of Wildlife Management*, Vol. 49, No. 1 (Jan., 1985), pp. 255-263
Published by: Wiley on behalf of the Wildlife Society
Stable URL: https://www.jstor.org/stable/3801881

J. W. Davis, R. C. Anderson, L. Karstad, and D. O. Trainer, eds. Infectious and parasitic diseases of wild birds. Iowa State Univ. Press, Ames.

———. 1972. The 1970–71 avian cholera epornitic's impact on certain species. J. Wildl. Dis. 8:75–78.

TACHA, T. C., AND P. A. VOHS. 1984. Some population parameters of sandhill cranes from mid-continental North America. J. Wildl. Manage. 48:89–98.

———, ———, AND G. C. IVERSON. 1984. Migration routes of sandhill cranes from mid-continental North America. J. Wildl. Manage. 48: 1028–1033.

U.S. DEPARTMENT OF COMMERCE. 1930–80. Climatological data Texas. Vols. 39–89. Natl. Oceanic and Atmos. Adm., Asheville, N.C.

———. 1978–80. Climatological data Texas. Vols. 87–89. Natl. Oceanic and Atmos. Adm., Asheville, N.C.

WOBESER, G., AND C. J. BRAND. 1982. Chlamydiosis in two biologists investigating disease occurrences in wild waterfowl. Wildl. Soc. Bull. 1: 170–172.

Received 2 May 1983.
Accepted 12 March 1984.

THE EFFECTS OF FOREST MANAGEMENT ON CAVITY-NESTING BIRDS IN NORTHWESTERN WASHINGTON

JILL E. ZARNOWITZ,[1] College of Forest Resources, University of Washington, Seattle, WA 98185
DAVID A. MANUWAL, College of Forest Resources, University of Washington, Seattle, WA 98195

Abstract: Population characteristics and nest-site preferences of 11 species of cavity-nesting birds were studied in the Olympic National Forest (ONF) of northwestern Washington in the spring and summer of 1979–80. We characterized breeding populations in four different forest successional stages where either high or low densities of snags occurred. Species richness ($N = 13$ vs. $N = 9$), densities ($P < 0.01$), and diversities ($P < 0.01$) of cavity-nesting birds increased with increasing snag densities. Active cavity-nests were five times more numerous on the 1980 plots (Snag Plots) than the 1979 plots (Clean Plots). Snag densities on the Snag Plots varied from 13.8/ha in a clear-cut to 97.1/ha in 25–50-year-old second-growth stand. Clean Plots contained from 0.5 snags/ha in a clear-cut to 37.3/ha in old-growth. Hairy woodpeckers (*Picoides villosus*), a primary cavity-nester, selected western hemlock (*Tsuga heterophylla*) snags for nest sites. In contrast, broken-topped Douglas-fir (*Pseudotsuga menziesii*) snags were preferred by secondary cavity-nesters. The average diameter at breast height (dbh) for active nest trees was substantially greater than the mean dbh for sampled snags in the ONF. Snags appear to be a limiting factor for breeding cavity-nesting bird populations. We discuss management recommendations for cavity-nesting birds in the ONF.

J. WILDL. MANAGE. 49(1):255–263

The rapid harvesting of old-growth and shortening of harvest rotation cycles in the Pacific Northwest western hemlock–Douglas-fir forests disrupt avifauna. Several authors have shown that snag removal during intensive forest management is highly detrimental to cavity-nesting birds (Balda 1975, Thomas et al. 1976, Evans and Conner 1979, Short 1979). Snag removal eliminates nest and roost sites that are crucial for successful breeding and overwinter survival. Although specific nest-site characteristics have been studied in other parts of the western United States (Bull and Meslow 1977, McClelland 1977, Mannan et al. 1980, Raphael and White 1984), only this study reports intensive research on cavity-nesting populations in the moist coastal climate of Washington. The objectives of our study were to: (1) estimate densities and diversities of cavity-nesting birds in four forest successional stages in northwestern Washington; (2) compare the influence of high and low snag densities in the successional stages on cavity-nesting populations; and (3) determine the nest-site requirements for breeding cavity-nesting birds.

This research was funded by the U.S. For.

[1] Present address: Washington Department of Game, 5405 N.E. Hazel Dell Ave., Vancouver, WA 98665.

Serv., Olympic Natl. For., Olympia, Wash. We are grateful to W. Brown, Jr., and the personnel of the Olympic Natl. For. for their assistance. We thank E. Dinerstein for help in the vegetation sampling. M. H. Huff, E. M. Davies, and N. J. Manuwal offered useful comments on the manuscript. We thank R. N. Conner and R. W. Mannan for their constructive critiques of the manuscript.

STUDY AREA AND METHODS

The Olympic National Forest includes much of the forested land in and around the Olympic Mountains in northwestern Washington. The mountainous topography creates a mosaic of different habitat types. Variation in tree and shrub composition within habitat types is strongly influenced by a rainshadow in the northern and eastern regions of the Olympic Peninsula (Fig. 1). Most of the ONF lies within the western hemlock–Douglas-fir zone (Franklin and Dyrness 1973). A more complete description of the study area is given in Zarnowitz (1982).

Two series of study plots were examined. The plots differed in levels of intensive silvicultural management, including snag removal. The Clean Plots, studied in spring and summer of 1979, were the most intensively managed and contained few snags. The Snag Plots, studied in 1980, contained obviously more and larger snags (>23 cm diameter at breast height [dbh]) than the Clean Plots. Of a total of 16 study plots, we chose 4 Clean and 4 Snag Plots on the Hoodsport and Quilcene ranger districts (RD) to represent the drier east-side habitat and 4 Clean and 4 Snag Plots on the Soleduck RD to represent the moist coastal belt (Fig. 1). The eight Clean and Snag Plots consisted of two replicates in each of the following age categories: (1) clear-cut, 1–15 years; (2) second-growth, 25–50 years; (3) second-growth, 60–120 years; (4) old-growth, >200 years.

Because of the patchy nature of accessible ONF stands, individual Clean Plots ranged from 6.5 to 13 ha in size. The total area sampled for Clean Plots was 31.5 ha on the east side and 36.5 ha on the west side. Snag Plots varied from 4.9 to 8.0 ha in size; 27.1 ha on the east side and 27.7 ha on the west side. Elevation of the study plots ranged from 146 to 869 m. Ten study plots faced south; three were flat, three were west-facing.

In each study plot, standing and down deadwood were inventoried in six randomly selected

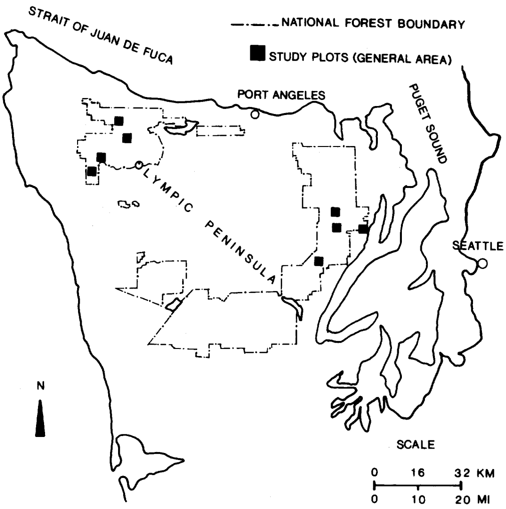

Fig. 1. Olympic Peninsula with east- and west-side study areas delineated.

30.5-m² sample plots. We classified standing and down deadwood into the following categories (adapted from McClelland 1977, Thomas et al. 1979): (1) snags, >1.50 m in height; (2) stumps, 0–1.49 m; and (3) logs, all down deadwood of any length within a 45° angle of the ground. We grouped all deadwood into the following dbh classes: (I) 13–23 cm; (II) 24–51 cm; (III) >51 cm. These dbh classes simulate the minimum nest tree sizes that small, medium, and large cavity-nesters require for successful nesting (McClelland 1977, Thomas et al. 1979).

Snag species were identified by remaining bark. External features, such as broken tops in snags and decay conditions of the tree bole, were recorded. The type of decay was sampled visually and by prying with a pocket knife. We classified decay as: (1) none (tree bole solid); (2) sapwood rotten (soft to breaking); (3) heartwood rotten (porous or soft); (4) both sap- and heartwood decayed; and (5) very rotten (both sap- and heartwood crumbling).

We censused the plots for cavity-nesting birds by the spot map method (Arbib 1970). Densely vegetated plots were divided into 30.5-m grids; plots with thinner vegetation were partitioned into 91-m grids. Clear-cuts were observed for cavity-nesters from several vantage points. All cavity-nesting birds observed or heard within a plot were recorded on a map noting location, activity, and flight direction.

Clean Plots were censused seven times at the rate of two plots per day; one census began

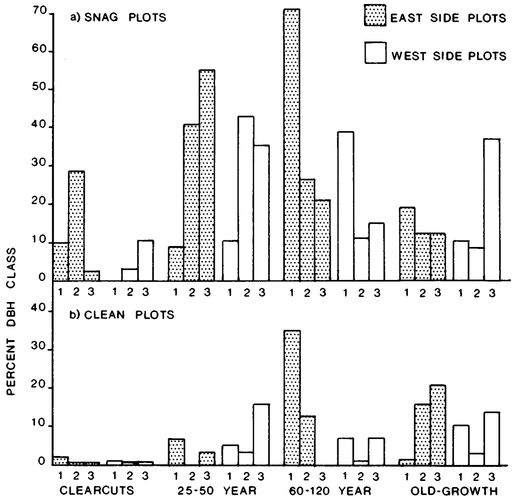

Fig. 2. Densities of class I–III snags per ha in the Clean and Snag Plots; Mann-Whitney U tests, $P = 0.003$ for densities and $P = 0.002$ for dbh class (1 = I, 2 = II, 3 = III).

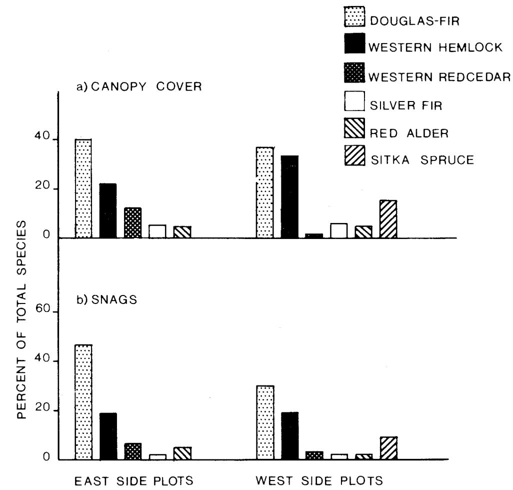

Fig. 3. Relative percent of (a) living canopy cover species and (b) snag species recorded in the combined study plots (without Sitka spruce, $\chi^2 = 2.46$, $P > 0.1$).

between 0500 and 0600 and the other between 1800 and 1900. We sampled each of the eight Clean Plots once per week. Plots censused in the morning 1 week were sampled in the evening the following week and vice versa. We censused plots on each side of the ONF alternately every 2 days.

Snag Plots were censused seven times in the early morning only. We sampled Snag Plots on each side of the ONF alternately every 4 days. Throughout plot censuses we examined standing dead trees for potential nest cavities. Using the combined censuses from each plot we calculated densities and the Brillouin Diversity Index (Pielou 1977).

Before or after plot censuses we performed road and foot transects during which we noted habitat use by cavity-nesters and sought active cavity-nests.

A potential cavity-nest was classified as active if, within 1 hour, we observed incubating behavior or evidence of nestlings. The pileated woodpecker (*Dryocopus pileatus*) has longer intervals (up to 3 hours) between incubation shifts (McClelland 1977), thus we adjusted our time accordingly.

At active cavity-nests we recorded characteristics of the nest hole and tree, such as nest hole orientation, height from ground, diameter at nest, relation to canopy, tree species, condition of top, and other characteristics described for the deadwood censusing. Qualities of the surrounding habitat were examined, such as slope and aspect, elevation, distance to openings, and habitat and forest cover type.

RESULTS

Snag Plots contained more and larger snags than the Clean Plots (Mann-Whitney U test, $P = 0.003$ for densities and $P = 0.002$ for dbh class) (Fig. 2). To compare snag species composition between the east and west sides of the ONF, we combined data from the Clean and Snag Plots (Fig. 3). Aside from Sitka spruce (*Picea sitchensis*), which occurred only on the west side, snag species composition was similar between the east and west sides of the ONF (without Sitka spruce, $\chi^2 = 2.46$, $P > 0.1$). Unidentifiable snags were a conspicuous element of the forest structure.

Mean dbh and height for all snags sampled was 45.8 cm ($N = 623$, standard deviation [SD] = 30.5 cm) and 9.6 m ($N = 623$, SD = 7.9 m). The average dbh by stand age was: (1) clearcuts, 44.2 cm ($N = 256$, SD = 25.3 cm); (2) 25–50-year-old, 54.1 cm ($N = 129$, SD = 26.7 cm); (3) 60–120-year-old, 33.9 cm ($N = 143$, SD = 33.5 cm); and (4) old-growth, 57.1 cm ($N = 95$, SD = 35.8 cm).

Characteristics of Cavity-Nesting Bird Populations

We found a total of 14 cavity-nesting bird species. The Snag Plots were richer in cavity-

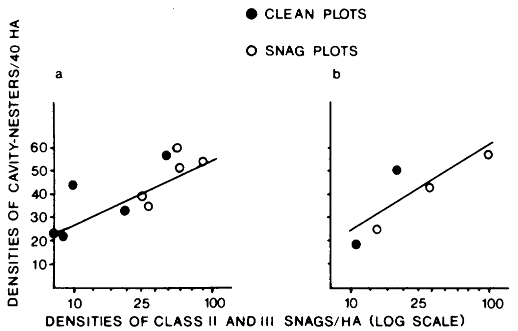

Fig. 4. Densities of cavity-nesting birds (pairs/40 ha) with densities of class II and III snags; (a) study plots 7.3–9.3 ha in size (N = 10, Spearman rank correlation coefficient, r = 0.80, $P < 0.01$), (b) study plots 4.9–6.7 ha in size (N = 5, r = 0.90, P = 0.05). Regression line is hand-drawn.

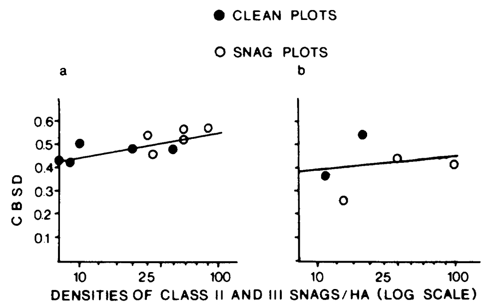

Fig. 5. Cavity-nesting bird species diversity (CBSD) with densities of class II and III snags within the plots; (a) plots 7.3–9.3 ha in size (N = 10, Spearman rank correlation coefficient, r = 0.77, $P < 0.01$), (b) plots 4.9–6.7 ha in size (N = 5, r = 0.50, $P > 0.05$). Regression line is hand-drawn.

nesting species (N = 13) than the Clean Plots (N = 9). The most cavity-nesting species occurred in the old-growth (N = 9) and 25–50-year-old (N = 9) Snag Plots. For all plots, secondary cavity-nesting species were more numerous than primary cavity-nesting species, which were represented by only a few species in each plot.

The highest densities of cavity-nesters on both the east- and west-side plots occurred in the Snag Plots (Table 1). Densities for all plots varied from 19.0 to 157.5 pairs/40 ha. Of the primary cavity-nesters, the hairy woodpecker was the most commonly observed within the plots. Densities of two common secondary (and facultative) cavity-nesters, western flycatchers (*Empidonax difficilis*) and winter wrens (*Troglodytes troglodytes*), were often high. The chestnut-backed chickadee (*Parus rufescens*) was the most abundant obligate cavity-nester.

Because of their dependence on snags for nesting, we compared obligate cavity-nesting bird densities with densities of class II and III snags within similar-sized plots. Densities of obligate cavity-nesters increased with dbh-class II and III snag densities (for plots 7.3–9.3 ha, N = 10, Spearman rank correlation coefficient, r = 0.80, $P < 0.01$) (Fig. 4a). In the smaller plots (4.9–6.7 ha, N = 5) a similar correlation resulted (r = 0.90, P = 0.05) (Fig. 4b). We never obtained a plateau or decline in densities of obligate cavity-nesting birds as snag densities increased.

Cavity-Nesting Bird Species Diversity

Cavity-nesting bird species diversity (CBSD) (Brillouin Index, Pielou 1977) was higher on Snag Plots than Clean Plots (Table 2). Unlike other successional stages, diversity levels calculated for all old-growth plots were consistently high. Plot age had no consistent effect upon CBSD (Spearman rank correlation coefficient, r = 0.37, $P > 0.05$).

Cavity-nesting BSD increased with class II and III snag densities in plots 7.3–9.3 ha in size (N = 10, r = 0.77, $P < 0.01$) (Fig. 5a). Smaller plots (4.9–6.7 ha, N = 5) failed to show the same tendency (r = 0.5, $P > 0.05$) (Fig. 5b).

In the ONF, cavity-nesting bird populations were influenced markedly by snag densities. Where snags occurred, the forest stand age also had a strong effect on cavity-nesting species.

Nest-Site Characteristics

We discovered 48 active cavity-nests of 11 bird species (Table 3). We found 13 nests (27% of the total) in the plots; we recorded only 2 of these (4% of the total) in the Clean Plots, those of the chestnut-backed chickadee. In contrast we noted 11 (23% of the total) active cavity-nests in the Snag Plots. Of all nests, more were located on the west side (N = 33, 69% of the total) than the east side of the ONF.

While conducting foot and road transects, we found 35 nests (73% of the total). However, the amount of time spent in each successional stage varied (Table 4). Because of logging and fire history, accessible habitat in each successional stage differed among ONF districts.

For both plots and transects, we discovered 15 nests (31% of the total) in the west-side 25–50-year-old successional stage; more than in other habitat ages. Because of extensive fires in 1951, nearly one-fourth of the forest on the west-side Soleduck RD was in this successional stage

Table 1. Densities of cavity-nesting birds (pairs/40 ha) recorded in the study plots, Olympic National Forest, Washington, 1979–80.

	East-side study plots								West-side study plots								
	Clear-cut		25–50-year		60–120-year		Old-growth		Clear-cut		25–50-year		60–120-year		Old-growth		
Species[a]	Clean	Snag	Clean	Snag	Clean	Snag	Clean	Snag	Clean	Snag	Clean	Snag	Clean	Snag	Clean	Snag	Average/40 ha
AmKe												5.2					
ScOw							5.2		3.1								4.2 ± 1.48
VaSw	4.4		5.3				5.2		3.1		4.6				6.3	5.4	4.9 ± 1.00
NoFl	4.4			6.4	6.1			5.7		8.2	4.6	5.2	4.9	5.4		5.4	5.6 ± 1.10
PiWo				6.4	6.1	5.1										5.4	5.8 ± 0.60
HaWo	8.7	14.4		6.4		5.1	10.4	5.7	3.1	8.2		5.2	9.8		6.3		7.4 ± 3.07
TrSw										8.2							
WeFl		7.2	10.6			10.2		28.2			13.8	5.2	14.7	10.8	18.8	16.3	13.6 ± 6.57
ChCh	4.4	21.6	15.9	38.5	6.1	30.5	30.9	16.9			23.1	26.2	29.4	16.1	31.3	27.2	22.7 ± 9.86
BrCr						10.2		5.7						10.8		10.9	9.4 ± 2.49
ReNu		7.2					5.2	5.7							6.3	5.4	6.0 ± 0.81
HoWr												5.2					
WiWr	4.4	7.2	21.2	51.3	12.1	35.5	50.2	50.9	9.7	74.1	18.4	26.2	19.0	43.0	25.0	81.5	33.1 ± 23.41
WeBl												5.2					
Total	26.3	57.6	53.0	109.0	30.4	96.6	107.1	118.8	19.0	98.7	64.5	83.5	77.8	86.1	94.0	157.5	80.0 ± 36.97
Obligate	21.9	43.2	21.2	57.7	18.3	50.9	56.9	39.7	9.3	24.6	32.3	52.2	44.1	32.3	50.2	49.7	38.4 ± 15.91
% of total	83	75	40	53	60	53	53	33	49	25	50	63	57	38	53	38	51 ± 14.92
Facultative	4.4	14.4	31.8	51.3	12.1	45.7	50.2	79.1	9.7	74.1	32.2	31.4	34.3	53.8	43.8	97.8	41.6 ± 26.22
% of total	17	25	60	47	40	47	47	67	51	75	50	37	43	62	47	62	49 ± 14.92

[a] Species abbreviations: AmKe, American kestrel; ScOw, screech owl (*Otus kennicottii*); VaSw, Vaux's swift (*Chaetura vauxi*); NoFl, northern flicker (*Colaptes auratus*); PiWo, pileated woodpecker; HaWo, hairy woodpecker; TrSw, tree swallow; WeFl, western flycatcher; ChCh, chestnut-backed chickadee; BrCr, brown creeper (*Certhia americana*); ReNu, red-breasted nuthatch (*Sitta canadensis*); HoWr, house wren (*Troglodytes aedon*); WiWr, winter wren; WeBl, western bluebird.

Table 2. Observed cavity-nesting bird species diversity.[a]

	West-side plots		East-side plots	
	Clean	Snag	Clean	Snag
Clear-cut	0.43	0.44	0.26	0.26
25–50-year	0.41	0.42	0.48	0.57
60–120-year	0.36	0.52	0.50	0.46
Old-growth	0.48	0.54	0.53	0.57

[a] Brillouin's Diversity Index (Pielou 1977):

$$H = \frac{1}{N} \log \frac{N!}{N_1!N_2! \ldots N_s!}$$

where N = total number of individuals, and N_i = number of individuals of each species.

(U.S. For. Serv., unpubl. data, Olympia, Wash.). Fourteen of these nests occurred in remnant snag patches created by fires. To increase our sample size, we initiated transects in areas of high snag densities. Though more time was spent searching 25–50-year-old stands than other-aged stands, the highest nest densities found per hour occurred in these and old-growth stands (Table 4). Clear-cuts harbored few nests, because they contained few snags.

We located more hairy woodpecker nests ($N = 16$, 33% of the total) than any other species. The hairy woodpecker nested in all successional stages, though more nests ($N = 9$) occurred in or at the edge of old-growth than elsewhere.

The snag species composition recorded on the east- and west-side plots was representative of the species composition of available snags for each side of the ONF, respectively. Hairy woodpeckers appeared to prefer western hemlock as a nest tree ($N = 9$) more often than its availability as a snag ($\chi^2 = 4.6$, $P < 0.05$ for the east side; $\chi^2 = 6.0$, $P < 0.025$ for the west side).

The mean nest tree dbh for hairies was 58 cm, which is greater than the average dbh of 45.8 cm for all sampled snags. Because hairies appeared to use large-diameter snags (>50 cm dbh) they may be restricted to old-growth or old-growth edge habitats. Under current forest management, large-diameter snags are more abundant in these habitats than in other successional stages.

Secondary cavity-nesters (excluding the winter wren, a facultative cavity-nester) generally nested in Douglas-fir snags. On the east side, secondary cavity-nesters used Douglas-fir and western hemlock for nest trees at the same frequency as their occurrence as snags ($\chi^2 = 4.20$, $P > 0.1$). On the west side of the ONF, nest tree species differed from the available snag species ($\chi^2 = 9.04$, $P < 0.005$).

Mean nest tree dbh for secondary cavity-nesters was 63 cm. This is larger than the average dbh for both hairy woodpecker nest trees (58 cm) and sampled snags (45.8 cm).

Secondary cavity-nesters, such as the American kestrel (*Falco sparverius*), tree swallow (*Tachycineta bicolor*), and western bluebird (*Sialia mexicana*), nested only in the early

Table 3. Nest tree characteristics for 11 cavity-nesting bird species of the Olympic Peninsula, Washington, 1979–80.

Species	Snag dbh (cm) $\bar{x}$	Snag dbh (cm) SE	DAN[a] (cm) $\bar{x}$	DAN[a] (cm) SE	Nest ht (m) $\bar{x}$	Nest ht (m) SE	% bark $\bar{x}$	% bark SE	Top condition In-tact	Top condition Bro-ken	Tree species[b]
American kestrel	81	58	36	29	13	18	21	28		2	Df(2)
Northern flicker (*Colaptes auratus*)	53	12	29	11	9	5	13	23	2	5	Df(2), wh(1), Ss(1), u(3)
Yellow-bellied sapsucker[c]	133	16	71	7	29	5	93	4		2	wh(2)
Hairy woodpecker	58	25	41	13	13	12	70	38		16	Df(3), wh(9), Ss(1), sf(1), ra(2)
Downy woodpecker (*Picoides pubescens*)	20		18		2		60			1	ra(1)
Tree swallow	63	21	31	9	18	4	23	6		3	Df(2), Ss(1)
Chestnut-backed chickadee	76	44	64	35	5	3	36	46		7	Df(2), wh(2), u(3)
Brown creeper	41	43	51[d]	62	2	2	46	22	1	2	Df(2), C(1)
Winter wren	93	17	79	29	3	2	31	47		4	Df(2), C(2)
Western bluebird	44	16	34	6	7	4	14	15		3	Df(2), u(1)

[a] Diameter of the tree at the nest.
[b] Df = Douglas-fir; wh = western hemlock; Ss = Sitka spruce; sf = silver fir (*Abies amabilis*); C = western redcedar (*Thuja plicata*); ra = red alder (*Alnus rubra*); u = unidentifiable species.
[c] Both species of sapsucker (*Sphyrapicus varius* and *S. ruber*), one nest of each, are represented.
[d] DAN was greater than snag dbh for brown creepers because one nest was below dbh.

Table 4. Active cavity-nests recorded in the combined plots and during foot and road transects.

	Successional stage									
	Clear-cut		25–50-year		60–120-year		Old-growth		Edge CC/OG[a]	
	E[b]	W	E	W	E	W	E	W	E	W
Plots[c]		2		2	4	1	3	1		
Trans.[d]		1	3	13	1	4		4	4	5
Hours[e]	9.0	7.5	4.0	23.3	15.0	7.0	5.4	4.8	42.1	37.6
Index[f]	0.0	0.13	0.75	0.56	0.07	0.57	0.0	0.83	0.09	0.13
%[g]	6	5	3	15	10	5	4	3	27	24
ONF[h]	11	30	13	22	20	11	35	31		

[a] Clear-cut/old-growth edge habitat.
[b] E = east side, W = west side of the ONF.
[c] *N* nests found in combined Clean and Snag Plots in each category.
[d] *N* nests found during foot and road transects.
[e] Hours spent during foot and road transects.
[f] Index = (*N* nests found/*N* hours of effort) (foot and road transects).
[g] Percent of hours spent conducting foot and road transects in each stage.
[h] Percent of forest in each successional stage on the three ONF districts (Olympic Natl. For., unpubl. data, Olympia, Wash.).

successional stage. Open plant cover composed of bushes and tree seedlings appeared to be the preferred habitat for these species. Because most of this habitat consists of clear-cuts with no remaining snags, these species are severely restricted in their distribution. We located nests of these species only in uncommon dense snag patches resulting from fires.

Though we found no active pileated woodpecker nests, we observed pileateds using all habitat ages for foraging. Pileateds were uncommon in the ONF.

The majority of all active nest trees had broken tops, a common condition of snags in the ONF. The average height of a nest tree (16 m) was greater than the average height of sampled snags (9.6 m) ($\chi^2 = 1.4$, $P > 0.1$).

DISCUSSION

Our results emphasize the dependence of cavity-nesting birds on snags. Species richness, densities, and diversities of breeding cavity-nesters increased as snag densities increased. Other studies report similar findings (Haapanen 1965, Balda 1975, Mannan et al. 1980, Brush 1981, Raphael and White 1984).

For obligate cavity-nesters, nesting cannot commence without a snag. Where snags are prevalent, richness and abundance of cavity-nesting birds theoretically will increase to a carrying capacity confined by food resources and other overall habitat qualities (Brown and Orians 1970, Short 1979, Franzblau and Collins 1980). Because our data show that cavity-nesting bird populations continue to increase as snag densities increase, snags in the ONF appear to be a limited and limiting resource.

Forest management practices in the ONF have reduced or eliminated snags from most stands up to 80 years of age. Partial and salvage cuts often remove snags from old-growth stands. In the ONF, standard silvicultural procedures involve clear-cutting followed by burning and reforestation with conifer seedlings. A stand may be thinned several times before harvest; snags are routinely removed. Currently timber is harvested between the ages of 50 and 120 years old. This silvicultural regime results in a forest mosaic of even-aged stands with homogeneous structure, simplified species composition, and few snags.

Though the mean number of snags per hectare has never been quantified for the entire ONF, the difficulty we had in finding Snag Plots indicates their paucity. During the 2 years of our foot and road transects we observed few areas where snags were intentionally left. Compared to studies in other western states (McClelland 1977, Mannan et al. 1980, Raphael and White 1984) our sample size of active cavity-nests was small, even though our search effort was intensive. This is further evidence that snags are scarce in the ONF.

As forest managers create extensive stands in early successional stages (<50 years old), cavity-nesting birds will be impacted further. Large snags will be eliminated from the managed forest. Our data and those of others show that hairy woodpeckers and secondary cavity-nesters generally nest in large trees (Kelleher 1963, Jackman 1975, McClelland 1977, Scott et al. 1977, Mannan et al. 1980). Because nest tree dbh is normally distributed, smaller than average dbh sizes are suboptimal nest sites (Conner 1979, Raphael and White 1984). This may reduce reproductive success, eventually reducing populations (Dennis 1969, Conner 1979).

Generally the early successional stages (0–50 years old) in the ONF have few snags. Secondary cavity-nesters, such as the American kestrel, tree swallow, and western bluebird, that use the brush/sapling stage are rare. The presence of snags in all successional stages is critical for maintaining cavity-nesting bird species diversity in forested habitats (Balda 1975, Wiens 1978, Mannan et al. 1980).

Richness and abundance of breeding cavity-nesting bird species is influenced by snag densities. Other factors not measured here, such as territorial behavior, forest physiognomy, and food abundance, also contribute to the abundance and richness of cavity-nesters.

Rot conditions within a snag may influence nest site selection (Conner et al. 1976, McClelland 1977, Cline et al. 1980, Mannan et al. 1980). Unless rot conditions are right, snags left by forest management may be unsuitable for excavation by cavity-nesters.

Forest management for timber harvest can limit cavity-nesting bird populations (Haapanen 1965, Diamond 1975, Wiens 1978, Mannan et al. 1980, Raphael and White 1984, this study). Habitat can be managed for cavity-nesting birds by retention of the necessary sizes and species of snags in all successional stages.

MANAGEMENT RECOMMENDATIONS

Our management recommendations for the ONF include:

1. Leave snags in all stand ages.
2. Retain a minimum of six hard and three soft (currently useable) snags per hectare at the time of harvest; this may allow for replacement of soft snags and choice by cavity-nesters. We consider this number to be minimum for maintaining cavity-nesting bird populations. This recommendation is based on a synthesis of our information and that for falling rates of firs from Raphael and White's (1984) definitive study on use of snags by birds. However, falling rates of snag species need to be assessed for the ONF before snag management guidelines are finalized.

   Greater numbers of snags in a stand will increase populations. Past management practices in the ONF may have reduced populations of cavity-nesters. Where snags have been routinely removed more snags than nine per hectare must be retained to enhance cavity-nesting bird populations.
3. Leave the bulk of snags >50 cm and some >23 cm and >75 cm dbh in all successional stages.
4. Maintain a mix of snag species, especially western hemlock and Douglas-fir, to accommodate the preferences of all cavity-nesting bird species.

Maintaining large snags in clear-cuts as rotation cycles shorten will require innovative silvicultural techniques. At each harvest rotation individual living trees should be left standing. These trees should be windfirm and allowed to grow until they reach a large diameter (at approximately 120–150 years). At this time they should be girdled or otherwise killed and left standing for nest trees. Long-term snag management and other methods for achieving the above goals are discussed in Thomas et al. (1979) and Raphael and White (1984).

Currently the ONF has a snag retention plan on record. In the past this plan served as a guideline rather than a requirement for the ranger districts. Snags were retained only if a district decided to implement the plan. A new snag management plan based on this and other studies will soon be established for the ONF. As snags are created in early successional stages, long-term monitoring of cavity-nesting bird populations may determine the effectiveness of an integrated snag management program.

LITERATURE CITED

ARBIB, R. S., JR., editor. 1970. Recommendations for an international standard for a mapping method in bird census work. Audubon Field Notes 24:722–726.

BALDA, R. P. 1975. The relationships of secondary cavity-nesters to snag densities in western coniferous forests. U.S. For. Serv. Wildl. Habitat Tech. Bull. 1, Albuquerque, N.M. 37pp.

BROWN, J. L., AND G. H. ORIANS. 1970. Spacing patterns in mobile animals. Annu. Rev. Ecol. Syst. 1:239–262.

BRUSH, T. 1981. Response of secondary cavity-nesting birds to manipulation of nest site availability. M.S. Thesis, Arizona State Univ., Tempe. 35pp.

BULL, E. L., AND E. C. MESLOW. 1977. Habitat requirements of the pileated woodpecker in northeastern Oregon. J. For. 75:335–337.

CLINE, S. P., A. B. BERG, AND H. M. WIGHT. 1980. Snag characteristics and dynamics in Douglas-fir forests, western Oregon. J. Wildl. Manage. 44: 773–786.

CONNER, R. N. 1979. Minimum standards and forest wildlife management. Wildl. Soc. Bull. 7:293–296.

———, O. K. MILLER, JR., AND C. S. ADKISSON. 1976. Woodpecker dependence on trees infected by fungal heart rots. Wilson Bull. 88:575–581.

DENNIS, J. V. 1969. The yellow-shafted flicker (*Colaptes auratus*) on Nantucket Island, Massachusetts. Bird-Banding 40:290–308.

DIAMOND, J. M. 1975. The island dilemna: lessons of modern biogeographic studies for design of natural preserves. Biol. Conserv. 7:129–146.

EVANS, K., AND R. N. CONNER. 1979. Snag management. Pages 214–225 *in* R. M. DeGraaf and K. E. Evans, eds. Management of north central and northeastern forests for nongame birds. U.S. For. Serv. Gen. Tech. Rep. NC-51, St. Paul, Minn.

FRANKLIN, J. F., AND C. T. DYRNESS. 1973. Natural vegetation of Oregon and Washington. U.S. For. Serv. Gen. Tech. Rep. PNW-8. 417pp.

FRANZBLAU, M. A., AND J. P. COLLINS. 1980. Test of a hypothesis of territory regulation in an insectivorous bird by experimentally increasing prey abundance. Oecologia 46:164–170.

HAAPANEN, A. 1965. Bird fauna of Finnish forests in relation to forest succession. I. Ann. Zool. Fenn. 2:153–196.

JACKMAN, S. M. 1975. Woodpeckers of the Pacific Northwest: their characteristics and their role in the forests. M.S. Thesis, Oregon State Univ., Corvallis. 147pp.

KELLEHER, K. E. 1963. A study of the hole-nesting avifauna of southwestern British Columbia. M.S. Thesis, Univ. British Columbia, Vancouver. 169pp.

MCCLELLAND, B. R. 1977. Relationships between hole-nesting birds, forest snags, and decay in western larch–Douglas-fir forests of the northern Rocky Mountains. Ph.D. Thesis, Univ. Montana, Missoula. 482pp.

MANNAN, R. W., E. C. MESLOW, AND H. M. WIGHT. 1980. Use of snags by birds in Douglas-fir forests, western Oregon. J. Wildl. Manage. 44:787–797.

PIELOU, E. C. 1977. Mathematical ecology. John Wiley & Sons, New York, N.Y. 385pp.

RAPHAEL, M. G., AND M. WHITE. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildl. Monogr. 86. 66pp.

SCOTT, V. E., K. E. EVANS, D. R. PATTON, AND C. P. STONE. 1977. Cavity-nesting birds of North American forests. U.S. For. Serv. Agric. Handb. 511, Washington, D.C. 112pp.

SHORT, L. L. 1979. Burdens of the picid hole-excavating habit. Wilson Bull. 91:16–28.

THOMAS, J. W., R. B. ANDERSON, C. MASER, AND E. L. BULL. 1979. Snags. Pages 60–70 *in* J. W. Thomas, ed. Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington. U.S. For. Serv. Agric. Handb. 553, Washington, D.C.

———, R. J. MILLER, H. BLACK, J. E. RODIEK, AND C. MASER. 1976. Guidelines for maintaining and enhancing wildlife habitat in forest management in the Blue Mountains of Oregon and Washington. Trans. North Am. Wildl. and Nat. Resour. Conf. 41:452–476.

WIENS, J. A. 1978. Nongame bird communities in northwestern coniferous forests. Pages 19–31 *in* R. M. DeGraaf, ed. Proceedings of the workshop on nongame bird habitat management in the coniferous forests of the western United States. U.S. For. Serv. Gen. Tech. Rep. PNW-64.

ZARNOWITZ, J. E. 1982. The effect of forest management on cavity-nesting bird populations in the Olympic National Forest, Washington. M.S. Thesis, Univ. Washington, Seattle. 111pp.

Received 10 December 1982.
Accepted 4 May 1984.