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The relationship between cavity-nesting birds and snags on clearcuts in western Oregon

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ABSTRACT

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Relationships between cavity-nesting birds (CNB) and density and characteristics of snags were investigated on 13 clearcuts in central coastal Oregon. Species richness and density of CNB were positively ($P<0.05$) related to snag density and were still increasing at the maximum snag density evaluated. Cavity-nesting birds selected ($P<0.05$) snags taller than 6.4 m and greater than 78–102 cm in diameter, and avoided ($P<0.05$) snags less than 28 cm in diameter. Snags of intermediate decay stages were used for nesting more ($P<0.05$) than snags of early and advanced stages of decay. Cavity-nesting birds selected snags with more ($P<0.05$) bark cover (greater than 11%) than the average cover found on available snags. Individual CNB species exhibited significantly different ($P<0.05$) selections for snag height, diameter, hardness and bark cover. To optimize density and richness of CNB, forest managers should provide ≥ 14 snags ha^{-1} between 28 and 128 cm diameter at breast height (dbh), between 6.4 and 25 m tall, with at least 10% bark cover, and with a majority in hardness stages 3 and 4.

INTRODUCTION

Snags provide nest sites and foraging and perching platforms for cavity-nesting birds (CNB). Numerous studies have described individual bird species' needs for snags and have suggested strategies and snag management techniques for maintaining populations of CNB on forest lands (Jackman, 1974; McClelland and Frissell, 1975; Conner, 1978; McClelland et al., 1979; Thomas et al., 1979; Miller and Miller, 1980; Bull et al., 1980; Scott et al., 1980; Nietro et al., 1985).

Individual CNB species partition habitats within which they breed and feed: e.g. CNB species requiring snags in open habitat do not use snags in nearby mature forests because they obtain their food(s) by foraging in the open and they remain in these sites to nest (Miller and Miller, 1980). Therefore, snags must be maintained in all seral stages to optimize diversity and density of

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birds (Jackman, 1974; Meslow, 1978; Thomas et al., 1979). Timber-cutting practices in the Siuslaw National Forest and other forest lands throughout the Oregon Coast Range created clearcuts with few remaining snags (Cline, 1977) and, consequently, low numbers of CNB (Mannan et al., 1980; Morrison and Meslow, 1983).

Research in other states demonstrated higher use by CNB of clearcuts with snags than without snags (Marcot, 1983; Dickson et al., 1983; Zarnowitz and Manuwal, 1984), but few guidelines are available to indicate the number of snags most beneficial to CNB species.

Height, diameter and condition of snags used as nest sites by CNB in mature forests have been described (McClelland et al., 1979; Scott, 1979; Bull, 1983; Raphael and White, 1984). As the CNB guild and vertical structure of vegetation on clearcuts differ from those in mature forests, snags selected by CNB for nesting in clearcuts may have characteristics different from those of snags selected in mature forests.

Recently, snags have been left standing after clearcut harvest on public lands in western Oregon, providing an opportunity for study of the relationships between CNB and snag density, and snag characteristics. The purpose of this study was to investigate the relationships between CNB and density, and characteristics of snags on clearcuts.

STUDY AREA

The study was conducted in the Oregon Coast Range on lands administered by the USDA Forest Service, Siuslaw National Forest, Alsea District. Study sites were located approximately 25 km south and west of the town of Alsea on 13 clearcuts (less than 4 years old). All had been clearcut-logged, slash-burned, grass-seeded, and planted with Douglas-fir (*Pseudotsuga menziesii*) seedlings. Snags were usually the only structural component taller than the shrub layer.

As a result of wildfire in the late 1800s, the climax plant association of western hemlock (*Tsuga heterophylla*) and western red cedar (*Thuja plicata*) is rare; subclimax Douglas-fir dominates the area. Deep soils, abundant rainfall, and relatively mild winters produce rapidly growing trees. Intensive timber-cutting in the past 35 years led to a patchwork of young, managed stands and new clearcuts, which together comprise approximately 50% of the forest lands managed by the USDA Forest Service (Steve Smith, personal communication, 1986).

METHODS

Design

The null hypotheses were: (a) neither species-richness nor density of CNB was related to snag density; and (b) CNB did not select for snag height, diameter breast height (dbh), or condition (hardness and amount of bark cover). Testing whether species-richness or density of CNB was related to snag density required comparing CNB species richness and density of CNB among sites with differing snag densities. Testing whether CNB selected for snag height, diameter or condition required comparing snags utilized by CNB as nest sites with all snags on clearcuts for height, dbh, hardness and bark cover.

Species richness and density of non-CNB were recorded in 1985 as a check against confounding factors. We assumed that if CNB and non-CNB exhibited similar species-richness and density of CNB at different levels of snag density, it would indicate that differences in richness and density of CNB were influenced by some factor other than snag density. Conversely, different responses of the two bird categories would suggest that CNB were affected by snag density rather than by some unqualified confounding factor.

Site layout

In 1985, we established 3.6 ha study sites for censusing birds on each of 12 clearcuts. Sites encompassed 4 predetermined snag densities: minimum (approximately 0.4 ha^{-1}), low (approximately 5.0 ha^{-1}), medium (approximately 10.0 ha^{-1}) and high (approximately 20.0 ha^{-1}). Sites were established at least 30 m from clearcut boundaries and away from major topographic features such as ridges or draws.

In 1986, 11 of the 12 clearcuts censused in 1985 and two additional clearcuts were censused in entirety (the entire clearcut, rather than a central 3.6-ha portion). One 29-ha clearcut with a low number of snags (3 ha^{-1}) from among the 1985 sites was replaced with two smaller clearcuts with medium-to-high snag density to provide a larger sample of small clearcuts. The reason for this change was to clarify a perceived effect of clearcut size: preliminary evaluation of 1985 data suggested that small size (< 10 ha) of clearcuts might mask the influence of snag density on CNB species-richness and -density. Niemi and Hanowski (1984) found no relationship between snag density and density of birds on clearcuts less than 15 ha.

Bird census – 1985

In 1985, an adaptation of the sample count method (Anderson, 1972) was used to estimate bird densities for each study site. Four stations, approximately 100 m apart, were established on each site, and CNB and non-CNB bird numbers in the surrounding 0.9 ha^2 sub-site were recorded for 10 min at each station, providing a uniform 40-min census per site. Censuses began at sunrise and were completed within 3 h. Two and occasionally 3 sites were censused daily. All sites were censused six times from May 1 through the end of July. Censuses were not conducted on days with heavy rain. The maximum number of male birds of a given species counted on any one of three or more censuses was considered to represent the number of breeding pairs. Species seen in fewer than three censuses or using a nest site located outside site boundaries were recorded as 'using' the site.

Bird census – 1986

It became apparent in 1985 that CNB could be observed and recorded easily over entire clearcuts. Therefore, an adaption of a spot map census (Arbib, 1970) was used in 1986. Entire clearcuts were surveyed from two to seven fixed points, the number varying with clearcut size, topography and number of snags requiring observation. Half an hour was spent at each census point, and snags surrounding each point were observed for CNB. Although censusing time on clearcuts varied, each snag was under observation for approximately the same amount of time. Only birds incubating or feeding young at these snag nest sites were counted as breeding pairs. Each clearcut was censused five times from 1 May to 10 July at 2-week intervals. Censuses were not conducted during periods of heavy rain. Non-CNB were not censused in 1986 because they apparently were not affected by the presence of snags (see Results).

The two census methods allow identification of many diurnal CNB, but it should be noted that early nesting (e.g. downy woodpecker (*Picoides pubescens*)) or 'nest-shy' birds (e.g. American kestrel (*Falco sparverius*)) are likely to be under-represented by these techniques. These species require a census period beginning earlier and ending later in the season and observations longer than half an hour for detection of all nest sites.

Snag classification

Height, dbh, hardness and percentage of bark cover were recorded for 1942 snags located within the 13 clearcuts. Dbh was measured with a diameter tape and height with an Abney level. Dbh and height were divided into six size groups each, with intervals of 24 cm (10 in.) for dbh and 3 m (10 ft.) for height. Snag hardness was divided into the five stages described by Cline et al. (1980). Stages were arranged chronologically after the death of the tree (stage 1, 0–6 years; stage 2, 7–18 years; stage 3, 19–50 years; stage 4, 51–125 years; stage 5, 126+ years), and by degree of deterioration (stage 1, minimal deterioration–stage 5, maximum deterioration). Bark cover was estimated as a percentage of bole covered with bark. Presence or absence of potential nest-sites (woodpecker holes, natural cavities) was also noted.

Analysis

Differences in densities of snags at the four snag levels used in 1985 were tested for significance using analysis of variance (Neter et al., 1985). Post-hoc tests were conducted to test for differences between individual snag levels. Differences in percent ground cover for grass/forb, shrub, and bare ground among sites with different snag levels were tested for significance using analysis of variance.

Responses to snag density for CNB and non-CNB for 1985 were evaluated by comparing mean species richness and density among four snag levels. Analysis of variance was used to detect significance of any differences. Responses in 1986 were evaluated using regression analysis (Snedecor and Cochran, 1968) which tested for significance of the correlation between snag density (independent variable) and bird density (dependent variable). As clearcut size appeared to affect CNB density, additional regressions were conducted only with the ten clearcuts smaller than 10 ha, excluding three clearcuts 5.3, 6.9 and 8.5 ha in size.

Comparison of CNB density and species-richness with density of snags containing identified nest sites was performed because it was anticipated that a stronger relationship between snag density and CNB species-richness and density could be determined, if density of snags only with nest sites was used as the independent variable.

Differences between mean dbh, height and percent bark cover of snags used by CNB (pooled) and of all snags (pooled) were tested for significance using analysis of variance. Differences of mean dbh and height of snags used as nest sites among individual bird species (for species with more than 15 nest sites) and between individual bird species, and all snags were tested using analysis of variance.

We anticipated considerable variation in snag dbh and height values which could mask selection or avoidance by CNB for snags exhibiting extreme dbh and height values. To circumvent this potential problem we compared availability and CNB use of snags by dbh and height values within successive intervals. Proportions of: (a) snags used by CNB for nest sites; and (b) all available snags within clearcuts were compared using chi-square analysis (Huntsburger and Billingsley, 1973). This method was also used to evaluate selection of, or avoidance of, snag hardness by CNB species with more than 15 nest sites.

Generally, dbh and height are highly correlated, so testing for relationships between CNB density and species-richness and height might not yield information of additional value if the relationships between CNB species-richness and -density and dbh were already known. However, because of fire, rot and wind-break, many snags of larger dbh were quite short. Correlation between height and dbh was conducted for all snags and for snags utilized by individual bird species to test for independence of the two parameters.

The 95% confidence level was used to evaluate significance of differences for all comparisons.

RESULTS

Study site snag density

The four densities of snags (three sites each) had group means of 0.8, 6.4, 11.1 and 23.3 snags ha^{-1} for minimum, low, medium and high groups respectively. These means were all significantly different from each other.

Bird census – 1985

Eighty-five pairs of CNB representing nine species were recorded more than twice on the 12-study sites. Fifty-five of these pairs, representing six species, were observed on three or more censuses and assumed to be nesting within site boundaries. Single observations of five additional CNB species were recorded within sites. No nest sites (snags with cavities observed being used by CNB) of CNB were observed on the three sites with minimum number of snags.

Six species (northern flicker (*Colaptes auratus*), hairy woodpecker (*Picoides villosus*), house wren (*Troglodytes aedon*), western bluebird (*Sialia mexicana*), tree swallow (*Tachycineta bicolor*), and violet-green swallow (*Tachycineta thalassina*) were common, nesting on or near 56–100% of the sites with snags. The American kestrel, starling (*Sturnus vulgaris*) and barn swallow (*Hirundo rustica*) used a few sites but were not recorded as nesting within the sites. The pileated woodpecker (*Dryocopus pileatus*), chestnut-backed chickadee (*Parus rufescens*), pygmy owl (*Glaucidium gnoma*), downy woodpecker (*Picoides pubescens*) and purple martin (*Progne subis*) were recorded only once each on sites.

Two-hundred-and-fifty-one pairs of non-CNB birds, representing 20 species, were recorded repeatedly (more than twice) on study sites. Two-hundred-and-fourteen of these pairs (17 species) were observed three or more times and were assumed to be nesting within site boundaries. An additional ten species were observed only once.

Non-CNB species assumed nesting on all 12 sites included the white-crowned sparrow (*Zonotrichia leucophrys*), song sparrow (*Melospiza melodia*), dark-eyed junco (*Junco hyemalis*) American robin (*Turdus migratorius*) and rufous hummingbird (*Selasphorus rufus*). Five additional species (Swainson's thrush (*Catharus ustulatus*), American goldfinch (*Carduelis tristis*), orange-crowned warbler (*Vermivora celata*), McGillivray's warbler

(*Oporornis tolmiei*) and Wilson's warbler (*Wilsonia pusilla*)) were also common nesters, present on 50% or more of the study sites. Snags were used frequently for perching and singing but not for nesting by non-CNB species.

Bird census – 1986

Nests of 188 pairs of the same 9 CNB species repeatedly identified in 1985 were located in 1986 in the 13 clearcuts surveyed. On any given clearcut, 3–36 pairs of birds representing 2–7 species nested on clearcuts. House wren nests, found on all clearcuts, accounted for 51% of all cavity nests; violet-green swallows, on 77% of the clearcuts, accounted for 18%; and the common flicker, western bluebird, hairy woodpecker and tree swallow, on 85%, 77%, 39% and 46% of the clearcuts, respectively, accounted for a combined 22% of nests. Forty-eight CNB birds that included an additional seven species were observed on clearcuts, but their nests were not found.

Response to snag density

Mean species-richness of non-cavity nesting birds at the four snag levels ranged from 2.5 to 3.6 ha^{-1}, and mean density ranged from 4.4 to 5.6 ha^{-1} (Fig. 1). Neither species richness nor density differed significantly with different snag density

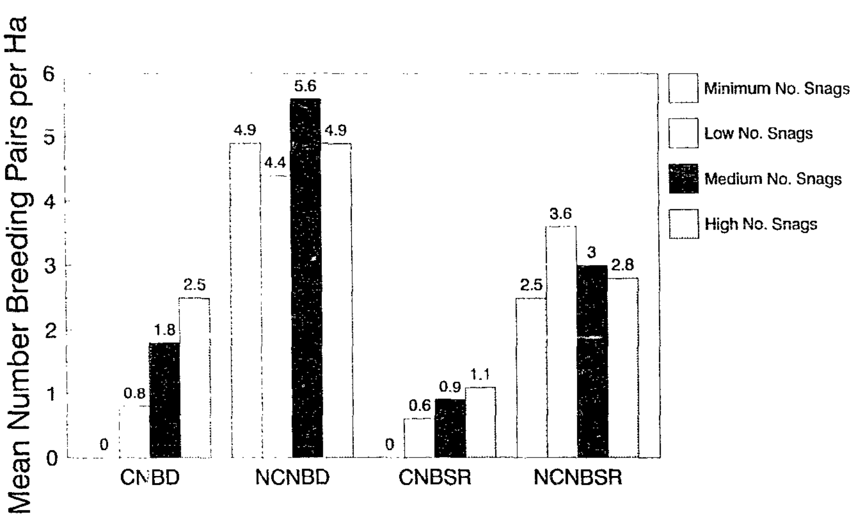

Fig. 1. Comparisons of density of cavity-nesting birds (CNBD), density of non-cavity-nesting birds (NCNBD), species-richness of cavity-nesting birds (CNBSR), and species-richness of non cavity-nesting birds (NCNBSR) for four levels of snag density.

Mean species richness of CNB at the four snag levels ranged from 0.0 to 1.1 birds ha^{-1} (Fig. 1); differences among snag density levels were significant. Species-richness at the two highest snag densities differed significantly from species-richness at the minimum snag density. In the three plots with highest snag density, CNB comprised 30% of bird species.

Mean density of CNB ranged from 0.0 to 1.8 birds ha^{-1} (Fig. 1): differences among snag density levels were almost significant ($P<0.06$). Cavity-nesting birds' densities on sites with minimum snag densities differed significantly from those on sites with high snag density. The three plots with highest snag density accounted for 32% of all birds.

For the 1986 census, regression of CNB density on snag density yielded a significant correlation coefficient (0.41) (Fig. 2). Regression of species-richness on snag density also yielded a significant correlation coefficient (0.56) (Fig. 2). However, restricting these regressions to the 10 sites of more than 10 ha resulted in smaller correlations (0.37 and 0.28 for CNB density vs. snag density, and CNB species-richness vs. snag density, respectively), contrary to our expectations.

As expected, the correlation coefficients for regression of CNB species-richness (0.54) and -density (0.52) on density of snags with potential nest sites were as high or higher than when CNB density and species-richness were regressed on all snags.

Of individual CNB identified in this study, 91% were secondary cavity-nesters (unable to create cavities). Abandoned woodpecker holes accounted

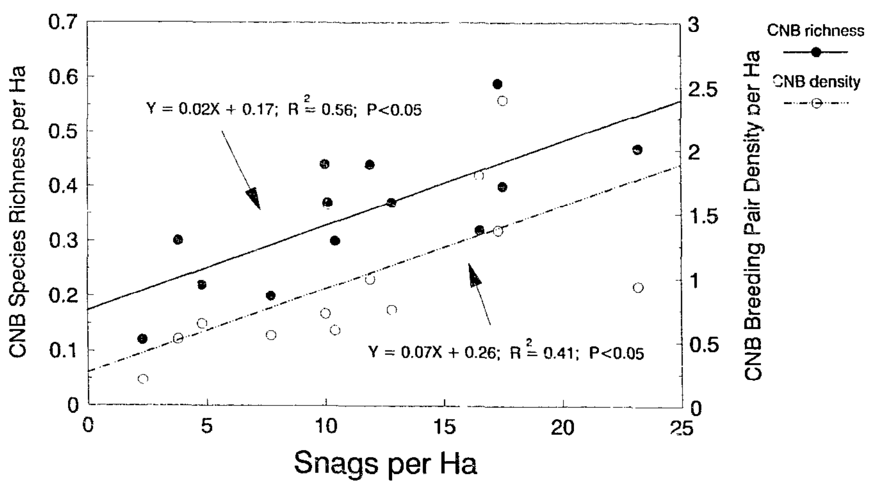

Fig. 2. Regressions of cavity-nesting bird species-richness and breeding pair density on snags ha^{-1}.

for most of nest sites (91%), and natural cavities were only occasionally used (9%).

The number of snags characterized as having potential nest sites (woodpecker holes or natural cavities) was undoubtedly high because it included incomplete woodpecker cavities (round holes without cavities), and possibly unsuitable natural cavities (crevices, cracks, indentations). Number of snags with truly suitable cavities, and of preferred size and condition may have been even more strongly correlated with bird nesting.

Snag characteristics

Diameter

Mean dbh for snags pooled across all sites (77.1 cm) was not significantly different from that for snags used by CNB pooled across all sites (78.3 cm) (Table 1). Mean dbh of snags pooled across all sites was significantly different from dbh of snags selected by violet-green swallows (97.2 cm) and tree swallows (60 cm). Violet-green swallows selected snags of significantly larger dbh than all other CNB, and tree swallows selected snags of significantly

TABLE 1

Mean dbh (cm), height (m), and bark cover (%) of snags available to, and used by, cavity-nesting birds. Superscripts indicate significant ($P<0.05$) differences among mean values with similar letters within columns

	dbh (range)	Height (range)	Bark cover (range)
All snags	$77.1^{a,b}$ (15.2–172.7)	5.7^{a-f} (0.9–45.5)	11.1^{a-e} (0–100)
All birds	$78.3^{h,i}$ (25.4–157.5)	$8.3^{a,g,h}$ (2.1–23.8)	22.8^{a} (0–100)
House wren	$77.1^{c,d}$ (30.5–149.9)	$7.1^{b,g,i,j}$ (2.1–21.9)	$24.6^{b,g}$ (0–100)
Bluebird	71.3^{e} (25.4–137.2)	$9.2^{c,i,k,l}$ (3.7–16.8)	$16.0^{c,h}$ (0–100)
Flicker	75.3^{f} (40.6–121.9)	8.4^{d} (3.7–21.0)	23.3^{d} (0–100)
VG swallow	$97.2^{a,c,e-h}$ (43.2–157.5)	$11.5^{e,h,j,k,m}$ (3.7–23.8)	$11.1^{e,g}$ (0–100)
Tree swallow	$60.0^{b,d,g,i,j}$ (33.0–119.4)	$7.5^{f,l,m}$ (3.7–15.5)	41.1^{f-h} (0–100)

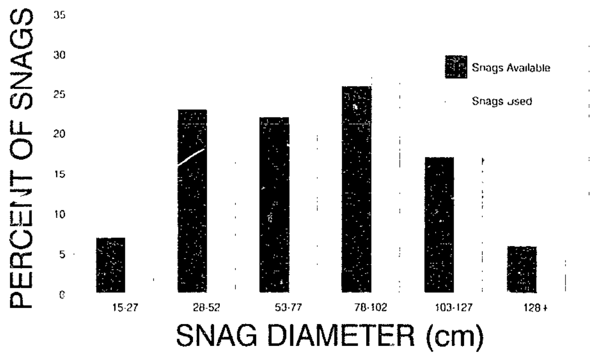

Fig. 3. Comparison of diameters of available snags (%) with diameters of snags used by cavity-nesting birds (%) over six diameter intervals.

smaller dbh than house wrens and violet-green swallows. Large ranges of dbh for snags pooled across all sites and for snags selected by CNB demonstrate the large variety in dbh of available snags and of snags used by all CNB species (Table 1).

Snag diameters arrayed by intervals approximated a Poisson distribution (Fig. 3), 87% falling between 28 and 127 cm dbh. Snags used by CNB mirrored availability, except for avoidance of snags with dbh less than 28 cm, and selection for snags of 78–102 cm dbh.

Height

Mean height for snags pooled across all sites (5.7 m) was significantly lower than mean height of snags selected by CNB pooled across all sites (8.3 m), and for individual CNB species (Table 1). Mean heights of snags selected by CNB differed significantly among species (Table 1). Ranges of snag heights available and selected by individual CNB species were wide, demonstrating the breadth of variety of heights available to and selected by CNB.

When snag heights were arrayed by intervals, their distribution was skewed to the shorter classes, as 71% were less than 6.4 m tall. Cavity-nesting birds selected snags taller than 6.4 m (Fig. 4), and avoided those in height intervals 1.8–3.3 and 3.4–6.3 m.

Correlation between dbh and height

Coefficients for correlation between dbh and height were not significant for four out of five CNB species, ranging from 0.004 for tree swallows to 0.168 ($P < 0.05$) for the house wren. Correlation coefficient for snags pooled across all sites was 0.03. These results suggested that dbh and height were independent and could be evaluated separately as variables for snag selection by CNB.

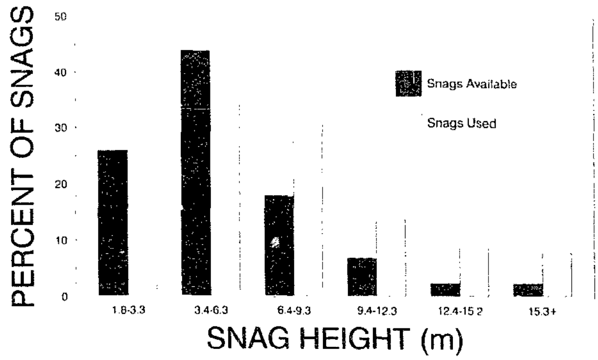

Fig. 4. Comparison of heights of available snags (%) with heights of snags used by cavity-nesting birds (%) over six height intervals.

TABLE 2

Frequency of availability of and selection by cavity-nesting birds of snags of five hardness stages. All pair-wise comparisons of all rows yield significantly different ($P<0.05$) chi-square values

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
All snags	0.015	0.059	0.233	0.412	0.283
All CNB	0.0	0.028	0.437	0.425	0.111
House wren	0.0	0.021	0.427	0.427	0.125
Bluebird	0.0	0.0	0.50	0.444	0.056
Flicker	0.0	0.062	0.438	0.50	0.0
VG swallow	0.0	0.0	0.303	0.512	0.182
Tree swallow	0.0	0.111	0.667	0.167	0.056

Hardness

Cavity-nesting birds as a group utilized snags of significantly different hardness than generally available (Table 2), selecting stage 3 snags and avoiding stage 1, 2 and 5 snags. Selection of snags for hardness was significantly different for all paired comparisons of CNB species.

Bark cover

Cavity-nesting birds as a group selected snags of significantly higher percent bark cover than available (Table 1). Selection of snags for bark cover were significantly different for 4 of 10 paired comparisons of CNB species. All species used the full range (0–100%) of bark cover.

DISCUSSION

Bird response to presence of snags

The common observation of CNB on clearcuts with snags and the high level of associated nesting is in striking contrast with previous evaluations of CNB use of clearcuts without snags on the Siuslaw National Forest. Mannan et al. (1980) and Morrison and Meslow (1983) reported CNB to be rare, (occasionally using the few remnant snags available) or totally absent from clearcuts.

The large and positive numerical response of the house wren and western bluebird to snag density was especially important, as these two species were previously classified as "rare to uncommon" in the Siuslaw National Forest (all successional stages) (Phillips, 1981).

The increase by over 30% of species-richness and densities of birds by addition of CNB on sites with high snag density is similar to the proportion predicted by Harmon et al. (1985). The proportion of the total bird community represented by CNB birds on clearcut sites may be higher than that of any subsequent seral stage except old-growth, and emphasizes the need for snag management in this earliest seral stage.

Previous studies demonstrated that non-cavity nesting birds are not significantly affected by the presence or absence of snags. Raphael and White (1984) reported a 6% decrease in non-cavity nesting species after snag removal on a brush site. Dickson et al. (1983) reported that density of non-CNB species was higher for some species and lower for others, and that overall densities were similar for clearcut sites with or without snags.

Although non-cavity nesting species were frequently observed perching on and singing from snags in this study, presence of snags apparently did not affect their population density, as similar numbers of non-cavity nesting birds were observed on clearcuts with few snags. Cavity-nesting birds ostensibly did not displace non-cavity nesting birds from clearcuts: densities of non-cavity nesting birds were similar on sites with differing snag and CNB densities.

Effect of snag density

The clearly increasing trend of CNB species-richness and -density associated with increasing snag density levels did not exist for non-cavity nesting birds. This observation suggested that differences in density of CNB birds among sites were most likely a function of snag density.

Most studies have indicated a positive correlation between snag density and CNB density (Balda, 1975; Mannan, 1977; Scott, 1979; Raphael and White, 1984; Zarnowitz and Manuwal, 1984). However, a few studies (Cunningham et al., 1979; Niemi and Hanowski, 1984) did not report this correlation. In our study, a significant positive correlation between CNB and snag density was observed.

Niemi and Hanowski (1984), who reported a lack of correlation between bird density and snag density, suggested that small size of logged areas (5–15 ha) influenced CNB use. Factors affecting bird density on small clearcuts may include use of surrounding habitats for nesting, edge effects or insufficient open ground for foraging and heightened intraspecific competition. However, we obtained better correlations between snag density and CNB density and species-richness when small clearcuts were included rather than excluded from our sample. This result suggests that the relationships between snag density and CNB density and species-richness hold for clearcuts of more than 5 ha.

Effect of snag density

A strong selection by CNB in mature forests for snags with diameters larger than 50 cm has been reported by many researchers (McClelland et al., 1979; Bull et al., 1980; Mannan et al., 1980). Densities of CNB were positively correlated with densities of large-diameter snags (> 52 cm) but not with densities of small-diameter snags in studies of forests of mixed seral stages (Raphael and White, 1984; Zarnowitz and Manuwal, 1984).

In our study, selection for large diameter snags was observed only for snags in one (78–102 cm) interval. Snags with diameters less than 23 cm were not used as nest sites, and snags falling within larger diameter intervals (103–127 cm, 128+ cm) were neither selected nor avoided. Many large-diameter snags were short, decayed remnants and may not have had all the beneficial aspects of large-diameter snags suggested by other studies.

The lack of use of small-diameter snags has been noted in studies other than ours. In a description of nest sites of primary CNB, Mannan et al. (1980) reported a minimum dbh of 36 cm. Raphael and White (1984) and Zarnowitz and Manuwal (1984) reported virtually no nests in trees of less than 23 cm dbh, the diameter of the smallest snag containing a nest in our study. Scott (1979) found virtually no use of snags smaller than 38 cm diameter.

Larger bird species require larger snags, whereas smaller species can use large and small snags (Thomas et al., 1979). More importantly, large-diameter snags remain standing significantly longer than smaller snags, providing nest sites for a longer period of time (Wright and Harvey, 1968; Lyon, 1977; Cline et al., 1980; Graham, 1982; Bull, 1983; Raphael and White, 1984). The potential standing time of newly created snags, which must provide nest sites for decades to come, becomes a crucial factor. Snags with the largest diameters possible should be retained or created, as they will stand longer. Cline et al. (1980) recommended retaining snags of more than 50 cm dbh.

Effect of snag height

Previous studies have not documented the importance of snag height. Raphael and White (1984) reported no height preference except reduced use of snags less than 6 m tall. Mannan (1977) also reported no correlation between height and use by CNB but found a preference for snags more than 15 m tall. Scott (1979) reported higher use of snags taller than 24 m but no preferences among shorter classes. Snags in our study were considerably shorter (71% less than 6.4 m) than those of other studies, which may have increased the attractiveness of the few taller snags available. The benefits of tall snags include greater protection from ground-dwelling predators (Kilham, 1971) and a potentially larger substrate for nesting and foraging (Raphael and White, 1984).

Snags less than 6.4 m tall comprised 37% of the nest sites in this study. However, as the canopy develops, short snags may not provide suitable nest sites for CNB of subsequent seral stages. In mature habitats, snags taller than 15 m are selected as nest sites (McClelland and Frissel, 1975; Mannan et al., 1980), but Cline et al. (1980) reported that snags shorter than 15 m are best for safety and timber-harvest reasons. We recommend retaining snags 6.4 m tall or taller with consideration of lower heights for safety reasons (e.g. sites fertilized via helicopter).

Effect of snag condition

Cavity-nesting birds avoided newer, harder snags and snags of advanced deterioration, selecting snags with decayed sapwood which had been dead for 20–50 years. As reported by others, (Conner et al., 1975; Scott, 1979; Mannan et al., 1980), newly dead trees were not used for nesting. Apparently, the wood is too hard for excavation by woodpeckers. More than 5 years must elapse before decay is sufficient to allow excavation (Cline et al., 1980). Therefore, the retention of newly-created snags alone will not meet CNB nesting requirements for some time.

Woodpecker species vary in their ability to excavate (Spring, 1965), and researchers have reported species-specific woodpecker preferences for snag condition (Raphael and White, 1984; Zarnowitz and Manuwal, 1984). Mannan et al. (1980) reported that flickers used hard and soft snags and hairy woodpeckers only hard snags. As with woodpeckers, individual non-excavating CNB species utilized snags of different hardness at different rates, which suggests that a full range of snag hardness should be available for CNB. Cavity-nesting birds selected snags with significantly greater bark cover than found on available snags, but also exhibited significant differences among species, suggesting that a full range of bark cover should be available for CNB.

Selection of snags by CNB

Cavity-nesting birds selected snags based on dbh, height, hardness and bark cover. As 91% of nest sites utilized by secondary CNB (those unable to excavate cavities) were cavities created by woodpeckers, sapsuckers and flickers, it is these, the primary CNB, that actually select for snag attributes; secondary CNB merely use what has been created by the excavators. In this study, only two species, the tree swallow and violet-green swallow appeared to partition the nesting resource between themselves consistently, selecting sites of significantly different dbh, height, hardness and bark cover.

MANAGEMENT IMPLICATIONS

The high proportion of CNB observed in this study emphasizes the need for retaining snags with cavities on clearcut sites. When enough snags (nest sites) are provided, CNB numbers should increase until food resources or other site factors limit populations.

Fixing a precise snag density that maximizes bird response is difficult because of the confounding effects of unit size, bird territoriality, snag distribution and snag quality. When fewer than 10 snags ha^{-1} were present, CNB density was no higher than 0.3 birds ha^{-1} and was probably constrained by lack of nest sites. Neither species-richness nor -density appeared asymptotic at the highest snag densities: possibly even higher species-richness and -density values would accrue from snag densities greater than the 25 ha^{-1} for all snags incorporated in our study, especially if the snags possessed preferred attributes.

The high degree of correlation between CNB species-richness and -density with density of snags with nest sites suggests that density of snags with nest sites may provide a more realistic number of snags to leave on clearcuts (14 snags ha^{-1}), if only snags of dbh, height, hardness and bark cover selected by CNB are retained.

To provide acceptable nesting conditions for CNB in central coastal Oregon, we recommend leaving 14 snags ha^{-1}, between 28 and 128+ cm dbh, between 6.4 and 25 m tall, with at least 10–40% bark cover, and with most in hardness stages 3 and 4. The above recommendations concern only provision of snags for CNB on the clearcut phase of a site's development. Provision of adequate numbers of trees that will become snags for CNB that will populate succeeding sera will require leaving additional trees of characteristics and density recommended by other studies.

In western Oregon, 70 years are required to produce the larger snags to provide for the full spectrum of CNB birds (Cline, 1977). Therefore, retaining existing snags (for immediate use) and green trees (for future use as snags) on clearcuts will provide CNB habitat for the earliest seral stage (grass-forb habitat) and subsequent successional stages. Selecting snags with the most likelihood of use by CNB may reduce the number of snags required. Therefore time and effort should be spent in selecting and retaining those snags with the desired attributes. As newly created snags are not suitable as nest sites for at least 5 years, and snags with a wide range of diameters are used as nest sites by CNB, we recommend providing for new and existing snags with a mix of sizes and condition.

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