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Bird Foraging on Incense-cedar and Incense-cedar Scale During Winter in California

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The response of birds to variations in the density of incense-cedar (*Calocedrus decurrens* [Torr.] Florin.), and through exclosure experiments, the impact of bird foraging on the density of the scale insect (*Xylococculus macrocarpae*), was studied in the mixed-conifer zone of the western Sierra Nevada during winter. Birds concentrated foraging activities on the bark of small (<20 cm d.b.h.) cedar. Indices of abundance for many bird species were lower on sites with low-cedar density. Analysis of foraging activities indicated that birds reduced the density of scale insects on cedar and avoided sites with low-cedar density. The results indicate that a minimum density of >150 small cedar/ha may be required to prevent a reduction in the abundance of birds overwintering in these study areas. Small cedar apparently provide needed cover and food for much of the bird community. These findings are contrary to current thinking of forest managers in the management of incense-cedar.

Retrieval Terms: avifauna, bird density, bird foraging behavior, bird habitat use, *Calocedrus decurrens*, incense-cedar, scale insect, *Xylococculus macrocarpae*, Sierra Nevada, California

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IN BRIEF . . .

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Seasonal differences in use of food and habitat have been shown for numerous bird species. Especially during winter, when insect food is often at its lowest availability, birds may be unable to secure enough food for survival. In earlier work in the mixed-conifer zone of the western Sierra Nevada (Blodgett Forest, El Dorado County), observers found that many birds significantly increased their relative use of incense-cedar (*Calocedrus decurrens* [Torr.] Florin.) for foraging in winter as compared to summer. Preliminary examination of cedar showed the presence of one predominant arthropod species: the incense-cedar scale (*Xylococculus macrocarpae* Coleman). Scales were abundant under the loose, flaky bark of small (<20 cm diameter breast height [d.b.h.]) cedar, and on limbs of larger cedar. Even bird species usually considered foliage-gleaners—for example, chickadees (*Parus*) and kinglets (*Regulus*)—flaked and pecked the thin cedar bark. It was concluded from these observations that incense-cedar could be an important foraging substrate for birds during winter. But, current forest management practices often result in stands without a substantial component of small cedar. Thus, a conflict may exist between preferred forest practices and overwinter survival of some birds.

These initial studies were observational and did not establish that birds actually favored cedar as a foraging substrate. In this paper the results of a study are reported that determined the response of birds to variations in cedar density, and through exclosure experiments, the effect of birds on scale abundance at Blodgett Forest.

Study sites were identified to determine the response of birds to variations in cedar density. During winter 1984-85, two groups of sites were selected: one ("high cedar") containing the characteristic basal area (30 to 40 pct) of cedar in naturally regenerated areas; the other ("low cedar") containing a lower (<20 pct) composition of cedar. During winter 1985-86, four 125- by 125-m plots were established with cedar composition characteristic of naturally regenerated areas. Within two plots, all cedar <26 cm d.b.h. and >2 m tall were removed. Site use was quantified by (1) observing bird foraging behavior (use of tree species) and (2) determining the amount of time birds spent in each site (intensity of use).

For both winter study periods, many bird species showed significantly higher use of high cedar (1984-85) or uncut (1985-86) plots compared to low cedar or cut plots, respectively. No species showed consistently greater use of low cedar or cut plots. Also during both winters, incense-cedar was the most common foraging substrate used by most bird species. Bird foraging was concentrated (by bark flaking) on small cedar.

During both winter study periods, 15 and 30 pairs, respectively, of cedar were selected for exclosure experiments. Sections of the bole and limbs of one tree in each pair were screened to prevent foraging by birds. Samples of bark were removed from both screened and unscreened trees and examined for the presence of the incense-cedar scale insect. For both winters, few significant differences between screened and unscreened samples were found. The differences, however, indicated that bird foraging reduced the density of the scale insect on small boles and limbs.

Overall, this study showed that the lower cedar availability on treated sites was associated with lower bird abundance. Although birds increased their use of other tree species on treated sites, these changes were not sufficient to prevent decreases in bird abundance on areas with low-cedar availability. Exclosure experiments indicated that bird foraging may be reducing the density of scale insects. Results of this and the previous study at Blodgett Forest indicate that small cedar provide both the foraging substrate and understory cover necessary for birds during winter. Thus, small incense-cedar, either scattered among other sapling species or isolated in dense clumps, would likely help supply the food and cover requirements of many birds during winter. Results indicate that managers should strive for retention of at least 150 small incense cedar/ha in managed stands. However, retention of small incense-cedar is contrary to current practices of forest managers. But because winter may be the most crucial time for bird survivorship, the requirements of birds for food and cover should not be underestimated during this period.

INTRODUCTION

Seasonal differences in use of food and habitat have been shown for numerous bird species (e.g., Conner 1981, Fretwell 1972, Hutto 1981, Lewke 1982, Morrison and others 1985, Travis 1977). During winter, when food (especially insects) is often at its lowest availability, insectivorous birds may be unable to secure adequate quantities of food. It is important, therefore, that resource managers supply necessary foraging substrates for such birds on a year-round basis.

Morrison and others (1985) found that birds in the western Sierra Nevada (Blodgett Forest, El Dorado County) significantly increased their relative use of incense-cedar (*Calocedrus decurrens* [Torr.] Florin.) for foraging in winter as compared to summer. Cursory examination of cedar showed the presence of one predominant species: the incense-cedar scale (*Xylococculus macrocarpae* Coleman). The scale excretes copious amounts of honeydew that is colonized by sooty mold (*Arthrobotryum spongiosum*) (Hepting 1971, p. 215). As a result, tree surfaces with high scale densities often have blackened boles or limbs or both. Scales were abundant under loose, flaky bark of small (<20-cm d.b.h.) cedars, and on limbs of larger cedars (*fig. 1*). In addition to bark-drilling and bark-gleaning birds, species usually considered foliage-gleaners—for example, chickadees (*Parus*) and kinglets (*Regulus*)—flaked and pecked the thin cedar bark. We concluded from these preliminary studies that incense-cedar could be an important foraging substrate for birds in the western Sierra Nevada (Morrison and others 1985). But, current forest management practices often contribute to the development of stands without small cedars because managers prefer other, more commercially valuable timber species (e.g., pine [*Pinus*]). Therefore, a conflict may exist between preferred forest practices and overwinter survival of certain species of insect-foraging birds. Other studies have established that birds can significantly reduce the density of their insect prey (e.g., Campbell and others 1983, Crawford and others 1983, Holmes and others 1979, Otvos 1965).

The incense-cedar scale was at endemic levels in the Blodgett Forest study area, raising the possibility that this scale may be an important prey species for birds. That initial study was observational and did not show that birds actually required cedar as a foraging substrate (Morrison and others 1985).

This paper reports a study to (a) determine the response of birds to variations in cedar density, and (b) determine—through exclosure experiments—the effect of birds on scale abundance at Blodgett Forest. The findings from the study are contrary to the current thinking of forest managers in the management of incense-cedar.

Figure 1—Bole of small (about 7 cm diameter) incense cedar from Blodgett Forest, El Dorado County, California, shows the characteristic loose bark covered with black sooty mold. The round, white structures are remnants of wax cuticles of scale insects.

STUDY AREA

All study sites were located within the University of California's Blodgett Forest, El Dorado County, California. The 1200-ha forest (1200-1450 m elevation) is in the mixed-conifer zone (Griffin and Critchfield 1972) of the western Sierra Nevada. Predominant tree species were incense-cedar, white fir (*Abies concolor* [Gord. & Glend.] Lindl.), sugar pine (*Pinus lambertiana* Dougl.), ponderosa pine (*P. ponderosa* Dougl. ex Laws.), Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), and California black oak (*Quercus kelloggii* Newb.). The forest upper canopy was primarily mature (i.e., 70 years old) second-growth timber divided into 5- to 37-ha compartments and managed under different silvicultural systems.

Cedar Manipulation and Bird Foraging Behavior

Study sites to assess variation in cedar abundance, and to quantify bird foraging behavior, were used during two time periods:

1984-85 Study Sites

During winter 1984-85, we selected two groups of three adjacent compartments. One group, designated "high cedar," contained 30 to 40 percent basal area of cedar in the naturally regenerated areas of the forest, which is characteristic of the mixed-conifer zone in California (Schubert 1957). The second group, designated "low cedar," contained a lower (i.e., <20 pct) composition of cedar; those compositions had been achieved independently of our study as a result of forest management practices. All sites were similar in percent composition of Douglas-fir (16 pct), ponderosa pine (12 pct), black oak (12 pct), and tanoak (2 pct; *Lithocarpus densiflorus* [Hook. & Arn.] Rehd.). Partly as a result of management practices, the low-cedar sites contained a higher percentage of sugar pine (12 pct vs. 1 pct) and white fir (32 pct vs. 12 pct), and a lower (15 pct vs. 44 pct) percentage of cedar, than the high-cedar sites.

1985-86 Study Sites

During winter 1985-86 we selected two compartments with a cedar composition characteristic of the mixed-conifer zone. The two compartments were adjacent, but separated by a dirt road. Within each compartment we centered one 125- by 125-m plot. Cedar <26 cm d.b.h. and >2 m tall were removed from those plots during October 1985. Most of the limbs were removed from the boles, with many of the boles removed from the site. Two additional 125- by 125-m plots, each about 75 m from the cut plots, were established as controls.

Bird Exclosures

During both 1984-85 and 1985-86, we used two adjacent compartments (total of 38 ha) to assess the effect of birds on the density of incense-cedar scales. Those compartments had a typical cedar composition (43 pct composition by basal area). Because of limited access to much of the forest during winter and the need to use heavy equipment and transport samples, those compartments were not chosen at random, but were adjacent to the main, all-weather road on the Forest.

METHODS

Vegetation Analysis

During 1984-85, the density of incense-cedar was determined by establishing two parallel transects, 100 m apart, in each group of compartments. We randomly located 35 sampling points along the transect, with the constraint that points be 25 to 50 m apart. During 1985-86, four parallel transects, each 25 m apart, were established in each plot. Along the transect, we randomly located 25 sampling points, each 15 to 20 m apart. For both winters, the point-centered quarter method (Mueller-Dombois and Ellenberg 1974) was used to select trees for which we measured the d.b.h. (using a tape), mold intensity (rating it none, low, medium, high), and percent flaking of bark on trunks and limbs (visual estimates) for cedar >2 m tall.

Bird Exclosures

1984-85 Sampling Design

During October 1984, we selected 15 pairs of incense-cedar 15 to 30 cm in d.b.h. Trees of this size were used because preliminary data indicated that bird species concentrated foraging activities on such trees (Morrison and others 1985). Pairs of cedars were selected from random points along a road bordering the compartment, with the constraint that pairs be at least 30 m apart (to allow for independence among samples). The nearest suitable pair at least 25 m from the road was used. Members of a pair were within about 10 m of one another and of the same general size and vigor. One member of a pair (randomly selected) was screened for protection from birds: 12.7-mm (1/2-inch) mesh hardware cloth was wrapped around the bole starting at the tree base and extending 2.5 m up the trunk; the wire was held about 5 cm from the bole by wooden blocks. The top of the wire was folded against the tree. Branches on the bole that would interfere with the wire were removed; a similar section of the bole was cleared of limbs on the paired unscreened tree. A 50-cm section (measured from the bole) on each of three limbs on the screened tree was covered with window screen (held in place by wire and/or staples).

Pre-screening densities of scales were not determined; obtaining adequate samples would have required destroying the entire tree. We thus assumed that our screened and unscreened trees—chosen randomly and in close proximity to one another—represented typical and similar densities of scale insects at the start of the experiments.

Five pairs of trees were randomly selected for sampling on three dates in 1985: January 7, March 23, and April 27. All trees were felled and boles cut into four equal sections. The screened limbs were collected, as were three limbs of the same size and height from the unscreened tree.

All samples were transported to Berkeley, California and stored in a cold room (5°C). Three 5-cm-wide subsamples, selected from around the entire bole diameter, were randomly taken from three of the four bole samples (the number of samples was reduced because dissecting bark was extremely time consuming). Each subsample was then examined for the presence of scale insects. The following were recorded: diameter and bark thickness at top and bottom of bole; diameter at top and bottom of branch; number of wax traces, exposed and under the bark; and number of scales by categories distinguishable by eye or dissecting microscope (legless stages, legged male stages, and female adults). A wax deposit surrounds the stationary scales; traces of wax remain after scales move or are removed. Because legged scales occurred on the last two sampling dates, we removed all subsamples from boles and limbs and stored them in freezer bags to prevent movement of scales off unprotected samples stored in the cold room.

1985-86 Sampling Design

On the basis of analysis of the 1984-85 bird foraging data and 1984-85 exclosure data, we modified our sampling design during 1985-86 as follows: size of trees selected was restricted to those 10 to 20 cm d.b.h. and showing heavy infestation of scale, as indicated by sooty mold. Instead of the entire lower bole, a single 1-m section of the mid-bole was covered with window screening (the stronger hardware cloth was found to be unnecessary). Two rather than three limbs were covered with screen as before. Thirty pairs of trees were selected (instead of 15 pairs as in 1984-85). Trees were enclosed on November 21-22, 1985. Fifteen pairs were randomly selected and cut on February 1 and March 22, 1986 (rather than three dates as in 1984-85).

Experience during 1984-85 indicated that subsamples should be removed from boles immediately after felling the trees because of loss of bark caused by handling and transport, and because of potential movement of scales. Therefore, subsamples (taken as in 1984-85) were removed in the field and transported immediately to the laboratory for analysis. Wax traces were not counted during 1985-86 because of concerns over accidental loss of bark that might pull scales from bark, and because many traces could not be counted individually. Parasitized scales were recorded separately from nonparasitized scales in 1985-86.

Raw data for both years were analyzed by using the SYSTAT statistical analysis program. Values were converted from totals/sample to density/dm^2 of bark and were combined for each tree. Bole and branch data were analyzed separately. The appropriate transformations, if necessary, were used on the raw data to reduce differences in variance between screened and unscreened samples.

Avian Foraging Behavior

We recorded foraging behavior in the same manner during both winters of study; the same amount of time was spent in each site or plot within each year. During 1984-85, between November and March, about 200 person-hours were employed on 25 dates to observe and record foraging behavior. During 1985-86, between December and February, about 150 person-hours were used on 25 dates; most data were collected during January.

Observers walked slowly through a site or plot and recorded the following data for each foraging bird: species; sex; foraging tree species, d.b.h., and vigor (of crown); mold intensity; and foraging mode (e.g., glean, peck, probe). The amount of time expended on each foraging substrate-foraging mode combination was recorded with a stopwatch. Observation periods were limited to 10 to 30 seconds. Data were recorded for only one individual of a particular species whenever a flock was encountered.

Strauss' (1979) index L was used to calculate the use by birds of various tree mold-intensity and size categories relative to the availability of the categories. The index is calculated as: $L = p - q$, in which p is the proportional use of foraging categories (in the ith category), and q is the proportional availability of that substrate. L ranges from 1 to -1. The estimated sampling variance, S, of L was calculated and used to determine if L differed from zero (using a t-statistic) (Strauss 1979).

Intensity of Use of Study Sites by Birds

Our interest was in the bird foraging time at each site or plot, rather than the absolute density (or index thereof) of birds present. We assumed that the foraging and residence time in an area was related to favorability of the area to a bird, especially with regard to food and cover. Observers counted birds by walking slowly through study sites and recording birds (not differentiated by sex) encountered while recording foraging behavior. Birds that showed persistent foraging behavior in an area were thus likely counted multiple times. Observers avoided double-counting individuals for 15 minutes after the initial encounter, however. An "index of intensity of use" was calculated as the number of individuals counted per unit time.

RESULTS

1984-85 Study

Vegetation Availability

Density of cedar on the high-cedar sites (360/ha) was over twice that present on the low-cedar sites (158/ha). Overall average d.b.h. (cm) of cedar on high-cedar sites ($\bar{x}$= 22.5, SD = 14.12) was higher than that on low-cedar sites ($\bar{x}$= 14.6, SD = 10.81).

Bird Foraging Behavior

Incense-cedar was the most common foraging substrate on high-cedar sites, ranging from about 39 to 56 percent use by each of the four bird species analyzed; however, use of cedar did not differ significantly from other foraging substrates that were available (*table 1*). On low-cedar sites red-breasted nuthatches and golden-crowned kinglets used slightly over 40 percent cedar and showed highly significant use of cedar relative to other tree species available (*table 1*). All species used a high component of white fir (about 20 to 40 pct) on the low-cedar sites relative to their use of fir on the high-cedar sites (about 10 pct); note the low availability of fir on the high-cedar sites (12 pct) compared to that on the low-cedar sites (32 pct). Birds tended to make more intensive use of sugar pine on the low-cedar sites (12 pct availability) than the high-cedar sites (1 pct availability), and a higher use of ponderosa pine on the high-cedar sites (*table 1*).

Amount of flaked bark on a cedar decreased as d.b.h. increased (r = -0.50, P < 0.001). Amount of limb flaking, however, increased as d.b.h. increased (r = 0.52, P < 0.001).

Table 1—*Percent use (upper value) and Strauss' L (lower value) of use versus availability of trees for birds on low- and high-cedar sites during winter 1984-85, Blodgett Forest, El Dorado County, California*

Species	Tree species[1]					
	Black oak	Douglas-fir	Incense-cedar	Ponderosa pine	Sugar pine	White fir
			Low-cedar Sites			
Chestnut-backed Chickadee	20.4 0.09	7.4 -0.08	16.7 0.02	5.6 -0.05	11.1 -0.01	38.9 0.07
Red-breasted Nuthatch	29.6 0.19***	6.5 -0.09	40.7 0.26***	2.8 -0.08*	0.0 -0.12**	20.4 -0.12*
Brown Creeper	9.1 -0.02	0.0 -0.15***	31.8 0.17	4.5 -0.06	18.2 0.06	36.4 0.04
Golden-Crowned Kinglet	1.8 -0.09**	14.2 -0.01	43.4 0.28***	4.4 -0.07	3.5 -0.08	32.7 0.01
Availability (pct)	11.0	15.0	15.0	11.0	12.0	32.0
			High-cedar Sites			
Chestnut-backed Chickadee	18.4 0.04	5.3 -0.12	42.1 -0.02	15.8 0.03	5.3 0.04	13.2 0.01
Red-breasted Nuthatch	13.8 0.00	9.2 -0.08	39.1 -0.05	27.6 0.15*	2.3 0.01	8.0 -0.04
Brown Creeper	4.6 -0.09*	12.3 -0.05	52.3 0.08	20.0 0.07	1.5 0.01	9.2 -0.03
Golden-crowned Kinglet	2.1 -0.12**	13.6 -0.03	55.7 0.12	13.6 0.01	2.1 0.01	11.4 -0.01
Availability (pct)	14.0	17.0	44.0	13.0	1.0	12.0

[1]Significant differences (*$P < 0.05$, **$P < 0.01$; ***$P < 0.001$) based on a *t*-statistic.

Table 2—*Index of intensity of use (no. birds/unit time) for birds on low- and high-cedar sites during winter 1984-85, Blodgett Forest, El Dorado County, California*[1]

Species	Low-cedar sites		High-cedar sites	
	x̄	SD	x̄	SD
Downy Woodpecker (*Picoides pubescens*)	0.1	0.1	0.1	0.1
Hairy Woodpecker (*P. villosus*)	0.5	0.7	1.1	0.8*
White-headed Woodpecker (*P. albolarvatus*)	0.2	0.4	1.4	4.1*
Pileated Woodpecker (*Dryocopus pileatus*)	0.1	0.3	0.2	0.3
Mountain Chickadee (*Parus gambeli*)	1.3	1.9	1.7	2.4
Chestnut-backed Chickadee (*P. rufescens*)	6.0	4.6	4.1	3.8
Red-breasted Nuthatch (*Sitta canadensis*)	7.8	4.3	6.4	2.6
Brown Creeper (*Certhia americana*)	1.7	1.7	2.8	2.5*
Golden-crowned Kinglet (*Regulus satrapa*)	15.4	7.1	17.1	10.5
Ruby-crowned Kinglet (*R. calendula*)	0.2	0.5	1.0	1.1**
American Robin (*Turdus migratorius*)	0.0	0.1	0.4	0.6*
Yellow-rumped Warbler (*Dendroica coronata*)	0.1	0.4	0.5	2.0
Dark-eyed Junco (*Junco hyemalis*)	0.4	1.0	1.5	1.8**
TOTAL	39.8	18.3	43.3	15.3

[1]Tabular values are original values times 100 ([index][100]). Significant differences (*$P < 0.05$, **$P < 0.01$) based on Mann-Whitney U-test.

Table 3—*Density of scale insects (no./dm²) for each of three sampling dates during winter 1984-85, Blodgett Forest, El Dorado County, California*[1,2]

Date	Live scale		Trace under bark		Exposed trace	
(1985)	Screen	Unscreen	Screen	Unscreen	Screen	Unscreen
			Bole Samples			
Jan. 7	1.4 (1.55)	1.4 (1.65)	2.9 (2.00)	2.9 (1.60)	0.1 (0.05)	0.1 (0.05)
Mar. 23	0.6 (0.33)	0.7 (1.05)	1.9 (2.23)	3.5 (6.43)	0.1 (0.09)	0.3 (0.57)
Apr. 27	0.6 (0.87)	0.7 (0.85)	8.5 (8.73)	3.8 (2.23)	0.4 (0.79)	0.2 (0.28)
			Limb Samples			
Jan. 7	13.8 (14.21)	6.1 (5.72)	5.4 (10.52)	12.9 (17.42)	21.9 (24.39)	20.7 (29.26)
Mar. 23	18.6 (19.94)	4.7 (5.21)	18.8 (14.56)	7.9 (6.78)	0.7 (1.53)	16.3* (12.72)
Apr. 27	1.0 (0.97)	0.7 (0.70)	18.3 (12.69)	6.9 (4.39)	3.5 (6.26)	21.7 (25.08)

[1]Significant differences (*$P < 0.05$), based on t-test.

[2]Values for each date represent the mean of three subsamples taken from five screened and five unscreened trees; therefore, n = 5 samples/category/date for incense-cedar sampled during winter 1984-85, Blodgett Forest, El Dorado County, California. Standard deviation in parenthesis.

Intensity of Use of Study Sites by Birds

The overall intensity index did not differ significantly between low- and high-cedar sites (*table 2*). Significantly higher indices were noted on high-cedar sites for six of the 13 species observed; none of the species gave significantly higher indices on low-cedar sites. The golden-crowned kinglet—the most numerous species present—showed similar indices on high- and low-cedar sites.

Exclosure Experiments

We found no significant ($P > 0.05$) differences between the screened and unscreened bole samples for any sampling period (*table 3*); *P*-values were 0.1-0.2 for most comparisons for limbs. Exposed traces—indicating that cedar bark was pulled from the trees—were significantly greater on unscreened limbs than screened limbs only for the second sampling date (*table 3*).

1985-86 Study

Vegetation Availability

We found an average of 595 incense-cedar/ha on the two experimental plots before cutting. Among these cedars, 72 percent were ≤15-cm d.b.h., 21.5 percent were 15- to 30-cm d.b.h., and the remaining 6.5 percent were >30-cm d.b.h. Some cedars <26-cm d.b.h. remained on cut plots because they were missed during cutting. Density declined 75 percent after cutting to about 150 cedar/ha (*fig. 2*). After cutting, only 39.4 percent of the cedars were ≤15cm d.b.h., whereas larger (>30-cm d.b.h.) trees accounted for 51.3 percent of the cedar; only 9.3 percent were 15- to 30-cm d.b.h.

Bird Foraging Behavior

No significant difference between use and availability of cedar was found for any bird species except the golden-crowned kinglet. This kinglet showed highly significant use of cedar (*table 4*). Use of cedar was nearly equal to availability for red-breasted nuthatches and brown creepers on cut plots (*table 4*).

Figure 2—The surrounding nontreated area in one of the experimentally cut plots, Blodgett Forest, El Dorado County, California, shows boles and stumps of some of the felled cedar. The cedar thicket in the adjacent stand is typical of such sites in Blodgett Forest.

Table 4—*Percent use (upper value) and Strauss' L (lower value) of use versus availability of trees for birds on uncut and cut plots during winter 1985-86, Blodgett Forest, El Dorado County, California*

Species	Tree species[1]						
	Black oak	Douglas-fir	Incense-cedar	Ponderosa pine	Sugar pine	White fir	Other
				Uncut Plots			
Chestnut-backed Chickadee	12.8	10.3	38.5	7.7	7.7	12.8	10.3
	0.11	0.02	-0.16	-0.01	0.05	-0.05	0.05
Red-breasted Nuthatch	7.3	6.3	44.8	28.1	4.2	6.3	3.1
	0.05	-0.02	-0.10	0.20**	0.01	-0.12	-0.02
Brown Creeper	0.0	9.1	40.9	29.5	15.9	4.5	0.0
	-0.02	0.01	-0.14	0.21*	0.13	-0.13	-0.05
Golden-crowned Kinglet	1.5	5.9	82.4	3.7	0.7	5.9	0.0
	-0.01	-0.03	0.28**	-0.05	-0.02	-0.12	-0.05
Availability (pct)	2.2	8.5	54.9	8.5	3.1	17.9	4.9
				Cut Plots			
Chestnut-backed Chickadee	15.4	0.0	0.0	7.7	7.7	61.5	7.7
	0.12	-0.14	-0.23**	-0.07	0.02	0.31	-0.01
Red-breasted Nuthatch	9.7	1.6	22.6	29.0	25.8	9.7	1.6
	0.06	-0.13	-0.01	0.15	0.20**	-0.21*	-0.07
Brown Creeper	4.5	4.5	22.7	18.2	45.5	4.5	0.0
	0.01	-0.10	-0.01	0.04	0.40**	-0.26*	-0.08
Golden-crowned Kinglet	4.9	4.9	63.4	14.6	2.4	9.8	0.0
	0.01	-0.09	0.40***	0.00	-0.03	-0.21*	-0.08
Availability (pct)	3.8	14.4	23.5	14.4	5.3	30.3	8.3

[1] Significant differences (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$) based on a t-statistic.

The chestnut-backed chickadee, however, did not use cedar, but the kinglet continued to show significant use of cedar, on cut plots. The nuthatch and creeper both showed significant use of sugar pine on cut plots (but not on uncut plots); these two species showed significant use of ponderosa pine on uncut plots. Most species showed a negative use of white fir (relative to availability) on both cut and uncut plots, although the relative availability of fir was much higher on the cut plots.

The average size (d.b.h.) of cedar used for foraging was significantly ($P < 0.05$) greater on cut than uncut plots for the creeper and kinglet (unpubl. data). The low number of birds on cut plots precluded more detailed analyses of the use of specific foraging substrates between plots, except for the golden-crowned kinglet. For this kinglet, use of small branches on uncut plots (42 pct) was half that on cut plots (82 pct), while use of trunks on uncut plots (58 pct) was much higher than that on cut plots (18 pct); this pattern of use was significantly different (chi-square = 7.95, d.f. = 1, $P < 0.005$ after Yates correction) between cut and uncut plots.

Intensity of Use of Study Plots by Birds

The overall intensity index on uncut plots was about twice that of cut plots (*table 5*). Five of six species analyzed (i.e., that had adequate numbers to examine) had higher overall indices on uncut plots. Both uncut plots had higher intensity indices than the cut plots, although the difference between one uncut and one cut plot was not significantly different (*table 5*). A similar pattern was seen for species-specific comparisons: uncut site-1 tended to have the highest indices; uncut site-2 was similar to, but usually slightly higher than, cut site-2; and cut site-1 had the lowest indices (*table 5*).

Exclosure Experiments

For the first sampling period, densities of total scales and live-immature scales on screened bole samples were significantly higher than on unscreened samples (*table 6*). Virtually no differences in scale density were found for limbs or boles during the second sampling period (*table 6*).

Table 5—*Index of intensity of use of study plots (no. birds/unit time) by birds on plots with (uncut) and without (cut) small (<26 cm dbh) incense-cedar during winter 1985-86, Blodgett Forest, El Dorado County, California*[1]

Species	Uncut		Cut		Total		
	Site 1	Site 2	Site 1	Site 2	Uncut	Cut	Pct difference
Hairy Woodpecker	0.0 (0.0)A	0.2 (0.5)AB	0.6 (1.0)B	0.5 (1.1)B	0.1	0.6	83
White-headed Woodpecker	0.0 (0.0)A	0.4 (0.7)B	0.2 (0.7)AB	0.0 (0.0)A	0.2	0.1	-50
Chestnut-backed Chickadee	6.2 (8.3)AB	8.6 (11.4)A	0.8 (1.3)C	2.4 (5.1)BC	7.4	1.5	-80
Red-breasted Nuthatch	5.8 (3.8)A	5.5 (4.1)A	3.8 (4.3)A	4.0 (3.7)A	5.6	3.9	-30
Brown Creeper	2.0 (2.9)A	1.7 (2.3)A	0.8 (1.3)A	1.7 (1.9)A	1.9	1.2	-37
Golden-crowned Kinglet	25.0 (21.8)A	11.0 (12.8)B	4.1 (8.6)B	10.1 (12.9)B	18.3	6.9	-62
Total	40.0 (21.9)A	29.0 (23.5)AB	12.5 (16.1)C	20.0 (16.4)BC	34.3	16.0	-53

[1]Tabular values are original indices times 100 ([index][100]). SD in parenthesis. Values for each bird species (read horizontally) with same letters (A,B,C) do not differ significantly ($P < 0.05$) as determined by Duncan's new multiple range test.

Table 6—*Mean (SD) density of scale insects (no./dm²) for each of two sampling dates taken from 15 screened and 15 unscreened trees for incense-cedar sampled during winter 1985-86, Blodgett Forest, El Dorado County, California*[1]

Date	Live scale[2]		Immature scale[3]		Total scale[4]	
(1986)	Screen	Unscreen	Screen	Unscreen	Screen	Unscreen
			Bole Samples			
1 Feb.	11.3 (18.98)	3.6 (5.02)	10.4 (17.82)	3.0* (5.03)	13.1 (20.49)	4.0* (5.66)
22 Mar.	3.2 (3.75)	4.1 (3.81)	2.8 (3.64)	3.7 (3.56)	3.9 (4.69)	5.3 (4.30)
			Limb Samples			
1 Feb.	16.4 (18.45)	9.2 (13.03)	16.0 (18.44)	9.1 (13.02)	22.7 (18.69)	11.3 (13.80)
22 Mar.	4.5 (5.00)	3.4 (3.38)	4.2 (4.87)	3.3 (3.27)	8.2 (6.18)	7.2 (6.22)

[1]Significant difference (*$P < 0.05$) based on *t*-tests (values for each date represent the means of 3 subsamples).
[2]Includes all unparasitized scales.
[3]Legless, unparasitized scales.
[4]Live and parasitized scales.

DISCUSSION

Birds concentrated foraging activities in incense-cedar during winter, although this use was usually in proportion to availability of cedar. In an earlier study at Blodgett Forest, Morrison and others (1985) found similar results for an even wider array of species. The golden-crowned kinglet—the most abundant bird species at Blodgett Forest during winter—consistently used cedar in greater proportion than other foraging substrates that were available. The lower cedar availability on treated sites was associated with a lower bird abundance on low-cedar sites (1984-85) and cut plots (1985-86). Further, number of birds observed foraging on low-cedar sites and cut plots was considerably lower than that on the high-cedar sites and uncut plots despite a similar sampling effort on all plots within each year of study. Although birds increased their use of other tree species on low-cedar sites and cut plots, these changes were apparently not sufficient to prevent decreases in abundance on areas with low-cedar density. Although densities of cedar on low-cedar sites and cut plots were similar (about 150 trees/ha), low-cedar sites contained a higher proportion of small cedar than cut plots. This difference likely accounted for the more similar indices of abundance between low- and high-cedar plots compared to cut and uncut plots.

Exclosure experiments indicated that birds may reduce densities of scale insects. Experimental trees used during 1984-85 were larger than those apparently preferred by birds, revealing a problem in study design for bole samples during that period (because of bark thickness on trunks); thus, data were most relevant to scale density on limbs during that year. The similarity in scale density between screened and unscreened trees for the last sampling dates was apparently due to movement of females off the bole samples and on to branches to reproduce (Tait 1986).

Results of the two-winter study showed a similar pattern and indicated that several bird species responded to a low density of small cedar by changing patterns of foraging behavior and avoiding areas without adequate cedar. Birds, such as the hairy woodpecker, that can obtain alternate prey by drilling into bark, did not rely heavily on cedar. Alternate prey is apparently unavailable to most birds overwintering at Blodgett Forest, however (Morrison and others 1985).

We believe the absolute density of cedar, while important, is secondary to the size (d.b.h.) of the trees. A few large cedar (with many limbs) may supply a surface area of thin-barked limbs that is similar to that provided by many small cedar (with few small limbs). Small cedars, however, also create a dense understory that apparently supplies needed cover in addition to food (Morrison and others 1986). Therefore, it appears that a few large cedars will not replace numerous small trees. Although the saplings of other conifer species at Blodgett Forest would not supply food found on incense-cedar, they would likely provide most if not all of the necessary cover. Thus, small incense-cedar, either scattered among other sapling species, or isolated in dense clumps, would likely supply the food and cover requirements for certain bird species during winter. Thus, we suggest that managers strive for retention of >150 small cedar/ha. However, retention of small incense-cedar is contrary to current practices of forest managers. Because winter may be the most critical time for bird survivorship (Fretwell 1972), we should not underestimate the food and cover requirements of birds during this period.

Our results are based on the assumption that changes in bird abundance and foraging behavior are indicative of an effect caused by cedar density. Although caution must be exercised when relating abundance to habitat "quality" (Van Horne 1983), our results are strengthened by the experimental nature of our study and the consistent patterns shown. We could not determine scale densities before screening because such a procedure would have destroyed the bark and made further evaluations meaningless. More rigorous experimental manipulations are necessary to refine our results. Although our study area was typical of other areas in the mixed-conifer zone of the western Sierra Nevada, further work in other areas is clearly warranted.

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