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Home range and habitat use by pileated woodpeckers (*Dryocopus pileatus*) were studied in the Coast Ranges of western Oregon. Radio-telemetry was used to determine home ranges of 11 woodpeckers and habitat use of 14 woodpeckers after young had fledged during summers from 1982 to 1985. Home range size for individual bird averaged 480 ha; home ranges for pairs of birds were larger. Home ranges were larger than those reported in other studies. The larger home range sizes effectively reduce minimum snag densities calculated with formulas based on densities of birds. There was some overlap (11-160 ha) between adjacent home ranges. Pileated woodpeckers preferred forest habitat classes older than 40 years of age and deciduous riparian habitats for foraging and other diurnal activities. Nesting and roosting occurred in forest stands older than 70 years of age. The amount of foraging habitat within the home ranges averaged 306 ha; the amount of nesting and roosting habitat averaged 200 ha. Because pileated woodpeckers use immature forest stands for foraging they may not be a good "indicator" species for mature forest habitats.

Characteristics of 15 nest and 13 roost trees (live and dead) and sites were measured from 1983 to 1986; characteristics were compared to those from other studies. Mean dbh differed significantly ($P \leq 0.05$) between nest trees (68.9 cm) and roost trees (118.2cm). Trees used for nesting and roosting were taller than 11.5 m. A typical nest or roost tree had a broken top and retained most of the bark. Forest characteristics within a 0.3 ha circular plot at nest and roost sites were highly variable between sites. Discriminant analysis did not reveal a significant ($P \leq 0.05$) difference between nest and roost sites found within 70- to 100-year-old stands and 100- to 200-year old stands. Mean dbh of nest trees was smaller, mean height of nest trees (26.5 m) was intermediate, and mean height of nest cavities (20 m) was higher than those reported from most other studies. Measured forest characteristics at nest sites were very different between studies because of differences in forests in terms of species composition, site productivity, climate and amount of disturbance. Findings were consistent with a previously recommended "minimum" dbh for pileated woodpecker nest trees of 63.5 cm (with bark). However, provision of nest trees with average characteristics would enhance management schemes which are directed toward minumum population numbers and a minimum amount of reserved habitat.

HOME RANGE AND HABITAT USE OF PILEATED WOODPECKERS, WESTERN OREGON

by

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PREFACE

The thesis is presented in two parts to facilitate publication of manuscripts. Part I addresses home range and habitat use by pileated woodpeckers as assessed with the aid of radio-telemetry. Habitat characteristics at nest and roost sites of pileated woodpeckers are discussed in Part II. Supplemental information for both parts is given in the appendices. The format is similar in both parts of the thesis. This approach resulted in some redundancy in descriptions of study area and methods.

PART I

HOME RANGE AND HABITAT USE OF PILEATED WOODPECKERS, WESTERN OREGON

INTRODUCTION

Large snags (standing dead trees), defective trees, and down logs are used by pileated woodpeckers (*Dryocopus pileatus*) for nesting, roosting, and foraging (Bull and Meslow 1977, McClelland 1979, Mannan et al. 1980). These characteristics are prominent structural components of mature and old-growth Douglas-fir (*Pseudotsuga menziesii*) forests of western Oregon (Cline et al. 1980, Franklin et al. 1981). Mature timber stands usually support higher densities of pileated woodpeckers than do younger forests in western Oregon (Mannan et al. 1980).

Pileated woodpeckers have been identified as a minimum management requirement (MMR) and indicator species of mature forest habitats on the National Forests in the Pacific Northwest (Sirmon 1983). However, most information available on habitat use by pileated woodpeckers in the Pacific Northwest has been collected from forests east of the Cascade Mountains (Bull and Meslow 1977, Bull 1980, Madsen 1985). Home range and habitat requirements on the west side of the Cascade Mountains may differ from other areas because of differences in forest types and productivity. Information on home range size and habitat use on the west side of the Cascade Mountains is needed to effectively manage for pileated woodpeckers in that portion of the Pacific Northwest.

The purpose of this study was to provide resource managers with part of the information needed to manage for populations of pileated woodpeckers in forests of the Pacific Northwest. The objectives were to describe home range size and habitat selection of pileated woodpeckers in the Coast Ranges of western Oregon.

STUDY AREA

Study sites were located in the Oregon Coast Ranges 15 to 30 km west to southwest of Corvallis on lands controlled or owned by Siuslaw National Forest, Bureau of Land Management, City of Corvallis, and several private landowners. The area is within the western hemlock (*Tsuga heterophylla*) vegetation zone described by Franklin and Dyrness (1973). Because of disturbance caused by fire and logging operations, forests are dominated by subclimax stands of Douglas-fir rather than climax stands of western hemlock (Franklin and Dyrness 1973). The area is intensively managed for timber, and as a result mature stands are scattered and old growth stands are rare; of areas suitable for timber management on the Siuslaw National Forest, 60% support mature forest stands (70-110 years old) and 5% support stands with old-growth characteristics (USDA Forest Service 1986a).

METHODS

Location of pileated woodpeckers and nests

During April and May of 1983-1985 pairs of pileated woodpeckers were located by eliciting responses to tape recorded pileated woodpecker calls and drumming, by listening for unsolicited vocalizations, and by searching for excavations made by foraging pileated woodpeckers in snags along logging roads. Emphasis was placed on searching areas in which fresh foraging excavations were observed.

During the period of cavity excavation, pileated woodpeckers often call and drum early in the morning near their nests. Males and females often vocalize at nests when exchanging incubation duties (Kilham 1959). Vocalizations from the young in the cavity increase as they near fledging. These auditory cues were used to locate nest stands, which were then searched visually for nests. Each snag was checked for cavities. Fresh wood chips at the base of a snag indicated the presence of a freshly excavated cavity. Because pileated woodpeckers often excavate more than one cavity each spring, nests were confirmed as active only when an exchange of incubation duty was observed or young were seen or heard in the cavity.

Pileated woodpeckers were located at 4 sites in 1983, 14 sites in 1984, and 25 sites in 1985. Because of limitations in time and personnel only 30 of these sites were actively searched for nests; 14 nests were located from 1983 to 1985.

Habitat classification

Twelve forest habitat classes were described (Table 1). Aerial photos and type maps of forest stands from Bureau of Land Management, U.S. Forest Service, and Starker Forests Inc. were used to map habitats. The area encompassed by each habitat was then measured with a digitizer. Classification of areas not defined on type maps were determined in the field. Ages of stands which were adjacent to recent clearcuts were confirmed by counting rings in stumps in the clearcuts.

Radio-telemetry data collection

Adult pileated woodpeckers were trapped at the nest only after young had hatched to avoid nest abondonment. An adjacent tree was climbed and a long pole was used to place a dipnet frame with mist net webbing over the cavity. Birds were trapped as they left the nest to exchange incubation duties or after feeding young. Snags were not climbed because of safety concerns, and as a result birds could not be trapped at 4 nests. Retrapping efforts at roost sites were unsuccessful.

Radio transmitters (Wildlife Materials, Inc. or AVM Instrument Co.) were attached to the birds with a backpack-type harness of teflon tubing. Transmitter packages including transmitter, battery, antenna, acrylic, and harness weighed approximately 8 gm ($\leq$ 3% body weight of the birds). With one exception, both members of each pair were trapped and equipped

Table 1. Forest habitat classes used to describe habitat use of pileated woodpeckers, western Oregon.

Class	Age (years)	Description
1	0-15	Clear cut, seedlings and/or saplings
2	16-40	Saplings and small poletimber, conifer (<30% shrub)
3	16-40	Saplings and small poletimber, conifer/shrub mix (>30% shrub)
4	41-70	Immature, poletimber and/or small sawtimber, conifer (<20% deciduous)
5	41-70	Immature, poletimber and/or small sawtimber, conifer/deciduous mix (>20% deciduous)
6	71-100	Mature, small and/or large sawtimber, conifer (<20% deciduous)
7	71-100	Mature, small and/or large sawtimber, conifer/deciduous mix (>20% deciduous)
8	100-200	Older mature, large sawtimber, conifer (<20% deciduous)
9	100-200	Older mature, large sawtimber, conifer deciduous mix (>20% deciduous)
10	200+	Old-growth forest
11	----	Deciduous riparian, primarily red alder (*Alnus rubra*) and big-leaf maple (*Acer macrophyllum*)
12	----	Non-forest land (eg. agricultural land, meadows, lakes)

with transmitters.

Birds were monitored during daylight hours for up to 3 months (maximum life of the transmitters). Radio-telemetry locations were recorded at 10-minute intervals; if a bird flew out of receiving range, the next location was recorded when the bird was relocated. Each position was located on an aerial photograph and grid coordinates superimposed on the photograph were recorded.

Telemetry locations were determined at as close range as possible to accurately locate birds, but not so close as to disturb the behavior of the birds. Eleven percent of locations were confirmed by visual or aural contact, which allowed an estimate that telemetry locations were accurate to within at least 100 m. Locations were assigned to a forest habitat class (Table 1) in the field at the time the fix was recorded. Locations near boundaries of habitats were assigned to a forest habitat class only when the class the bird was using could be confirmed; these locations were verfied by visual or aural contact, or by direction of the radio signal in relation to the boundary of the habitat class.

During the study radio transmitters were attached to 19 pileated woodpeckers; however, problems were encountered with many of the radio transmitters. It appeared that the woodpeckers were breaking or bending the transmitter antennas, which greatly reduced the range of the transmitters and made it difficult or often impossible to locate and monitor some of the birds. This reduction of transmitter range began within a few days to several weeks after transmitters were attached to birds; thus, a number of birds were located only sporadically. Complete home ranges could not be determined for birds located sporadically. Adequate data were collected for calculation of home range sizes for 8 birds, and for evaluation of habitat use for 11 birds.

R.W. Mannan provided original data on 3 pileated woodpeckers from his 1982 preliminary investigation, which were collected on the same area and with the same methods as in this study (Mannan 1984). Mannan's data were added to the data collected in 1983-85 for analysis and reporting in this paper.

Test for independence of locations

An assumption of statistical home range models is that animal locations are independent. Independence implies that an animal's position in the past does not influence its current position (Swihart and Slade 1985). Schoener's (1981) t^2/r^2 ratio was used to test for independence of locations within subsets of the location data with a variety of time intervals between telemetry locations; t^2 is the mean squared distance between successive observations, and r^2 is an estimate of the mean squared distance to the geometric center of the locations. The expected value of the t^2/r^2 ratio equals 2.0 when locations are statistically independent. Autocorrelation steadily decreased as time interval between locations increased from 10 minutes (t^2/r^2

= 0.19) to at least 4 hours (t^2/r^2 = 1.45). There was little decrease in autocorrelation between the subset of data with a 4 hour time interval and a subset in which 1 location was randomly selected from each sampling day (t^2/r^2 =1.46), averaging 1 location every 3 days. Sample sizes of subsets with longer time intervals were too small for further testing.

Home range calculations

The minimum convex polygon (a non-statistical method) was selected as the most appropriate model to use in calculating home range sizes with this data set. Swihart and Slade (1985) suggested use of a non-statistical method when data must be collected over a short period of time and autocorrelation cannot be avoided. Minimum convex polygon estimates involve no assumptions about the distribution of data. The program AMAP (Rexstad 1984) was used on an IBM PC computer to calculate minimum convex polygon estimates.

An area-observation (AO) curve (Odum and Kuenzler 1955) was used in conjunction with minimum convex polygon estimates to determine if an adequate number of locations had been collected for each bird to estimate home range size. Home range sizes were reported for birds for which the AO curve exhibited an asymptotic relationship (Sanderson 1966, Smith et al. 1981, Laundre and Keller 1984). Additional locations which did not increase home range estimates were collected for some birds.

Home range sizes were also calculated using 3 statistical models: 95% ellipse (Jennrich and Turner 1969), harmonic mean (Dixon and Chapman 1980), and fourier transformation (Anderson 1982). The programs McPaal (Stuwe and Blohowiak 1985), and Anderson (Anderson 1980) were used on an IBM AT computer for calculation of home range sizes. Problems were encountered with statistical home range models with this data set. It was impossible to collect adequate sample sizes to accurately estimate home range during the 3 months the transmitters functioned and still meet the independence of locations assumption of these models. In addition, the bivariate normality assumption of the 95% ellipse method was violated. The grid density used to calculate the harmonic mean influenced the size of the home range estimate, and the choice of grid density was a subjective decision. Because of these problems estimates from the statistical models were reported only in Appendix 1; further discussion of these methods is also given in Appendix 1.

<u>Habitat use evaluation</u>

Habitat use was determined by calculation of the proportion of locations in each forest habitat class. All locations were used to ensure adequate information was collected within the restricted sampling period. Habitat use was compared to the proportion of each forest habitat class available within the home range (minimum convex polygon) of the woodpeckers (Byers et al. 1984). Because the birds were never observed in non-forest habitats and the habitat consisted of less than 3% of the home range, that class was eliminated from available habitat calculations. Habitat selection by individual birds was estimated by dividing habitats into 3 arbitrary categories based on the distribution of the data: those used in a proportion 50% less or 50% greater than expected based on availabilty, and those used in proportion equal to availability (between 50% less and 50% greater).

Preference ranking was calculated based on the difference between use rank and availability rank of each forest habitat class averaged across all birds (Johnson 1980). The program PREFER (Frank 1985) was used with an IBM AT computer to calculate preference ranking.

Observations were collected in such a manner that the data represented an unbiased estimate of habitat use by pileated woodpeckers during summer. Because the birds were able to travel to any point within their home range within the 10 minutes between recorded locations, all habitats within the home range were considered available to the bird for each location.

There are no set guidelines for minimum sample sizes per individual for the preference ranking method (Alldredge and Ratti 1986). To ensure adequate sampling effort, guidelines for sample size for Bonferroni-z confidence intervals were used; habitat use was evaluated only for birds for which there were at least 5 expected observations per habitat, based on percent of availablility of habitats (Neu et al. 1974, Byers et al. 1984).

RESULTS AND DISCUSSION

Home range size

Home ranges were calculated for 11 pileated woodpeckers including 3 birds monitored by R.W. Mannan in 1982. Reported home range sizes are minimum estimates of actual home range sizes for individual pileated woodpeckers during summer, after young had fledged. Five birds were accompanied by young.

Birds typically used a portion of their home range for 5 to 10 days and then shifted to another portion. Birds had used most portions of their home range by 30 to 40 days after monitoring began, and AO curves began to exhibit an asymptotic relationship between home range size and number of radio-locations.

Home ranges averaged 480 ha with a wide range in sizes (267 ha to 1056 ha) (Table 2). The largest home range, occupied by Peak Creek male, was 85% larger than the next largest home range. This male, accompanied by at least 1 young, flew to the home range of a neighboring pair of pileated woodpeckers during 4 of 33 days of monitoring. There was a large area in the center of his home range used only as a travel corridor during the observation period; however, because these excursions were frequent they were included in the home range estimate.

Estimated home range size was not significantly correlated ($r=0.32$, $p \leq 0.05$) with the minimum number of consecutive locations necessary to calculate those estimates. The radio on the bird

Table 2. Home range sizes of 11 pileated woodpecker during summer in western Oregon (1982-1985). Home range sizes were estimated using a minimum convex polygon.

Bird	Home range size (ha)	Minimum number of locations for estimate[a]	Total number of locations	Sex (M/F)	With young (Y)
PECRM85	1056	400	550	M	Y
RESRF85	570	479	522	F	
MANBM82	546	400	400	M	
HUPAM85	533	357	386	M	Y
MANAM82	485	400	400	M	
RESRF83	431	386	392	F	Y
MANAF82	430	355	355	F	
ROCRF85	363	211	335	F	
PECRF85	300	452	453	F	Y
LRCRM84	293	402	454	M	Y
BORDM85	267	218	255	M	
Mean	480 ha				

[a] Additional locations which were collected did not increase home range size.

with the largest home range transmitted longer than any of the other radios, so the greatest number of locations were collected for this bird. The much larger home range and large sample size for this bird contributed to a significant relationship (r=0.65) between home range size and total number of locations (Appendix 2). However, the last 150 locations for this bird did not increase its home range estimate, and the home range size was 78% larger than the next largest home range after only half the locations had been collected.

McClelland (1979) speculated that home range sizes of pileated woodpeckers in his study were largest in areas with a low proportion of mature forest areas because it was necessary for these birds to use larger areas in order to encompass adequate foraging habitat. The largest home range in this study was in an area with a high proportion of young habitats with small patches of mature forest scattered throughout. However, some of the smallest home ranges were also in areas with little mature forest. Those birds in areas with large amounts of older forests used home ranges of average size.

The summer home ranges (post-fledging of young) measured in this study were larger than breeding territories estimated in northeastern Oregon (130-240 ha, Bull and Meslow 1977) and winter home ranges in Georgia (70 ha, Kilham 1976). Foraging areas in Montana were estimated to range from 200 to over 400 ha (McClelland 1979), the upper limit being similar to home range sizes in this study.

Differences in forest characteristics between study areas may account for much of the difference in home range sizes reported from other studies. However other researchers did not use radio telemetry to determine home range sizes and may have underestimated home range size.

Overlap of home ranges

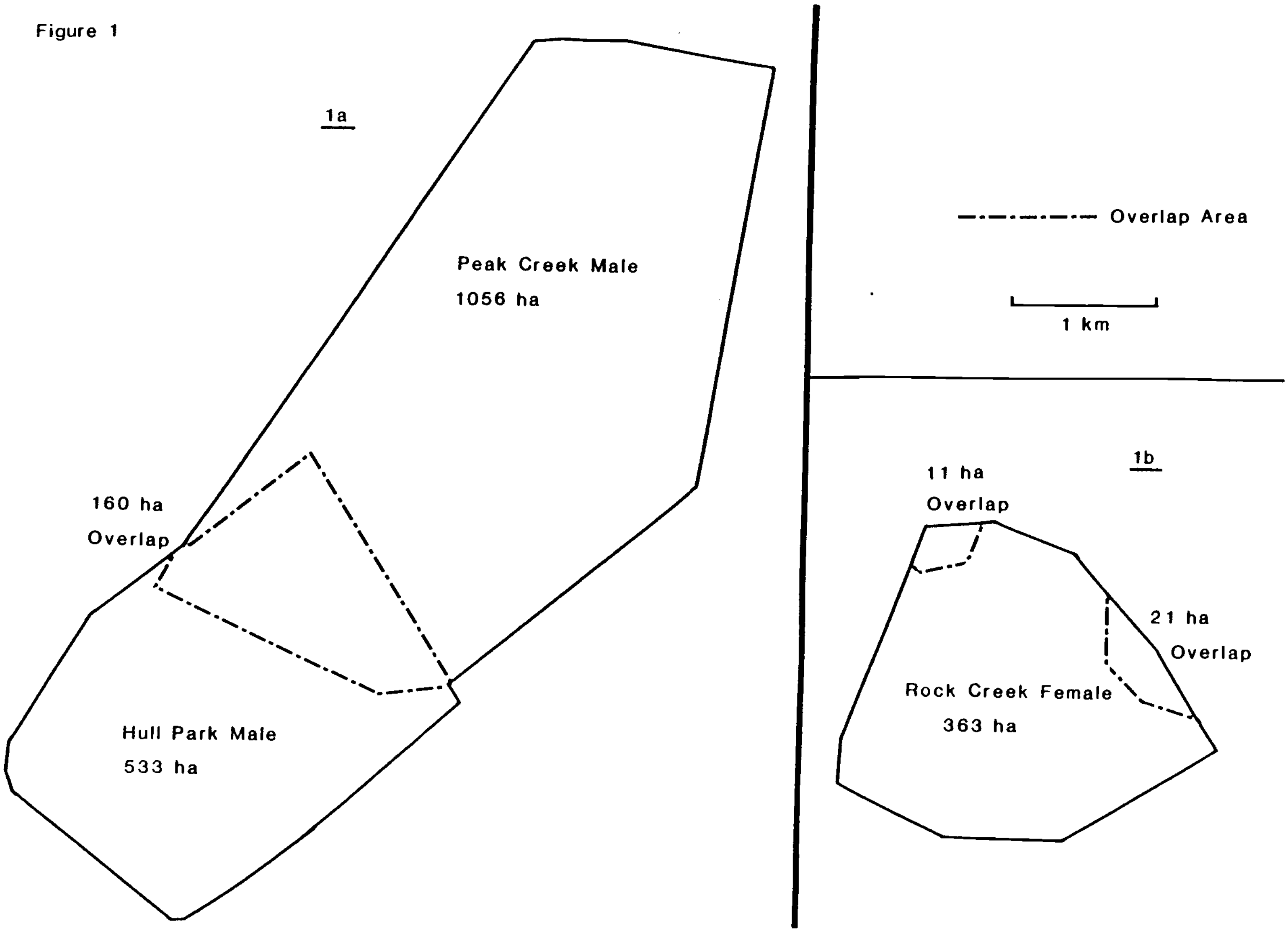
Most areas within the home ranges were defended by the resident pileated woodpeckers. Both males and females reacted to intruding birds on the boundaries by calling and drumming. Two incidents were observed in which 1 or both members of a pair chased an intruding pileated woodpecker from the immediate vicinity of their nest.

Even though there were vocal territorial displays at the peripheries, there was some overlap in home ranges of adjacent pairs (Figure 1a and b). The area of overlap between Peak Creek male and Hull Park male was 160 ha (Figure 1a). Hull Park male and his mate, Peak Creek male, and an undetermined number of young were located in close proximity to one another within the overlap area on 1 occasion. There was much calling by all birds, but no chasing behavior was observed.

Rock Creek female, her mate and 2 other adult birds were located and heard within the largest overlap area (21 ha) on 2 occasions (Figure 1b). A third pair of pileated woodpeckers were seen and heard in another area (11ha) of Rock Creek female's home

Figure 1. Overlap of home ranges between adjacent pairs of pileated woodpeckers, western Oregon.

Figure 1


1a
Peak Creek Male
1056 ha
160 ha
Overlap
Hull Park Male
533 ha
Overlap Area
1 km
1b
11 ha
Overlap
21 ha
Overlap
Rock Creek Female
363 ha

range on 1 occasion. A minimum of 32 ha of Rock Creek female's home range overlapped with home ranges of other pairs.

Use of home ranges by pairs

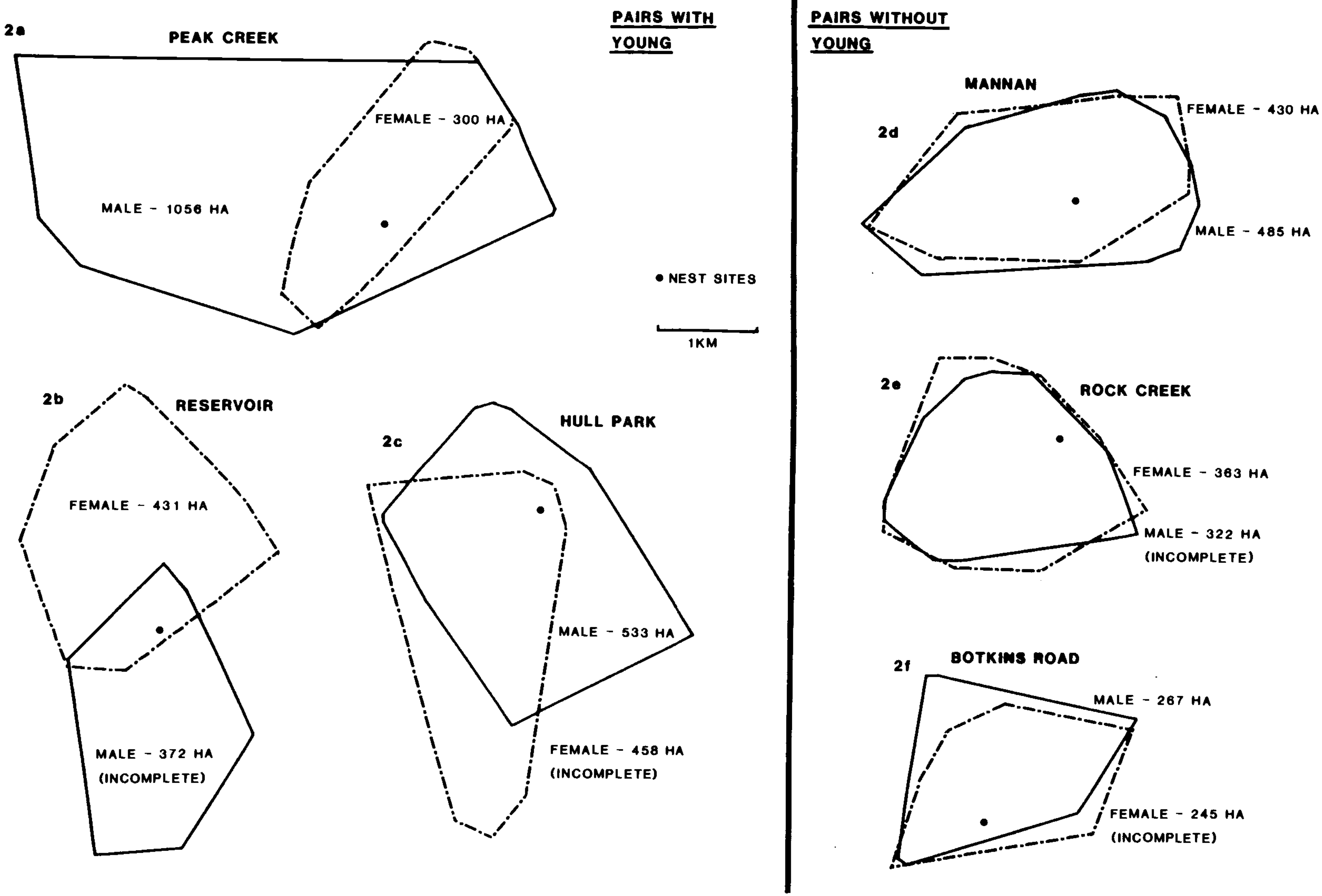
Home range sizes for pairs of pileated woodpeckers were larger than home ranges of individuals (Figure 2). Complete home range data were collected for 2 pairs of birds, the Peak Creek birds and a pair of Mannan's birds. Complete home range information was collected for 1 member of each of 4 additional pairs of birds; sporadic information was collected on their mates.

Home ranges of pairs with fledged young were much larger than the home ranges of either member of the pair, and each member of the pair used a different home range (Figure 2a,b, and c). Peak Creek female's home range was almost entirely interior to the home range of her mate, the bird with the largest home range. The home ranges of members of 2 other pairs with young diverged, but the core area around the nest was used in common (Figure 2b and c). Divergence of home ranges of males and females accompanied by young was observed despite only sporadic data on 1 member of each of 2 pairs (Figure 2b and c).

The combined home ranges of the members of pairs without young (measured after failed nesting attempts) were only slightly larger than home ranges of the individuals (Figure 2d,e and f). Members of the pair of pileated woodpeckers monitored by Mannan had similar home range boundaries (Figure 2d). The members of

Figure 2. Summer home ranges of 6 pairs of pileated woodpeckers, western Oregon. Three pairs were accompanied by young, 3 pairs were not accompanied by young.

FIGURE 2


2a
PEAK CREEK
FEMALE - 300 HA
MALE - 1056 HA
PAIRS WITH YOUNG
NEST SITES
1KM
2b
RESERVOIR
FEMALE - 431 HA
MALE - 372 HA
(INCOMPLETE)
2c
HULL PARK
MALE - 533 HA
FEMALE - 458 HA
(INCOMPLETE)
PAIRS WITHOUT YOUNG
MANNAN
2d
FEMALE - 430 HA
MALE - 485 HA
2e
ROCK CREEK
FEMALE - 363 HA
MALE - 322 HA
(INCOMPLETE)
2f
BOTKINS ROAD
MALE - 267 HA
FEMALE - 245 HA
(INCOMPLETE)

the 2 other pairs of birds without young also had nearly congruent home ranges (Figure 2e and f). The Rock Creek male and Botkins Road female could not be located regularly and estimates of their home ranges are thus minimal.

Because of incomplete data on 4 pairs of birds, combined home ranges of males and females were not calculated. However, complete data could have only increased home range estimates of pairs. Home ranges of individuals may not be of adequate size to encompass resources to support a pair of pileated woodpeckers which are accompanied by young birds.

Bull (1980) reported a difference in foraging behavior and use of forest types between male and female pileated woodpeckers, and suggested that competition between the sexes may be reduced by this behavior. Food or other resources may become limiting for birds with young, which may account for the observed use of different home ranges by each member of pairs with young in this study.

Habitat Selection

Habitat use examined in this study pertains to use of habitats within home ranges. Because data were collected during daylight in summer after young had fledged, use of habitat primarily for foraging was examined and not use of nesting or roosting habitat.

Habitat selection, for the purposes of this paper, was defined as use of a habitat disproportionate to its availability

(Johnson 1980). Forest habitat classes used in a proportion 50% greater than expected based on availability were interpreted as selected for; forest habitat classes used in proportions 50% less than expected based on availability were interpreted as selected against. Not all forest habitat classes were available to each bird (Appendix 3).

In general, pileated woodpeckers selected for the mature forest habitat classes greater than 70 years of age, and selected against forest habitat classes less than 40 years of age (Table 3). Deciduous riparian areas were selected for or used in equal proportion to availability by most birds. Deciduous riparian habitat was selected against by only 3 birds; most of the riparian area available to 1 of these birds was composed of immature red alder (Alnus rubra), and the riparian area available to a second bird was being logged during the monitoring period.

Habitats 41 to 70 years of age were selected against or used in proportion to availability. In some of these stands high densities of trees and branches inhibited the flight of these large woodpeckers, and were avoided by the birds.

Habitat preference

Habitat preference, as addressed in this paper, "is a reflection of the likelyhood of" a habitat "being chosen if offered on an equal basis with others", and habitats can be ranked from most preferred to least preferred (Johnson 1980). Preference may be independent of availability, but is usually

Table 3. Selection of forest habitat classes by 14 pileated woodpeckers during summer in western Oregon (1982-1985). Forest habitat classes used in a proportion 50% greater than expected based on availability were interpreted as selected for; forest habitat classes used in proportions 50% less than expected based on availability were interpreted as selected against.

			Number of birds		
Forest habitat class description	Percent available[a]	Percent used[b]	Selected for	No selection	Selected against
0-15 years, clear cut	7-27	0-8	0	1	13
16-40 years, conifer (<30% shrub)	0-13	0-4	0	1	10
16-40 years, conifer/ shrub (>30% shrub)	0-36	0-9	0	5	6
41-70 years, conifer (<20% deciduous)	0-45	1-43	1	9	2
41-70 years, conifer/ deciduous (>20% deciduous)	0-12	0-12	1	4	3
71-100 years, conifer (<20% deciduous)	0-37	6-65	7	6	0
71-100 years, conifer/ deciduous (>20% deciduous)	0-29	2-44	6	2	0
101-200 years, conifer (<20% deciduous)	0-21	1-35	6	3	2
101-200 years, conifer/ deciduous (>20% deciduous)	0-10	0-25	2	3	4
201+ years, old-growth	0-68	1-87	1	4	1
Deciduous riparian	0-11	0-30	5	4	3

[a] Range of availability of forest habitat classes in home ranges of individual birds.
[b] Range of percent use of forest habitat classes by individual birds when available within their home range.

defined relative to availability (Johnson 1980). Preferred habitat is not necessarily required habitat; preferred habitat may not even be available to every animal. Selection of habitat by individual pileated woodpeckers is influenced by the other habitats available to each bird. In the absence of preferred habitat, selection may be exhibited for less preferred habitat over least preferred habitats. In contrast a preferred habitat may be so abundant that no selection for the habitat may be shown.

To increase accuracy of preference ranking, the number of forest habitat classes was reduced (Alldredge and Ratti 1986). Results from the habitat selection analysis indicated that age of the forest habitat class was more important in determining use than presence or absence of a deciduous component, so classes were combined by age, which resulted in 6 age classes and a deciduous riparian habitat class.

The preference ranking method produced the following relative ordering from most to least preferred (left to right):

<u>riparian 101-200 71-100 200+ 41-70</u> <u>16-40 0-15</u>

Numbers are ages of forest habitat classes in years. Preference for classes underscored by the same line was not significantly different ($P \leq 0.05$) relative to the other classes; preference for those classes lacking a common underscore was significantly different relative to the other classes.

Forest habitat classes were ranked in order of the likelyhood a class would be selected if offered in equal availablitly to the other classes. However, there was no significant difference between relative preference for deciduous riparian habitat and any forest habitat classes older than 40 years, or between any of the habitat classes older than 40 years. Forest habitat classes less than 40 years of age were ranked as significantly less preferred relative to the older classes and deciduous riparian habitat.

Deciduous riparian habitat and 101-200 year age classes were highly ranked because there was a large difference between use-rank and availability-rank. These habitats were available in small amounts to most birds, and birds that selected for these 2 habitats exhibited a strong selection (using them in proportions 2 to 3 times greater than the proportion of availability). Old-growth habitat (200+ years) was available to only 43% of the birds, and those birds that selected for old-growth did not exhibit strong selection for the habitat. As a result old-growth was not one of the highest ranked habitats.

Composition of home range

The evaluation of habitat use suggested that forest habitat classes older than 40 years of age and deciduous riparian areas provided habitat for foraging and other diurnal acitvities for pileated woodpeckers. The amount of these habitats within the home ranges of the birds ranged from 159 to 571 ha, averaging 306 ha, or 69% of the available habitat.

Nests and roosts were located in habitat classes older than 70 years of age; one roost was located in a large big-leaf maple (Acer macrophyllum) in a deciduous ripairan area (Table 4). Trees and snags were not large enough to accomodate pileated woodpecker cavities in stands younger than 70 years of age, where diameter at breast height (dbh) often averaged less than 50 cm (Curtis et al. 1982, Neitro et al. 1985). Forest habitat classes older than 70 years of age averaged 44% of the home range; the amount of these older habitat classes within the home range averaged 200 ha and ranged from 55 to 328 ha.

McClelland (1979) recommended that to sustain pileated woodpeckers in the Rocky Mountains of Montana, a minimum of 200 ha of suitable feeding area should be maintained within a 400 ha planning unit. These area recommendations are at the low end of the range used by individual birds in this study (Table 2).

Habitat use from other studies

Pileated woodpeckers exhibited preference for snags and trees greater than 50 cm dbh (X^2 test, $P \leq 0.01$) in northeast Oregon (Bull 1980) and 53 cm dbh (binomial test, $P<0.05$) in eastern Washington (Madsen 1985). Trees between 25 to 50 cm dbh were neither preferred nor avoided as foraging substrate (Bull 1980); dead wood less than 18 cm dbh was used in lower proportion than occurrence (Bull 1975). In western Oregon and Washington, in managed stands with an average site index, trees

Table 4. Number of pileated woodpecker nests and roosts found in each forest habitat class, western Oregon.

Forest habitat class description	Number of nests	Number of roosts
$\leq$70 years	0	0
71-100 years, conifer	4	3
71-100 years, conifer/ deciduous	1	3
100-200 years, conifer	6	4
100-200 years, conifer/ dediduous mix	3	2
201+ years, old-growth	0	0
Deciduous riparian	0	1

reach 50 cm dbh by about 70 years of age, 25 cm dbh at about 35 years of age, and 18 cm dbh at about 25 years of age (Curtis et al. 1982, Neitro et al. 1985).

McClelland (1979) stated that "in the northern Rocky Mountains, the elimination of old-growth would mean the elimination of the Pileated Woodpecker". In western Oregon old-growth is not required by pileated woodpeckers; it was not available within the home range of 57% of the birds in this study. Birds used habitats younger than old-growth for nesting, roosting, and foraging. However, due to the lower productivity of forests in the Rocky Mountains, trees and snags large enough to be used for nesting by pileated woodpeckers are not produced in stands younger than 140 to 200 years of age. In the Rocky Mountains Douglas-fir trees average 38 to 63 cm dbh at 200 years of age, and ponderosa pine (Pinus ponderosa) averages 40 to 61 cm dbh at 140 years of age (Buttery and Gillam 1984).

CONCLUSIONS

Summary

Summer home range size for individual pileated woodpeckers after fledging of young averaged 480 ha; home ranges for pairs of pileated woodpeckers were larger. Estimates of home range from other parts of the woodpeckers range were smaller than home ranges calculated in this study. There was some overlap of home ranges between adjacent pairs of birds.

Pileated woodpeckers preferred forest habitat classes older than 40 years of age and deciduous riparian habitats for foraging and other diurnal activities significantly more than younger stands. Nesting and roosting occurred in stands older than 70 years of age. The amount of habitat used for foraging and other diurnal activities available within the home range averaged 306 ha; nesting and roosting habitat averaged 200 ha.

Management Implications

Because home ranges of pileated woodpeckers in western Oregon are larger than estimates for other regions, densities of pileated woodpeckers in this area will be lower than densities from other parts of the range of the species. Density of birds enters into the formulas for calculating minimum density of snags required to support a woodpecker species (Neitro et al. 1985). Neitro et al. (1985) reported densities of pileated woodpeckers from the literature ranging from 0.5 to 5.4 birds per 100 acres

(40 ha). Results from this study indicate an average density, based on home range size, approximately 0.2 birds per 40 ha. The lower density estimate would result in reduced estimates in calculations of minimum density of snags. Caution should be exercised in using the pileated woodpecker as an "indicator species" for snag dependent species; meeting snag density requirements for this species may not meet snag density requirements of other primary cavity excavators which occur at higher densities. Requisite snag densities should be calculated for each species individually.

Although habitat use evaluation indicated that pileated woodpeckers exhibited preference for mature forest habitats, they also exhibited preference for deciduous riparian areas and used immature stands for foraging and other diurnal activities. Because they used other habitats, the pileated woodpecker may not be a good "indicator" for mature forest habitats west of the Cascade Mountains. Indicator species should have specific habitat requirements and a narrow ecological niche (Graul et al. 1976). Nesting and roosting occurred entirely in mature habitats; however, some birds appeared to be surviving, at least during summer, with little mature habitat available within their home range. The presence of pileated woodpeckers may not necessarily indicate adequate habitat exists for other species which may have more stringent requirements for mature forest habitats.

Minimum management requirement (MMR) guidelines for pileated woodpeckers (U.S. Forest Service, Pacific Northwest Region) are the same east and west of the Cascade Mountains (U.S. Forest Service 1986b). MMR guidelines recommend that at least 300 acres (120 ha) of mature forest greater than 80 years old should be provided for nesting within a 1000 acre (400 ha) pileated woodpecker habitat area. These recommended acreages are smaller than averages for individual pileated woodpeckers in this study - 480 ha home range with 200 ha of mature forest habitat for nesting and roosting. The recommended areas should be increased by at least 50% for each breeding pair until more information can be collected on home range size for pairs of pileated woodpeckers.

Conner (1979) suggested that managing for minimum habitat factors may lead to reduced reproductive success, abundance, and genetic variability, which leave species "extremely vulnerable to future human or natural habitat alterations". I support Conner's recommendation that management should be directed towards providing habitat close to the mean used by a species rather than towards providing minimum habitat.

PART II

CHARACTERISTICS OF PILEATED WOODPECKER NEST AND ROOST SITES, WESTERN OREGON

INTRODUCTION

Pileated woodpeckers (*Dryocopus pileatus*) use snags (standing dead trees) and defective trees for nesting, roosting and feeding (Bull and Meslow 1977, McClelland 1979, Bull 1980, Mannan et al. 1980). The birds are primary cavity nesters, excavating a new nest cavity each year (Hoyt 1957; Bull 1975, 1980), and provide many cavities for secondary cavity-nesting animals (McClelland et al. 1979, Bull 1980). The pileated woodpecker is the largest woodpecker in the Pacific Northwest and requires snags and trees of large diameter for nest cavities (Bull and Meslow 1977, McClelland et al. 1979). Intensive timber management which involves salvage logging or harvesting at young ages may result in a scarcity or the elimination of large snags and trees used by the woodpecker and its associated secondary cavity nesting species. For this reason minimum management requirement guidelines have been developed for pileated woodpeckers on the National Forests of the Pacific Northwest (Sirmon 1983) to ensure adequate habitat is provided for the species.

Most information on nest trees and sites of pileated woodpeckers in the Pacific Northwest is for forest habitats east of the Cascade Mountains (Bull and Meslow 1977, Bull 1980, Madsen 1985). Bioloigists have necessarily used this information to manage pileated woodpeckers in Douglas-fir (Pseudotsuga menziesii) forests west of the Cascade Mountains. Because of differences in forest types and high productivity of coastal Douglas-fir forests, nesting habitat used on the west side of the Cascades may differ from other areas.

The objectives of this study were to describe characteristics of nest and roost trees, and characteristics of nest and roost sites of pileated woodpeckers in western Oregon. These characteristics were compared to measurements from other studies, and management implications are considered.

STUDY AREA

Nest and roost sites were located in the central Coast Ranges 15 to 30 km west to southwest of Corvallis, Oregon. Lands were controlled or owned by Siuslaw National Forest, Bureau of Land Management, City of Corvallis, and private individuals. The area is part of the western hemlock (*Tsuga heterophylla*) vegetation zone described by Franklin and Dyrness (1973). Forest stands are dominated by subclimax stands of Douglas-fir, rather than climax stands of western hemlock, because of disturbance caused by fire and logging operations (Franklin and Dyrness 1973). Most of the area is intensively managed for timber and immature stands predominate. Mature stands are scattered and old-growth stands are rare. Of the areas suitable for timber management on the Siuslaw National Forest 60% support mature forest stands (70-110 years old) and 5% support stands with old-growth characteristics (USDA Forest Service 1986a). However, the Mary's Peak Watershed, managed by the City of Corvallis and Siuslaw National Forest, contains a higher proportion of mature and old-growth forest stands than the rest of the Coast Ranges, and several nests and roosts were located in this area.

The area receives 150 to 300 cm of precipitation annually, most occuring during winter and primarily in the form of rain (Franklin and Dyrness 1973). Winters are cool and summers are warm; January mean minimum temperatures range from 2.5 to -2.5^{o} C, and July mean maximum temperatures range from 22.5 to 27.0^{o} C. Elevation of the study area ranges from 100 to 1250 m. The topography is characterized by peaks and ridges with steep slopes and frequent deep valleys cut by streams.

METHODS

Location of pileated woodpecker nests and roosts

Pileated woodpeckers and their nests were located as described in Part I. One additional nest was located in 1986 during a revisit to a site.

Roosts were located by following radio-marked birds to the roost in the evenings. Cavities were not found at all roost sites, especially at roosts in live trees. A roost was confirmed if the bird was observed entering a cavity or flying to a tree in the evening and remaining until dark. In this paper the term "tree" will be used for both snags and live trees; differentiation will be made when necessary.

Measurement of tree and site characteristics

Several characteristics were recorded for each nest and roost tree. Species, condition (live or dead), top condition (broken or intact), and percent bark cover were determined visually. Diameter at breast height (dbh) was measured with a dbh tape. A Spiegel-Relaskop was used to measure height, height of cavity, and diameter at cavity.

Characteristics of each nest and roost site were measured within a 0.3 ha circular plot (radius = 31 m) centered on the nest or roost tree (Mueller-Dombois and Ellenberg 1974). Within each plot the dbh of each tree ($\geq$8 cm dbh) and each snag ($\geq$8 cm dbh and $\geq$3 m high) was measured and the species determined.

Densities and basal area of live and dead trees were calculated with the nest or roost tree included. Species and numbers of stumps (≥8 cm in diameter and <3 m high) were recorded and densities caculated.

The line interception method described by Canfield (1941) was used to measure percent shrub cover (woody vegetation <8 cm dbh) and percent cover of logs (≥8 cm diameter). Transects, 31 m long, were set in the cardinal directions from the nest or roost. Percent canopy cover was measured every 6 m by a modification of Emlen's (1967) method; percent canopy cover at each point was estimated by looking vertically at the canopy through a tube approximately 4 cm in diameter. Estimates for each transect point were averaged for each site. Canopy height was measured using a range finder and a clinometer.

Type maps, aerial photos, and number of rings in stumps of adjacent clear cuts were used to classify stands in which nest and roost sites were located. Stands were classified by age and presence (>20%) or absence (<20%) of a deciduous tree component in the overstory.

Statistical analysis

Mean, standard deviation (SD), and range were calculated for each measured characteristic. T-tests were used to test for significant differences between nest and roost trees for dbh, height, height of cavity, diameter at cavity, and percent bark cover (McClave and Dietrich 1979, pg. 292). Simple linear regression was used to analyze relationships between nest tree characteristics (Zar 1984, pg. 261); regressions were calculated for height of cavity on height of snag, diameter at cavity on height of cavity, diameter at cavity on dbh, height of cavity on dbh, and height of cavity on canopy height at the nest site. Discriminant analysis was used to evaluate differences between nest and roost sites, and between sites located within 2 age classes (Klecka 1975). Five variables were selected for discriminant analysis: large tree density ($\geq$ 40 cm dbh), basal area, dead basal area, percent log cover, and percent canopy cover. Selection of the variables was determined by correlation between site characteristics and relative biological importance of the characteristics to pileated woodpeckers, based on information in the literature.

Statistical tests were conducted at the 0.05 significance level. The Bonferroni technique was used to adjust significance levels for t-tests and regressions with multiple comparisons (Harris 1985, pg. 7). Data were tested for skewness and kurtosis (Nie et al. 1975, pg. 184) and for equal variances (Zar 1984, pg. 122); data for dead basal area, percent log cover, dbh, and height of snag were log-transformed, and percent bark cover was exponentially transformed (inverse natural log) prior to discriminant analyses and t-tests to correct for skewed distributions and unequal variances (Zar 1984, pg. 236).

RESULTS

Characteristics of nest and roost trees

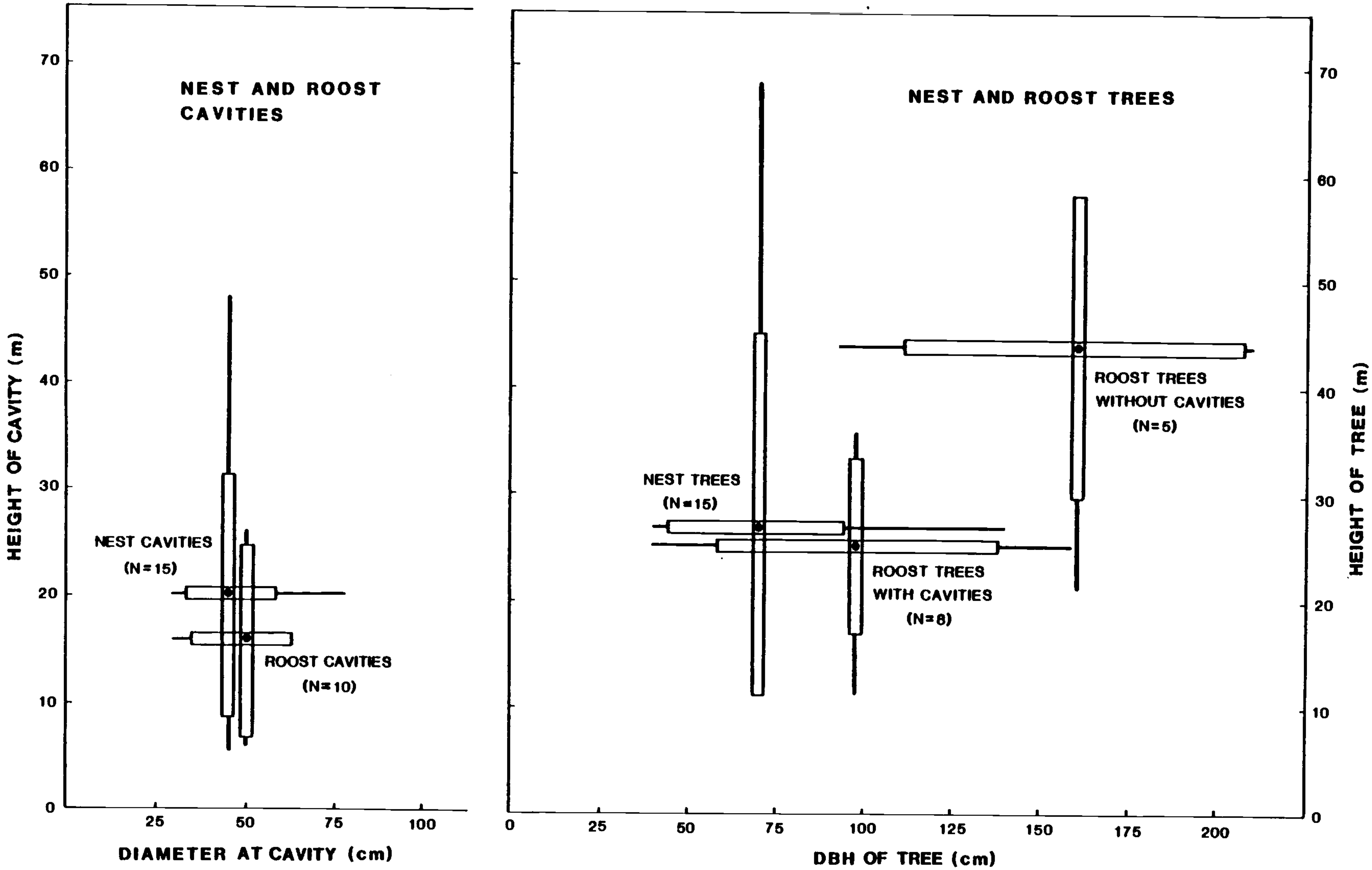
Fifteen active nests of pileated woodpeckers were located from 1983 to 1986. Nests were found in 11 Douglas-fir snags, 3 alder (*Alnus rubra*) snags, and 1 live Douglas-fir tree. One nest snag was used both in 1983 and 1985, however, a new cavity was excavated in 1985. Eleven of the nest snags contained more than 1 apparent pileated woodpecker cavity, however it was not confirmed that all these holes were completely excavated.

Roosts were found in 5 Douglas-fir snags, 5 live Douglas-fir trees, 1 alder snag, 1 big-leaf maple (*Acer macrophyllum*) tree, and 1 western redcedar (*Thuja plicata*) snag, for a total of 13 roosts. One nest cavity was used as a roost by the adult male after the young had fledged; the female of that pair roosted in a second cavity in the same snag. Five roost trees contained 2 or more cavities. No cavities were visible at 5 roost trees, but branches could have obscured cavities.

Mean dbh differed significantly ($P \leq 0.05$) between nest trees (68.9 cm) and roost trees (118.2 cm); no other significant differences were found between characteristics of nest and roost trees. The mean dbh of the 8 roost trees with cavities was 97.6 cm; five roosts in live trees with no apparent cavities had a mean dbh of 159.5 cm (Figure 3). Mean height of nest trees (26.5 m) and roost trees with cavities (24.9 m) were similar; mean

Figure 3. Mean, standard deviation, and range of diameter at cavity (cm), height of cavity (m), dbh (cm), and height (m) of pileated woodpecker nest trees and roost trees with and without cavities, western Oregon.

FIGURE 3


NEST AND ROOST CAVITIES
NEST CAVITIES (N=15)
ROOST CAVITIES (N=10)
HEIGHT OF CAVITY (m)
DIAMETER AT CAVITY (cm)
0
10
20
30
40
50
60
70
25
50
75
100
NEST AND ROOST TREES
NEST TREES (N=15)
ROOST TREES WITH CAVITIES (N=8)
ROOST TREES WITHOUT CAVITIES (N=5)
HEIGHT OF TREE (m)
DBH OF TREE (cm)
0
25
50
75
100
125
150
175
200

height of roosts without visible cavities was 43.7 m. Trees used for nesting and roosting were larger than 39.5 cm dbh and taller than 11.5 m (Appendices 4 and 5).

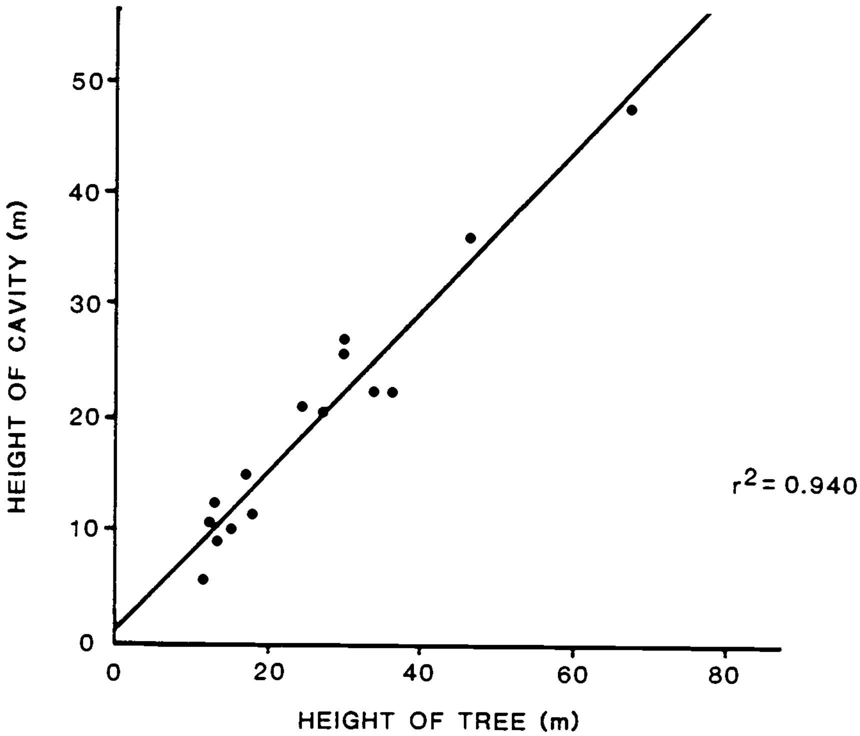
Nest and roost cavities were 5.5 m or higher above the ground, averaging 19.9 m for nests and 15.6 m for roosts (Figure 3). The 1 nest cavity in a live tree was the highest above the ground (48 m). The diameter at nest cavities ranged from 29 cm to 78 cm and averaged 46 cm. Diameters at roost cavities were similar, averaging 50 cm and ranging from 30 to 62 cm.

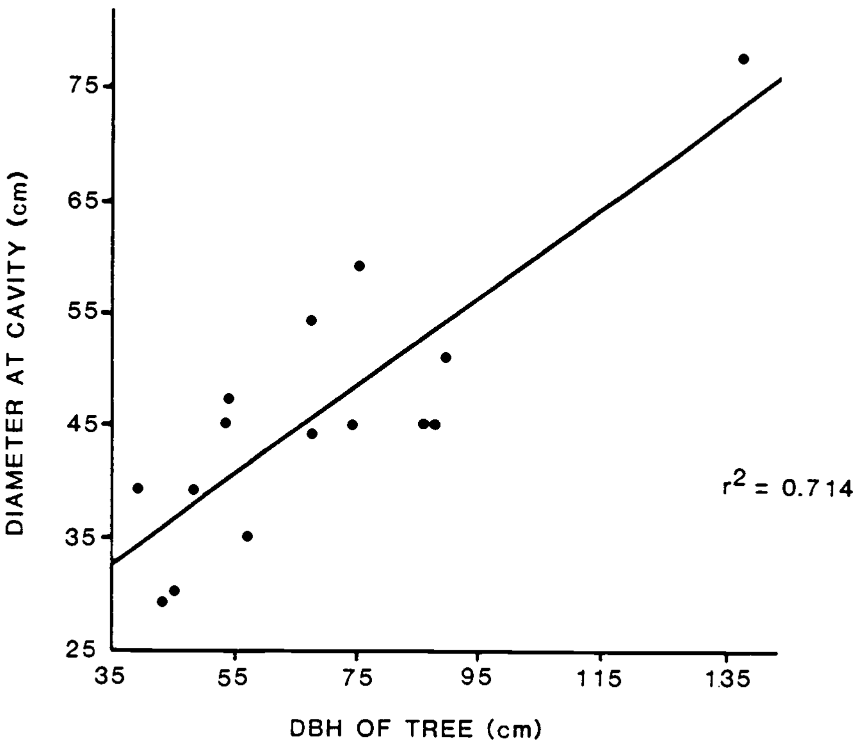
A typical nest or roost snag had a broken top and retained most of the bark. All nest trees except 1 snag and the live tree had broken tops. All roost snags and 1 live tree had broken tops. Five live roost trees had intact tops. Bark cover averaged 88 % for nest snags and 70 % for roost snags. Live trees used for nesting and roosting averaged 99 % bark cover. Few limbs remained on most nest and roost snags, whereas numerous limbs were present on live nest and roost trees.

Regressions of height of nest cavity on height of nest tree (r^2=0.940) and diameter at cavity on dbh of nest tree (r^2=0.714) were significant ($P \leq 0.05$) (Figure 4). Regressions of diameter at cavity on height of cavity (r^2=0.014), height of cavity on dbh of nest tree (r^2=0.108), and height of cavity on canopy height at nest site (r^2=0.092) were not significant ($P>0.05$).

Figure 4. Regression analysis of height of nest cavity on height of nest tree (N=15) and diameter at cavity on dbh of nest tree (N=15) for pileated woodpeckers, western Oregon.

Figure 4


50
40
30
20
10
0
HEIGHT OF CAVITY (m)
0
20
40
60
80
HEIGHT OF TREE (m)
r^2 = 0.940


75
65
55
45
35
25
DIAMETER AT CAVITY (cm)
35
55
75
95
115
135
DBH OF TREE (cm)
r^2 = 0.714

Characteristics of nest and roost sites

Nests and roosts occurred in both coniferous and mixed coniferous-deciduous forests (Table 5). Six nest sites and 6 roost sites were located in forest stands in the 70- to 100-year age class, and 9 nest sites and 6 roost sites were located in the 100- to 200-year age class. One roost was found in a large big-leaf maple within a deciduous riparian zone composed of big-leaf maple and red alder. Eight roosts were in remnant old-growth trees and snags within the younger stands; no nests were found in remnant trees or snags. Discriminant analysis did not significantly ($P \leq 0.05$) discriminate between sites within 70- to 100-year-old stands and 100- to 200-year-old stands, or between nest and roost sites for the variables large tree density ($\geq$ 40 cm dbh) density, basal area, dead basal area, percent log cover, and percent canopy cover.

Douglas-fir was the dominant overstory species at nest and roost sites. Red alder and big-leaf maple contributed to the overstory at a few sites. Typical understory species included big-leaf maple, vine maple (*Acer circinatum*), Pacific dogwood (*Cornus nuttallii*) and western hemlock.

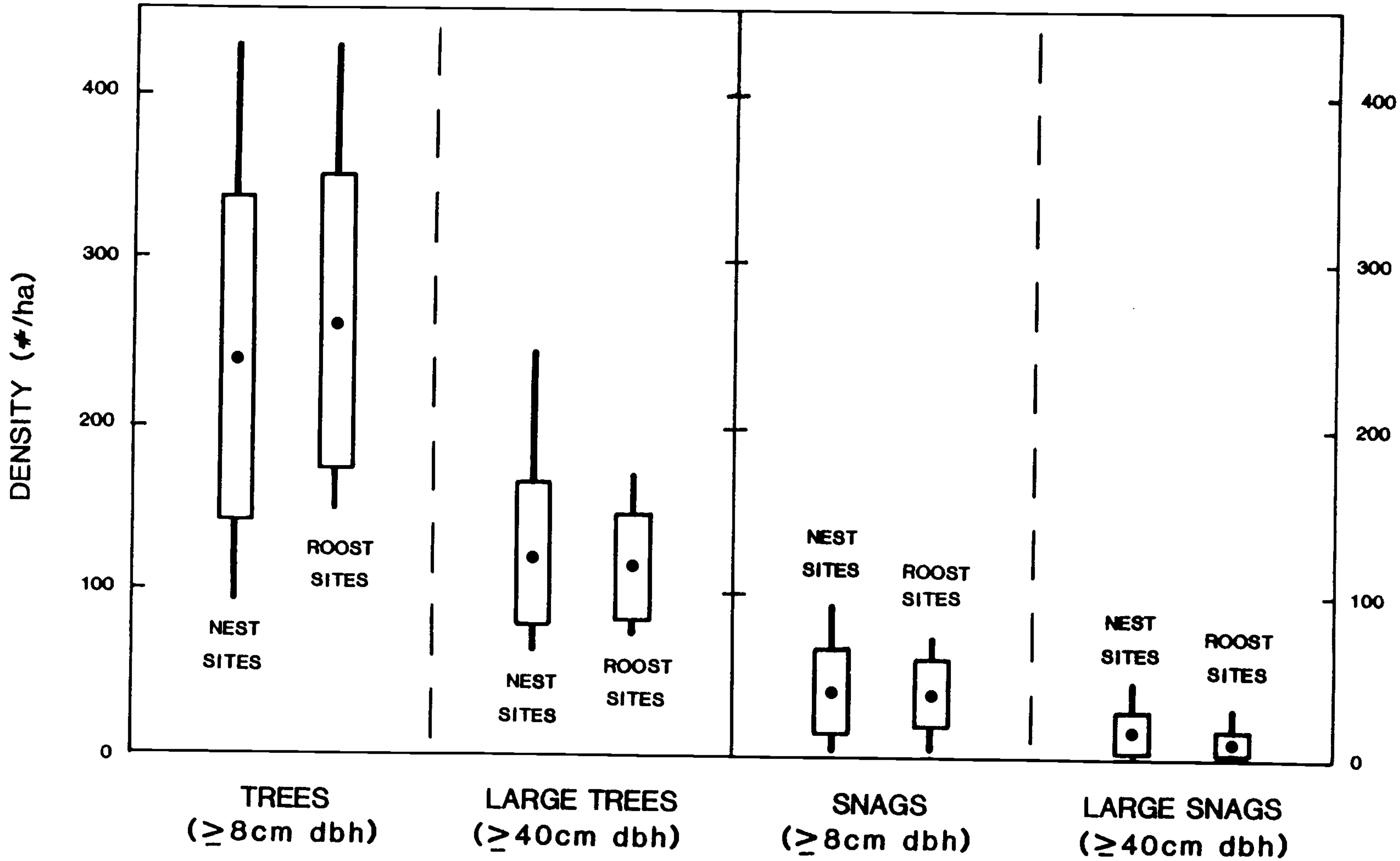
Tree density averaged 239 trees/ha at nest sites and 262 trees/ha at roost sites (Figure 5). Tree densities were highly variable among sites ranging from 97 to 430 trees/ha (SD=98) at nest sites, and from 150 to 430 trees/ha (SD=88) at roost sites (Appendices 6 and 7). Trees larger than 40 cm dbh accounted for

Table 5. Number of pileated woodpecker nests and roosts found in various forest stands.

Stand Description	Number of Nests	Number of Roosts
70 - 100 years, coniferous (<20% deciduous)	4	3
70 - 100 years, coniferous-deciduous mix (>20% deciduous)	2	3
100 - 200 years, coniferous (<20% deciduous)	6	4
100 - 200 years, coniferous-deciduous mix (>20% deciduous)	3	2
Deciduous riparian, red alder and big-leaf maple	0	1

Figure 5. Mean, standard deviation, and range of tree and snag densities (#/ha) at pileated woodpecker nest sites (N=15) and roost sites (N=13) in the Coast Ranges, western Oregon.

Figure 5


DENSITY (#/ha)
400
300
200
100
0
NEST SITES
ROOST SITES
NEST SITES
ROOST SITES
NEST SITES
ROOST SITES
NEST SITES
ROOST SITES
400
300
200
100
0
TREES (≥8cm dbh)
LARGE TREES (≥40cm dbh)
SNAGS (≥8cm dbh)
LARGE SNAGS (≥40cm dbh)

about 50 % of the trees at nest and roost sites, averaging 123 per ha at nest sites and 114 per ha at roost sites.

Average snag densities were 41 snags/ha at nest sites and 40 snags/ha at roost sites (Figure 5). Snag densities also were highly variable ranging from 3 to 93 snags/ha at nest sites (SD=24), and 6 to 73 snags/ha (SD=20) at roost sites (Appendices 8 and 9). Large snags ($\geq$40 cm dbh) accounted for about 40 % of total snag density at nest sites ($\bar{x}$=16/ha) and about 25 percent at roost sites ($\bar{x}$=9/ha).

Basal area of live trees averaged 65.2 m^2/ha at nest site and 62.9 m^2/ha at roost sites (Figure 6). Measurements ranged from 39.5 to 96.9 m^2/ha (SD=16.2) at nest sites and 41.6 to 91.2 m^2/ha (SD=15.6) at roost sites (Appendices 6 and 7).

Average basal area of dead trees at roost sites was 6.1 m^2/ha and 10.3 m^2/ha at nest sites (Figure 6). Measurements at roost sites were less variable (SD=4.1) than those at nest sites (SD=9.4). Basal area ranged from 1.4 to 12.8 m^2/ha at roost sites and 0.3 to 35.5 m^2/ha at nest sites (Appendices 8 and 9).

Percent canopy cover and canopy height were the least variable site characteristics. Canopy cover ranged from 42 to 82 % and averaged 68 % (SD=10) at nest sites (Figure 7). At roost sites canopy cover ranged from 62 to 83 % and averaged 74 % (SD=7). Canopy height at nest sites averaged 58 m (SD=6) and 54 m (SD=9) at roost sites; ranges were 50 m to 70 m at roosts and 40 m to 71 m at nests (Appendix 10).

Figure 6. Mean, standard deviation, and range of live and dead basal area (m^2/ha) at pileated woodpecker nest sites (N=15) and roost sites (N=13) in the Coast Ranges, western Oregon.

Figure 6

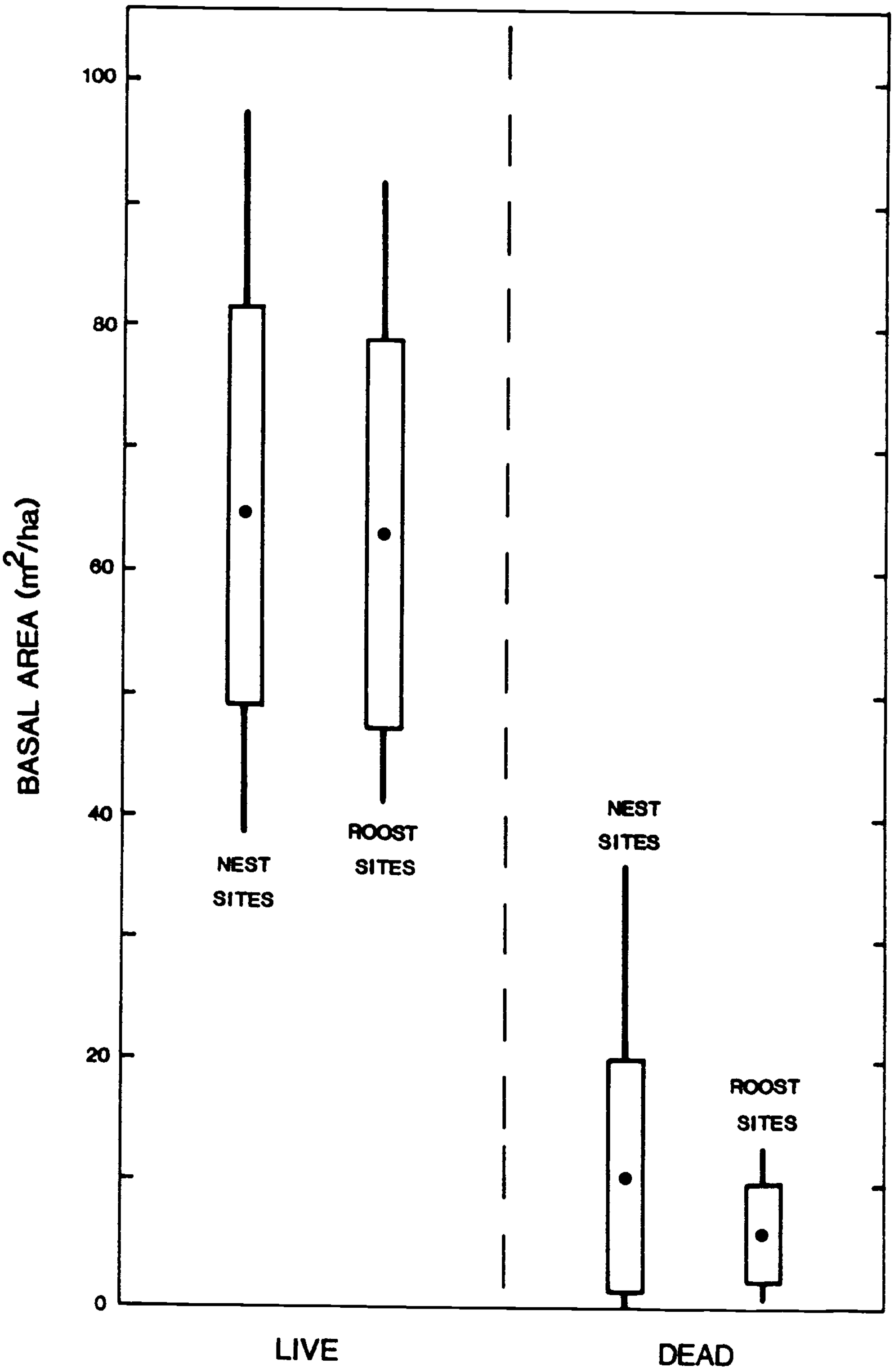
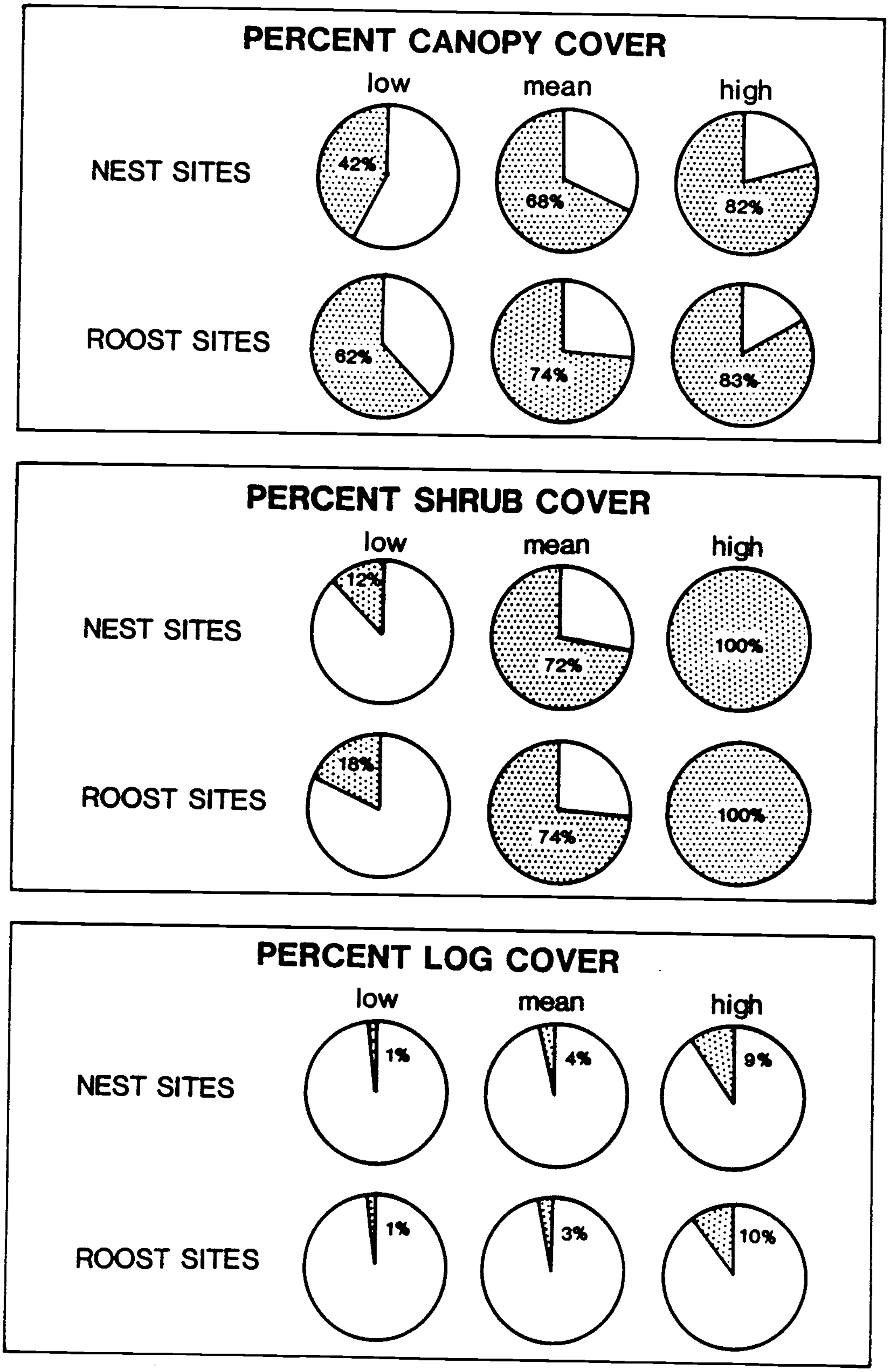

100
80
60
40
20
0
BASAL AREA (m2/ha)
NEST SITES
ROOST SITES
NEST SITES
ROOST SITES
LIVE
DEAD

Figure 7. Mean and range of percent canopy cover, percent shrub cover, and percent log cover at pileated woodpecker nest sites (N=15) and roost sites (N=13) in the Coast Ranges, western Oregon.

Figure 7


PERCENT CANOPY COVER
low
mean
high
NEST SITES
42%
68%
82%
ROOST SITES
62%
74%
83%
PERCENT SHRUB COVER
low
mean
high
NEST SITES
12%
72%
100%
ROOST SITES
18%
74%
100%
PERCENT LOG COVER
low
mean
high
NEST SITES
1%
4%
9%
ROOST SITES
1%
3%
10%

The most common species of shrubs at nest and roost sites were vine maple, salal (Gaultheria shallon), Oregon grape (Berberis sp.), California hazel (Corylus cornuta), and oceanspray (Holodiscus discolor). Shrub cover averaged 72 % (SD=31) at nest sites and 74 % (SD=25) at roost sites (Figure 7). Shrub cover ranged from 12 to 100 % at nest sites and 18 to 100 % at roost sites (Appendix 10).

Dead wood on the ground, including logs and stumps, was similar at nest and roost sites. Log cover at nest sites averaged 4 % (SD=2) and ranged from 1 to 9 % (Figure 7). Log cover at roost sites averaged 3 % (SD=2) and ranged from 1 to 10 % (Appendix 10). Stump density averaged 51 per ha (SD=24) at nest sites and 52 per ha (SD=30) at roost sites. Ranges were 20 to 97 stumps/ha at nest sites and 13 to 120 stumps/ha at roost sites (Appendices 8 and 9).

DISCUSSION

Nest and roost trees

Western Oregon is the only area where pileated woodpeckers have been found extensively nesting in Douglas-fir. Of 54 nests located by McClelland (1979) in Montana and 10 nests located by Madsen (1985) in eastern Washington none were in Douglas-fir, although it was the most abundant species of snag in these areas. Of 63 nests found by Bull (1980) in northeastern Oregon none were located in Douglas-fir snags; however Bull and Meslow (1977) found the birds preferred these snags for foraging (X^2 test, $P<0.05$). Western larch (*Larix occidentalis*) and ponderosa pine (*Pinus ponderosa*) were the preferred nest trees in Montanta (X^2 test, $P<0.05$) (McClelland 1979), and were used almost exclusively for nesting in eastern Oregon and eastern Washington (Bull 1980, Madsen 1985). McClelland (1979) suggested Douglas-fir was not used for nesting due to decay characteristics. Sapwood of Douglas-fir decays more quickly than heartwood (Wright and Harvey 1967, Cline et al. 1980). In western larch, however heartwood decays more quickly than sapwood, leaving a hard protective and supportive shell and an easily-excavated center (McClelland 1979). Ponderosa pine has a thick sapwood and does not deteriorate as rapidly as Douglas-fir (Bull 1980). In western Oregon, however, Douglas-fir snags are the only snags large enough to accomodate pileated woodpecker cavities available in most forest stands.

Pileated woodpeckers will excavate cavities in live hardwood trees, usually in a dead section, but rarely in a live conifer (Carriger and Wells 1919, Conner et al. 1975, Bull 1980, Harris 1982). Bull (1980) reported only 1 of 63 nests in a live conifer, a grand-fir (Abies grandis). Harris (1982) found 1 nest in a live coast redwood (Sequoia sempervirens) in California. The 1 nest I found in a live Douglas-fir apparently was uncommon. However, I did not focus nest searches on live trees. There were pairs of woodpeckers for which nests could not be located; some of these birds may have been nesting in live trees.

Although mean dbh of nest trees (69 cm) in this study was smaller than means from most other studies, mean diameter at the nest cavities (46 cm) was intermediate to mean diameters from other studies (Table 6). Douglas-fir are taller than most trees in other studies, so the taper to the cavity should be less. Regression analysis indicated that 71% of the variation in diameter of a tree at the nest cavity in this study was accounted for by dbh of the tree. Mean dbh of nest trees (55 cm) and mean diameter at cavity (38 cm) were the smallest in Virginia (Conner et al. 1975) where the subspecies of pileated woodpecker is smaller than the subspecies in the Pacific Northwest (Bent 1939). The largest mean dbh and mean diameter at cavities were reported for coast redwood and giant sequoia trees (Sequoiadendron giganteum) in California (Harris 1982).

Table 6. Characteristics of pileated woodpecker nest trees from this and previous studies.

Study	Area	N	DBH (cm) $\bar{x} \pm$ SD (range)	Height (m) $\bar{x} \pm$ SD (range)	Diameter at cavity (cm) $\bar{x} \pm$ SD (range)	Height cavity (m) $\bar{x} \pm$ SD (range)
This Study	W. Oregon	15	69 ± 25 (39-138)	26 ± 16 (12-68)	46 ± 12 (29-78)	20 ± 11 (6-48)
Madsen (1985)	E. Washington	6	84 ± 18	37 ± 9		16 ± 3
Madsen (1985)	E. Washington (off-site)[a]	4	86 ± 30	27 ± 4		12 ± 4
Mannan (1982)	W. Oregon	3	82 (57-98)	28 (19-39)		20 (18-25)
Harris (1982)	California (Pinacea)	24	67 ± 15[b] (44-108)	24 ± 7[b] (7-37)	41 ± 10[b] (27-60)	18 ± 6[b] (6-30)
Harris (1982)	California (hardwood)	10	76 ± 34[b] (44-122)	18 ± 8[b] (11-30)	45 ± 17[b] (25-73)	10 ± 4[b] (5-19)
Harris (1982)	California (redwood)	2	134 (97-170)	38 (27-48)	62 (25-63)	15 (8-11)
Harris (1982)	California (sequoia)	2	404 (361-446)	63 (47-79)	205 (195-215)	32 (26-38)
Bull (1980)	N.E. Oregon	63	76 ± 13	28 ± 9	57 ± 13	15 ± 6
Mannan (1980)	W. Oregon	7	78 (46-172)			15 (7-24)
McClelland (1979)	Montana	54	75 (39-119)	28 (12-47)		15 (6-30)
Conner et al. (1975)	Virginia	14	55 (33-91)	20 (11-37)	38 (30-51)	14 (9-19)

[a] Nests found outside the study area boundary were analyzed separately.
[b] Reported as standard error and converted to standard deviation.

Bull and Meslow (1977), McClelland et al. (1979), and Madsen (1985) recommended managing for trees with a minimum dbh of 50.8 cm (20 in.) for pileated woodpecker nest trees. Because most nest trees in these studies had little or no bark remaining, this minimum dbh should be used only for trees without bark. Neitro et al. (1985) recommended a minimum dbh of 63.5 cm (25 in.) for pileated nest snags in western Oregon and Washington. Douglas-fir snags retain most of the bark so tree dbh is routinely measured including bark thickness. I found birds used snags less than 63.5 cm in dbh for nesting (Appendix 4), but I would still recommend this minimum dbh for Douglas-fir trees. Three nest snags smaller than 63.5 cm dbh were in alder snags, which have thin bark in comparison to Douglas-fir. One nest in a Douglas-fir snag below this minimum broke at the nest cavity shortly after the young fledged.

Regression of diameter at cavity on dbh predicts that a tree with a dbh of 63.5 cm will have a diameter of 43 cm, including bark, at the cavity. Pileated woodpeckers excavate cavities 22 to 25 cm in diameter (personal observation, Bull 1980). A diameter at the cavity of 43 cm would allow for a shell around the nest cavity of approximately 10 cm of sapwood and bark, which was sufficient to support the trees in this study. However, due to taper of trees, I would expect diameters at cavities of above average height to be smaller than 44 cm, given a dbh of 63.5 cm. Regression analysis indicated that height of cavity is not related to diameter at cavity (r^2=0.014) or to dbh (r^2=0.092).

Conner (1979) suggested that managing for minimum habitat factors, such as nest tree dbh, may be biologically unsound and may lead to reduced reproductive success. Birds forced to nest in smaller diameter trees may excavate smaller cavities, leading to overcrowding of nestlings which may increase fraticide (Conner 1979). Karlsson and Nilsson (1977) found that cavity-nesting birds produced smaller clutches in smaller cavities. Chances of the tree breaking at the cavity are also increased with minimum diameter trees (Conner 1979). Conner (1979) recommended managing for mean habitat factors to avoid providing suboptimal habitat. If management schemes are directed toward minimum population numbers and a minimum of reserved habitat, I believe the reserved habitat should be high quality habitat.

Mean height of nest trees in this study (26 m) was intermediate to mean heights from other studies (Table 6). However, mean heights of nest cavities reported for western Oregon, in this study (20 m) and by Mannan (1982) (20 m), are higher than reported in other studies, except for nests in giant sequoias (32 m) (Harris 1982). This indicates that cavities were excavated closer to the top of the trees in western Oregon than in other study areas. The height of the live Douglas-fir in this study (68 m) was taller than nest trees in the other studies, except for a giant sequoia (79 m) (Harris 1982); the nest cavity in this live Douglas-tree was higher (48 m) than any cavity in the other studies.

In contrast to findings from this study, Bull (1975, 1980) and Madsen (1985) reported that pileated woodpeckers nested in snags with a low percentage of remaining bark. Bull (1980) suggested that bark and limbs hindered movement of the birds, and that ponderosa pine and western larch snags were selected because most bark and limbs were usually absent. The nest snags studied in western Oregon retained a high percentage of the bark, averaging 88% in this study and 98% in Mannan's (1982) study. Bark cover is probably a function of the decay characteristics of the species of tree used, and does not appear to be an important characteristic in determining which snags are used for nesting by pileated woodpeckers. Douglas-fir snags retain more bark compared to larch or ponderosa pine snags which are used for nests and roosts in eastern Oregon (Bull 1980) and eastern Washington (Madsen 1985).

Data in the literature and from this study indicate that tops of most pileated woodpecker nest trees are broken. McClelland (1979) found that 83 % of nest snags had broken tops, though snags with intact tops were more abundant. Other studies also report large percentages of nest snags with broken tops: Bull and Meslow (1977) reported 92 %, Harris (1982) reported 83 %, Bull (1980) reported 58 %, and Conner et al. (1975) reported 67 %.

Broken tops provide an entrance point for fungi which create heartrot necessary for excavation of nest cavities (McClelland and Frissell 1975). Progression of heartrot from top to bottom of snags may partially explain the strong relationship found in this study between height of cavities and height of snags and trees (r^2=0.940). Bull (1975) found the hardness of wood (specific gravity) was similar at nest cavities, and was just slightly softer than live white fir (Abies concolor). As rot progresses down the snag the top sections may become too soft, and the lower sections remain too hard, for excavation by pileated woodpeckers. Mannan et al. (1980) found 70% of active nests of cavity-excavating birds were within the upper 1/3 of snags. Of 11 broken-topped nest snags in this study with more than 1 pileated cavity, 9 nests were in the lowest cavity. The relationship between height of snags and height of cavities is maintained as the birds use lower sections of the snag because heights of snags decrease as decayed top sections break off (Cline et al. 1980).

Although all the roosts reported by McClelland (1979) (N=28) and Mannan (1982) (N=2) were cavities, it appears that pileated woodpeckers do not always roost in cavities during summer. I found birds roosting in live trees with no visible cavities. The most feasible way to locate non-cavity roosts is by using radio telemetry.

Eight of the roost cavities located by McClelland (1979) were in live trees, and 2 the of roost cavities in this study were in live trees; both roost cavities located by Mannan (1982) were in snags. Both roost trees located by Mannan (1982) had broken tops, and 75 % of roost trees found by McClelland (1979) had broken tops. I found only 1 roost cavity in a tree with an intact top.

Tree height and cavity height of roosts in this study were comparable to the heights from 2 other studies (Table 7). The mean dbh of roost trees with cavities (98 cm) in this study was larger than reported by Mannan (1982) (78 cm) or McClelland (1979) (77 cm).

McClelland (1979) found that roost tree characteristics were similar to those of nest trees, and speculated that most roosts originally were nests. I believe this is also the case in this study area; discriminant analysis revealed no significant ($P>0.05$) differences between nest and roost sites. However, as reflected by the large dbh of roost trees in comparison to dbh of nest trees in this study, the pileated woodpeckers were roosting in the largest trees that were available. Eight roost trees were larger than 90 cm dbh; three of these were snags with roost cavities. Snags this large are rare and are only of adequate soundness for excavating cavities for a few years. Since pileated woodpeckers excavate a new nest cavity each year, they must often rely on smaller snags which are more abundant and provide a continuous supply of sound nest trees for excavation. The rarer large trees are used when available and of adequate

Table 7. Mean dbh, height and height of cavity for pileated woodpecker roost trees from this and previous studies.

	This study W. Oregon N=8[a]	Mannan (1982) W. Oregon N=2	McClelland (1979) Montana N=28
DBH (cm)	98	78	77
Height (m)	24	23	28
Height cavity (m)	15[b]	22	14

[a] 13 roosts were located, but for comparison only roosts in which birds used cavities are used here.
[b] N=10; 2 trees contained more than one roost cavity.

soundness for excavation, and once excavated they provide roost sites for as long as they remain standing; large snags remain standing longer than small snags (Cline et al. 1980, Raphael and White 1984). In addition to the use of large trees for apparent non-cavity roosts, selective reuse of the largest old nest trees for roosting may account for the difference in dbh between roost and nest trees.

Nest and roost sites

Discriminant analysis revealed no significant (P>0.05) difference between nest and roost sites found within 70- to 100-year-old stands and 100- to 200-year-old stands for the variables large tree density, basal area, dead basal area, log cover, and canopy cover. High basal area, high densities of trees and snags, and high densities of large trees and snags are typical characteristics of pileated woodpecker nest sites (Bull 1975, 1980; Conner et al. 1975; Conner and Adkisson 1977; Harris 1982; Madsen 1985). Dead basal area in my study was correlated to snag (r=0.408) and large snag (r=0.893) density. Younger stands used for nesting and roosting were probably located on highly productive sites, and as a result characteristics were similar to those of older stands on less productive sites. Harris (1982) found that pileated woodpeckers selected for nest stand characteristics independent of age or productivity of the site.

Forest characteristics at nest sites were very different between studies (Table 8). Comparisons between studies were

Table 8. Mean measurements of forest site characteristics at pileated woodpecker nests from this and previous studies. Ranges shown parenthetically.

Study	Area	N	Tree density[a] (#/ha)	Snag density[b] (#/ha)	Large tree[c] density (#/ha)	Large snag[c] density (#/ha)	Basal area (m^2/ha)
This Study	W. Oregon	15	239 (97-430)	41 (3-93)	123 (67-246)	16 (0-46)	65 (40-97)
Madsen (1985)	E. Washington	6	725	35		18	39
Mannan (1982)	W. Oregon	3	168 (164-174)	41 (28-50)	100 (44-140)	13 (6-24)	
Harris (1982)	California (Pinacea)	24	581[d] (160-1020)	[d]	141 (30-260)	21 (0-70)	65 (12-124)
Harris (1982)	California (hardwood)	10	526[d] (390-670)	[d]	70 (3-242)	8 (0-40)	45 (12-59)
Harris (1982)	California (redwood)	2	780[d] (670-890)	[d]	102 (66-138)	0	107 (90-123)
Harris (1982)	California (sequoia)	2	310[d] (280-340)	[d]	55 (50-60)	0	227 (45-409)
Bull (1980)	N.E. Oregon	63	380	70			30
McClelland (1979)	Montana	54					25
Conner et al. (1975)	Virginia	14	140				32

[a] Minimum tree dbh: This Study - 8cm, Madsen - 4cm, Bull - 10cm, Mannan - 2.5cm, Conner et al. - 7cm. Densities will vary due to differences in minimum dbh.
[b] Minimum snag dbh: This Study - 8cm, Madsen - 15cm, Bull - 10cm, Mannan - 2.5cm.
[c] Minimum large tree and snag dbh: This Study - 40cm, Madsen - 38cm, Mannan - 51cm, Harris - 41cm.
[d] Tree and snag densities combined; no minimum dbh given.

Table 8. (con't)

Study	Area	N	Dead basal area (m^2/ha)	Stump density[e] (#/ha)	Canopy cover (%)	Shrub cover (%)	Log cover (%)	Canopy[f] height (m)
This Study	W. Oregon	15	10 (0-36)	51 (20-97)	68 (42-82)	72 (12-100)	4 (1-9)	58 (50-70)
Madsen (1985)	E. Washington	6			49			32
Mannan (1982)	W. Oregon	3			70 (60-87)	55 (26-100)	2 (2-3)	
Harris (1982)	California (Pinacea)	24	11 (0-28)	145 (0-740)	81 (57-96)	25 (0-80)		44 (25-74)
Harris (1982)	California (hardwood)	10	7 (0-30)	26 (0-60)	90 (71-94)	58 (20-95)		30 (14-50)
Harris (1982)	California (redwood)	2	1 (0-1)	27 (4-49)	97 (96-97)	18 (10-25)		41 (32-50)
Harris (1982)	California (sequoia)	2	5 (0-10)	5 (0-10)	84 (77-90)	34 (26-41)		63 (48-78)
Bull (1980)	N.E. Oregon	63		10	74	46	13	28
McClelland (1979)	Montana	54						
Conner et al. (1975)	Virginia	14						

[e] Definition of stump: This Study - ≥8 cm dbh and ≤3 m tall, Harris - >8 cm dbh and <2 m tall, Bull - ≥10 cm dbh and ≤1 m tall.

[f] This Study and Harris - canopy height equal to tallest tree, Bull - canopy height equal to lower canopy height.

difficult because sampling techniques used for measurement of characteristics differed. Tree and snag densities were particularly difficult to compare because each study had a different definition of a tree or snag based on a minimum dbh.

Forests in the studies were different in terms of species composition, site productivity, climate, and amount of disturbance; characteristics at nest and roost sites are a reflection of these differences. Mean basal area and canopy height from this study are larger than those reported in other studies, with the exception of coast redwood and giant sequoia nest sites (Harris 1982) (Table 8). Mean basal area from Pinacea sites in California were similar to those found in this study. High basal areas and canopy heights were a reflection of high productivity of forests in western Oregon; this study was conducted on some of the most productive lands in the United States for growing conifers (Waring and Franklin 1979). Mean basal areas from studies conducted on the drier, less productive areas east of the Cascade Mountains and in Montana were much smaller than in western Oregon.

Snag density and percent log cover reported by Bull (1980) in northeastern Oregon were higher than reported for other areas. Her study was conducted during the peak of an infestation of mountain pine beetle (*Dendroctonus ponderosae*) and a large number of trees were killed, creating an abundance of snags and logs.

CONCLUSIONS

In other studies investigators concluded pileated woodpeckers nest at sites with the highest basal area and highest densities of large trees and snags available (Bull 1975,1980, Conner et al. 1975, Conner and Adkisson 1977, Harris 1982, Madsen 1985). Because of high productivity of forests in western Oregon basal area measurements for nest sites in this study were higher than reported for other areas; basal area should not be a limiting factor in this area. Densities of large snags and trees could become limiting in managed stands under short rotations. I found very low snag densities at some nest sites, indicating that pileated woodpeckers are adaptable; however snags provide an important foraging substrate for the birds (Bull 1975, 1980; Madsen 1985).

Both McClelland (1979) and Madsen (1985) suggested that an old-growth component was necessary in nest stands. In Montana and eastern Washington an old-growth component may be necessary to provide sufficient densities of large trees and snags. But in western Oregon trees grow faster and thus reach large diameters at an earlier age (Buttery and Gillam 1984, Hall et al. 1985). I did not find that old-growth was necessary to provide large trees and snags for nests of pileated woodpeckers; nests were found in snags and trees within stands less than 100 years old. However, the woodpeckers regularly used remnant old-growth trees within these stands for roosting.

Pileated woodpeckers require large diameter trees or snags to accomodate their large nest cavities. I support the previously recommended "minimum" dbh of 63.5 cm for nest snags for western Oregon (Neitro et al. 1985). However, I suggest that management directed towards providing snags closer to the mean of 70 cm dbh from this study would be preferable. This strategy would help avoid managing for suboptimal habitat that may lead to low reproductive success and a gradual decline in pileated woodpecker abundance (Conner 1979).

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APPENDICES

APPENDIX 1

Home range sizes were calculated using 4 methods: minimum convex polygon, 95% ellipse (Jennrich and Turner 1969), harmonic mean (Dixon and Chapman 1980), and fourier transformation (Anderson 1982). The 95% ellipse method, harmonic mean estimation, and fourier transformation method are statistical analyses and require independent location data. A 10 minute interval between locations resulted in highly autocorrelated data, as determined by Schoener's (1981) t^2/r^2 ratio, so a random subsample of locations was taken with at least 4 hours between locations to avoid using highly autocorrelated data. The use of autocorrelated data will underestimate home range size (Swihart and Slade 1985). A total of 383 locations, averaging 35 per bird and ranging from 25 to 52 per bird, were used to calculate home range sizes with these statistical methods.

All locations (4502), averaging 409 locations per bird and ranging from 255 to 550 locations per bird, were used for calculation of the minimum convex polygon (MCP) estimate. MCP is a non-statistical home range method so autocorrelation of data is important only in that it can result in misleadingly large sample sizes. The method has a strong sample size bias (Jennrich and Turner 1969, Anderson 1982). To compensate for this, an area-observation curve (Odum and Kunzler 1955) was used to determine if the relationship between home range size and locations was asymptotic (Smith et al. 1981, Laundre and Keller 1984).

The 95% ellipse method gave the largest estimates, averaging 717 ha and ranging from 410 to 1626 ha (Table 1A). This method typically gives larger estimates than MCP (Jennrich and Turner 1969, Dixon and Chapman 1980). However, part of the reason for the larger estimates was that the assumption of bivariate normality of the data was violated, which resulted in an overestimate of home range size (Schoener 1981). Ford and Krumme (1979) found that violating this assumption lead to overestimates of up to 39% for small mammal home ranges. The bivariate normality assumption is usually violated with heterogeneous habitat, and with territorial animals, such as the pileated woodpecker, which spend time at the periphery of their home range (Schoener 1981). Dunn and Brisbin (1982) calculated that a sample size of 386 locations would be necessary to achieve 10% confidence with the 95% ellipse.

The home range estimates with the harmonic mean method varied depending on the number of grid cell divisions used in the calculation (Table 1A). There is no objective method to determine the number of grid cell divisions that will result in an accurate home range estimate. According to Dixon and Chapman (1980), the choice of grid cell density should not effect estimates, however Spencer and Barrett (1984) found that variation in the grid density resulted in miscalculatin of the

Table 1A. Estimates of home range size (ha) of 11 pileated woodpeckers using 4 estimation methods: minimum convex polygon (using all locations), and (using a random subset of locations with at least a 4 hour interval) 95% elipse (Jennrich and Turner 1969), harmonic mean (Dixon and Chapman 1980), and fourier transformation (Anderson 1982).

Birds		PECRM85	RESRF85	MANBM82	HUPAM85	MANAM82	RESRF83	MANAF82	ROCRF85	PECRF85	LRCRM84	BORDM85	MEANS
Total number of locations		550	522	400	386	400	392	355	335	453	454	255	409
Minimum convex polygon (ha)		1056	570	546	533	485	431	430	363	300	293	267	480
Number of random locations		52	37	25	33	37	31	34	26	42	40	26	35
95% ellipse (ha)		1626	743	664	616	410	788	642	778	462	556	603	717
Harmonic mean (ha)	contour												
grid size - 300 m	50%	115	77	57	37	42	70	54	50	110	82	45	67
	95%	860	530	275	574	376	347	608	321	367	272	346	443
grid size - 150 m	50%	122	53	35	25	43	36	51	35	58	41	29	48
	95%	799	384	244	221	313	259	462	267	275	227	287	340
Fourier transformation (ha)	MAP(50)	158	63	47	29	46	77	71	76	52	57	45	66
	MAP(95)	528	196	130	114	161	223	263	226	179	175	141	212

harmonic mean especially with multimodal or platykurtic distributions. Many of my data sets had multimodal distributions. The problem may also be intensified by small sample sizes. Home ranges calculated with coarser grids include areas not actually used by the birds, including clearcuts and probably some suitable but unused habitat. A finer grid eliminated some of these areas from the estimate, and accuracy of the center of activity was improved (Dixon and Chapman 1980). Independent sampling is not necessarily required for the harmonic mean method (Dixon, personal communication). However, data should be collected randomly; data collected in bursts may result in calculation of false harmonic centers. No guidelines are available for minimum sample sizes for this method, but it is sensitive to small sample sizes (Dixon, personal communication).

The Anderson fourier transformation method gave very small home range estimates, averaging 66 ha for MAP(50) and 212 ha for MAP (95) (Table 1A). In contrast to the 95% ellipse and MCP, this method did not include any interspersed, unused areas, such as clearcuts, in the estimate because the estimate is based on a utilization distribution. With small sample sizes MAP(95) estimates are not precise because of lack of data in the tail of the utilization distribution; with sample sizes of 100 and bivariate normal data the area may be underestimated by 25% (Anderson 1982). MAP(50) has little sample size bias, but is only useful in comparison of home ranges, not for calculating total area used (Anderson 1982). The MAP(50) estimates are somewhat similar to the harmonic mean 50% calculations (Table 1A).

Home range sizes calculated using MCP averaged 480 ha and ranged from 267 to 1056 ha (Table 1A). Because of the problems encountered with other methods it was decided that the MCP was the most appropriate estimate to use with this data set. Restrictions caused by short radio life, and the improbability of being able to retrap birds and replace radio transmitters, made it impossible to collect adequate sample sizes of independent locations needed to properly use a statistical home range estimate. Under these circumstances it was more appropriate to use a short sampling interval and a nonstatistical method, such as MCP, to determine home range size (Swihart and Slade 1985).

The MCP calculations included interspersed areas not actually used by the birds. Some of this area was probably suitable habitat that would have shown use if the birds had been monitored for a longer period of time; other areas were probably unsuitable habitat that would never have been used. These areas were within defended boundaries and thus were not available to other pairs of pileateds, so I feel the MCP estimate is appropriate for determining minimum areas required by the birds for management purposes.

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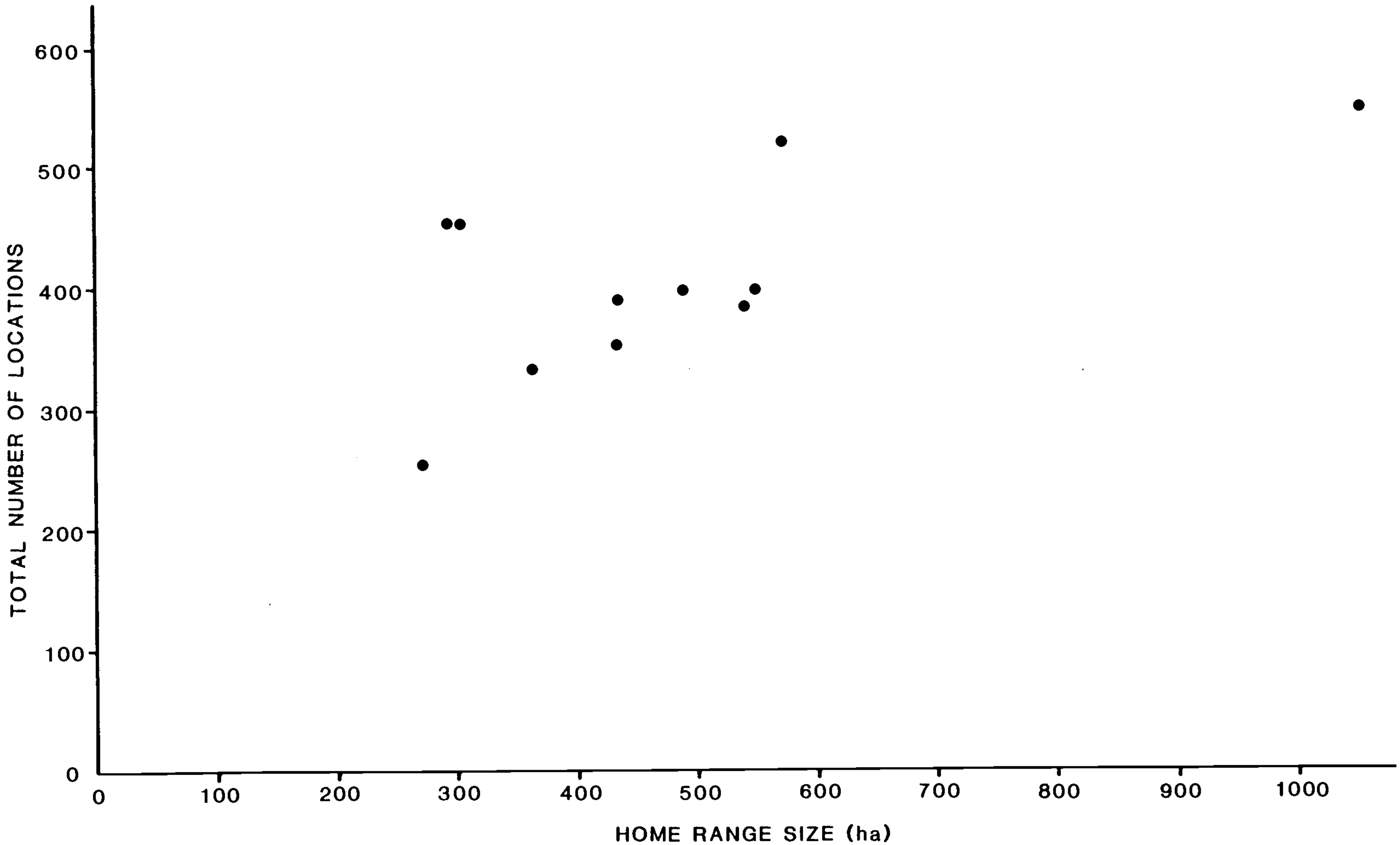
Appendix 2. Scatter plot of home range size and total number of locations for 11 pileated woodpeckers, western Oregon (1982-1985).

Appendix 2



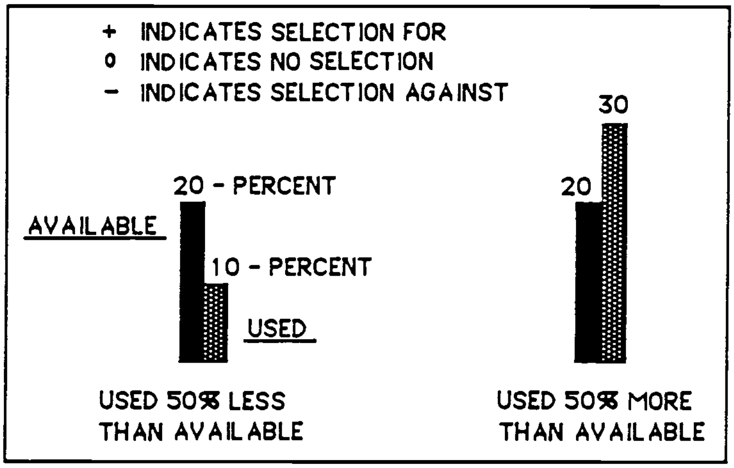
TOTAL NUMBER OF LOCATIONS
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
1000
HOME RANGE SIZE (ha)

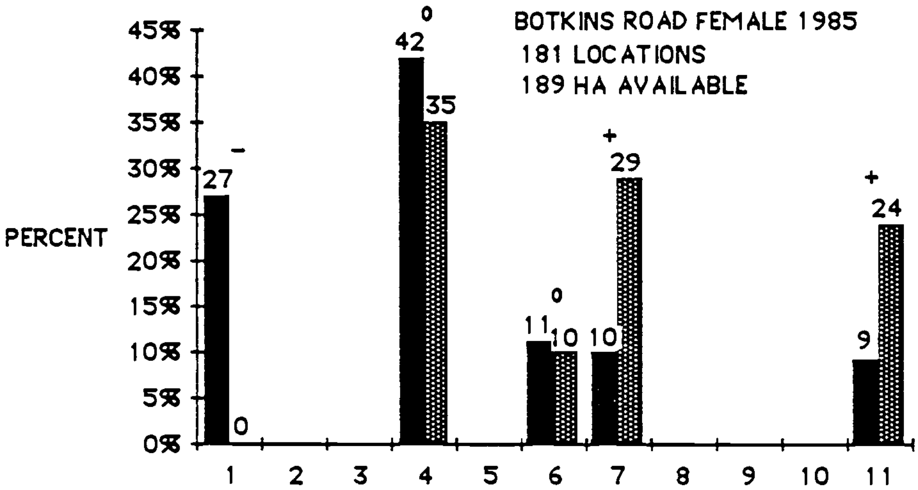
Appendix 3. Availability and use of forest habitat classes of 14 pileated woodpeckers, western Oregon. Habitat classes used in a proportion 50% greater than expected based on availability were interpreted as selected for; habitat classes used in a proportion 50% less than expected based on availability were interpreted as selected against. Percentages printed on the graphs were rounded to the nearest whole number; calculations for selection were performed using percentages with 2 significant digits.

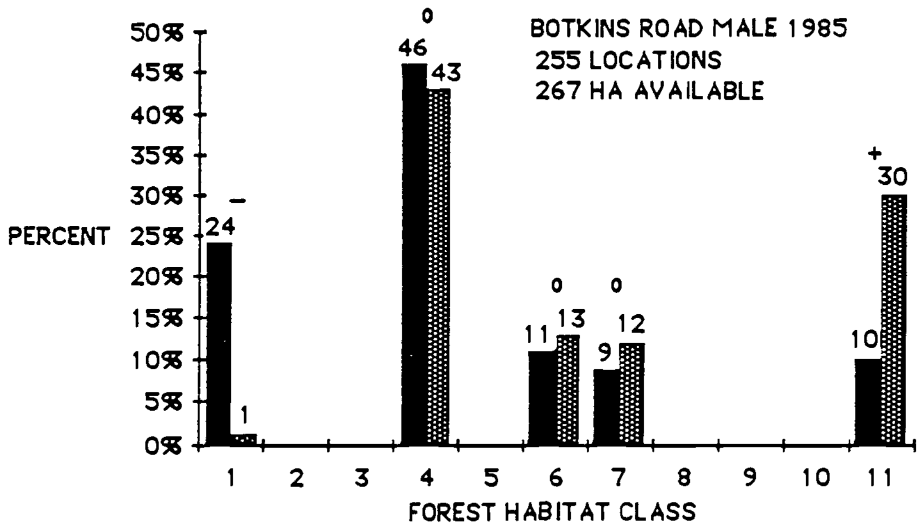
Forest Habitat Classes

Class	Age (years)	Description
1	0-15	Clear cut, seedlings and/or saplings
2	16-40	Saplings and small poletimber, conifer (<30% shrub)
3	16-40	Saplings and small poletimber, conifer/ shrub mix (>30% shrub)
4	41-70	Immature, poletimber and/or small sawtimber, conifer (<20% deciduous)
5	41-70	Immature, poletimber and/or small sawtimber, conifer/deciduous mix (>20% deciduous)
6	71-100	Mature, small and/or large sawtimber, conifer (<20% deciduous)
7	71-100	Mature, small and/or large sawtimber, conifer/deciduous mix (>20% deciduous)
8	100-200	Older mature, large sawtimber, conifer (<20% deciduous)
9	100-200	Older mature, large sawtimber, conifer deciduous mix (>20% deciduous)
10	200+	Old-growth forest
11	----	Deciduous riparian, primarily red alder (*Alnus rubra*) and big-leaf maple (*Acer macrophyllum*)

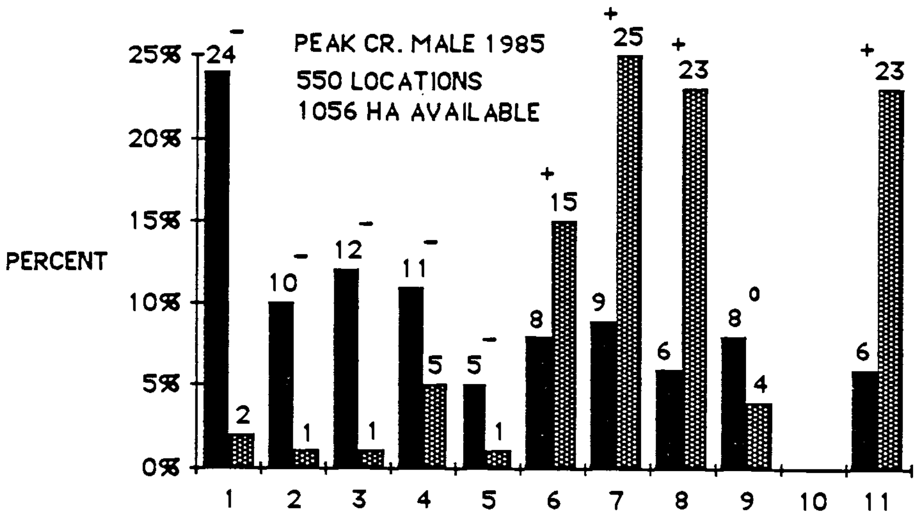
APPENDIX 3

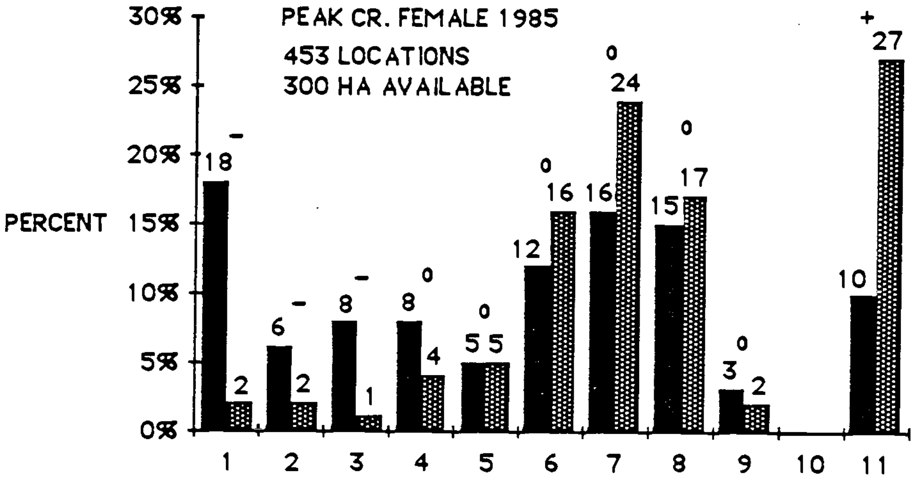

+ INDICATES SELECTION FOR
o INDICATES NO SELECTION
- INDICATES SELECTION AGAINST
20 - PERCENT
AVAILABLE
10 - PERCENT
USED
USED 50% LESS THAN AVAILABLE
30
20
USED 50% MORE THAN AVAILABLE

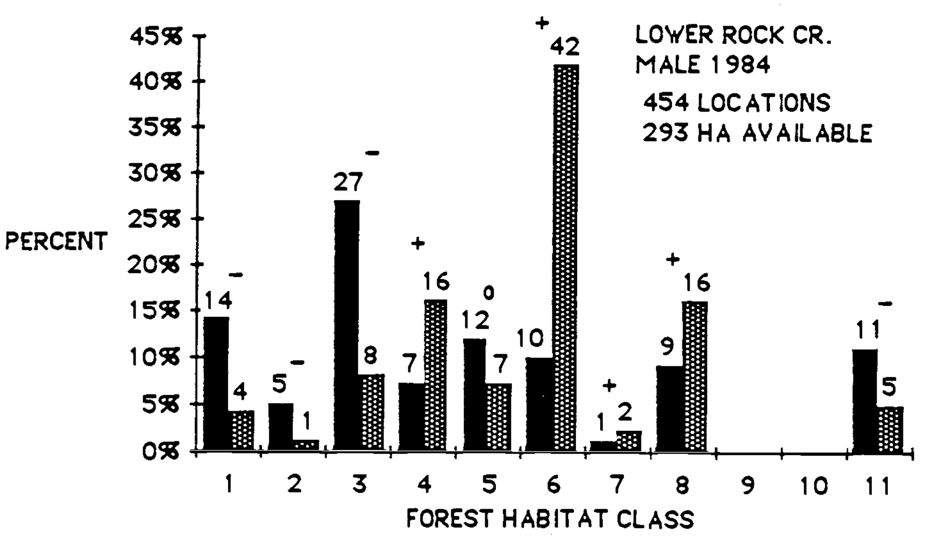

BOTKINS ROAD FEMALE 1985
181 LOCATIONS
189 HA AVAILABLE
PERCENT
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
27
0
42
35
11
10
10
29
9
24
1 2 3 4 5 6 7 8 9 10 11


BOTKINS ROAD MALE 1985
255 LOCATIONS
267 HA AVAILABLE
PERCENT
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
24
1
46
43
11
13
9
12
10
30
1 2 3 4 5 6 7 8 9 10 11
FOREST HABITAT CLASS

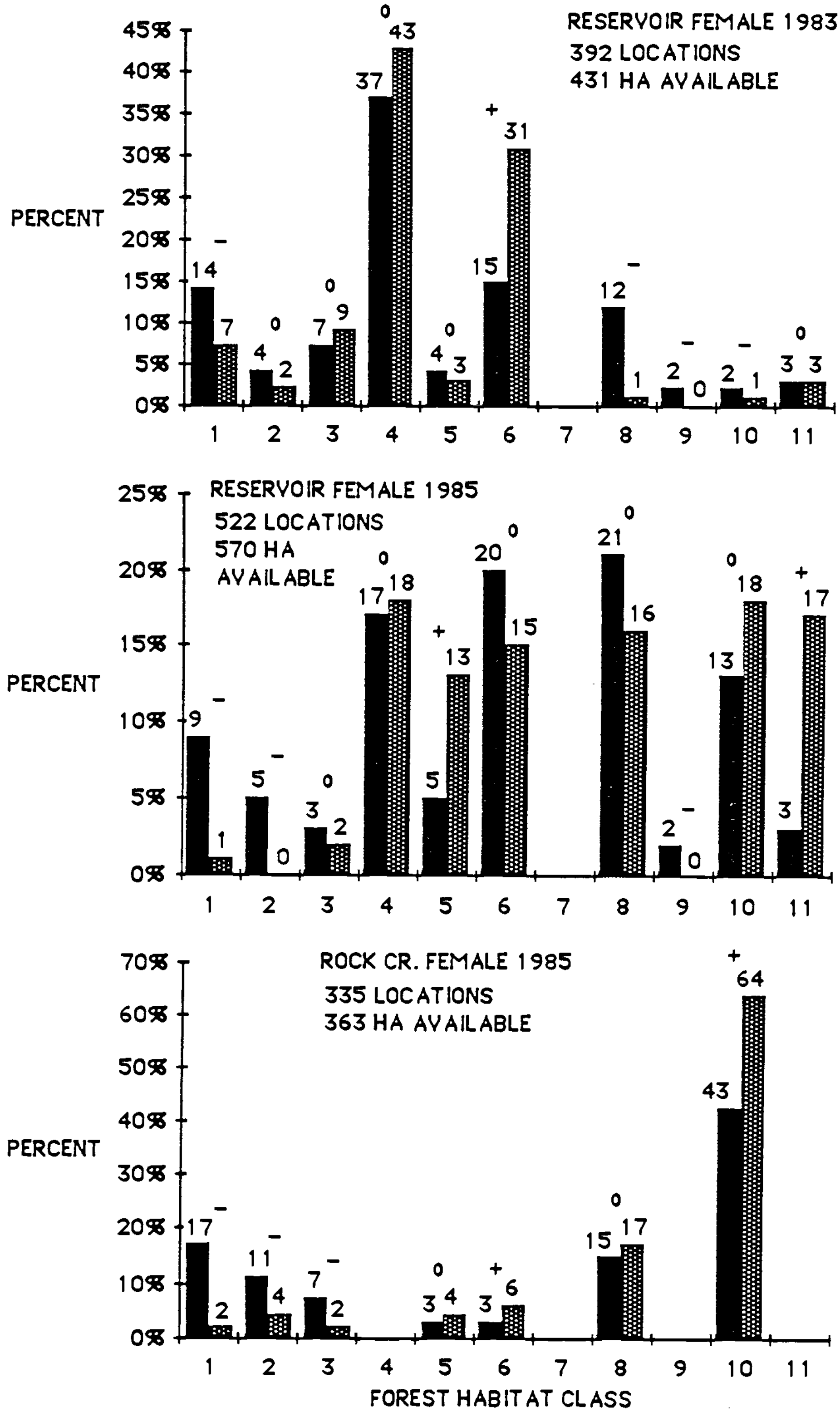
APPENDIX 3 (con't)



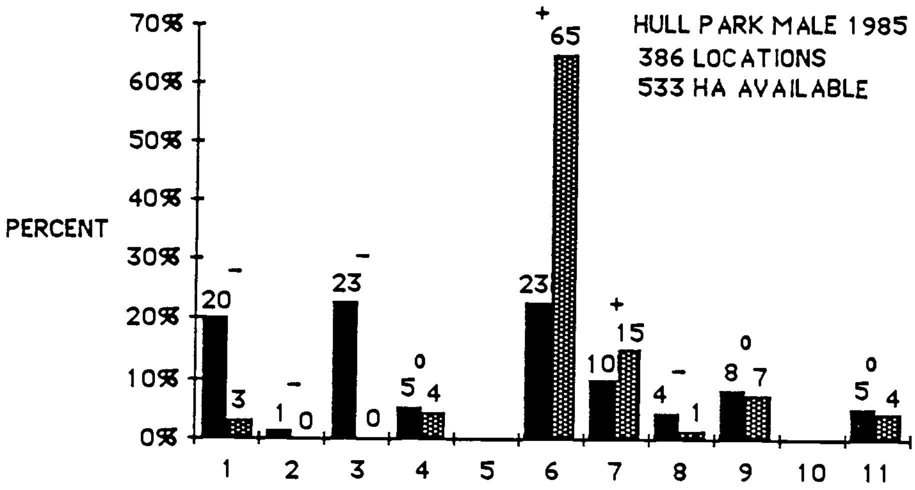


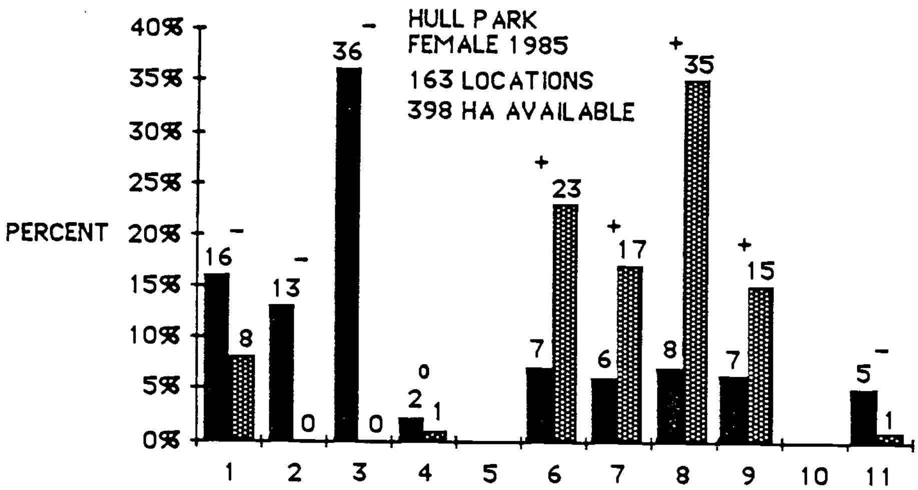


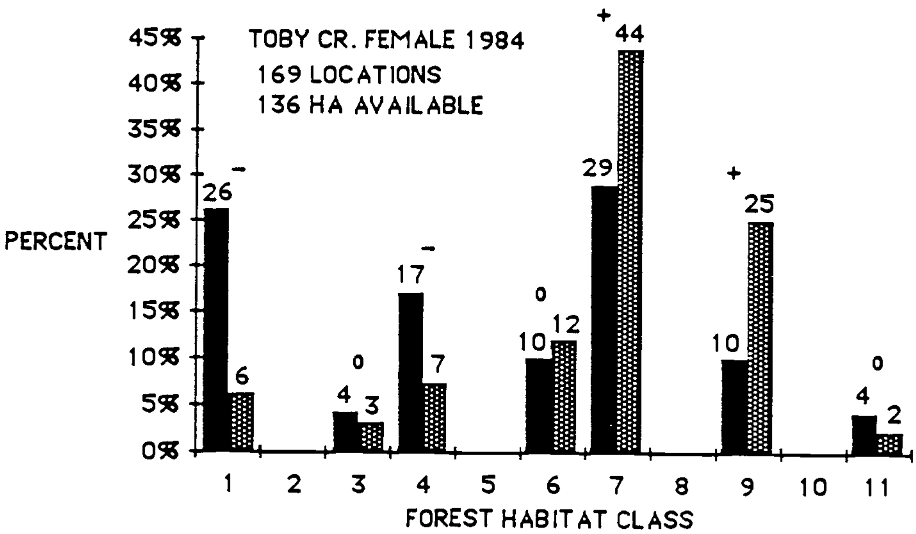
APPENDIX 3 (con't)



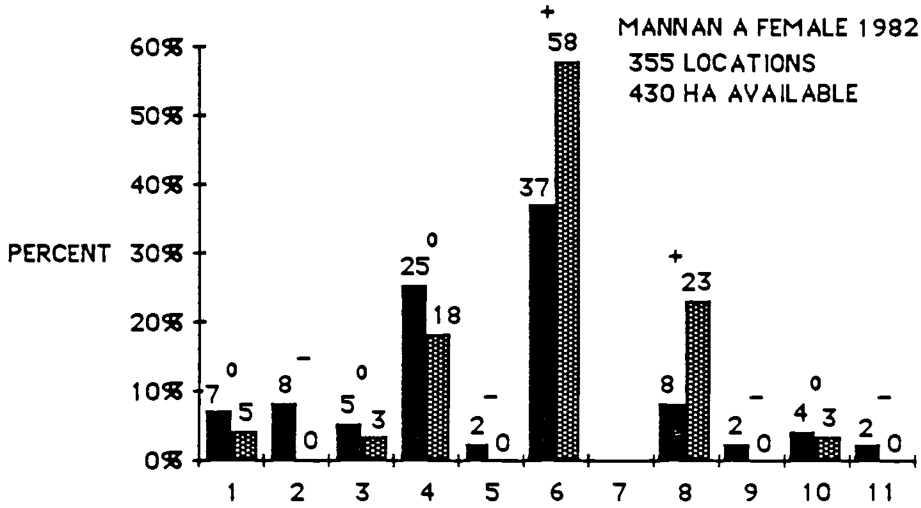
APPENDIX 3 (con't)

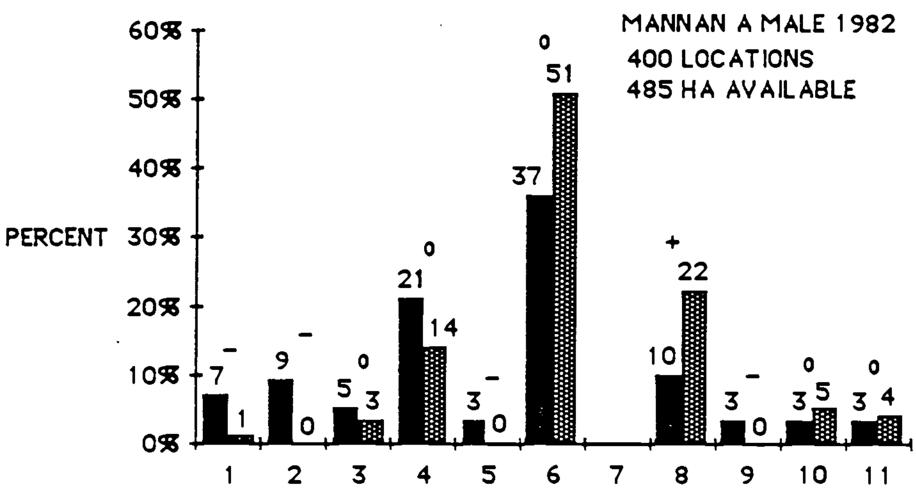


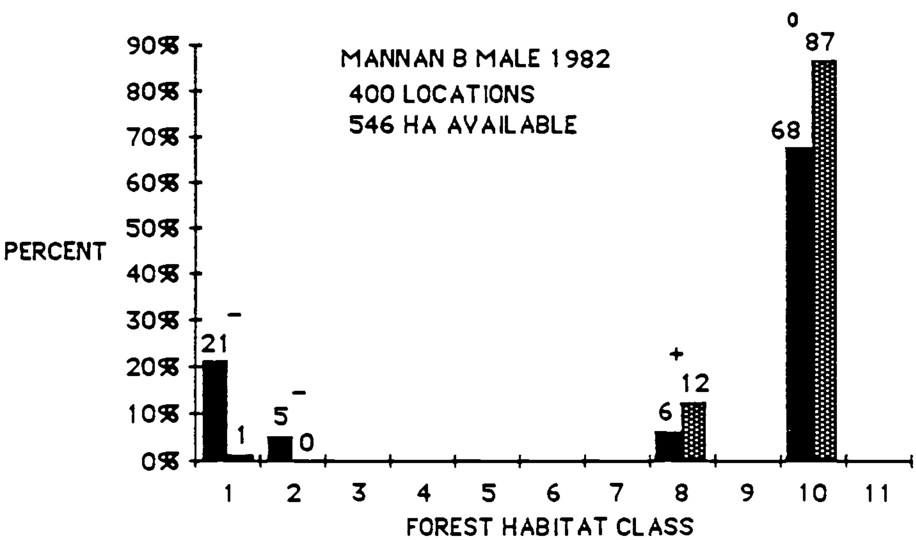




APPENDIX 3 (con't)







Appendix 4. Characteristics of pileated woodpecker nest snags and trees, western Oregon, 1983-1985.

Area & year	Species[a]	Condition live/dead	DBH (cm)	Height (m)	Diameter at cavity (cm)	Height of cavity (m)	Bark cover (%)	Top condition	# pileated cavities
RESR83	DF	dead	57.5	12.5	35	11.0	95	broken	2
ALPI83	DF	dead	76.0	34.0	59	22.5	95	broken	2
HUPA83	DF	dead	68.0	30.0	44	26.0	100	broken	2
LRCR84	DF	dead	138.5	15.5	78	10.0	10	broken	3
HUPA84	RA	dead	48.5	17.0	39	15.0	95	broken	2
TOCR84	RA	dead	39.5	11.5	39	5.5	98	broken	3
TOTA84	DF	dead	88.5	46.5	45	36.5	100	intact	1
HUPA85	DF	dead	68.0	30.0	54	27.0	100	broken	5
ALPI85	DF	live	90.0	68.0	51	48.0	100	intact	1
PECR85	DF	dead	43.5	27.5	29	20.5	100	broken	2
KESS85	DF	dead	74.5	36.0	45	22.5	98	broken	2
ROCR85	DF	dead	87.0	24.5	45	21.0	100	broken	1
BORD85	DF	dead	54.5	18.0	47	11.5	95	broken	2
RESR85	DF	dead	54.0	13.5	45	9.0	100	broken	4
TOCR86	RA	dead	45.5	13.0	30	12.5	40	broken	1
$\bar{x}$			68.9	26.5	45.7	19.9	88.4		
SD			25.5	15.5	12.1	11.4	26.4		
Range			39.5-138.5	11.5-68.0	29-78	5.5-48.0	10-100		

[a] DF - douglas fir (Pseudotsuga menziesii), RA - red alder (Alnus rubra).

Appendix 5. Characteristics of pileated woodpecker roost snags and trees, western Oregon, 1983-1985.

Area & year	Species[a]	Condition live/dead	DBH (cm)	Height (m)	Diameter at cavity (cm)	Height of cavity (m)	Bark cover (%)	Top condition	# pileated cavities
RESRA83	BLM	live	73.0	36.5	60	6.0	100	intact	1
RESRB83	DF	dead	131.5	28.5	62	26.0	90	broken	1
RESRC83[b]	DF	live	164.5	39.5	unknown	unknown	100	intact	unknown
TOCR84	RA	dead	39.5	11.5	30,33,39[c]	6,9,11[c]	98	broken	3
LRCR84	DF	dead	118.5	23.0	56,60[c]	21,22[c]	100	broken	9
HUPAA85	DF	dead	60.5	24.0	56	15.0	100	broken	1
HUPAB85	DF	dead	109.5	32.0	56	31.0	10	broken	4
HUPAC85[b]	DF	live	unknown[d]	50.5	unknown	unknown	100	intact	unknown
PECR85[b]	DF	live	208.0	57.5	unknown	unknown	100	intact	unknown
KESS85	WRC	dead	89.0	16.0	52	8.5	0	broken	6
BORD85[b]	DF	live	93.0	50.0	unknown	unknown	100	intact	unknown
RESR85	DF	live	159.0	27.5	unknown	unknown	95	broken	2
ROCR85[b]	DF	dead	172.5	21.0	unknown	unknown	90	broken	unknown
$\bar{x}$			118.2	32.1	50.4	15.6	83.3		
SD			50.6	14.0	11.8	8.9	35.0		
Range			39.5-208.0	11.5-57.5	30-62	6.0-26.0	0-100		

[a] BLM - big-leaf maple (*Acer macrophyllum*), DF - douglas fir (*Pseudotsuga menziesii*), RA - red alder (*Alnus rubra*), WRC - western redcedar (*Thuja plicata*).
[b] Roost cavity not found.
[c] More than 1 cavity used for a roost within the same tree.
[d] Tree forked near base, it was not known which fork the bird used for a roost.

Appendix 6. Tree density and basal area at pileated woodpecker nest sites, western Oregon, 1983-1986.

Area & year	TREE DENSITY (#/ha) DBH class (cm) ≥8-15	≥15-40	≥40-70	≥70-100	≥100-300	≥130+	Total	Total ≥40	BASAL AREA (m^2/ha)
RESR83	0	73	180	63	3	0	319	246	83.1
ALPI83	13	10	13	27	17	17	97	74	65.1
HUPA83	10	20	40	60	3	0	133	103	47.4
LRCR84	103	67	40	33	33	3	279	109	67.4
HUPA84	13	67	70	37	0	0	187	107	39.5
TOCR84	110	163	130	20	7	0	430	157	55.0
TOTA84	100	50	43	37	27	7	264	114	69.2
HUPA85	10	20	43	60	3	0	136	106	47.4
ALPI85	20	60	7	13	37	10	147	67	74.6
PECR85	77	37	47	37	50	7	255	141	96.9
KESS85	220	53	87	30	27	3	420	147	75.8
ROCR85	57	70	37	37	23	0	224	97	61.3
BORD85	50	70	87	50	10	0	267	147	67.1
RESR85	23	83	47	50	27	7	237	131	83.1
TOCR86	37	43	67	13	10	3	193	93	45.2
$\bar{x}$	56.2	59.1	62.5	37.8	18.5	3.8	239.2	122.6	65.2
SD	58.7	36.1	44.8	16.2	14.9	5.0	98.0	43.2	16.2
Range	0-220	10-163	7-180	13-63	0-50	0-17	97-430	67-246	39.5-96.9

Appendix 7. Tree density and basal area at pileated woodpecker roost sites, western Oregon, 1983-1985.

Area & year	TREE DENSITY (#/ha) DBH class (cm) ≥8-15	≥15-40	≥40-70	≥70-100	≥100-300	≥130+	Total	Total ≥40	BASAL AREA (m^2/ha)
RESRA83	43	230	40	30	7	0	350	77	46.2
RESRB83	30	40	13	43	40	10	176	106	91.2
RESRC83	30	90	50	20	7	3	200	80	41.6
TOCR84	110	163	130	20	7	0	430	157	55.0
LRCR84	17	70	83	60	17	10	257	170	85.3
HUPAA85	20	27	73	63	3	0	186	139	55.9
HUPAB85	17	123	97	23	17	7	284	144	69.2
HUPAC85	33	67	70	63	3	0	236	136	59.4
PECR85	87	227	63	0	0	20	397	83	67.5
KESS85	7	117	77	27	0	7	235	110	51.7
BORD85	27	83	23	33	20	3	189	79	45.6
RESR85	90	133	20	43	20	7	313	91	70.3
ROCR85	0	40	23	57	27	3	150	110	78.5
$\bar{x}$	39.3	108.5	58.6	37.1	12.9	5.4	261.8	114.0	62.9
SD	34.4	66.4	34.6	19.7	11.9	5.8	88.3	32.0	15.6
Range	0-110	27-227	13-130	0-63	0-40	0-20	150-430	77-170	41.6-91.2

Appendix 8. Snag and stump density, and dead basal area (snags only) at pileated woodpecker nest sites, western Oregon, 1983-1986.

Area & year	SNAG DENSITY (#/ha) DBH class (cm) ≥8-15	≥15-40	≥40-70	≥70-100	≥100-300	≥130+	Total	Total ≥40	DEAD BASAL AREA (m^2/ha)	STUMPS (#/ha)
RESR83	7	70	13	0	3	0	93	16	8.3	93
ALPI83	3	0	0	7	0	3	13	10	12.1	40
HUPA83	0	23	13	0	3	3	42	19	12.7	67
LRCR84	7	23	20	10	0	13	73	43	35.5	30
HUPA84	0	20	3	0	0	0	23	3	1.7	47
TOCR84	7	33	7	0	3	0	50	10	6.4	97
TOTA84	7	3	10	7	0	3	30	20	11.3	70
HUPA85	0	20	13	0	3	3	39	19	12.3	67
ALPI85	0	3	0	0	0	0	3	0	0.3	27
PECR85	7	17	7	0	0	0	31	7	1.6	33
KESS85	7	27	10	7	3	0	54	20	11.3	33
ROCR85	0	10	23	17	3	3	56	46	25.1	47
BORD85	10	40	7	3	0	0	60	10	6.0	67
RESR85	0	13	10	0	0	0	23	10	2.4	20
TOCR86	0	13	7	0	0	3	23	10	7.3	30
$\bar{x}$	3.7	21.0	9.5	3.4	1.2	2.1	40.9	16.2	10.3	51.2
SD	3.8	17.5	6.4	5.2	1.5	3.4	23.9	13.0	9.4	24.2
Range	0-10	0-70	0-23	0-17	0-3	0-13	3-93	0-46	0.3-35.5	20-97

Appendix 9. Snag and stump density, and dead basal area (snags only) at pileated woodpecker roost sites, western Oregon, 1983-1985.

Area & year	SNAG DENSITY (#/ha) DBH class (cm) ≥8-15	≥15-40	≥40-70	≥70-100	≥100-300	≥130+	Total	Total ≥40	DEAD BASAL AREA (m^2/ha)	STUMPS (#/ha)
RESRA83	17	10	3	0	0	0	30	3	1.4	120
RESRB83	0	17	13	0	0	3	30	17	8.3	26
RESRC83	7	7	0	3	0	0	17	3	2.8	53
TOCR84	10	30	7	0	3	0	50	10	6.4	97
LRCR84	7	27	3	0	3	3	42	9	11.1	63
HUPAA85	0	17	27	3	0	0	47	30	9.6	33
HUPAB85	23	30	3	0	7	3	66	13	12.8	40
HUPAC85	3	47	7	0	0	0	57	7	4.0	63
PECR85	50	23	0	0	0	0	73	0	1.1	53
KESS85	10	30	3	3	0	0	46	6	4.3	27
BORD85	0	3	0	3	0	0	6	3	2.6	13
RESR85	10	3	3	3	0	0	19	6	2.9	53
ROCR85	0	17	7	3	0	3	30	13	11.6	30
$\bar{x}$	10.5	17.7	5.8	1.4	1.0	0.9	39.5	9.2	6.1	51.6
SD	13.8	13.5	7.3	1.6	2.1	1.4	19.7	8.0	4.1	29.9
Range	0-50	3-47	0-27	0-3	0-7	0-3	6-73	0-30	1.4-12.8	13-120

Appendix 10. Percent shrub cover, percent log cover, percent canopy cover, and canopy height at pileated woodpecker nest and roost sites, western Oregon, 1983-1986.

NEST SITES					ROOST SITES				
Area & year	Shrub cover (%)	Log cover (%)	Canopy cover (%)	Canopy[a] height (m)	Area & year	Shrub cover (%)	Log cover (%)	Canopy cover (%)	Canopy[a] height (m)
RESR83	12	4	72	54.5	RESRA83	100	3	82	40.1
ALPI83	100	3	42	70.3	RESRB83	82	4	76	46.7
HUPA83	100	2	74	54.2	RESRC83	58	3	68	53.3
LRCR84	100	3	70	68.6	TOCR84	75	4	62	58.4
HUPA84	53	3	68	58.6	LRCR84	49	2	76	56.4
TOCR84	75	4	62	58.4	HUPAA85	56	5	66	63.3
TOTA84	53	9	64	unknown[b]	HUPAB85	100	2	83	41.2
HUPA85	14	2	69	54.2	HUPAC85	65	2	82	58.6
ALPI85	87	3	55	68.1	PECR85	76	2	75	54.7
PECR85	100	5	78	51.0	KESS85	88	1	72	59.7
KESS85	97	5	82	56.6	BORD85	18	10	74	unknown[b]
ROCR85	89	2	76	57.5	RESR85	100	1	65	44.4
BORD85	52	1	69	50.4	ROCR85	100	3	76	70.9
RESR85	54	1	80	57.4					
TOCR86	100	5	62	55.0					
$\bar{x}$	72.4	3.5	68.2	58.2	$\bar{x}$	74.4	3.2	73.6	54.0
SD	31.0	2.0	10.3	6.4	SD	24.8	2.4	6.8	9.3
Range	12-100	1-9	42-82	50.4-70.3	Range	18-100	1-10	62-83	40.1-70.9

[a] Canopy height equal to tallest tree.
[b] The site was logged before canopy height was measured.