INFORMATION TO USERS

This reproduction was made from a copy of a document sent to us for microfilming. While the most advanced technology has been used to photograph and reproduce this document, the quality of the reproduction is heavily dependent upon the quality of the material submitted.

The following explanation of techniques is provided to help clarify markings or notations which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting through an image and duplicating adjacent pages to assure complete continuity.

2. When an image on the film is obliterated with a round black mark, it is an indication of either blurred copy because of movement during exposure, duplicate copy, or copyrighted materials that should not have been filmed. For blurred pages, a good image of the page can be found in the adjacent frame. If copyrighted materials were deleted, a target note will appear listing the pages in the adjacent frame.

3. When a map, drawing or chart, etc., is part of the material being photographed, a definite method of "sectioning" the material has been followed. It is customary to begin filming at the upper left hand corner of a large sheet and to continue from left to right in equal sections with small overlaps. If necessary, sectioning is continued again—beginning below the first row and continuing on until complete.

4. For illustrations that cannot be satisfactorily reproduced by xerographic means, photographic prints can be purchased at additional cost and inserted into your xerographic copy. These prints are available upon request from the Dissertations Customer Services Department.

5. Some pages in any document may have indistinct print. In all cases the best available copy has been filmed.

University Microfilms International

300 N. Zeeb Road
Ann Arbor, MI 48106

Order Number 1332417

Effects of prescribed burning on breeding birds in a ponderosa pine forest, southeastern Arizona

Horton, Scott Patterson, M.S.

The University of Arizona, 1987

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

EFFECTS OF PRESCRIBED BURNING ON BREEDING BIRDS IN A PONDEROSA PINE FOREST, SOUTHEASTERN ARIZONA

by

Scott Patterson Horton

A Thesis Submitted to the Faculty of the

SCHOOL OF RENEWABLE NATURAL RESOURCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN WILDLIFE AND FISHERIES SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 8 7

STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: _____

APPROVAL BY THE THESIS DIRECTOR

This thesis has been approved on the date shown below:

R W Mannan
R. W. MANNAN
Assistant Professor of Wildlife Ecology

12/10/87
Date

ACKNOWLEDGMENTS

I could not have completed this project without the advice, assistance, and encouragement of many people. Bill Mannan provided me with the opportunity to work on this study, and invaluable advice throughout my graduate program. I thank Jeannie Cole, Michelle Brown, Terry Myers, and Mark Brown for their hard work and companionship in the field. Bill Standley, Kurt Rautenstrauch, Ted Kerpez, Holly Hobart, Peter Horton, and Ellen Weintraub also helped in the field. Bruce Leopold helped with computer programming. Ted Moore, Steve Hensel, and Lynn Thomas of the Coronado National Forest directed the planning and conduct of the prescribed burns. My wife, Susan Keilman, helped in the field and provided support and encouragement at home. This study was supported by McIntire-Stennis funds to the Arizona Agriculture Experiment Station, the U.S.D.A. Coronado National Forest, and the Arizona Game and Fish Department.

TABLE OF CONTENTS

TABLE OF CONTENTS--Continued

LIST OF TABLES

LIST OF TABLES--Continued

LIST OF ILLUSTRATIONS

ABSTRACT

A moderately intense, broadcast, understory, prescribed burn in 3 previously unburned ponderosa pine stands in southeastern Arizona felled or consumed 50% of all ponderosa pine snags $\geq$ 15 cm dbh. Large moderately decayed snags were most susceptible to burning. Large snags in the early stages of decay were preferred as nest sites by cavity-nesting birds. Numbers of live woody plants were reduced by 40%, mortality was greatest among shrubs and small trees. Canopy volume was reduced by 19%, the greatest impact was below 5 m. No species of cavity-nesting birds, or birds that associated with understory vegetation disappeared in the first season after burning, but 3 species decreased, and 1 species increased in abundance. The minor impacts of a single treatment with broadcast understory burning on bird populations will be ephemeral, but a repeated burns could have greater, and more lasting effects on the avian community.

INTRODUCTION

Fires burned naturally every 5-12 years in southwestern ponderosa pine (Pinus ponderosa) forests prior to the initiation of fire suppression by man in the late 19th century (Weaver 1951, Cooper 1960, Dieterich 1980). These frequent, usually light, surface fires produced forests that were generally open and park-like, with a mosaic pattern of small groups of even-aged trees forming uneven-aged stands (Schubert 1974, but see White 1985). Effective and widespread fire suppression in the last half century has altered the structure and composition of pine forests in the southwest by allowing dense thickets of small pines to persist, and dead wood and other organic material to accumulate. Forest managers in the southwest use prescribed burning as one way to reverse some of these man-induced changes. In the 40 years since the initiation of prescribed burning on the Fort Apache Indian Reservation, northern Arizona, hundreds of thousands of hectares of ponderosa pine forests in the southwest have been burned and reburned.

Fire managers in the southwest conduct broadcast, understory burning mainly for the purpose of reducing accumulations of woody debris left by logging or natural

processes, thus lowering the risk of catastrophic crown fires. Application of prescribed fire to reduce accumulations of wood on the ground also changes the number of standing dead trees, or snags. Prescribed fires burn some pre-existing snags and create others by killing trees. Changes in the number and characteristics of snags may affect populations of cavity-nesting birds because snags provide sites for nesting, roosting, and foraging (Mannan et al. 1980, Raphael and White 1984). Abundance of cavity-nesting birds in western coniferous forests has been shown to be positively correlated with the density of large snags (Cunningham et al. 1980, Mannan et al. 1980). Conner (1981) and Granholm (1982) suggested that prescribed burning may negatively impact cavity-nesting birds by removing snags that serve as actual or potential nest sites, but data are lacking.

The objectives of my study were (1) to compare the number and characteristics of dead trees (standing and fallen) before and after prescribed burning in a ponderosa pine forest, (2) to describe the snags used by birds for nesting and compare the availability of these snags before and after prescribed burning, and (3) to compare breeding populations of cavity-nesting birds before and after prescribed burning to identify species that were affected in the first year after treatment.

STUDY AREA AND METHODS

The study was conducted on the Coronado National Forest, southeastern Arizona. Study plots were located about 50 km north of Tucson in the Santa Catalina Mountains, Pima County, Arizona. Montane forests in southeastern Arizona are isolated on scattered, small, steep mountain ranges surrounded by desert. These forests support a diverse flora and fauna with organisms from the Mexican Sierra Madres complementing the dominant Rocky Mountain biota. Five-needled ponderosa pine (P. ponderosa var arizonica, plant names follow U.S. Dep. Agric. 1982) is the dominant tree species on the study area; other common trees are Mexican white pine (P. strobiformis), Douglas-fir (Psuedotsuga mensiezii), and 2 evergreen oaks - - silver leaf oak (Quercus hypoleucoides) and Arizona white oak (Q. arizonica). The oaks also grow as shrubs. Perennial grasses and forbs occur in scattered patches.

Effective fire suppression has limited the size of wildfires on the study sites to less than 2 ha over the last 65 years and to less than 0.1 ha over the last 10 years (data on file, Catalina District, Coronado N. F.). The study area was never treated with prescribed burning (before this study), and was never extensively logged.

Study Plots

I sampled dead trees (standing and fallen), located active cavity-nests, and counted birds in 3 experimental plots before (1984) and after (1985) prescribed burning. Similar studies were conducted in 3 control plots.

I selected the experimental plots from a list of potential sites considered for burning by the U.S.D.A. Forest Service. Two sites were in southwest draining canyons, and were 22 and 28 ha. The third site was on a west-facing mountain side, and was 45 ha. All experimental plots were between 2075 and 2410 m in elevation. I selected 3 control plots, similar in area, vegetation, aspect, slope, and elevation to the experimental plots. All study plots were within 3 km of each other.

Prescribed Burning

The Coronado National Forest planned to reduce accumulations of fallen wood by 70% for twigs <0.6 cm diameter, by 55% for branches 0.6-7.6 cm, and by 25% for logs >7.6 cm diameter in the prescribed fires (see Appendix B for results of fuel inventories). Their secondary objectives were to enhance reproduction and growth of ponderosa pine by creating areas of mineral soil for establishment of seedlings, and by thinning overstocked thickets of small trees. Prescribed conditions

for burning were (1) temperature range 4.4-24° C, (2) relative humidity 25-40%, (3) wind speed 0-16 km/hr, and (4) fuel stick moisture 8-12%. Prescribed fire parameters were (1) flame height 0.3-1 m, (2) flame length 0.3-1.2 m, and (3) rate-of-spread 40-120 m/hr. Personnel from the Coronado National Forest ignited all prescribed fires with hand-held drip torches and contained the fires with natural fuel breaks (roads, rocky cliffs, creeks) or narrow (1 m), hand-constructed fire lines. All fires were broadcast, understory burns that backed downslope into the wind. Two plots were burned 6-12 November 1984. Flame lengths in these burns were 0.3-0.6 m, rate of spread of the backing flame front averaged 30 m/hr. One plot was burned 8-10 May 1985, Flame lengths in this burn were 0.5-1.0 m and rate of spread averaged 45 m/hr. No efforts were made to protect snags before or during the fires.

Dead Trees

I selected 20 permanent sampling points in each plot by generating random coordinates which were placed on enlarged topographic maps. I located the random points in the field using a compass and tape to measure from landmarks or established points. Points in the experimental plots were located > 40 m inside plot boundaries (proposed fire lines) to avoid sampling unburned areas.

I located and marked (by blazing with an ax) all snags $\geq$ 15 cm diameter at breast height (dbh) and $\geq$ 3 m tall within 0.5 ha circular plots (39.9 m radius) centered on the random points. For each snag, I recorded species, dbh, height, top condition, percent bark cover on the trunk, numbers and degree of branching of the limbs, condition of wood on the base and trunk, and presence or absence of cavities and woodpecker foraging. I identified cavities from the ground, thus I was not certain whether all cavities recorded actually provided potential nest or roost sites. Conifer snags < 15 cm dbh were located, marked, and described within 0.1 ha circular plots (17.8 m radius) centered on random points.

Downed wood was inventoried by a standard method (Brown 1975) along 1 randomly oriented 15 m transect originating from each point. Three other 15 m transects were spaced at 90^{o} intervals from the 1st transect. Fallen dead wood $\geq$ 15 cm diameter at the middle (logs) were counted along all 4 transects and described by length, diameter at the middle, percent bark cover, wood condition, and presence or absence of woodpecker foraging.

After prescribed burning, I (1) relocated all snags left standing and recorded major changes in dbh, height, and condition of wood, (2) counted and described newly created snags in the 0.5 and 0.1 ha circular plots, and (3) repeated the inventories of downed wood and logs.

Cavity-nests

I searched for active cavity-nests in the study plots from May through July, 1984 and 1985. I described all nest trees with the measurements used for snags (see above), and by the condition of the tree (living, living with a dead portion, dead).

Bird Populations

I surveyed birds at 5 permanent stations in each plot, using the variable circular plot method (Reynolds et al. 1980) . The census stations were randomly selected from among the 20 sampling points in each plot with the limitation that they were not within 150 m of a plot boundary or another census station. One plot was visited per morning (0530-0830) from early May to late June 1984 and 1985. I counted birds at each station for 8 minutes at 2 separate, non-consecutive visits per morning. I visited each plot 5 times in 1984, and 6 times in 1985. Observations from both years were pooled and the likelihood ratio (Ramsey and Scott 1979) was used to calculate detection distances for each species with more than 40 observations annually. Mean annual density was estimated for each of those species within each treatment group (i.e., experimental and control) based on the number of observations within the area defined by the detection distance, nesting census stations within plots within

treatment groups. For most species, data from the entire census period were used to estimate density. Four species varied markedly in detectability over the breeding season, with peak detectability occurring early, mid, or late in the 6 week census period. Densities for these species were estimated using data from the 3 consecutive weeks during the peak for each species.

RESULTS

Snags and Logs

Large Snags

Availability and evidence of use by birds. I sampled 1180 snags $\geq$ 15 cm dbh on all study plots before prescribed burning (Table 1). Ponderosa pine snags dominated in abundance as well as presence of cavities and evidence of woodpecker foraging, therefore, I focused my analyses on them. Subsequent use of the term "snag" refers to ponderosa pine snags $\geq$ 15 cm dbh, unless stated otherwise. I placed snags into 3 dbh classes (Figure 1), and 6 decay classes (Figure 1, Table 2). I found cavities that, from the ground, appeared suitable for nesting in snags $\geq$ 50 cm dbh and in decay classes III and IV more frequently than expected, based on the availability of snags (Figure 1). Evidence of foraging was distributed among the dbh and decay classes in proportion to their availabilities (X^2=3.12, df=2, P>0.10 for dbh classes; X^2=1.83, df=4, P>0.50 for decay classes).

Table 1. Density[a] of snags and evidence of use by birds in ponderosa pine forests, southeastern Arizona, 1984-1985.

Species	Number per ha	Number per ha with cavities[b] (% of species)	Number per ha with woodpecker foraging sign (% of species)
ponderosa pine	12.3	3.0 (24)	11.4 (93)
oaks[c]	4.7	< 0.1 (<1)	0.9 (20)
Mexican white pine	1.3	0.1 (8)	1.0 (77)
Douglas-fir	0.6	< 0.1 (10)	0.4 (66)
other[d]	0.8	0 (0)	0.1 (12)
total	19.7	3.2 (16)	13.8 (69)

[a]Average density of all species of snags ≥ 15 cm dbh, from all plots (experimental and control) before burning was calculated by dividing total numbers of snags by the total area in the sampling units.

[b]Cavities were determined by inspection from the ground.

[c]Most oak snags were Q. hypoleucoides or Q. arizonica, a few Gambel oaks (Q. gambelii) and gray oaks (Q. grisea) were included in the sample (< 5%).

[d]Other species of snags were: New Mexico locust (Robinia neomexicana), Arizona madrone (Arbutus arizonica), alligator juniper (Juniperus deppeana), and Chihuaha pine (P. leiophylla var. chihuahuana).

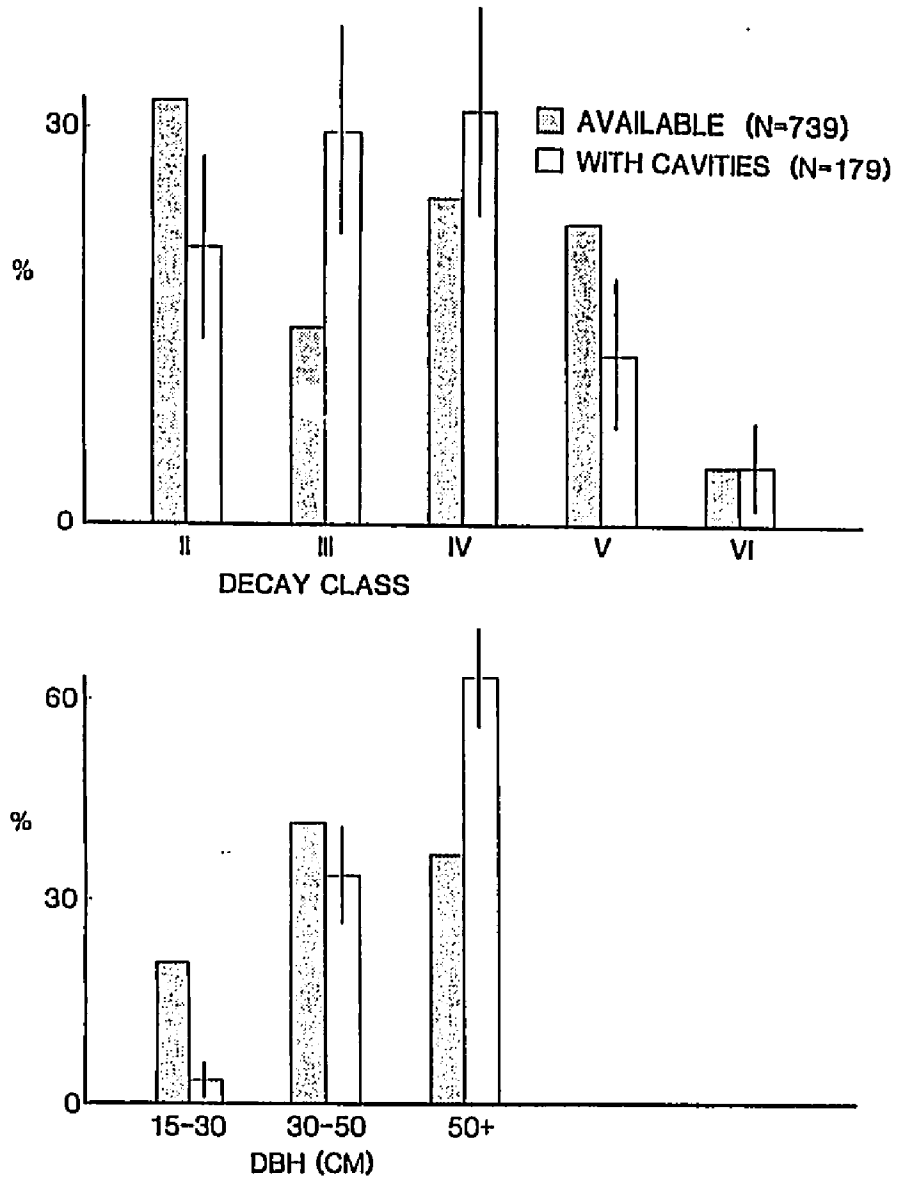

Figure 1. Occurrence of cavities in ponderosa pine snags of different decay and dbh classes, southeastern Arizona, 1984-1985. Available snags were $\geq$15 cm dbh, from the control and pre-burn experimental plots. One snag in decay class I was excluded from analysis (the only one sampled). Chi-square goodness-of-fit tests: decay classes $X^2=44.02$, df=4, $P<0.001$; dbh classes $X^2=64.18$, df=2, $P<0.001$. Confidence intervals were calculated by the method of Neu et al. (1974).

Table 2. Characteristics and abundance of decay classes of ponderosa pine snags ≥ 15 cm dbh in an unburned forest, southeastern Arizona, 1984-1985.

Decay Class[a]	Condition of Branches	Condition of Sapwood	Bark Cover (%)	Density[c] (N/ha)
I	foliage on twigs	sound	100	< 0.1
II	fine twigs present	sound-intact/rotting	75-100	4.0
III	secondary branches present	intact/rotting	25-85	1.9
IV	branch stubs present	some sloughed	10-50	3.0
V	none	much sloughed	0-50	2.5
VI	secondary branches present	sound-intact/rotting	< 10	0.5

[a]Decay classes were based on a classification system developed by Cline et al. (1980) to describe Douglas-fir snags in Oregon. I modified their system slightly to better describe the stages of decay of ponderosa pine.

[b]Decay classes I-V are numbered in order of increasing decay. Snags in class VI were a relatively uncommon, but distinct group of snags that lost their bark before the wood had decayed to any great extent. These snags appeared to have decayed at a slower rate than other snags.

[c]Average density from the pre-fire experimental and control plots.

Effects of prescribed burns. I compared effects of the 3 prescribed burns by examining the percent change-in-density of snags in a 1-way analysis of variance. Percent values were transformed using the arcsine transformation prior to the analyses (Zar 1984). The prescribed burns did not differ in their effects ($F=1.085$, $df=2,57$, $P>0.50$), therefore, I combined results from all experimental plots in subsequent analyses. Over 40% (N=219) of all snags burned down or were drastically changed by prescribed burning (Table 3). Half of the newly created snags $\geq$ 15 cm dbh were oaks (N=68) or madrones (N=6). Most snags (75%, N=114) were created from newly killed trees < 30 cm dbh. Changes in the numbers of snags on the control plots were small (< 0.5 % decrease).

The diameter of snags influenced their fate in the prescribed fires (one-way analysis of variance of the effect of dbh class on % change-in density after burning, $F=3.083$, $df=2,118$, $P<0.05$). Larger snags (snags $\geq$ 30 cm dbh) burned down more frequently. The state of decay of snags also influenced whether or not they burned down ($F=15.921$, $df=4,161$, $P<0.001$). The abundance of snags in decay classes II and VI were least affected by burning, those in classes III and V were intermediate, and snags in class IV burned down most frequently (Figure 2).

Table 3. The effect of prescribed burning on the abundance[a] of snags ≥ 15 cm dbh in a ponderosa pine forest, southeastern Arizona, 1984-1985.

	Pre-fire	Post-fire		
		Burned[b]	Added	Total
Species	N/ha	N/ha	N/ha	N/ha
ponderosa pine	11.1	5.5	0.5	6.1
oaks[c]	3.2	1.1	0.6	2.7
Mexican white pine	1.6	0.5	0.1	1.2
Douglas-fir	0.5	0.1	0.1	0.5
other[c]	0.6	0.1	0.1	0.6
total	17.0	7.3	1.4	11.1

[a]Mean density of snags, based on pre and post-fire counts at all sampling points (N=60) in the experimental plots.

[b]Snags that burned down, or were reduced > 50% in height, or with most of the sapwood removed by burning.

[c]See Table 1 for species names.

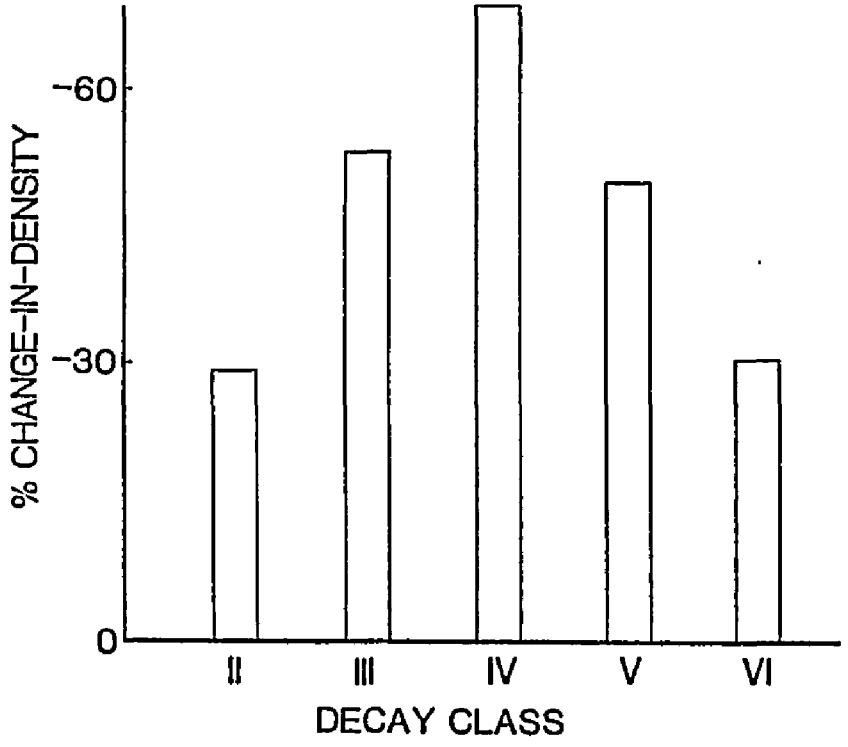

Figure 2. Influence of state-of-decay on the effects of prescribed burning of ponderosa pine snags ≥15 cm dbh, southeastern Arizona, 1984-1985. One snag in decay class I was excluded from analysis. Analysis of variance, using the arcsine transformation (Zar 1984) of % change-in-density, $F=15.92$, $df=4,161$, $P<0.001$. The histograms of % change-in-density present the untransformed statistic.

Small Snags

Availability and evidence of use by birds. Before prescribed burning, conifer snags < 15 cm dbh on the control and experimental plots were created from trees that had been killed by suppression or by fires caused by lightning. Small snags did not stand long enough to show the decay stages seen in larger snags (see Keen 1955), thus all snags of a species were grouped for analysis of abundance and evidence of woodpecker foraging (Table 4). I found no cavities in these small snags.

Effects of prescribed burns. Conifer snags < 15 cm dbh increased 24 fold in abundance after prescribed burning; 64% of these snags had been used for foraging by woodpeckers within 1 year of being created (Table 4).

Logs

Availability and evidence of use by birds. Ponderosa pines predominated in samples of logs as they did in samples of snags (Table 5). Evidence of woodpecker foraging occurred exclusively on ponderosa pine logs. Woodpecker foraging was proportionately more frequent on logs with sapwood (foraging on 43% of logs with sapwood, on 28% of logs without sapwood; $Z=1.84$, $P<0.05$).

Effects of prescribed burns. The number, and volume of logs decreased by about half after prescribed

Table 4. Abundance of conifer snags <15 cm dbh, and evidence of their use as foraging sites by woodpeckers in a ponderosa pine forest before and after prescribed burning, southeastern Arizona, 1984-1985.

	All Plots[a]		Experimental Plots[b]		
Species	N/ha	N/ha with woodpecker foraging sign	1984 N/ha	1985 N/ha	N/ha with woodpecker foraging sign
Ponderosa Pine[c]	13.0	6.5	11	221	155
Mexican White Pine	1.4	0.9	<1	48	26
Douglas-fir	0.6	0.2	<1	22	6
total	15.0	7.6	12	291	187

[a]Mean density from all sampling points (N=120) in the control and experimental plots before prescribed burning.

[b]Mean density from all sampling points (N=60) in the experimental plots, before (1984) and after (1985) prescribed burning.

[c]A few Chihuahuaha pines (<0.5%) are included in this group.

Table 5. Relative abundance of logs and evidence of use by birds on all experimental plots, southeastern Arizona, 1984-1985.

Species	Pre-fire			Post-fire		
	Total Number[a]	Number with foraging[b]	Total Volume[c]	Total Number[a]	Number with New Foraging[d]	Total Volume[c]
Ponderosa pine	134	49	93.9	78	9	41.2
Mexican white pine	1	0	0.1	1	0	0.9
Douglas-fir	4	0	0.9	2	2	5.0
Oaks	17	0	1.3	2	0	0.2

[a]Pieces of down wood $\geq$ 15 cm diameter at mid-length that intersected 1 of 4 15 m transects centered at the sampling points.

[b]Evidence of foraging by woodpeckers that appeared to have occurred after the log had fallen.

[c]m^3 [(radius at mid-length)^2 x π x length]

[d]Evidence of foraging by woodpeckers that appeared to have occurred after the fires.

burning (Table 5). Ponderosa pine logs with sapwood, which were preferred foraging sites before burning were proportionately less numerous after the fires (57% of pre-fire logs, 37% of post-fire logs; $Z=2.73$, $P<0.01$).

Cavity-nests

I located 139 active cavity-nests of 15 species of birds (Appendix C). Most nests (82%, N=114) were in ponderosa pine snags, others were in dead portions of living trees (12 ponderosa pines, 8 oaks, 1 madrone, 1 locust) or in snags of other species (1 oak, 2 Douglas-fir). I compared snags with active nests located in the control and pre-fire experimental plots (N=80) to the available snags in these plots to evaluate the preferences of 7 species of common cavity-nesting birds.

Primary Cavity-nesting Birds

I placed birds that excavate nest cavities into 2 groups: pygmy nuthatches and woodpeckers. Nests of hairy woodpeckers, acorn woodpeckers, and northern flickers were examined as a group due to the small sample of nests (N=15), and because they nested in snags with similar characteristics. Pygmy nuthatches and woodpeckers preferred snags $\geq$ 50 cm dbh as nest sites (Figure 3). Woodpeckers nested in snags in decay class II, and pygmy nuthatches nested in snags in decay class III more

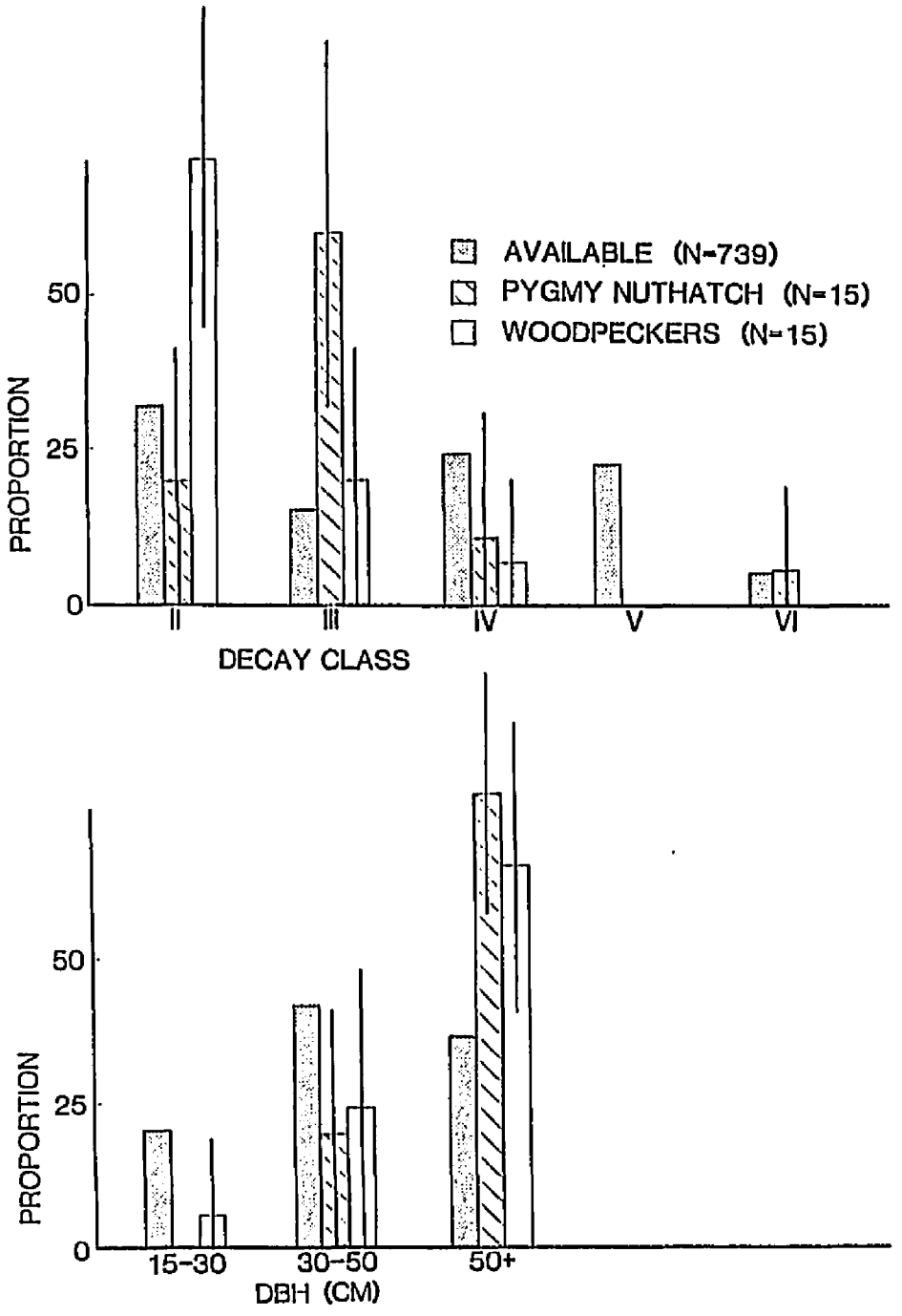

Figure 3. Selection of nest-sites by primary cavity-nesting birds among ponderosa pine snags of different decay and dbh classes, in unburned forests of southeastern Arizona, 1984 and 1985. Chi-square goodness-of-fit: nuthatches and decay class $X^2=24.62$, df=4, $P<0.001$; nuthatches and dbh class $X^2=12.44$, df=2, $P<0.01$; woodpeckers and decay class $X^2=14.35$, df=4, $P<0.01$; woodpeckers and dbh class $X^2=5.91$, df=2, $P=0.05$. Confidence intervals were calculated by the method of Neu et al. (1974).

frequently than expected, based on the availability of snags (Figure 3).

Secondary Cavity-nesting Birds

Violet-green swallows, house wrens, mountain chickadees, and western bluebirds were the common secondary-cavity nesters in my study area. Because these birds do not excavate cavities, they can select nest sites only from among snags with pre-existing cavities.

Western bluebirds and house wrens used snags for nesting in proportion to their availability with regard to dbh, but violet-green swallows did not (Figure 4). This is probably an artifact caused by 2 swallow nests found in snags in the smallest dbh class (both snags > 25 cm dbh). I did not test selection by mountain chickadees since I found only 5 nests, however they were all in snags $\geq$ 50 cm dbh.

Western bluebirds and violet-green swallows preferred snags in decay class III for nesting (Figure 4). House wrens did not select snags for nesting based on decay class (Figure 4). I found 4 of 5 mountain chickadee nests in decay class II snags.

Post-fire Cavity-nests

I did not analyze preferences for nest snags by cavity-nesting birds after prescribed burning because of the small sample of nests located (N=22 for the species

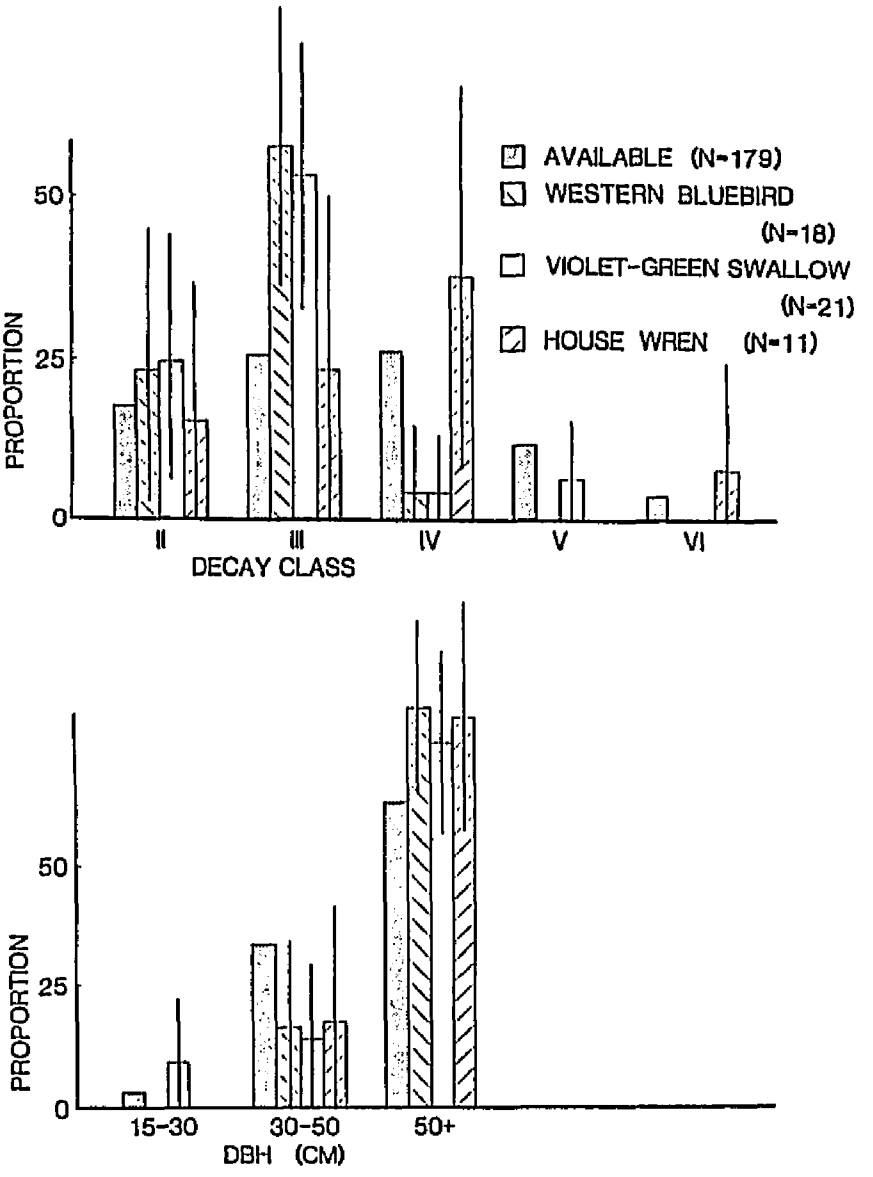

Figure 4. Selection of nest-sites by secondary cavity-nesting birds among ponderosa pine snags with cavities, of different decay and dbh classes, in unburned forests of southeastern Arizona, 1984 and 1985. Chi-square goodness-of-fit: bluebirds and decay class $X^2=14.49$, df=4, $P<0.01$; bluebirds and dbh class $X^2=3.26$, df=2, $P=0.20$; swallows and decay class $X^2=13.54$, df=4, $P<0.05$; swallows and dbh class $X^2=6.39$, df=2, $P<0.05$; wrens and decay class $X^2=2.90$, df=4, $P=0.60$; wrens and dbh class $X^2=1.88$, df=2, $P=0.40$. Confidence intervals were calculated by the method of Neu et al. (1974).

discussed above). After prescribed burning, cavity-nesting birds seemed to nest in snags that had characteristics similar to those used in the non-fire plots (i. e., 15 of 20 nests in snags were in decay classes II or III, average dbh was 64.5 $\pm$ 6.5 cm).

Bird Populations

Nineteen species of cavity-nesting birds were present in the study plots in 1984 or 1985 (Table 6, and Appendix C). No species disappeared after prescribed burning, but northern flickers and violet-green swallows decreased on the experimental plots relative to the control plots, while mountain chickadees increased (Table 6). I examined the effects of the individual prescribed burns (2 in the fall, and 1 in the spring) on numbers of cavity-nesting birds. Effects of plot within treatment on change-in-density from 1984 to 1985 were not significant ($P > 0.10$; nested analysis of variance, Hull and Nie 1981) for all species except the acorn woodpecker. The patchy distribution of acorn woodpeckers (they did not occur in 1 experimental and 1 control plot) was partially responsible for the apparent influence of the individual plots on changes in their abundance. There was a modest increase in abundance of acorn woodpeckers on the plot burned in the spring and a relatively large decrease on 1 of the fall burn plots. I can not explain these differences.

Table 6. Densities[a] (number/40 ha) of cavity-nesting birds in a ponderosa pine forest during the breeding seasons of 1984 and 1985, southeastern Arizona.

Species	Experimental		Control		D/S[b]
	1984	1985	1984	1985	
flammulated owl *Otus flammeolus*	P[c]	P	P	P	
whiskered screech-owl *Otus trichopsis*	P	P	P	P	
northern saw-whet owl *Aegolius acadicus*		P			
acorn woodpecker *Melanerpes formicivorus*	4.1	2.8	1.1	1.5	-/NS
hairy woodpecker *Picoides villosus*	0.8	1.0	0.7	0.8	0/NS
northern flicker *Colaptes auratus*	2.6	2.1	1.7	2.3	-/.07
western flycatcher[e,f] *Empidonax difficilis*	39.2	67.0	62.4	48.0	+/NS
dusky-capped flycatcher *Myiarchus tuberculifer*	P[c]	P	P	P	
ash-throated flycatcher *Myiarchus cinerascens*		P			
violet-green swallow[f] *Tachycineta thalassina*	37.4[d]	17.6[d]	31.7[d]	34.0[d]	-/.06
mountain chickadee *Parus gambeli*	5.6	12.2	7.2	7.0	+/.03
bridled titmouse *Parus wollweberi*	P	P	P	P	
white-breasted nuthatch *Sitta carolinensis*	7.0	4.2	4.4	2.9	0/NS

Table 6. Continued

Species	Experimental 1984	Experimental 1985	Control 1984	Control 1985	D/S[b]
pygmy nuthatch *Sitta pygmaea*	24.4	14.2	26.2	15.8	0/NS
brown creeper[d] *Certhia americana*	9.8	7.9	5.8	7.3	-/NS
Bewick's wren *Thryomanes bewickii*	P	P	P	P	
house wren[d,f] *Troglodytes aedon*	15.0	46.2	53.2	91.8	+/NS
eastern bluebird *Sialia sialis*				P	
western bluebird[f] *Sialia mexicana*	12.5	6.2	11.3	6.1	0/NS

[a]I estimated the density of cavity-nesting birds based on the number of observations within species-specific detection distances at census stations, which were nested within plots which were nested within treatment groups (i.e., experimental and control).

[b]I tested changes in abundance from 1984 to 1985 on the experimental plots relative to changes on the control plots. Changes-in-density were used in nested analysis of variance (Hull and Nie 1981), with census stations nested within plots which were nested within treatments, to evaluate the impacts of prescribed burning on abundance of common species of cavity-nesting birds. I reported direction (D) (+, 0, or -), and significance (S) of changes. I reported $P < 0.10$, changes with $P > 0.10$ were considered not significant (NS).

[c]I did not count nocturnal birds, their presence (P) was determined by chance diurnal observations and non-systematic nocturnal visits to study plots. Several diurnal species were present (P), but were at the upper limits of their elevational ranges and were too rare to permit calculation of meaningful density estimates.

Table 6. Continued

[d]Birds noted in flight within a 50 m radius were counted.

[e]Estimates of density derived exclusively from counts of singing males were doubled (Emlen 1971, Franzreb 1976).

[f]Estimates of density were derived from the 3 consecutive censuses within that species peak of detectability.

DISCUSSION

Characteristics of Snags Used for Nesting

Cavity-nesting birds in western coniferous forests are highly selective in their choices of nest sites (McLelland and Frissell 1975, Scott 1978, Cunningham et al. 1980, Mannan et al. 1980, Raphael and White 1984). Most cavity-nesting birds in my plots nested in ponderosa pine snags $\geq$ 50 cm dbh, and in decay classes II or III. These types of snags comprised only 13% of all snags $\geq$ 15 cm dbh before prescribed burning. In contrast to evidence provided by observations of active nests, cavities that appeared to an observer on the ground to be suitable for nesting, occured most frequently in snags of decay classes III and IV. Snags in the later stages of decay had the opportunity to accumulate cavities over a greater period of time than did less decayed snags. Most cavities in snags in decay class IV probably did not provide suitable nest sites due to changes in their internal structure associated with the more advanced state of decay of the snags. Cavities were rare in snags of decay class V, because the boles of these snags had broken off during the process of decay.

Effects of Prescribed Burning

Snags

The prescribed fires in my study burned nearly half of all ponderosa pine snags ≥ 15 cm dbh, but the snags that burned were not a random sample. Large snags (>30 cm dbh) and snags in decay class IV burned down more frequently than did other snags. The flammability and caloric content of the broken limbs, sloughed wood and bark at the base of a snag probably influenced whether or not that particular snag burned. Snags with large amounts of loose, relatively undecayed woody material at their bases, such as snags in decay class IV and many large snags, tended to be susceptible to burning because the material formed a pyre which often ignited the snag it surrounded. Snags in decay class V, however had much woody material at their bases but were only moderately susceptible to burning because the fallen wood had lost much of its caloric content in the decay process and was becoming incorporated into the forest floor and thus was not as well aerated as the less decayed material around "younger" snags.

Potential Nest Sites

Snags with the characteristics preferred by most cavity-nesting birds (i.e., ponderosa pine snags ≥ 50 cm dbh and in decay classes II or III) were reduced from

1.5/ha to 1.0/ha by prescribed burning. Snags with these characteristics made up a higher proportion of the population of snags after burning (13% before, 18% after), due to the higher rate of loss of less suitable snags. Ponderosa pine trees $\geq$ 50 cm dbh, that died in the first year after burning created 0.2 large snags/ha. These snags could become suitable for excavation of cavities within 5-20 years, and continue to provide nest sites for over 30 years (Cunningham et al 1980). The numerous small snags ($<$ 15 cm dbh) created by the fires frequently showed evidence of foraging by woodpeckers. The breeding season censuses did not document an influx of woodpeckers as has been noted after some wildfires (e.g., Blackford 1955, Koplin 1969), however I did notice that woodpeckers appeared to be especially abundant in the post-fire plots in the late summer and fall.

Bird Populations

Northern flickers and violet-green swallows decreased after prescribed burning. Although fewer snags were available for nesting after the fires, I can not attribute the decreases in abundance of either of these species to reduced availability of nest-sites.

Northern flickers appeared to nest in snags similar to those used by other primary cavity-nesting birds in my study area. Raphael and White (1984) suggested

that the minimum density of suitable snags necessary to provide the annual requirements for populations of primary cavity-nesting birds could be estimated by multiplying the density of pairs of each species by the average number of cavities excavated annually by that species, then summing the results for all species. Using this method, the minimum density of suitable snags necessary to provide the annual requirements for pre-fire populations of all primary cavity-nesters on the experimental plots was 25-40/ha. Post-fire density of snags $\geq$ 50 cm dbh in decay classes II and III was 40/40 ha. Note that by using snags $\leq$ 50 cm dbh in these calculations (i.e., "preferred" rather than "acceptable"), I am providing a conservative estimate of suitable nest sites.

Western bluebirds and mountain chickadees nested in snags similar to those used by violet-green swallows. I estimated the combined populations of bluebirds and chickadees to be about 9 pairs/40 ha. My census method for violet-green swallows resulted in estimates of relative abundance, however Balda (1975), and Szaro and Balda (1979) reported absolute densities of 3-9 pairs/40 ha from southeastern and central Arizona ponderosa pine forests. Using the method of Raphael and White (1984), and assuming 3-9 pairs of swallows in 40 ha, I estimated that the minimum annual requirements of the pre-fire population of

common secondary cavity-nesters was 12-18 suitable snags/ha (snags in classes II and III with cavities). The density of suitable snags was about 28/40 ha after burning (calculated by applying the % of all class II and III snags with cavities to post-fire densities of classes II and III).

I suspect that the post-fire decrease in abundance of northern flickers on the experimental plots with a concurrent increase on the control plots was due to post-fire decreases in the abundance of prey and subsequent shifts in areas used for foraging by flickers. Northern flickers have home ranges that could have included portions of both burned and unburned areas, and they feed heavily on ants (Bent 1939) in logs and forest floor duff. If ants and other prey decreased along with the volume and number of logs, and depth of duff (see Appendix B) which did decrease after prescribed burning, flickers may have shifted some of their foraging activities to unburned portions of their home ranges. A similar reasoning may be applied to the post-fire decrease in violet-green swallow numbers, but I have no data to support or refute this hypothesis.

Mountain chickadees increased dramatically in abundance after prescribed burning, but showed little change on the control plots. Granholm (1982) found consistent decreases in mountain chickadee populations .

after prescribed burning in Sierra Nevada coniferous forests. He proposed that the population changes were related to decreases in prey resources. Mountain chickadees feed primarily on arthropods gleaned from foliage in the canopy. Canopy foliage was scorched to a much greater extent in the Sierra Nevada fires (8-12 m scorch height) than in this study (2-5 m, see Appendix A), however I have no explanation for the increase in the abundance of mountain chickadees I observed.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

A single application of moderately intense surface fire caused a large reduction in the abundance of ponderosa pine snags $\geq$ 15 cm dbh, but had only a small impact, in the breeding season after burning, on the abundance of cavity-nesting birds in a ponderosa pine forest with many snags suitable for nesting. Snags in the early stages of decay were preferred as nest sites by most species of cavity-nesting birds and were less affected by burning than were snags in the later stages of decay. I believe that the post-fire decreases in abundance of cavity-nesting birds were due more to ephemeral changes in food resources than to the availability of nest sites. The prescribed fires killed some trees and weakened others so that they may be susceptible to fatal attacks by insects or pathogens in the future (Dieterich 1979). Snags created by the prescribed fires will probably be available for nesting for 30 or more years post-fire. Cavity-nesting birds in my study area will probably not be limited by the availability of nest-sites from the single application of prescribed burning reported here.

Forest managers suggest burning at regular intervals for the reduction of fire hazards in ponderosa

pine forests, recommended intervals are often 5-10 years. Frequent prescribed burning would result in further reduction of forest floor fuels with successively lower-intensity fires. I hypothesize that the large snags used most frequently for nesting by cavity-nesting birds (i.e., those in the early stages of decay) may not require active protection during low intensity fires in ponderosa pine forests subject to regular prescribed burning. This hypothesis needs to be examined experimentally before being applied by fire managers in ponderosa pine forests with abundant snags.

Low densities of snags limit cavity-nesting bird populations in ponderosa pine forests subject to intensive management for timber production (Franzreb and Ohmart 1978, Scott 1979, Szaro and Balda 1979). In these areas, active protection of individual snags should be considered when planning prescribed fires. Wildlife managers should not assume that all snags with cavities provide suitable nest sites for cavity-nesting birds, as snags in the more advanced stages of decay retain many cavities that are seldom used as nest sites. Snags $\geq$ 50 cm dbh in decay classes II and III will provide most cavity-nesting birds with appropriate nesting substrates, while snags in decay class I will provide future nest sites. Fire crews can construct fuel breaks around these snags during pre-burn preparation or while igniting the burns. Snags in the

early stages of decay will usually be relatively easy to protect due to the small amounts of flammable debris at their bases.

APPENDIX A

THE EFFECTS OF PRESCRIBED BURNING ON VEGETATION AND BIRDS THAT NEST OR FORAGE ON THE GROUND OR IN THE UNDERSTORY, IN A PONDEROSA PINE FOREST OF SOUTHEASTERN ARIZONA, 1984-1985

INTRODUCTION

Effective and widespread fire suppression during the 20th century has altered successional patterns and changed the composition and structure of vegetation in southwestern ponderosa pine forests that developed in a regime of frequent natural fires. Fire intolerant, and shade tolerant species have increased in abundance (Weaver 1974). Prolonged periods without fire have allowed dense thickets of small trees to persist, and altered the historically open, park-like structure of these forests (Cooper 1960).

The distribution and abundance of birds is affected by the composition and structure of vegetation (MacArthur and MacArthur 1961, Willson 1974, James and Wamer 1982), and thus bird communities can change with successional changes in plant communities (Karr 1968, Bock and Lynch 1970, Shugart and James 1973, Engstrom et al. 1984). Removal of fire as an ecological factor in

ponderosa pine forests may have changed bird communities by creating conditions favorable for species that prefer dense, brushy areas at the expense of those that prefer openings (Marshall 1963).

Prescribed burning is advocated as a means to reduce the incidence of disastrous wildfires by reducing woody fuels and thinning dense sapling thickets that act as "fuel ladders" to carry fire into the crowns of overstory trees (Biswell et al. 1973, Harrington 1981). Periodic prescribed burning can reverse changes in forest vegetation brought about by long-term fire suppression, possibly changing southwestern pine forests so that they more closely resemble their historic condition. The changes in abundance and distribution of bird species that presumably occurred in these forests over the last 50 years may also be reversed, however few studies have documented the effects of prescribed fire on birds. Emlen (1970), Kilgore (1971), and Granholm (1982) suggested that prescribed burning may have negative impacts on some birds that nest or forage on the ground or in understory vegetation, but that species associated with forest openings and some aerial and ground foraging species may benefit.

My objectives were (1) to compare the structure and composition of vegetation before and after prescribed

burning in a ponderosa pine forest to describe the major short-term impacts of burning, (2) to compare breeding populations of birds that nest or forage on or near the ground before and after prescribed burning to identify species that responded to the treatment with changes in abundance in the first year after burning, (3) to describe nesting and foraging sites of birds that nest or forage on or near the ground and evaluate the effects of prescribed burning on similar sites, in order to suggest explanations for changes in the abundance of any of these bird species.

STUDY AREA AND METHODS

This study was conducted concurrently with the study of cavity-nesting birds reported in the previous section. The study area, plots, prescribed burning, and sampling points are described on pages 3-5.

Vegetation

I counted and described all trees and shrubs within 0.05 ha circular plots (12.6 m radius) centered on the 20 sampling points in each experimental plot (Mueller-Dombois and Ellenberg 1974). Edges of the circular plots were permanently marked by blazing trees on the boundaries. In the control plots, the sampling units for trees <15 cm dbh and shrubs were 0.025 ha circular plots (8.9 m radius), trees $\geq$15 cm dbh were sampled in 0.05 ha

plots. Trees and large shrubs were placed into 4 groups; 1) oaks, 2) ponderosa pines 3) other conifers (Douglas-fir and Mexican white pine), and 4) other hardwoods (madrone, locust, and other uncommon trees and shrubs). Canopy volumes of all trees and shrubs were estimated by a modification of the method described by Sturnam (1968). Maximum height, height of the lower canopy, canopy width, and width of the inner, leafless portion of the canopy were estimated for each plant. Plants were designated as belonging to 1 of 3 geometric shapes (cylinder, cone, or hemi-ellipsoid). Volumes in horizontal slices (0.25 m tall from 0-2 m above ground, 0.5 m tall from 2-10 m, and 1 m tall above 10 m) were calculated by integrating the dimensions of each plant over the height intervals described above. I estimated canopy cover above 2 m using the method described by Emlen (1967), vertical sightings were taken at 1 m intervals along 4 transects 15 m in length that were spaced at 90^{o} intervals. I sampled ground cover vegetation along each transect using the planar-intercept method (Canfield 1941). I classified ground cover vegetation into 4 groups based on life-form; 1) grasses, 2) small shrubs, 3) forbs, and 4) ferns.

All measurements were repeated in the experimental plots after prescribed burning.

Bird Populations

Bird census techniques are described on page 7.

Nest Sites

I searched for active nests of 4 species of birds that nest on or near the ground (western flycatcher, Virginia's warbler, red-faced warbler, and yellow-eyed junco) from May through June, 1984 and 1985. I described nest sites by the same measurements used to describe vegetation in the control plots.

Foraging Behavior

I studied foraging behavior of 4 species of birds that forage on the ground or in the understory (western flycatcher, Virginia's warbler, red-faced warbler, and yellow-eyed junco). I followed individual birds in the control and experimental plots, and recorded information about their foraging activities from May through June, 1984 and 1985. I described the foraging acts that occurred closest in time to soft tones produced at 15 second intervals by an electronic timer (Wiens et al. 1970) until I lost sight of the bird, but for no longer than 5 minutes for any individual. I classified the foraging activity (glean, hover-glean, or sally), and described foraging locations by plant species, height above ground, and site (foliage, bark, ground, air, etc.).

RESULTS

Vegetation

Woody Vegetation

The understory was primarily composed of shrubs and small trees of silver-leaf and Arizona white oaks, and small ponderosa pines, Mexican white pines, and Douglas-firs. Shrubs and small trees of the oak species were the most abundant understory plants, followed by small ponderosa pines, then the other conifer species (Table 1). Oaks made the greatest contribution to the volume of live canopy in the understory (41% of the total canopy volume below 5 m, see Table 2). Combined canopy volume of Douglas-fir and Mexican white pine in the understory was slightly greater than that of ponderosa pine (Table 2). Oaks were the most abundant trees $\leq$30 cm dbh, while ponderosa pines were the most abundant trees $\geq$50 cm dbh (Table 1). Oaks made only a minor contribution to the overstory (5% of total canopy volume above 5 m, Table 2). Canopy volume of ponderosa pine in the overstory was 7 times that of the other conifers (83% vs. 12% of the total canopy volume above 5 m, Table 2).

Ground Cover

Ground cover by grasses, shrubs, forbs, and ferns was abundant in patches but sparse overall (Table 1).

Effects of Prescribed Burns

I examined the effects of the individual prescribed burns (2 in the fall, 1 in the spring) on the change in abundance of live woody plants (mortality), and on the change in total volume of live canopy (scorching). There were no significant differences between the individual burns in their effects on mortality (Kruskal-Wallis statistic=2.87, P=0.24). The individual burns did differ in the amounts of scorching they produced (Kruskal-Wallis statistic=10.22, $P<0.01$), with the greatest scorching loss occurring in the spring burn. However, the plot burned in the spring had the highest volume of canopy in the understory (i.e., below 5 m), and scorching was strongly correlated with understory canopy volume ($r=0.84$, $P<0.001$). Therefore I lumped all burn plots in subsequent analyses. Prescribed burning caused a 40% decrease in the abundance of living woody plants (Table 1). Shrubs and small trees (<15 cm dbh) experienced far greater mortality than trees $\geq$15 cm dbh (Table 1). The total volume of living canopy decreased by 19% (see Figure 1). Prescribed burning reduced total canopy volume below 2 m by 61%, by 32% from 2-5 m, and by 5% above 5 m (Figure 1). Canopy volumes of all species of woody plants were reduced in the fires; oaks by 30%, ponderosa pines by 10%, other conifers by 35%, and other hardwoods by 43% (Figure 1).

Table 1. The effects of prescribed burning on the composition of vegetation in a ponderosa pine forest, southeastern Arizona, 1984-1985.

	Experimental Plots	
	Before burning	After burning[a]
Oaks[b] (N/ha)		
Shrubs>0.25 m tall	570	180**
Trees<15 cm dbh	1726	936**
15≤trees<30 cm dbh	196	182**
30≤trees<50 cm dbh	72	66*
Trees≥50 cm dbh	8	8
Ponderosa pine (N/ha)		
Trees<15 cm dbh	1087	559**
15≤trees<30 cm dbh	96	86*
30≤trees<50 cm dbh	38	38
Trees≥50 cm dbh	26	25
Other conifers[c] (N/ha)		
Trees<15 cm dbh	237	124**
15≤trees<30 cm dbh	28	24*
30≤trees<50 cm dbh	4	4
Trees≥50 cm dbh	2	2

Table 1. Continued

Other hardwoods[d] (N/ha)		
Shrubs>0.25 m tall	140	78[f]
Trees<15 cm dbh	14	9*
30≤trees<30 cm dbh	4	4
30≤trees<50 cm dbh	<1	<1
Ground cover (%)		
Grasses[e]	2.5	1.1**
Shrubs[f]<0.25 m tall	2.0	0.6**
Forbs	0.5	0.4
Ferns[g]	1.5	1.3

[a]Post-fire averages that differ significantly from pre-fire averages are marked by; * ($P<0.05$), or ** ($P<0.01$).

[b]Most oaks were Q. hypoleucoides or Q. arizonica, a few Gambel oaks (Q. gambelii) and gray oaks (Q. grisea) were included in the sample (total<5%).

[c]Other conifers were primarily Douglas-fir and Mexican white pine, a few (< 1%) alligator junipers (Juniperus deppeana) were included in the sample.

[d]Common species were: New Mexico locust (Robinia neomexicana), Arizona madrone (Arbutus arizonica), and birchleaf buckthorn (Rhamnus betulafolia).

[e]Includes sedges and rushes.

[f]Includes seedlings of oaks, conifers, and other hardwood trees. Shrubs taller than 0.25 m were included in the canopy volume estimates and were not recorded here.

[g]Over 99% of cover of ferns was by bracken (Pteridium aquilinum).

Table 2. Height-relative canopy volumes (CV) of woody plants and relative abundance of ground cover vegetation around random points, and nests of Virginia's warblers in an unburned ponderosa pine forest, southeastern Arizona, 1984-1985.

	Random points (n=120)	Nest-sites[a] (n=15)
CV oaks[b] (m^3/ha)		
0-2 m	846	1138*
2-5 m	2452	2596
>5 m	646	442
CV ponderosa pine (m^3/ha)		
0-2 m	436	304
2-5 m	1836	1214
>5 m	10558	7650
CV other conifers[b] (m^3/ha)		
0-2 m	962	540
2-5 m	1738	1514
>5 m	1500	1102
CV other hardwoods[b] (m^3/ha)		
0-2 m	68	34
2-5 m	52	72
>5 m	10	330**

Table 2. Continued.

Ground cover vegetation (%)		
Grasses[b]	2.9	7.2**
Forbs	0.5	0.9**
Ferns[b]	1.7	0*
Shrubs[b]	1.8	1.0

[a] Significant differences (Mann-Whitney-Wilcoxon tests) are marked by; * ($P<0.05$), or ** ($p<0.01$).

[b] See the footnotes in Table 1 for descriptions of these groups of species.

Following prescribed burning, areal cover of ground-cover vegetation was reduced by 49% (Table 1). Cover of grasses and shrubs declined drastically, however forbs and ferns were little affected (Table 1).

Bird Populations

I recorded 57 species of birds in my study areas between early May and late June, 1984 and 1985 (Appendix C). No species disappeared following prescribed burning. There were 10 species of birds that nested, or foraged on or near the ground (Table 3). The individual prescribed burns did not differ in their effects on the abundance of 9 of these species. Effects of plot (i.e., the individual control and experimental plots) within treatment (burn and non-burn) on change-in-density from 1984 to 1985 were not significant ($P>0.10$; nested analysis of variance, Hull and Nie 1981) for all species except the rufous-sided towhee. This difference was due to the local occurrence of towhees rather than to effects of the individual burns (they occurred on only 1 of the plots burned in the fall, and on 2 of the control plots). Two species increased in abundance on the post-fire plots but decreased on the control plots, while 3 species showed the opposite trend after burning (Table 3). The abundance of Virginia's warblers decreased by 49% after burning, with a concurrent 47% increase in the control plots. They were the only

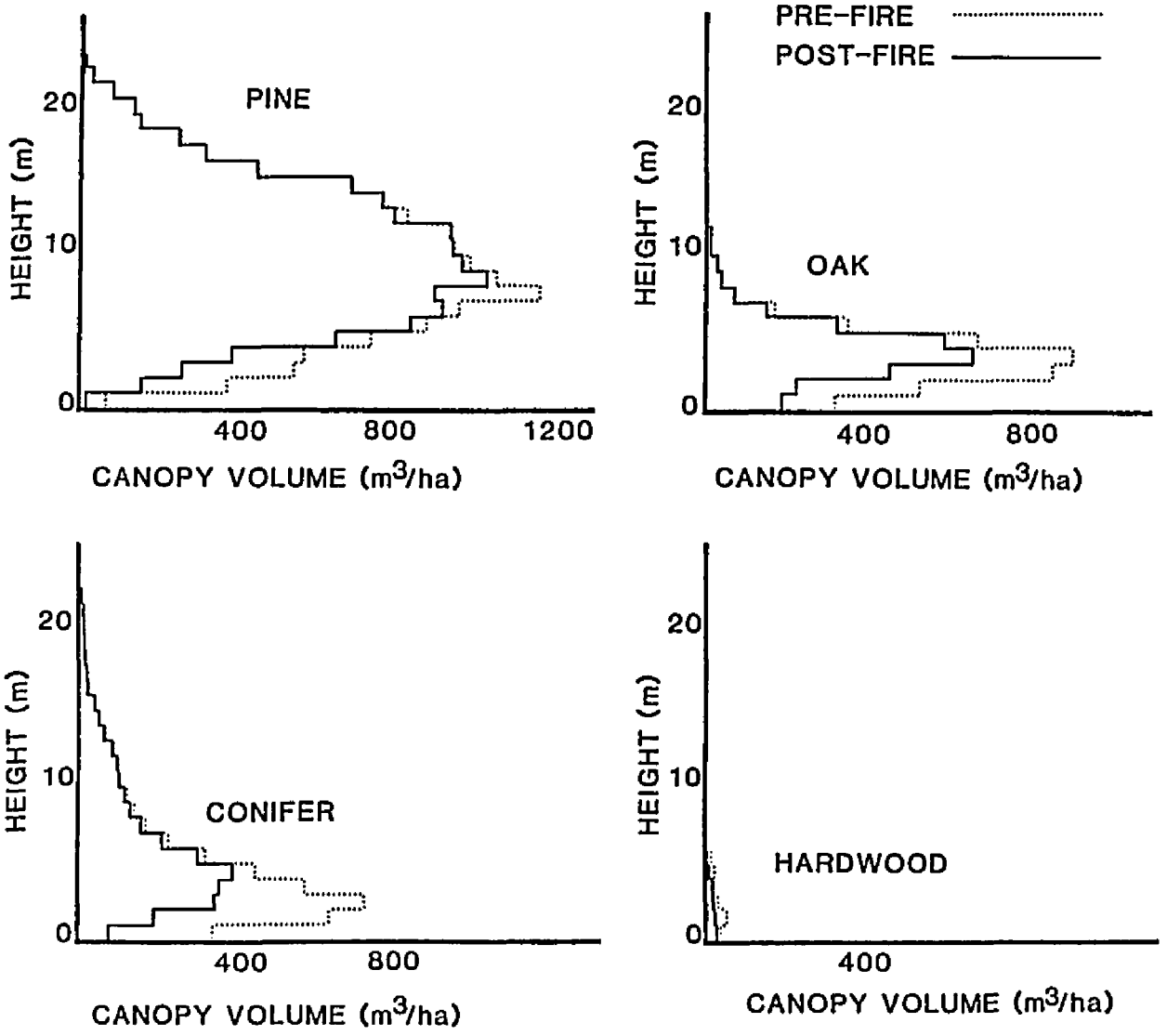

Figure 1. Effects of prescribed burning on the vertical distribution of volume of living canopy of 4 groups of species of woody plants in a ponderosa pine forest, southeastern Arizona, 1984-1985. (See Table 1 for descriptions of the groups of species)

Table 3. The abundance of birds that nest or forage on or near the ground in a ponderosa pine forest of southeastern Arizona, breeding seasons of 1984 and 1985.

	Mean Number[a] of Birds/40 ha				
	Experimental		Control		
	Pre-fire	Post-fire			
Species	1984	1985	1984	1985	D/S[b]
whip-poor-will[c,e] *Caprimulgus vociferus*	P	P	P	P	
western flycatcher[d,f,h] *Empidonax difficilis*	39.2	67.0	62.4	48.0	+/NS
western bluebird[g] *Sialia mexicana*	12.5	6.2	11.3	6.1	0/NS
hermit thrush[d,f,g] *Catharus guttatus*	4.4	9.0	3.0	8.8	0/NS
American robin[f,g] *Turdus migratorius*	1.8	1.1	2.5	2.1	0/NS
Virginia's warbler[d,e,h] *Vermivora virginiae*	85.4	43.8	101.6	149.8	-/.04
red-faced warbler[d,e,h] *Cardinella rubifrons*	105.2	92.6	95.8	102.6	-/NS
painted redstart[d,e,h] *Myioborus pictus*	13.2	19.0	8.4	25.8	0/NS
rufous-sided towhee[e,g] *Pipilo erythrophthalmus*	7.8	15.8	33.0	22.0	+/NS
yellow-eyed junco[d,e,g] *Junco phaeonotus*	62.6	62.4	50.6	70.6	-/NS

Table 5. Continued

[a]Mean annual abundances were based on counts at each census station which were nested within plots, which were nested within treatment groups.

[b]I tested changes in abundance from 1984 to 1985 on the experimental plots relative to changes on the control plots. Changes-in-density were used in nested analysis of variance (Hull and Nie 1981), with census stations nested within plots which were nested within treatments, to evaluate the impacts of prescribed burning on abundance of common species of birds that nested or foraged on or near the ground. I reported direction (D) (+, 0, or -), and significance (S) of changes. I reported $P < 0.10$, changes with $P > 0.10$ were considered not significant (NS).

[c]I did not count nocturnal birds, their presence (P) was determined by chance diurnal observations and non-systematic nocturnal visits to study plots.

[d]Densities derived from counts of singing males were doubled (Emlen 1971, Franzreb 1976).

[e]Nests on the ground.

[f]Commonly nests < 5 m from the ground.

[g]Commonly forages on the ground.

[h]Commonly forages < 5 m from the ground.

species that showed a population response to prescribed burning that was statistically significant ($P<0.1$).

Virginia's Warbler

I examined the effects of prescribed burning on the nesting and foraging habitat of Virginia's warblers, because they were the only species that showed a significant change in abundance following prescribed burning.

Nest Sites

Characteristics of nest sites. I located 15 active nests of Virginia's warblers in the pre-fire experimental or control plots. I was not able to locate any nests in the post-fire plots. All nests were on the ground. Nine nests were hidden among the thatch of a species of perennial bunchgrass, pine dropseed (*Blepharoneuron tricholepis*). Six nests were hidden under low foliage of oaks (4 silver-leaf, 2 Arizona white oaks). The structure and composition of vegetation around nests of Virginia's warblers generally resembled that around random points in the unburned forest (Table 2). Nesting cover (i.e., canopy volume of oaks below 2 m, and cover of grasses) was more abundant around nest-sites than random points (Table 2). The average canopy volume of hardwoods (other than oaks) above 5 m was much greater around nest-

sites than random points, however this varied tremendously (range 0-1360 m^3/ha) around the 15 nests studied.

Availability of nest sites. I estimated the availability of nest sites for Virginia's warblers by comparing the characteristics of vegetation used for nesting cover (i.e., canopy of oaks below 2 m , and cover of grasses) at each of the 120 random sampling points (control and pre-fire experimental) to 95% confidence intervals around mean values of these characteristics from nest sites of Virginia's warblers. Random points with estimates of these characteristics that were within the confidence intervals around the mean values from nest sites of Virginia's warblers were considered to represent available nest sites. Nearly 1/3 (37/120) of all random points resembled warbler nests in the volume of canopy of oaks below 2 m, however, many fewer points (9/120) resembled warbler nests when cover of grasses was considered.

Effects of prescribed burns. Fifteen of 60 random points in the pre-fire experimental plots resembled Virginia's warbler nest sites with regard to the volume of oak canopy below 2 m, but only 4 of 60 resembled nest sites when the cover of grasses was included in the comparison. No random points that had previously been unlike nest sites were changed by prescribed burning to

unlike nest sites were changed by prescribed burning to resemble nest sites. Random points that resembled warbler nests in the canopy volume of oaks below 2 m were reduced by 67% (to 5/60) after burning. No post-fire random sites resembled warbler nests when cover of grasses was included in the comparison.

Foraging Sites

Availability and use of foraging sites. I recorded 339 observations of foraging behavior of Virginia's warblers during the breeding seasons of 1984 and 1985, in the pre-fire experimental and control plots. Virginia's warblers foraged almost exclusively by gleaning living foliage (334 of 339 observations). Virginia's warblers foraged below 5 m, and in oaks more frequently than expected, based on the availability of volume of living canopy (Figure 2).

Effects of prescribed burns. I was not able to record enough instances of foraging behavior of Virginia's warblers in the post-fire plots to draw any conclusions about habitat use after the burns. Total volumes of living canopy in the height strata, and of the plant species used predominantly when foraging before prescribed burning (below 5 m, and oaks, respectively) were much less available after the burns (see Figure 1).

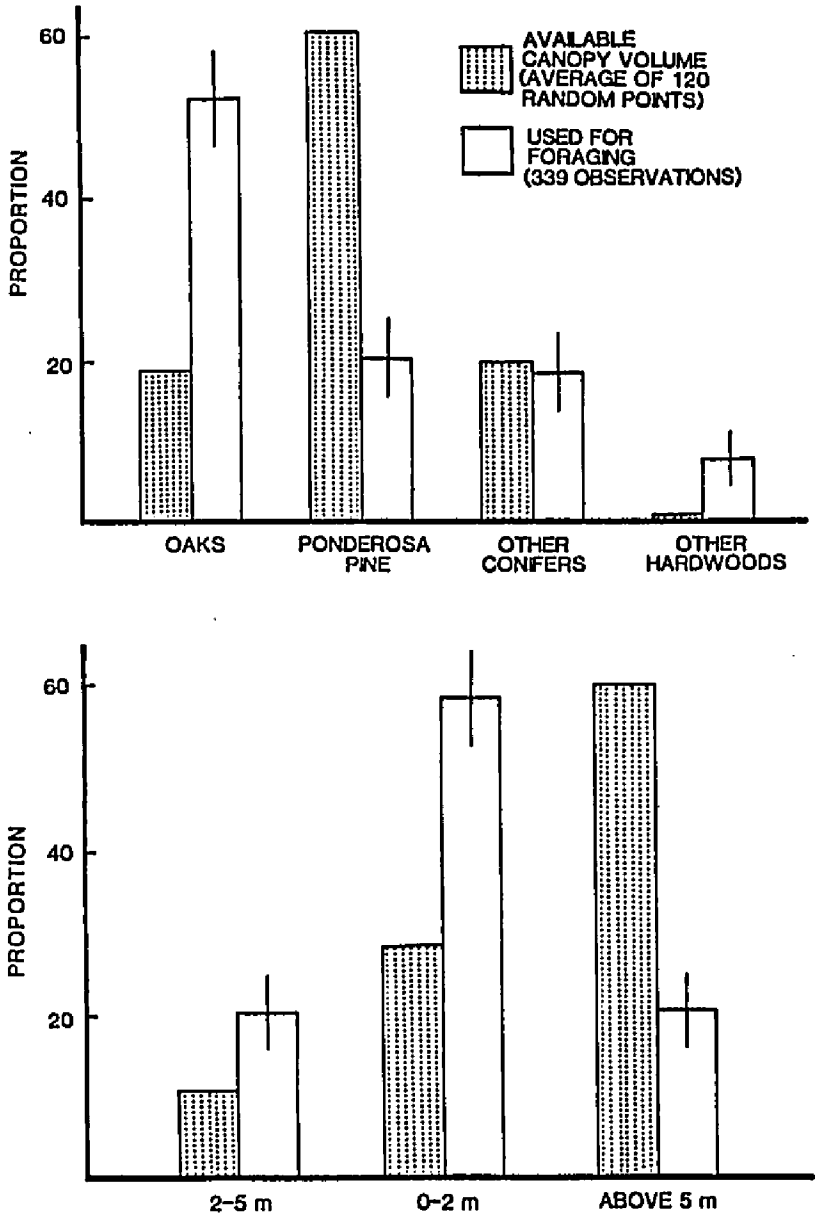

Figure 2. Selection of foraging sites by Virginia's warblers among living canopy of woody plants with regard to species of plant and height of foraging, unburned ponderosa pine forests of southeastern Arizona, 1984-1985. Chi-square goodness-of-fit: species of plant $X^2=577$, df=3, $P<0.0001$; height of foraging $X^2=218$, df=2, $P<0.0001$. Confidence intervals were calculated by the method of Neu et al. (1974).

DISCUSSION

Composition and Structure of Woody Vegetation Before Prescribed Burning

Ponderosa pine forests of the mountains of southeastern Arizona differ from the better studied forests of central Arizona by possessing an important component of evergreen oaks. Even in light of the somewhat different plant community, the rather dense understory of oaks and small conifers in my study areas contrasts sharply with historical accounts that describe the open, park-like structure of ponderosa pine forests in the southwest prior to the advent of widespread fire suppression. In my study areas, small ponderosa pines outnumbered small Douglas-firs and Mexican white pines by more than 4 to 1, however in the understory, canopy volume of the other conifers was slightly greater than that of ponderosa pine. This phenomenon was accentuated by an artifact caused by my method of estimating canopy volumes. The method provided an estimate of the volume containing the living canopy, but not of the actual amount of foliage within that space. Small Mexican white pines characteristically had broadly conical, open canopies that contained relatively little foliage within a large volume. Living canopy of Douglas-fir and Mexican white pine was

over-represented in the understory, relative to the contribution to the overstory by these species. Mature individuals of these shade-tolerant, climax species occurred primarily in areas of northerly aspect or in mesic canyons, but small trees occurred throughout the plots. The high proportion of small shade-tolerant conifers to mature trees of these species indicates that recent conditions have been especially favorable for the establishment and growth of these climax species. Fire suppression favored the establishment and growth of shade-tolerant conifers in my study areas as it has in other western coniferous forests (Parsons and DeBenedetti 1979). Other understory vegetation was probably also more abundant due to fire suppression than it would have been under a natural fire regime. Ponderosa pines dominated the overstory due to their superior ability to grow and reproduce under the regime of frequent natural fires that occurred in the area until the early 20th century.

Effects of Prescribed Burning

Woody Vegetation

Prescribed burning reduced the abundance of woody plants, and the amount of live foliage of trees and shrubs. The effects of fire were greatest among shrubs and small trees of all species, and among understory foliage in general. Low foliage was exposed to more intense

heating during the surface fires, thus it suffered greater mortality. Small trees of all species often grew in dense highly flammable thickets. The interlaced canopies in these thickets allowed flames to spread from tree to tree, killing many. Prescribed burning killed trees and low foliage of conifers of all species similarly, but overall the impact on volume of live canopy was greater on the climax species. Most (82%) of the live canopy of ponderosa pine was above 5 m, and thus was exposed to less heating, whereas 64% of the canopy of the shade-tolerant conifers was below 5 m. Most of the mortality suffered by oaks was to shrubs and the smaller trees. By the first fall following the burns, many oaks that had been killed above ground were sprouting vigorously from the stumps.

Ground Cover

Cover of small shrubs and grasses were the components of ground cover vegetation most affected by the fires. The grasses were mainly perennials, and many plants survived the burns. The new shoots of these plants were lush and vigorous by the end of the first season after burning. After the summer rainy season following the prescribed burns, I noted many seedlings of several species of shrubs.

Bird Populations

Breeding season populations of most species of birds that associated with ground cover or understory vegetation showed little change, one season after prescribed burning. No species disappeared from the post-fire plots. Only 1 of 5 species that changed in abundance relative to changes on the control plots, changed with sufficient magnitude and consistency to be statistically significant. I suggest 3 reasons that could apply singly or in combination, for the apparently minor impact of burning on the breeding season abundance of birds that associated with ground cover and understory vegetation that was much affected by prescribed burning: 1) I censused birds mainly by counting territorial males. These birds may have been singing in areas that no longer provided adequate resources for fledging young, but continued to attract birds that retained a fidelity to territories of the previous seasons. Other birds may have been unable to maintain territories in more suitable areas, but found the post-fire areas marginally acceptable (see Brown 1969). 2) Although there were large reductions of understory and ground cover vegetation, much survived the fires and many small patches were entirely unburned. The post-fire vegetation may have been sufficiently similar to pre-fire vegetation to minimize impacts (either

positive or negative) on breeding birds. 3) The small sample size, 3 experimental and 3 control plots, may have limited my ability to discern relatively subtle population changes.

Virginia's Warbler

The Virginia's warbler was one of the most abundant species of breeding birds in the unburned plots. After prescribed burning, Virginia's warblers declined drastically in abundance on the burned plots, with a concurrent increase on the unburned plots. This decline was almost certainly due to the effects of prescribed burning on the availability of vegetation used for nesting cover and as foraging sites. Prescribed burning reduced the cover of grasses, and the amount of low foliage of oaks. This was a direct reduction of nesting cover for the warblers. Their preferred foraging sites, i.e., foliage below 5 m, and foliage of oaks, were also much reduced by the fires.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The ponderosa pine forest in my study areas was typical of forests in which the frequent natural fires that held back succession of the plant community have been largely eliminated by management activities. The forest understory was relatively dense, and small trees of

species typical of the climax community were well represented in the understory, but uncommon in the overstory. Prescribed burning effectively altered the composition and structure of vegetation by killing large numbers of shrubs and small trees of all species, and scorching understory foliage. After prescribed burning, the structure and composition of vegetation in my study areas was probably more similar to that of a ponderosa pine forest subject to a natural fire regime, i.e., with a relatively open understory, and the dominant vegetative feature being overstory ponderosa pines.

Oaks were the dominant feature of the understory before and after prescribed burning, although they were much reduced by the fires. Many oaks were vigorously sprouting from the stumps in the first growing season after burning, and shrubby growth of these oaks will become increasingly abundant over the coming seasons. The perennial grasses that had been burned back were also putting out vigorous new growth. Within 10 years after these fires, there will probably be a greater abundance of oak shrubs in the understory, higher cover of grasses in local patches, new ponderosa pine seedlings in some openings, and a lesser contribution of shade tolerant conifers to the understory than there was before burning.

The effects of a single application of moderately intense surface fire on birds that associated with understory or ground cover vegetation appeared to be minor, 1 breeding season post-fire. Only 1 of 10 breeding species, the Virginia's warbler, declined significantly in abundance. The decline of Virginia's warbler populations appeared to be the result of post-fire reductions in the availability of vegetation used for nesting cover and foraging. I hypothesize that in the absence of further prescribed burning, the bird community would return fairly rapidly to its pre-fire condition.

Periodic prescribed burning at intervals of 5-10 years would affect the plant community to a greater extent than a single treatment with prescribed fire, and could cause greater, and more permanent, changes in the bird community than the minor changes seen in this study. Birds of the ponderosa pine forests of southeastern Arizona evolved in an ecosystem that was subject to frequent light fires. To the extent that prescribed burning at intervals mimics a natural fire regime, the avian community of a ponderosa pine forest subject to frequent prescribed burning could come to resemble that of a primeval forest.

APPENDIX B

The results of fuel inventories, using Brown's (1974) method, before and after prescribed burning, are presented below.

Table 1. Weights of down woody fuels, in metric tons/ha, before (1984) and after (1985) prescribed burning, in a ponderosa pine forest, southeastern Arizona. Lizard Rock (LR) and Organization Ridge (OR) plots were burned 6-12 November, 1984. Green Mountain North (GMN) plot was burned 8-10 May, 1985.

	Diameter of particles (cm)				
Plot/ Year	≤0.63	0.64-2.53	2.54-7.61	>7.62 sound	>7.62 rotten
LR/84	0.55	1.65	3.07	4.05	0.42
LR/85	0.16	0.06	0.87	3.29	3.15
%-change	-71	-96	-72	-19	+650
OR/84	0.39	2.81	3.84	29.16	3.18
OR/85	0.33	1.26	0.96	28.41	1.82
%-change	-15	-55	-75	-3	-43
GMN/84	0.36	1.12	1.56	10.17	4.12
GMN/85	0.28	0.67	1.39	5.94	0.14
%-change	-22	-40	-11	-42	-97

Table 2. Depths of forest floor fuels, before (1984) and after (1985) prescribed burning in a ponderosa pine forest, southeastern Arizona. Lizard Rock (LR) and Organization Ridge (OR) plots were burned 6-12 November, 1984. Green Mountain North (GMN) plot was burned 8-10 May, 1985.

	Depth of fuel (cm)	
Plot/Year	Duff	Surface fuels
LR/84	2.95	4.83
LR/85	1.68	3.00
%-change	-43	-38
OR/84	5.16	10.11
OR/85	2.95	3.22
%-change	-43	-68
GMN/84	3.35	6.25
GMN/85	1.52	3.25
%-change	-55	-48

APPENDIX C

CHARACTERISTICS OF TREES WITH ACTIVE CAVITY-NESTS, PONDEROSA PINE FORESTS OF SOUTHEASTERN ARIZONA, 1984-1985.

Bird Species	Number of nests						
	Snags			Live trees			
	pp[a]	oak	df[a]	pp	oak	other	total
hairy woodpecker	1						1
acorn woodpecker	7						7
northern flicker	13						13
pygmy nuthatch	21			1			22
flammulated owl	1						1
western flycatcher[b]	3		2				5
dusky-capped flycatcher		1					1
violet-green swallow	24						24
Bewick's wren					2		2
house wren	13			4	2		19
brown creeper	2			3			5
bridled titmouse					1		1
mountain chickadee	5						5
white-breasted nuthatch				3	2	1[c]	6

APPENDIX C. Continued

western bluebird	24			1	1	1[d]	27
total	114	1	2	12	8	2	139

[a]pp=Ponderosa pine, df=Douglas-fir

[b]Other western flycatcher nests were on fallen logs (9) or stumps (2), within 1.5 m of the ground. Nests on snags were not in excavations, but were placed on the edges of natural cavities.

[c]One nest was in an Arizona madrone.

[d]One nest was in a New Mexico locust.

APPENDIX D

DENSITIES (NUMBER/40 HA) OF BIRDS DURING THE BREEDING SEASONS, PONDEROSA PINE FORESTS OF SOUTHEASTERN ARIZONA, 1984 AND 1985.

Species	Burn		Non-burn		D/S[a]
	1984	1985	1984	1985	
turkey vulture Cathartes aura	P[b]	P	P	P	
Cooper's hawk Accipiter cooperii	P	P	P	P	
northern goshawk Accipiter gentilis	P	P	P	P	
zone-tailed hawk Buteo albonotatus	P	P	P	P	
red-tailed hawk Buteo jamaicensis	P	P	P	P	
prairie falcon Falco mexicanus	P				
band-tailed pigeon Columba fasciata	P	P	P	P	
flammulated owl Otus flammeolus	P	P	P	P	
whiskered screech-owl Otus trichopsis	P	P	P	P	
whip-poor-will Caprimulgus vociferus	P	P	P	P	

APPENDIX D. (Continued)

Species	Burn 1984	Burn 1985	Non-burn 1984	Non-burn 1985	D/S[a]
white-throated swift *Aeronautes saxatalis*	P	P	P	P	
magnificent hummingbird *Eugenes fulgens*	P	P	P	P	
Anna's hummingbird *Calypte anna*	P	P			
broad-tailed hummingbird *Selasphorus platycercus*	14.3[c]	14.1[c]	13.3[c]	8.8[c]	0/NS
acorn woodpecker *Melanerpes formicivorus*	4.1	2.8	1.1	1.5	-/NS
hairy woodpecker *Picoides villosus*	0.8	1.0	0.7	0.8	0/NS
northern flicker *Colaptes auratus*	2.6	2.1	1.7	2.3	-/.07
greater pewee[e] *Contopus pertinax*	3.0	6.2	3.2	5.0	0/NS
western wood-pewee[e] *Contopus sordidulus*	7.4	4.2	8.8	9.2	-/NS
western flycatcher[e] *Empidonax difficilis*	39.2	67.0	62.4	48.0	+/NS
dusky-capped flycatcher *Myiarchus tuberculifer*	P	P	P	P	
ash-throated flycatcher *Myiarchus cinerascens*		P			
violet-green swallow *Tachycineta thalassina*	37.4[d]	17.6[d]	31.7[d]	34.0[d]	-/.06
Steller's jay *Cyanocitta stelleri*	2.8	3.2	4.9	3.9	+/NS

APPENDIX D. (Continued)

Species	Burn 1984	Burn 1985	Non-burn 1984	Non-burn 1985	D/S[a]
gray-breasted jay *Aphelocoma ultramarina*	1.7	3.2	P	P	+/NS
common raven *Corvus corax*	P	P	P	P	
mountain chickadee *Parus gambeli*	5.6	12.2	7.2	7.0	+/.03
bridled titmouse *Parus wollweberi*	P	P			
bushtit *Psaltriparus minimus*	P	P	P	P	
white-breasted nuthatch *Sitta carolinensis*	7.0	4.2	4.4	2.9	0/NS
pygmy nuthatch *Sitta pygmaea*	24.4	14.2	26.2	15.8	0/NS
brown creeper[e] *Certhia americana*	9.8	7.9	5.8	7.3	-/NS
canyon wren *Catherpes mexicanus*	P	P	P	P	
Bewick's wren *Thryomanes bewickii*	P	P	P	P	
house wren[e] *Troglodytes aedon*	15.0	46.2	53.2	91.8	0/NS
blue-gray gnatcatcher *Polioptila caerulea*	P	P	P	P	
eastern bluebird *Sialia sialis*				P	
western bluebird *Sialia mexicana*	12.5	6.2	11.3	6.1	0/NS

APPENDIX D. (Continued) Densities (Number/40 ha) of birds during the breeding seasons, ponderosa pine forests of southeastern Arizona, 1984 and 1985.

Species	Burn		Non-burn		D/S[a]
	1984	1985	1984	1985	
hermit thrush[e] *Catharus guttatus*	4.4	9.0	3.0	8.8	0/NS
American robin *Turdus migratorius*	1.8	1.1	2.5	2.1	0/NS
solitary vireo[e] *Vireo solitarius*	40.0	48.2	36.0	55.2	0/NS
Hutton's vireo[e] *Vireo huttoni*	8.2	7.8	11.2	3.8	0/NS
warbling vireo *Vireo gilvus*		P		P	
Virginia's warbler[e] *Vermivora virginiae*	85.4	43.8	101.6	149.8	-/.04
yellow-rumped warbler[e] *Dendroica coronata*	25.4	33.4	13.8	26.0	0/NS
black-throated[e] gray warbler *Dendroica nigrescens*	9.8	16.0	18.6	21.6	0/NS
Grace's warbler[e] *Dendroica graciae*	37.8	64.4	40.8	58.2	0/NS
red-faced warbler[e] *Cardinella rubifrons*	105.2	92.6	95.8	102.6	-/NS
painted redstart[e] *Myioborus pictus*	13.2	19.0	8.4	25.8	0/NS
olive warbler *Peucedramus taeniatus*	24.1	19.6	30.7	27.0	0/NS
hepatic tanager *Piranga flava*	13.6	3.2	5.5	6.1	-/.01

APPENDIX D. (Continued)

Species	Burn 1984	Burn 1985	Non-burn 1984	Non-burn 1985	D/S[a]
western tanager[e] *Piranga ludoviciana*	31.2	30.0	24.4	34.4	-/NS
black-headed grosbeak[e] *Pheucticus melanocephalus*	52.0	55.4	59.0	65.4	0/NS
rufous-sided towhee[e] *Pipilo erythrophthalmus*	7.8	15.8	33.0	22.0	+/NS
yellow-eyed junco[e] *Junco phaeonotus*	62.6	62.4	50.6	70.6	-/NS
red crossbill *Loxia curvirostra*	P	P	P	P	
pine siskin *Carduelis pinus*	P	P	P	P	

[a] I tested changes in abundance from 1984 to 1985 on the experimental plots relative to changes on the control plots. Changes-in-density were used in nested analysis of variance (Hull and Nie 1981), with census stations nested within plots which were nested within treatments, to evaluate the impacts of prescribed burning on abundance of common species of cavity-nesting birds. I reported direction (D) (+, 0, or -), and significance (S) of changes. I reported $P < 0.10$, changes with $P > 0.10$ were considered not significant (NS).

[b] I did not count nocturnal birds, their presence (P) was determined by chance diurnal observations and non-systematic nocturnal visits to study plots. Several diurnal species were present (P), but were at the upper limits of their elevational ranges and were too rare to permit calculation of meaningful density estimates.

[c] Not a true density estimate, birds noted in flight within a 50 m radius were counted.

[d] Densities derived from counts of singing males were doubled (Emlen 1971, Franzreb 1976).

REFERENCES CITED

Balda, R. P. 1975. The relationship of secondary cavity nesters to snag densities in western coniferous forests. U.S. For. Serv. Southwest Reg. Wildl. Habitat Tech. Bull. 1. 37pp.

Bent, A. C. 1939. Life histories of North American woodpeckers. Smithsonian Inst., U.S. Natl. Mus. Bull. 174. U.S. Gov. Printing Off., Wash. D. C., 334pp.

Biswell, H. H., H. R. Kallander, R. Komarek, R. J. Vogl, and H. Weaver. 1973. Ponderosa pine management. Tall Timbers Res. Stn., Tallahassee, Florida. Misc. Pub. 2. 49pp.

Blackford, J. L. 1955. Woodpecker concentrations in burned forests. Condor 57:28-30.

Bock, C. E., and J. F. Lynch. 1970. Breeding bird populations of burned and unburned forests in the Sierra Nevada. Condor 72:182-189.

Brown, J. K. 1975. Handbook for inventorying downed woody material. U.S. For. Serv.Gen. Tech. Rep. INT-16. 24pp.

Brown, J. L. 1969. Territorial behavior and population regulation in birds: A re-evaluation. Wilson Bull. 81:293-329.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. J. For. 39:388-394.

Cline, S. P., A. B. Berg, and H. M. Wight. 1980. Snag characteristics and dynamics in Douglas-fir forests, western Oregon. J. Wildl. Manage. 44:773-786.

Conner, R. N. 1981. Fire and cavity-nesting birds. Pages 61-66 in Proc. symposium on prescribed fire and wildlife in southern forests. Southeast. For. Exp. Stn., Asheville SEFES-83-2. 174pp.

Cooper, C. F. 1960. Changes in vegetation, structure and growth of southwestern pine forests since white settlement. Ecol. Monogr. 30:129-164.

Cunningham, J. B., R. P. Balda, and W. S. Gaud. 1980. Selection and use of snags by secondary cavity-nesting birds of the ponderosa pine forest. U. S. For. Serv. Res. Pap. RM-222. 15pp.

Dieterich, J. H. 1979. Recovery potential of fire-damaged southwestern ponderosa pine. Rocky Mt. For. Range Exp. Stn., Res. Note RM-379. 8pp.

Dieterich, J. H. 1980. Chimney Spring fire history. U.S. For. Serv. Res. Pap. RM-220. 8pp.

Emlen, J. T. 1967. A rapid method for measuring arboreal cover. Ecology 48:158-159.

Emlen, J. T. 1970. Habitat selection by birds following a forest fire. Ecology 51:343-345.

Emlen, J. T. 1971. Population densities of birds derived from transect counts. Auk 88:323-342.

Engstrom, R. T., R. L. Crawford, and W. W. Baker. 1984. Breeding bird populations in relation to changing forest structure following fire exclusion: a 15 year study. Wilson Bull. 96:437-450.

Franzreb, K. E. 1976. Comparison of variable strip transect and spot-map methods for censusing avian populations in a mixed-coniferous forest. Condor 78:260-262.

Franzreb, K. E., and R. D. Ohmart. 1978. The effects of timber harvesting on breeding birds in a mixed-coniferous forest. Condor 80:431-441.

Granholm, S. L. 1982. Effects of surface fires on birds and their habitat associations in coniferous forests of the Sierra Nevada, California. Ph.D. Thesis, Univ. California, Davis. 130pp.

Harrington, M. G. 1981. Preliminary burning prescriptions for ponderosa pine fuel reductions in southeastern Arizona. Rocky Mt. For. Range Exp. Stn., Res. Note RM-392. 6pp.

Hull, C. H., and N. H. Nie. 1981. SPSS update 7-9: New procedures and facilities for releases 7-9. McGraw-Hill Book Co., New York, N. Y. 402pp.

James, F. C., and N. O. Wamer. 1982. Relationships between temperate forest vegetation and avian community structure. Ecology 63:159-171.

Karr, J. R. 1968. Habitat and avian diversity on strip-mined land in east-central Illinois. Condor 70:348-357.

Kilgore, B. M. 1971. Response of breeding bird populations to habitat changes in a giant sequoia forest. Am. Midl. Nat. 85:135-152.

Koplin, J. R. 1969. The numerical response of woodpeckers to insect prey in a subalpine forest in Colorado. Condor 71:436-438.

Mannan, R. W., E. C. Meslow, and H. M. Wight. 1980. Use of snags by birds in Douglas-fir forests, western Oregon. J. Wildl. Manage. 44:787-797.

Marshall, J. T. 1963. Fire and birds in the mountains of southern Arizona. Proc. Tall Timbers Fire Ecol. Conf. 2:134-141.

McArthur, R. and J. McArthur. 1961. On bird species diversity. Ecology 42:594-598.

McLelland, B. R., and S. S. Frissell. 1975. Identifying forest snags useful for hole-nesting birds. J. For. 73:414-417.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, Inc., New York. 675pp.

Nue, C., W., C.R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Parsons, D. J., and S. H. DeBenedetti. 1979. Impact of fire suppression on a mixed-conifer forest. For. Ecol. Manage. 2:21-33.

Ramsey, F. L., and J. M. Scott. 1979. Estimating population densities from variable circular plot surveys. Pages 155-181 in R. M. Cormack, G. P. Patil, and D. S. Robson, eds. Sampling biological populations. Stat. Ecol. Ser., vol. 5. Int. Co-op. Publ. House, Fairland, Md.

Reynolds, R. T., J. M. Scott, and R. A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82:309-313.

Raphael, M. G., and M. White. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildl. Monogr. 86:1-66.

Schubert, G. H. 1974. Silviculture of southwestern ponderosa pine: A status of our knowledge. U.S. For. Serv. Res. Pap. RM-123. 71pp.

Scott, V. E. 1978. Characteristics of ponderosa pine snags used by cavity-nesting birds in Arizona. J. For. 76:26-28.

Scott, V. E. 1979. Bird response to snag removal in ponderosa pine. J. For. 77:26-28.

Shugart, H. H., and D. James. 1973. Ecological succession of breeding bird populations in northwestern Arkansas. Auk 90:62-77.

Sturnam, W. A. 1968. Description and analysis of breeding habitats of the chickadees, Parus atricapillus and P. rufescens. Ecology 49:418-431.

Szaro, R. C., and R. P. Balda. 1979. Bird community dynamics in a ponderosa pine forest. Stud. Avian Biol. 3. 66pp.

U.S. Dep. Agric. 1982. National list of scientific plant names. U.S. Dep. Agric. Soil Conserv. Serv. SCS-TP-159. 2 vols.

Weaver, H. 1951. Fire as an ecological factor in the southwestern ponderosa pine forests. J. For. 49:93-98.

Weaver, H. 1974. Effects of fire on temperate forests: Western United States. Pages 279-319 in J. T. Koslowski, and C. E. Ahlgren, eds. Fire and ecosystems. Academic Press, San Francisco.

White, A. S. 1985. Presettlement regeneration patterns in a southwestern ponderosa pine stand. Ecology 66:589-594.

Wiens, J. A., S. G. Martin, W. R. Holthaus, and F. A. Iwen. 1970. Metronome timing in behavioral ecology studies. Ecology 51:350-352.

Willson, M. F. 1974. Avian community organization and habitat structure. Ecology 55:1017-1029.

Zar, J. H. 1984. Biostatistical analysis. 2nd ed. Prentice-Hall, Inc., Englewood Cliffs, N. J. 718pp.