**Heather L. Bateman**[1], Department of Biology, MSC03 2020, 1 University of New Mexico, Albuquerque, New Mexico 87131

and

**Margaret A. O'Connell**, Department of Biology and Turnbull Laboratory for Ecological Studies, Eastern Washington University, Cheney, Washington 99004

# Effects of Prescribed Burns on Wintering Cavity-Nesting Birds

## Abstract

Primary cavity-nesting birds play a critical role in forest ecosystems by excavating cavities later used by other birds and mammals as nesting or roosting sites. Several species of cavity-nesting birds are non-migratory residents and consequently subject to winter conditions. We conducted winter bird counts from 1998 to 2000 to examine the abundance and habitat association of cavity-nesting birds in prescribed burned and unburned ponderosa pine (*Pinus ponderosa*) stands. Even though bird diversity indices did not differ between burned and unburned stands, species-specific bird abundance was associated with habitat variables in three burned and four unburned stands. Total cavity-nesting bird abundance was greater in burned stands. Most cavity-nesting birds were observed in mixed-species flocks. Individual species of these flocks were associated with different habitat variables within stands. Numbers of woodpeckers were significantly greater in burned stands and numbers of chickadees were significantly greater in unburned stands. Bark foragers such as woodpeckers (*Picoides* spp.) and pygmy nuthatches (*Sitta pygmaea*) were associated with fewer small trees and recently decayed snags and logs. Foliage gleaners such as the chickadees (*Poecile* spp.) were associated with small diameter snags. The juxtaposition of burned and unburned stands is important for individual birds reliant upon other members of a mixed-species flock and habitat heterogeneity within stands is important for maintaining a diverse cavity-nesting bird assemblage.

## Introduction

Primary cavity-nesting birds, such as woodpeckers (*Picoides* spp.) and nuthatches (*Sitta* spp.), play important roles in forest ecosystems and are considered keystone species because they excavate cavities that, once vacated, provide nesting and roosting sites for other birds and mammals (Johnsson 1993). In addition, woodpeckers are the primary vertebrate that prey on wood-boring beetles (Otvos 1965, Koplin 1972). Within ponderosa pine (*Pinus ponderosa*) forests, foraging for beetles by woodpeckers in the genus *Picoides* may promote fungal invasion, thus promoting snag decay and providing substrate for excavation of additional cavities (Farris et al. 2004). Several species of cavity-nesters are resident birds (Scott 1977) and rely on snags for roosting, and foraging during the winter. Due to limited food and cover resources (Chambers and McComb 1997), winter can be a critical season determining survival of primary cavity-nesters and success of avian communities in general (Smith 1971, DellaSala et al. 1996). Understanding factors associated with cavity-nesting birds' use of snags during winter provides insight into forest management approaches that might promote overwinter survival of these keystone species.

Cavity-nesters have evolved in forests containing a substantial amount of decaying wood (Dickson et al. 1983) and are associated with habitats of high snag densities for nesting, roosting, and foraging (Mannan et al. 1980, Dickson et al. 1983, McComb and Muller 1983, Zarnowitz and Manuwal 1985, Chambers et al. 1997, Chambers and McComb 1997). There may be competition for snags containing cavities (Nilsson 1986) suggesting that snags may be a limiting resource for cavity-nesting bird populations in conifer forests (Cline et al. 1980, Mannan et al. 1980, Zarnowitz and Manuwal 1985).

In unmanaged forests, snag densities are maintained through natural fire, insects, and disease. For example, historical snag densities in ponderosa pine forests east of the Cascade Mountains in Washington were estimated to be between 14.5 and 34.6 snags ha$^{-1}$ (Harrod et al. 1998). Within managed forests, silvicultural practices typically decrease snag densities (Cline et al. 1980, Zarnowitz and Manuwal 1985). Prescribed burning

[1]Author to whom correspondence should be addressed.
Email: hbateman@unm.edu

is one management practice that may increase snag density but may also cause existing snags to be consumed by fire or to fall (Pilliod et al. 2006). Several studies have examined the effects of prescribed burns on the habitat selection of cavity-nesting birds during the breeding season (e.g., Bock and Lynch 1970, Raphael and White 1984, Hutto 1995) but few studies have looked at the effects of prescribed burns on habitat selection during winter.

The purpose of our research was to determine the effects of prescribed burns in a ponderosa pine forest on winter cavity-nesting birds in eastern Washington. Specifically, we examined: (1) cavity-nesting bird diversity and relative abundance in burned and unburned stands, (2) flocking behavior of these birds in burned and unburned stands, and (3) the habitat associations of birds in burned and unburned stands.

## Methods

### Study Area

We conducted research at the 6,500 ha Turnbull National Wildlife Refuge (TNWR) in the Channeled Scablands of the Columbia Basin in eastern Washington (Weis and Newman 1989). The TNWR has experienced fire suppression since early European settlement (Kinateder 1998). Consequently, ponderosa pine stands at TNWR, became densely stocked with small-diameter trees. To create a more open overstory canopy and reduce the number of small trees, managers at TNWR initiated a program of prescribed burns with some mechanical thinning in 1990.

### Transect Design

We sampled cavity-nesting birds in prescribed burned and unburned stands during the winters of 1998 -1999 and 1999 - 2000. Birds were counted at stations placed in three burned stands and two unburned stands during both winters. One unburned stand, sampled during winter 1998-1999, was replaced with an adjacent unburned stand during winter 1999-2000 because the original stand was logged. Stations were placed systematically with centers 100 m from stand edge and 150 m from another station. Twenty-eight point count stations were sampled each winter in burned unburned stands.

Prescribed burns were ground fires with flame lengths not reaching the crowns of the trees (Robert Plantrich, USFS, personal communication). The unit size and dates of the burns were as follows: 251 ha (1990); 119 ha (1992); 266 ha (1997). The unit size of the two control stands used in both years were 200 ha and 226 ha. The unit size of the control stand used only in the first year was 119 ha and that used only in the second year was 269 ha. All stands were ≥ 4 km apart.

### Habitat Measurements

To assess cavity-nesting bird habitat associations in winter we measured 41 vegetation characteristics during August 1999 and April 2000 (Huff et al. 1999). We measured vegetation characteristics of live trees, snags, logs, stumps, regeneration, and overstory. Live trees and snags were measured within a 12-m radius at each of the point count stations. Live trees were counted in categories by condition (live, live burned, live broken top, live dead top) and dbh (7-19.9 cm, 20-39.9 cm, > 40 cm). Snag heights were measured and snags were counted by: 1) snag condition (burned, unburned, broken top); 2) dbh (as above for live trees), and 3) decay class (class I: intact top, branches, needles and bark remaining; class II: no needles, few branches and some bark remaining; class III: no needles, possibly broken tops, and little bark and branches remaining). The numbers of snags with evidence of cavity excavations or holes created by woodpeckers searching for beetle larvae were also counted. Logs, seedlings, and overstory were measured along four 1- x 12-m transects at each station. Logs were counted by: 1) condition (unburned, burned), 2) size (measured at breast height and placed in same size classes as above), and 3) decay class (class I: branches and bark intact, elevated off the ground;, class II: few limbs and little bark remaining, flush to ground; class III: extensive rotting as evidenced by soft wood). Pine seedlings were defined as trees <2.5 cm dbh and <7 cm tall. Overstory cover was averaged from four measurements taken midway along each 12-m transect using a spherical densiometer.

### Winter Bird Sampling

We sampled cavity-nesting birds using a point count method to assess diversity, abundance, and flocking behavior in winter following Bibby et al. (1992). Surveys were conducted between 0830 and 1600 hours from 12 December through

25 February, each winter. Surveying occurred on days with little or no precipitation and wind speeds under 32 km/hr. Each station was surveyed 7 times each winter. Visitations were on a rotation schedule where the first station in a stand was surveyed last on the following visit to account for hourly variation in bird activity and equal sampler bias (Chambers and McComb 1997).

Surveying began immediately upon arrival to the station and lasted for 8 minutes. All cavity-nesting birds seen and heard < 100 m were counted and identified to species, and whether observed singly, or in a same-species or mixed-species flock. Flocks were defined as two or more birds and direction of flock movement was noted during the survey to prevent recounting birds from previous stations. Birds seen flying over the station were recorded as such, but not used in analyses; whereas birds flushed upon arrival were counted. Trees around each station were flagged at 25 m, 50 m and 100 m intervals to aid in distance estimates.

### Data Analysis

We calculated species richness, diversity, and evenness for each station. We used the Shannon-Weaver index to determine diversity (Ricklefs 1993). Relative cavity-nesting bird abundance was defined as the mean number of birds per point count station and was recorded for individual species and for three bird groups (woodpeckers, nuthatches, and chickadees) following Ehrlich et al. (1988). We used a Mann-Whitney *U*-test to detect differences in diversity indices between burned and unburned stands (SPSS Inc. 2004). To meet the basic assumptions of parametric analyses we used a square root transformation (Zar 1996). A General Linear Model (GLM) and Tukey's comparison was used to detect differences in the mean number of birds per stand between burned and unburned stands and between the first and second year (SAS Institute 1990).

Flocking of cavity-nesting birds was recorded as flock type (same-species or mixed-species flocks per stand), flock size (mean number of members in each flock per stand), and flock richness (mean number of species within mixed flocks). We used a 2-way ANOVA on the square root transformed data to test for differences in mean number of flock types, mean number of flock size and mean flock richness in burned and unburned stands (Minitab 1998).

A Student *t*-test was used to compare habitat characteristics between burn and unburned stands. We used a stepwise multiple regression analysis on the square root transformed data to determine which habitat variables best explained variance in bird abundance (SAS Institute 1990). Bird abundances were combined from year 1 and year 2 since only one species differed significantly between years. We combined 3 of the 41 habitat variables for a total of 38 variables to include in the regression analysis. Specifically, snags in decay classes II and III in each of the three size classes were combined because there were few observations in decay class III. All tests were considered significant at the $P \leq 0.05$ level.

## Results

Burned and unburned stands differed in 13 out of 38 habitat variables (Table 1). Both burned and unburned stands were generally similar with respect to snag variables, except that burned stands had more burned snags and more large young decay snags. Overall, burned stands were more open had fewer small diameter trees and less evidence of recent decay. Unburned stands had twice as much canopy cover, and five times more live trees compared to burned stands. Unburned stands had 23 times more small trees.

During 14 surveys over two winters at TNWR we recorded 2,706 cavity-nesting birds of eight species. Those observations included 76 downy woodpeckers (*Picoides pubescens*), 125 hairy woodpeckers (*P. villosus*), 69 Northern flickers (*Colaptes auratus*), 22 unidentified woodpeckers, 1,485 pygmy nuthatches (*Sitta pygmaea*), 315 white-breasted nuthatches (*S. carolinensis*), 152 red-breasted nuthatches (*S. canadensis*), 70 black-capped chickadees (*Poecile atricapillus*), 49 mountain chickadees (*P. gambeli*), and 343 unidentified chickadees.

Species richness did not differ between burned ($5.03 \pm 0.56$) and unburned ($4.85 \pm 0.40$) stands (U = 4, df = 5, $P = 0.827$). Similarly, species diversity did not differ between burned ($1.09 \pm 0.06$) and unburned ($1.17 \pm 0.01$) stands, (U = 3, df = 5, $P = 0.513$). Also, species evenness did not differ between burned ($0.72 \pm 0.03$) and unburned ($0.81 \pm 0.05$) stands (U = 2, df = 5, $P = 0.275$).

Overall abundance of winter cavity-nesting birds averaged $2.50 \pm 0.14$ in burned stands and $2.22 \pm 0.32$ in unburned stands during 1998 to 2000.

TABLE 1. Mean and standard error of habitat measurements recorded in a 12 m radius at each winter bird survey point count station in burned and unburned stands, Turnbull National Wildlife Refuge, WA. 1998-2000. Small = 7 to19.9 cm diameter, medium = 20 to 39.9 cm diameter, large = ≥40 cm diameter. Student *t* test n = 68, df = 66 of square root transformed data. Habitat variables with $P \leq 0.05$ are in bold.

| Habitat Variable | Burned mean ± SE | Unburned mean ± SE | *t* | *P* |
|---|---|---|---|---|
| **Live Stems** | | | | |
| number of live | 3.00 ± 0.56 | **16.40 ± 1.61** | 8.70 | <0.001 |
| live burned | 2.96 ± 0.57 | 3.70 ± 0.95 | -0.53 | 0.600 |
| live broken top | 0.18 ± 0.07 | 0.35 ± 0.12 | 0.79 | 0.430 |
| live dead top | 0.21 ± 0.08 | **0.65 ± 0.16** | 1.98 | 0.052 |
| live small | 0.61 ± 0.25 | **8.00 ± 1.23** | 7.49 | <0.001 |
| live medium | 1.57 ± 0.47 | **6.45 ± 0.64** | 7.31 | <0.001 |
| live large | 0.82 ± 0.21 | **1.95 ± 0.26** | 3.32 | 0.002 |
| **Snags** | | | | |
| number of snags | 1.43 ± 0.39 | 1.75 ± 0.35 | 0.51 | 0.610 |
| snag height | 4.25 ±1.16 | 3.59 ± 0.68 | -0.12 | 0.900 |
| snags burned | **1.43 ± 0.39** | 0.60 ± 0.18 | -2.12 | 0.038 |
| snag broken tops | 0.68 ± 0.28 | 0.88 ± 0.22 | 0.72 | 0.470 |
| snag young small | 0.39 ± 0.16 | 0.85 ± 0.23 | 1.28 | 0.210 |
| snag young medium | 0.29 ± 0.12 | 0.13 ± 0.07 | -1.44 | 0.160 |
| snag young large | **0.27 ± 0.11** | 0.03 ± 0.03 | -2.67 | 0.010 |
| snag old small | 0.07 ± 0.05 | 0.48 ± 0.18 | 1.91 | 0.060 |
| snag old medium | 0.36 ± 0.20 | 0.15 ± 0.06 | -0.59 | 0.560 |
| snag old large | 0.04 ± 0.04 | 0.13 ± 0.07 | 0.84 | 0.410 |
| number cavities | 0.43 ± 0.30 | 0.48 ± 0.26 | 0.34 | 0.740 |
| snags with cavities | 0.11 ± 0.08 | 0.15 ± 0.07 | 0.57 | 0.570 |
| evidence of forage | 1.25 ± 0.37 | 1.45 ± 0.29 | 0.63 | 0.530 |
| snags in a cluster | 1.04 ± 0.39 | 0.93 ± 0.32 | -0.25 | 0.800 |
| number of stumps | 0.04 ± 0.04 | 0.13 ± 0.05 | 1.27 | 0.210 |
| **Logs** | | | | |
| number of logs | 1.82 ± 0.46 | **3.58 ± 0.61** | 2.30 | 0.025 |
| logs burned | 1.68 ± 0.44 | 1.65 ± 0.40 | -0.38 | 0.710 |
| log decayI small | 0.36 ± 0.13 | 0.95 ± 0.29 | 1.47 | 0.150 |
| log decayI medium | **0.54 ± 0.16** | 0.05 ± 0.04 | -3.63 | <0.001 |
| log decayI large | 0.18 ± 0.09 | 0.08 ± 0.04 | -1.02 | 0.310 |
| log decayII small | 0.21 ± 0.09 | **1.08 ± 0.26** | 2.53 | 0.014 |
| log decayII medium | 0.29 ± 0.14 | 0.13 ± 0.05 | -0.94 | 0.350 |
| log decayII large | 0.04 ± 0.04 | 0.05 ± 0.05 | -0.01 | 0.990 |
| log decayIII small | 0.18 ± 0.07 | **0.78 ± 0.23** | 2.45 | 0.017 |
| log decayIII medium | 0.04 ± 0.04 | 0.18 ± 0.07 | 1.56 | 0.120 |
| log decayIII large | 0 ± 0 | 0.08 ± 0.06 | 1.18 | 0.243 |
| **Regeneration** | | | | |
| number seedlings | 2.69 ± 1.77 | **24.02 ± 8.71** | 2.70 | 0.009 |
| number saplings | 0.13 ± 0.05 | 0.24 ± 0.08 | 0.82 | 0.410 |
| number large shrubs | 1.79 ± 1.68 | 1.03 ± 0.39 | 0.39 | 0.700 |
| small shrub % cover | 7.71 ± 2.18 | 10.82 ± 2.52 | 1.03 | 0.310 |
| **Overstory** | | | | |
| overstory % cover | 24.79 ± 3.24 | **51.10 ± 2.78** | 6.19 | <0.001 |

TABLE 2. Mean and standard error of number of birds per stand in prescribed burned (n = 3) and unburned (n = 3) stands during winters of 1998-2000, Turnbull National Wildlife Refuge, WA. Significant *P* values bolded for differences due to year or treatment from GLM and Tukey's test.

| | Burned mean ± SE | Unburned mean ± SE | Year *P* value | Treatment *P* value |
|---|---|---|---|---|
| downy woodpecker | | | | |
| year 1 | 0.90 ± 0.70 | 0.24 ± 0.05 | 0.540 | 0.396 |
| year 2 | 0.33 ± 0.21 | 0.33 ± 0.13 | | |
| hairy woodpecker | | | | |
| year 1 | 0.87 ± 0.10 | 0.38 ± 0.17 | 0.875 | **0.002** |
| year 2 | 1.00 ± 0.22 | 0.14 ± 0 | | |
| Northern flicker | | | | |
| year 1 | 0.10 ± 0.05 | 0.05 ± 0.05 | 0.199 | 0.199 |
| year 2 | 0.38 ± 0.21 | 0.10 ± 0.10 | | |
| All woodpeckers | | | | |
| year 1 | 1.90 ± 0.84 | 0.67 ± 0.25 | 0.966 | **0.046** |
| year 2 | 1.90 ± 0.55 | 0.62 ± 0.27 | | |
| pygmy nuthatch | | | | |
| year 1 | 10.86 ± 4.08 | 6.10 ± 1.98 | 0.754 | 0.114 |
| year 2 | 12.57 ± 4.16 | 6.38 ± 0.58 | | |
| white-breasted nuthatch | | | | |
| year 1 | 2.48 ± 0.10 | 2.38 ± 0.39 | **0.037** | 0.866 |
| year 2 | 1.43 ± 0.65 | 1.38 ± 0.29 | | |
| red-breasted nuthatch | | | | |
| year 1 | 0.38 ± 0.21 | 0.52 ± 0.13 | 0.201 | 0.130 |
| year 2 | 0.43 ± 0.25 | 1.38 ± 0.55 | | |
| black-capped chickadee | | | | |
| year 1 | 0.10 ± 0.05 | 1.14 ± 0.43 | 0.806 | **0.052** |
| year 2 | 0.38 ± 0.31 | 1.05 ± 0.53 | | |
| mountain chickadee | | | | |
| year 1 | 0.24 ± 0.13 | 1.00 ± 0.58 | 0.691 | 0.434 |
| year 2 | 0.57 ± 0.30 | 0.38 ± 0.21 | | |
| All chickadees | | | | |
| year 1 | 1.38 ± 0.83 | 7.24 ± 1.45 | 0.362 | **0.008** |
| year 2 | 1.90 ± 0.25 | 4.43 ± 1.65 | | |

Individual species exhibited a mixed response to burn treatment (Table 2). The abundance of all woodpeckers combined as well as that of hairy woodpeckers was greater in burned stands (Table 2). The abundance of all chickadees combined was greater in unburned stands (Table 2). Observations included many "unknown chickadees" because chickadees do not use their species-specific note calls during winter, making it difficult to identify them to species.

Of the total 2,706 cavity-nesting birds, 98% were observed in flocks. Of those flocking, 90% were in mixed-species flocks, and 10% were in same-species flocks. Flocking behavior was similar in burned and unburned stands with regard to number of flocks ($F = 0.85$, df = 11, $P = 0.384$; Figure 1A) and flock size ($F = 0.74$, df = 11, $P = 0.415$; Figure 1B), but differed by flock type. Mixed-species flocks occurred more frequently ($F = 29.79$, df = 11, $P = 0.001$; Figure 1A) and were larger ($F = 84.65$, df = 11, $P < 0.001$; Figure 1B). Woodpeckers, chickadees, and nuthatches were observed together in mixed-species flocks. Pygmy nuthatches, the most abundant cavity-nesting bird in our study, had the most members in both mixed-species and same-species flocks. Woodpeckers did not form same-species flocks, but did join mixed-species flocks or occurred as individuals. Pygmy nuthatches made up 54.2% of birds in mixed-species flocks and other members included chickadees (19.1% of birds) and woodpeckers (8.2% of birds). Over 78% of birds flocking in same-species groups were pygmy nuthatches and 7.2% were chickadees.

Stepwise regression analysis revealed that 26 of the 38 habitat variables were good predictors

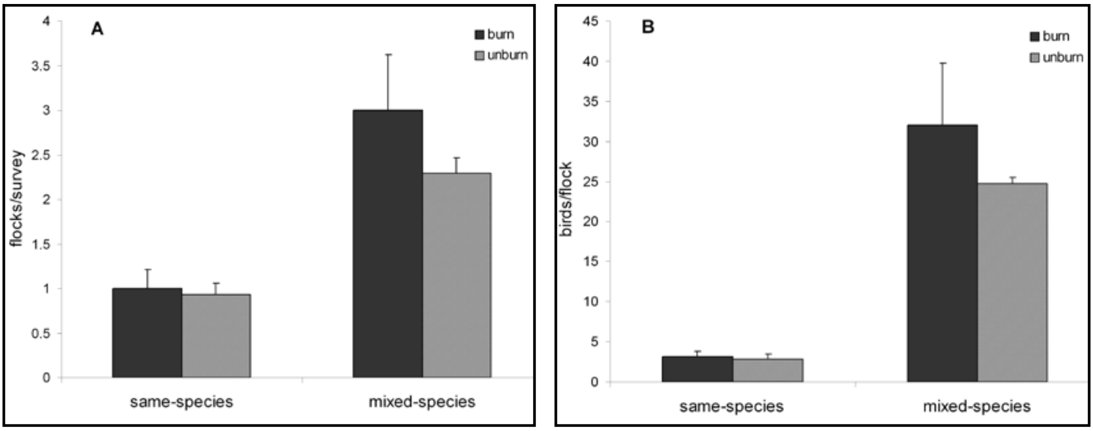


Figure 1. Mean and standard error of winter cavity-nesting bird (A) flocks per survey and (B) birds per flock in burned and unburned pine stands during winters of 1998-2000, Turnbull National Wildlife Refuge, WA. Flocks per survey and flock size differed between mixed-species and same-species flocks ($P < 0.05$).

of winter cavity-nesting bird species abundance (Table 3). Downy woodpeckers, hairy woodpeckers, and pygmy nuthatches were all positively associated with burn treatment, with > 20% of the variation explained by this variable alone. There was a mixed response to snag and log variables, with woodpeckers and pygmy nuthatches positively associated with the larger size classes and negatively correlated with the smaller size classes and older decay classes (Table 3). Northern flicker abundance was negatively associated with increasing numbers of small live trees. The best predictors of white-breasted nuthatches were high numbers of seedlings and low numbers of small logs in decay class III. High percent overstory cover was the best predictor of red-breasted nuthatch abundance. High numbers of recently dead snags of small-diameter were the best predictor of black-capped chickadee abundance.

## Discussion

The ponderosa pine stands at TNWR had been unaltered by fire in over half a century (Kinateder 1998). The initiation of prescribed burns created a more open landscape with many recently dead snags of large-diameter, that was in marked contrast to the dense, small-diameter trees in unburned stands. Even though most thinning and prescribed burns in ponderosa pine may result in losses of large-diameter snags and creation of small-diameter snags which are of limited use to cavity-nesting birds (Pilliod et al. 2006), we found that our burned stands had significantly greater number of recently dead large diameter snags than unburned stands (See Table 1).

Overall, cavity-nesting bird diversity indices did not differ between burned and unburned stands. This result was likely due to small samples. However, species-specific abundances were greater in burned than unburned stands. Downy woodpecker, hairy woodpecker, and pygmy nuthatch abundances were positively associated with burn treatment. Our results are similar to previous studies of cavity-nesting birds (e.g., Raphael and White 1984, Hutto 1995, Zarnowitz and Manuwal 1985). We found an association of these bark foragers (i.e., hairy and downy woodpeckers, Northern flickers and pygmy nuthatches) with snags and dead wood. Snags provide roosting habitat (Raphael and White 1984, Walsberg 1986) and insects for bark foragers during winter (Otvos 1965, Zarnowitz and Manuwal 1985). These bark foragers were also associated with snags and logs in early decay classes that are characteristic of recently burned stands. A study in a dry conifer forest in Idaho found that cavity excavations increased with time since fire (Saab et al. 2004), which could explain why most woodpecker species were significantly correlated with burned stands in our study. Woodpeckers may be using these large-diameter snags as foraging substrate and for roosting in cavities during winter. Older snags and logs have little or no bark remaining, thus providing minimal foraging substrate for these birds. Brawn et al. (1982) found that cavity-nesting birds, such as downy woodpeckers, Northern flickers, and white-breasted

TABLE 3. Habitat variables that are best predictors of cavity-nesting winter bird species abundance, Turnbull National Wildlife Refuge, WA. Stepwise regression analysis, n = 68, df = 67, of square root transformed data. Habitat variables with partial $R^2 > 0.10$ are considered biologically meaningful and are in bold.

| Bird Species<br>habitat variable | variable<br>sign | model<br>$R^2$ | *P* | $R^2$ | F | *P* |
|---|---|---|---|---|---|---|
| downy woodpecker | | | | 0.62 | 7.35 | <0.001 |
| **burn treatment** | **+** | **0.21** | **<0.001** | | | |
| % overstory | + | 0.09 | 0.006 | | | |
| number seedlings | - | 0.05 | 0.015 | | | |
| number live | - | 0.05 | 0.027 | | | |
| number broken top snags | - | 0.04 | 0.038 | | | |
| evidence of forage | + | 0.04 | 0.042 | | | |
| large log decay I | + | 0.04 | 0.042 | | | |
| hairy woodpecker | | | | 0.54 | 10.11 | <0.001 |
| **burn treatment** | **+** | **0.35** | **<0.001** | | | |
| small log decay III | - | 0.05 | 0.022 | | | |
| number large shrubs | + | 0.05 | 0.031 | | | |
| medium log decay II | + | 0.04 | 0.040 | | | |
| Northern flicker | | | | 0.44 | 12.57 | <0.001 |
| **small live trees** | **-** | **0.34** | **<0.001** | | | |
| number seedlings | - | 0.05 | 0.034 | | | |
| pygmy nuthatch | | | | 0.59 | 8.28 | <0.001 |
| **burn treatment** | **+** | **0.22** | **<0.001** | | | |
| live burned trees | + | 0.09 | 0.005 | | | |
| small log decay III | - | 0.06 | 0.020 | | | |
| number stumps | + | 0.05 | 0.020 | | | |
| medium young snags | + | 0.04 | 0.038 | | | |
| medium log decay II | + | 0.03 | 0.051 | | | |
| white-breasted nuthatch | | | | 0.37 | 7.22 | <0.001 |
| **number seedlings** | **+** | **0.12** | **0.004** | | | |
| **small log decay III** | **-** | **0.13** | **0.002** | | | |
| burned snags | + | 0.06 | 0.022 | | | |
| red-breasted nuthatch | | | | 0.30 | 6.88 | <0.001 |
| **percent overstory** | **+** | **0.17** | **<0.001** | | | |
| number logs | - | 0.06 | 0.024 | | | |
| number stumps | + | 0.05 | 0.048 | | | |
| black-capped chickadee | | | | 0.12 | 8.77 | 0.004 |
| small young snags | + | 0.12 | 0.004 | | | |
| mountain chickadee | | | | 0.31 | 4.46 | <0.001 |
| small old snags | + | 0.08 | 0.018 | | | |
| live broken top | + | 0.06 | 0.039 | | | |
| number logs | - | 0.06 | 0.041 | | | |
| medium live trees | + | 0.05 | 0.042 | | | |

nuthatches foraged most frequently on recently decayed snags and least frequently on older snags, presumably because recently dead snags with rough bark offered more foraging surface area and abundance of insects. In northeastern Washington, woodpeckers selected large, thick-barked snags of western larch, ponderosa pine and Douglas-fir for foraging (Kreisel and Stein 1999). Morrison et al. (1985) showed that birds foraged in areas where insects were readily accessible overwintering just under loose bark of small trees. Greater abundance of bark foragers, like woodpeckers and pygmy nuthatches at the prescribed-burned sites reflect the availability of recent snags.

Similar to Blake (1982), foliage cleaners such as chickadees were more abundant in unburned ponderosa pine stands during winter in our study. Chickadees glean insects from the ends of branches and among pine needles. In Sweden, chickadees avoided pine stands with thinner canopies and few needles (Hake 1991). Pilliod et al. (2006) caution habitat removed through thinning and prescribed burns in dry conifer forests may result in a negative response by wildlife species using those removed features. We suspect that chickadees may be less abundant in burned stands because of there are fewer live trees available to chickadees to forage for food items among pine needles.

The similarities of flocking behavior between burned and unburned stands suggest that flocking behavior is more influenced by seasonal conditions than burn treatment. Many of the cavity-nesting birds wintering at TNWR foraged in mixed-species flocks, suggesting potential benefits by joining a 'selfish herd.' Members of a mixed-species flock can increase the number of eyes and ears to search for food and predators (Hamilton 1971, Pulliam 1973). Mixed-species flocks not only increase predator recognition, but also offer greater foraging efficiency due to different foraging behavior and diet selection (Klein 1988). For example, downy woodpeckers might forage with nuthatches and chickadees because they benefit from chickadee warning calls, spend less time being vigilant, and increase the likelihood of finding a rich food source (Sullivan 1984). Given that members of these mixed-species flocks, such as woodpeckers and chickadees, are associated with different habitat variables, forest management that results in a mosaic of burned and unburned stands, as well as heterogeneity within these stands, may promote the overwinter survival of cavity-nesting birds.

## Acknowledgements

We thank Turnbull National Wildlife Refuge Manager, Nancy J. Curry, and Wildlife Biologist, Mike I. Rule, for the opportunity to study at TNWR and logistic support. David Bienus helped with station preparation and Kristi Serr with data entry. Thanks to Dr. Steven J. Stein and two anonymous reviewers for comments on the manuscript. This research was supported by an Eastern Washington University Biology Mini-Grant, a Barry Memorial Research Grant through Eastern Washington University's Turnbull Laboratory for Ecological Studies, and a grant to James G. Hallett and Margaret A. O'Connell through Washington State's Timber, Fish, and Wildlife Program and the Washington State Department of Natural Resources.

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*Received 4 August 2006*
*Accepted for publication 13 December 2006*

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