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Short-term effects of fire and fire surrogate treatments on foraging tree selection by cavity-nesting birds in dry forests of central Washington

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Abstract

Dry forests of Washington are becoming increasingly susceptible to broadscale stand replacement fire and insect and disease epidemics. In response, land managers implement fuel reduction strategies. These situations could potentially affect numerous wildlife species, including cavity-nesting birds. Much information exists on nesting requirements of cavity-nesters, while little information is available on their foraging requirements, or how changes to their habitat affect foraging. We examined short-term responses of cavity-nesting birds in dry conifer forests of Washington, to fuel reduction treatments in 2004 and 2005, as part of the National Fire–Fire Surrogate Project (FFS). Our objective was to determine if altering the forest stand through mechanical thinning or prescribed burning or a combination of the two would alter foraging tree selection. We used linear logistic regression and Akaike's Information Criteria (AIC) to model foraging tree selection and to analyze the effects of treatments on foraging tree selection. Model averaged parameter estimates suggested that cavity-nesting birds selected for large diameter trees and FFS treatments had a positive impact on foraging for nuthatches and woodpeckers. Birds were more likely to be observed foraging in treated stands and the positive relationship was strongest in stands that received a combination of thinning and burning treatments. Enhanced foraging conditions in the thin–burn treatment may have resulted from a more complete removal of small trees, while the prescribed burn was so low-intensity, it did not remove many small trees. Bird groups selected for trees at least 1.6 times as large in diameter in treated stands as compared to control stands. Our results indicate activities such as thinning and burning may best enhance foraging habitat for bark gleaning species as a whole. Our data suggests that some important treatment design considerations include the removal of small trees and the retention of large trees and snags (>40 cm dbh) that provide important foraging substrate and nesting habitat.
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Keywords: Cavity-nesting bird; Foraging; Model; Fire; Fire-surrogate; Thinning

1. Introduction

Dry forests, composed of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*), provide important habitat for many wildlife species. Historic fire suppression, logging and grazing in the dry forests of the east Cascade Mountains have resulted in dense stands of trees and heavy fuel loads (Agee, 1993; Hejl, 1994; Belsky and Blumenthal, 1997; Stuart, 1997; Hessburg and Agee, 2003). These forest conditions are difficult to manage because they are at risk of broad scale stand replacement fire or insect and disease epidemics. A national interdisciplinary effort, the Fire and Fire Surrogate Study (FFS), has been initiated to study reduction of these fuel loads and possible alternatives, or surrogates, to prescribed burning. The overall objective of the FFS study is to examine the effects of burning and mechanical thinning, alone and in combination, on numerous forest attributes, including vegetation, fuel and fire behavior, wildlife and entomology.

One component of these wildlife studies includes examination of the effects of burning and thinning on the foraging behaviors of cavity-nesting birds. Bird species respond to changes in their habitats through numerical responses, such as changes in population density, or functional responses, such as changes in foraging behavior. Few studies have examined the foraging behaviors and habitat needs of cavity-nesting birds in response to the effects of burning and thinning. Most research in the Pacific Northwest has focused on the relationship between cavity-nesting birds (usually woodpeckers) and snags as nesting habitat (Mannan et al., 1980; Rohila, 2002; Bunnell et al., 2002a), resulting in management practices that assume

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maintaining snag habitat for nesting also provides adequate foraging habitat. However, management focused solely on nesting habitat may be inadequate in providing foraging habitat that supports cavity-nesting bird populations (Conner, 1980; Weikel and Hayes, 1999). Additionally, information on species responses to alterations in habitat will aid habitat managers in making choices regarding management activities.

Since implementation of FFS treatments alters habitat, we chose to examine cavity-nesting birds because they respond measurably to habitat management activities, including prescribed burning and thinning, and wildfire (Hutto, 1995; Aigner et al., 1998; Kotliar et al., 2007). These activities or disturbances generally result in less dense stands with a higher proportion of large trees. Because post-management/fire studies have shown that bird species are generally more abundant immediately following the disturbance, we would expect to see more birds foraging in treated stands. We assessed foraging habitats and foraging tree selection of cavity-nesting bird species in the dry forest stands of the northeastern Cascades study site of the FFS National Project during the spring breeding seasons of 2004 and 2005 following treatment implementation. We examined how foraging tree selection changed, in the short term, as a result of treating stands with prescribed burning only, thinning only, or a combination of thinning and burning. We hypothesized that cavity-nesting bird species would select for larger trees and snags within the treated stands.

2. Materials and methods

2.1. Study site

The northeastern Cascades study site was located in the Okanogan, Wenatchee National Forest, approximately 8 km southwest of Cashmere, WA, in the Mission Creek watershed. The study site was covered by dry coniferous forest types dominated by Douglas-fir and ponderosa pine. Other tree species included grand fir (*Abies grandis*), western larch (*Larix occidentalis*), and scouler willow (*Salix scouleriana*). Bitterbrush (*Purshia tridentata*), Oregon grape (*Berberis aquifolium*), serviceberry (*Amelanchier alnifolia*), snowberry (*Symphocarpos albus*), snowbrush ceanothus (*Ceanothus velutinus*), yarrow (*Achillea millefolium*), pine grass (*Calamagrostis rubescens*), blue-bunch wheatgrass (*Agropyron spicatum*), lupines (*Lupinus* spp.), arrowleaf balsamroot (*Balsamorhiza sagittata*) and silvercrown luina (*Luina nardosima*) were common understory species. Elevations within the project area ranged from 600 to 1200 m. Annual precipitation was approximately 49–64 cm, with the majority falling as snow (unpublished data, NW Weather and Avalanche Center).

The northeastern Cascades study site was one of 13 FFS sites. A similar experimental design was replicated in each of the sites located across the United States. Our study site was comprised of 12 randomly selected stands located across a 97-km^2 area, primarily within the Mission Creek watershed (Fig. 1). The study stands ranged from 9.5 to 37 ha, for a total sampled area of 270 ha. Three replicates of each treatment were monitored and included: burn only, thin only and a combination of thinning and burning (thin–burn), with three additional stands to serve as controls. Specific treatment objectives included restoration of low-density dry forest stands, and the reduction of fuels, high-severity fire risk, and extensive bark beetle attack. The thinning prescriptions were designed to reduce stand density to the estimated historical density for this area (Harrod et al., 1999), to leave the largest and most vigorous trees at irregular spacing, and favor drought and fire resistant species such as ponderosa pine and Douglas-fir. Prescribed burning was conducted to mimic a low intensity fire. Treatment prescriptions are described in detail by Harrod et al. (2007) and Agee and Lolley (2006). Thinning was conducted in the winter of 2002/2003 and prescribed burning was implemented in the spring of 2004. Individual stands were either mechanically thinned from below or burned. Stands were delineated prior to burning, and the burn was confined to that immediate area.

2.2. Data collection

2.2.1. Foraging activity

We used focal animal sampling (Martin and Bateson, 1986) to quantify foraging activities of a selection of cavity-nesting bird species. We focused on woodpeckers and other bark foraging cavity nesters. Methods for quantifying foraging activity generally followed protocols for the FFS project. We visited each study stand 12 times (six visits each time period from 18 May–2 July 2004, 17 May–1 July 2005). Birds were located within each stand by walking a grid transect pattern, with a random starting point, that covered the entire stand within a 2-h observation session, for a total of 24 h of observation time per stand. We conducted observations in the morning to take advantage of increased bird activity. Multiple observers rotated among stands to minimize observer bias. Upon visual observation of a woodpecker or bark foraging species, we recorded the first foraging behavior demonstrated by the bird (Hejl et al., 1990) after a 10-s delay to eliminate conspicuous behavior. To avoid collecting multiple observations of the same individual and to insure independence between observations, we collected data on individuals of the same species only if they were detected greater than 120 m apart during a sampling session (Hurlbert, 1984; Bell et al., 1990; Weikel and Hayes, 1999). We then recorded information for the tree upon which they were foraging at the observed moment. Tree variables were tree species, tree height (m), tree diameter at breast height (dbh, cm), status (alive or snag), beetle presence, fire effects (evidence of past fire), percentage of bark present, and vertical and horizontal strata of foraging location on tree. We chose variables that would likely explain the variability inherent in foraging tree selection patterns and could be useful to habitat managers in modeling foraging tree selection by cavity-nesting birds.

2.2.2. Available foraging trees

Available foraging tree data was collected for all trees greater than 1.3 m tall in three randomly located 20 m × 50 m

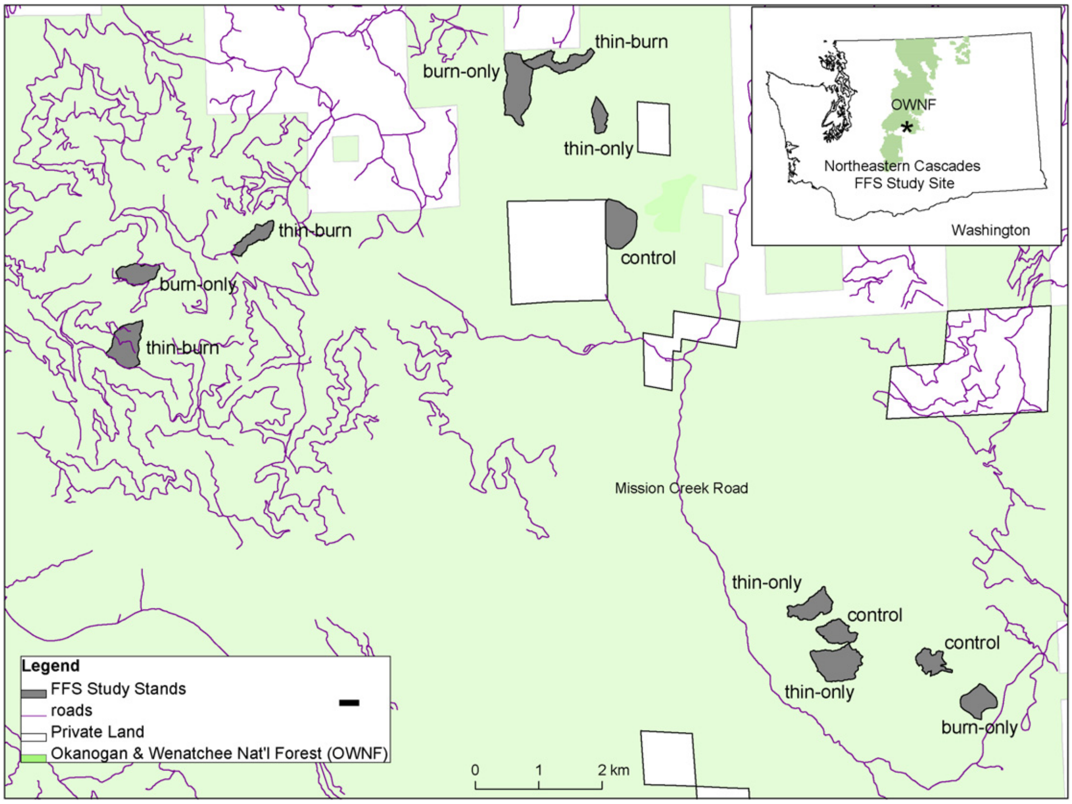

Fig. 1. Map of the northeastern Cascades study site in Washington (WA), 2004–2005. This study site consists of 12 stands located on the Okanogan and Wenatchee National Forests and is one of 13 sites being examined as part of the National Fire–Fire Surrogate Project.

modified Whittaker plots (Whittaker, 1960) per study stand. Foraging tree variables recorded were tree species, tree height (m), tree diameter at breast height (dbh, cm), and status (alive or snag). Beetle presence, fire effects and percentage bark were recorded for a subsample of available trees. The treatment goals for stand structure were achieved through decreased tree density, increased quadratic mean diameter and increased height in treated stands (Fig. 2, Harrod et al., 2007).

2.3. Statistical analyses

We analyzed the effects of FFS treatments on foraging habitat selection using a logistic regression modeling approach and on foraging rate using a repeated-measures analysis of variance (ANOVA). In order to increase our sample sizes we grouped species for our analysis into three groups: chickadees, nuthatches, and woodpeckers. The chickadee group consisted of black-capped chickadee (*Poecile atricapillus*), chestnut-backed chickadee (*Poecile rufescens*), and mountain chickadee (*Poecile gambeli*). The nuthatch group consisted of brown creeper (*Certhia americana*), pygmy nuthatch (*Sitta pygmaea*), red-breasted nuthatch (*Sitta canadensis*), and white-breasted nuthatch (*Sitta carolinensis*). The woodpecker group included black-backed woodpecker (*Picoides arcticus*), hairy woodpecker (*Picoides villosus*), and white-headed woodpecker (*Picoides albolarvatus*).

For each cavity-nesting species group, we also calculated an observation rate (number of foraging observations per 24 h time period) and conducted a repeated measures ANOVA to explore a possible treatment effect on the observation rate. Gaines et al. (2007) conducted point counts in a nearby study area with similar treatments and found detection probabilities of mountain chickadees and red-breasted nuthatches were nearly equal in treated and control stands out to a distance of 60–70 m. Our observation distances were well within that range so we assumed equal detection probabilities among treatments and did not correct for detectability.

2.3.1. Foraging tree selection model

We designated 61, a priori, binary linear logistic regression models (Neter et al., 1996) of foraging tree selection. The models represented all possible combinations of six variables (Table 1). These model variables were chosen because (1) a literature review indicated they are influential in foraging tree selection, (2) they are quantifiable components that can affect foraging selectivity, (3) they allow for examination of a potential treatment effect and (4) they may be altered through forest management. We used SAS Enterprise Guide 4.1 (SAS Institute Inc., 2006) to model foraging tree selection. We evaluated each of the candidate models separately using the ‘‘Full Model’’ method, where all variables are entered in a single step. The global logistic regression model had the format: $\ln[\pi(x)/1-\pi(x)] = \beta 0 + \sum_{i=1}^{n} \beta xi$. We used Akaike's Information Criterion (Anderson et al., 2001; Burnham and Anderson, 2002), adjusted for small sample sizes (AIC_c), to determine which of the models, or combination

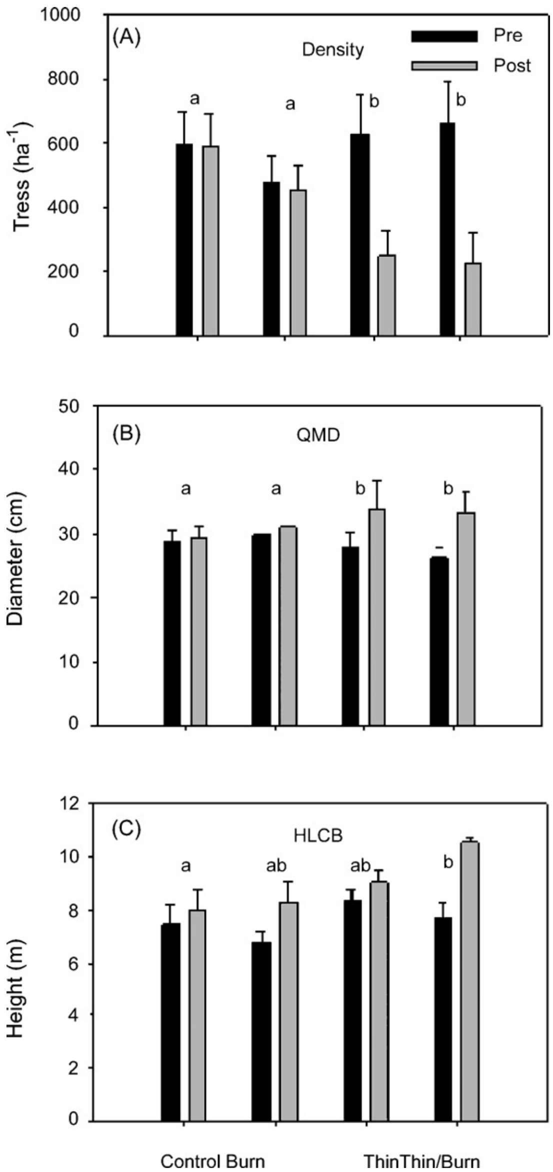

Fig. 2. Changes in (A) live tree density, (B) quadratic mean diameter, and (C) height to live crown base within the northeastern Cascades study site, WA, following implementation of Fire–Fire Surrogate Treatments, 2004–2005. Error bars represent standard deviation. Treatments with the same letter indicate no significant differences between the absolute change in the attribute from pre- to post-treatment ($P < 0.1$) (extracted from Harrod et al., 2007, p. 7).

of models, best approximated true patterns of foraging tree selection by cavity-nesting birds. Model-averaged parameter estimates were calculated to reduce bias and incorporate model selection uncertainty, while describing the effect of a variable on foraging tree selection. We calculated parameter estimates on variables found in models with substantial empirical support ($\Delta AIC_c < 2$) and used Akaike weights to calculate unconditional variances and standard errors (Burnham and Anderson, 2002).

3. Results

The available foraging tree dataset consisted of 10,937 trees, from which a subset of trees was randomly selected to describe foraging trees available to cavity-nesting birds. We analyzed foraging selection with a randomly drawn subset of available tree data at an approximate ratio of 2 available: 1 foraging observation, to prevent masking foraging patterns with an overwhelming available dataset (Gaines et al., 2005). The majority of trees available in treated stands were Douglas-fir and total tree canopy cover ranged from 66–91% (Table 2). Mean tree diameter ranged from 23.8 cm ± 01.7 to 25.7 cm ± 1.3, and mean tree height ranged from 17.2 m ± 1.0 to 19.2 m ± 1.5 (Table 3). Differences in dbh (d.f. = 3, $F = 0.24$, $P > 0.87$) and height (d.f. = 3, $F = 0.72$, $P > 0.54$) were not significant.

A total of 278 foraging observations were made for all cavity-nesting species. We observed (N = number of observations): black-capped chickadee ($N = 5$), chestnut-backed chickadee ($N = 4$), mountain chickadee ($N = 64$), brown creeper ($N = 13$), pygmy nuthatch ($N = 16$), red-breasted nuthatch ($N = 95$), white-breasted nuthatch ($N = 27$), black-backed woodpecker ($N = 5$), hairy woodpecker ($N = 36$), and white-headed woodpecker ($N = 13$). This resulted in 73 chickadee group observations, 151 nuthatch group observations, and 54 woodpecker group observations.

3.1. Foraging tree selection models

Logistic regression results suggested chickadees, nuthatches and woodpeckers exhibited selection for specific foraging tree attributes and were influenced by FFS treatments (Tables 4 and 5). Based on ΔAIC_c, the most parsimonious candidate model for chickadees ($\Delta AIC_c = 0$) contained dbh, height, status and

Table 1
Description of the variables tested to describe foraging selection of cavity-nesting birds in the dry forest of the northeastern Cascades study site, WA, following implementation of Fire–Fire Surrogate Treatments, 2004–2005

Variable	Definition
Tree spp.	Tree species (Douglas-fir, grand fir, ponderosa pine)
dbh	Tree diameter at breast height (cm)
ht	Tree height (m)
dbh × ht	Interaction term, diameter × height
Status	Tree status, alive or snag
Treatment	Treatment implemented at study stand (1) Burn only (2) Thin only (3) Thin–burn (4) Control

Table 2
Study stand canopy cover and tree species composition of random selection of available trees, within stands examined in the northeastern Cascades study site, WA, following implementation of Fire–Fire Surrogate Treatments, 2004–2005

Treatment	Canopy cover (%)	Ponderosa pine (%)	Douglas-fir (%)
Burn only	85	33	67
Thin only	75	48	52
Thin–burn	66	17	83
Control	91	55	45

Table 3
Mean (±S.E.) diameter at breast height (a) and height (b) of trees used by cavity-nesting birds and trees available (from random selection) within each treatment-type in the northeastern Cascades study site, WA, following implementation of Fire–Fire Surrogate Treatments, 2004–2005

Bird group	Control	Burn only	Thin only	Thin–burn
(a) Mean diameter (cm)				
Chickadee	41.6 ± 3.6	39.1 ± 5.2	50.3 ± 4.0	44.5 ± 6.4
Nuthatch	40.7 ± 3.2	38.5 ± 2.3	48.2 ± 2.5	52.1 ± 3.4
Woodpecker	24.9 ± 3.2	56.3 ± 5.2	52.3 ± 1.6	44.1 ± 1.2
Available	25.7 ± 1.3	24.2 ± 1.9	23.8 ± 1.7	24.8 ± 2.7
(b) Mean height (m)				
Chickadee	17.9 ± 2.0	20.9 ± 1.7	21.2 ± 1.7	24.1 ± 2.6
Nuthatch	21.2 ± 1.4	18.4 ± 1.4	21.3 ± 0.8	20.7 ± 0.9
Woodpecker	19.0 ± 3.6	23.7 ± 0.7	22.6 ± 1.6	21.2 ± 1.2
Available	18.7 ± 0.7	17.2 ± 1.0	18.4 ± 1.1	19.2 ± 1.5

treatment (Table 4). However, six additional chickadee models, also had substantial empirical support ($\Delta AIC_c < 1.7$). The most parsimonious model for nuthatches ($\Delta AIC_c = 0$), included the variables dbh, treatment, and dbh × ht (Table 4). Similarly, the most parsimonious candidate model for woodpeckers ($\Delta AIC_c = 0$), included the variables of tree species, dbh, treatment and dbh × ht (Table 4). Model averaged parameter estimates suggested that (1) chickadees selected for large diameter, live, Douglas-fir trees in treated stands, (2) nuthatches selected for large diameter, ponderosa pine in treated stands, and (3) woodpeckers selected for large diameter, ponderosa pine snags, in thinned and thinned–burned stands (Table 5).

Tree size appeared to influence selection for all three bird groups (Table 5). All three bird groups selected for trees with a diameter at least 1.6 times as large as the mean available diameter, in all treatments (Table 3). Most foraging observations occurred on 30–60 cm diameter trees (Fig. 3a) with a minimum average of approximately 40 cm (Table 3). Height was negatively correlated with use for chickadees, although the 95% confidence interval included 0, but only influential within the interaction term (dbh × ht) for nuthatch and woodpecker models (Table 5). Most foraging observations occurred on trees 10–21 m tall (Fig. 3b).

Table 5
Model-averaged parameter estimates, standard errors and 95% confidence intervals for foraging tree selection variables in the candidate set of models for each cavity-nesting bird group in the northeastern Cascades study site, WA, following implementation of Fire–Fire Surrogate Treatments, 2004–2005.

Bird group	Variable	$\beta \pm$ S.E.	95% confidence interval	
Chickadee	Tree species	−0.16 ± 0.26	−0.67	0.36
	Diameter	0.13 ± 0.03	0.07	0.19
	Height	−0.09 ± 0.09	−0.27	0.09
	Status	−0.39 ± 0.58	−1.54	0.76
	Treatment			
	Burn only	0.39 ± 0.44	−0.48	1.26
	Thin only	0.62 ± 0.50	−0.37	1.61
	Thin–burn	1.03 ± 0.67	−0.29	2.36
	Diameter × height	−0.01 ± 0.01	−0.01	0.01
	Intercept	−3.12 ± 0.91	−4.92	−1.32
Nuthatch	Tree species	0.21 ± 0.29	−0.37	0.78
	Diameter	0.25 ± 0.03	0.19	0.31
	Treatment			
	Burn only	0.07 ± 0.42	−0.77	0.90
	Thin only	1.16 ± 0.37	0.42	1.89
	Thin–burn	1.83 ± 0.42	0.99	2.66
	Diameter × height	−0.01 ± 0.01	−0.01	−0.01
	Intercept	−5.83 ± 0.56	−6.93	−4.72
Woodpecker	Tree spp.	1.21 ± 0.48	0.26	2.16
	Diameter	0.20 ± 0.04	0.12	0.28
	Status	0.41 ± 0.55	−0.68	1.49
	Treatment			
	Burn only	−0.57 ± 0.89	−2.33	1.19
	Thin only	0.89 ± 0.62	−0.34	2.11
	Thin–burn	2.98 ± 0.62	1.75	4.21
	Diameter × height	−0.01 ± 0.01	−0.01	−0.01
	Intercept	−7.35 ± 0.88	−9.09	−5.60

Chickadees selected for live trees, while woodpeckers selected for snags relative to availability. However, both 95% confidence intervals included 0 (Table 5). Status was not included in any nuthatch models (Table 4).

Table 4
Candidate models determined to be the best approximating models for describing foraging tree selection in three cavity-nesting bird groups in the northeastern Cascades study site, WA, following implementation of Fire–Fire Surrogate Treatments, 2004–2005

Bird group	Model	K[a]	AIC_c	ΔAIC_c	Akaike weight (w_i)
Chickadee	dbh + ht + status + treat	6	280.51	0	0.16
	dbh + ht + treatment	5	280.56	0.05	0.15
	Tree spp. + dbh + ht + treatment + dbh × ht	7	281.32	0.81	0.11
	Tree spp. + dbh + ht + treatment	6	281.49	.098	0.10
	dbh + ht + status + treatment + dbh × ht	7	281.53	1.02	0.09
	Tree spp. + dbh + ht + status + treatment	7	281.77	1.26	0.08
	dbh + treatment + dbh × ht	5	282.21	1.69	0.07
Nuthatch	dbh + treatment + dbh × ht	5	347.49	0	0.31
	tree spp. + dbh + treatment + dbh × ht	6	347.53	0.04	0.30
Woodpecker	tree spp. + dbh + treatment + dbh × ht	6	176.40	0	0.36
	tree spp. + dbh + status + treatment + dbh × ht	7	176.61	0.21	0.32

We used Akaike's Information Criterion, adjusted for small sample sizes, AIC_c (Burnham and Anderson, 2002).
[a] Number of parameters.

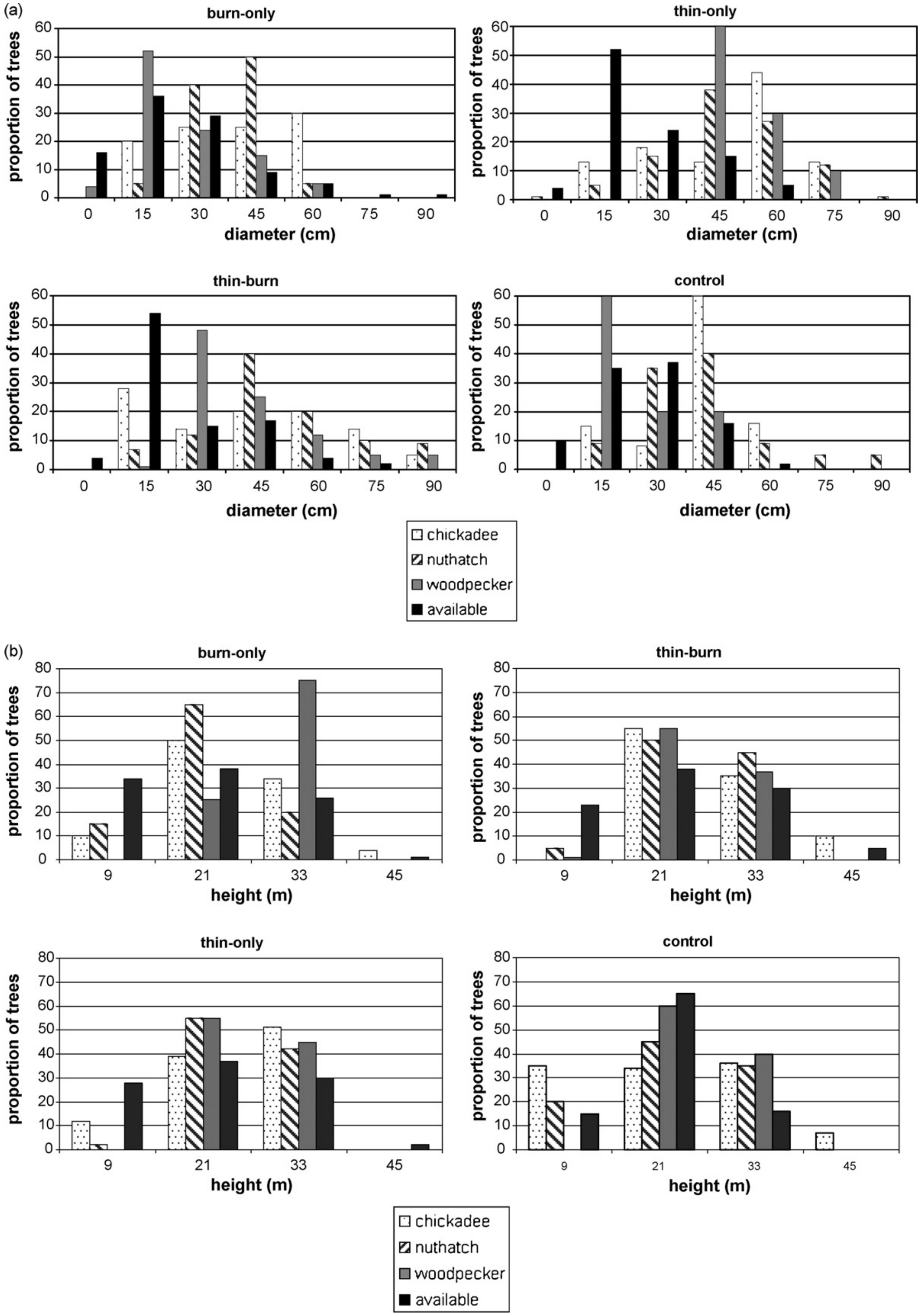

Fig. 3. (a) Diameter of trees selected as foraging substrate by cavity-nesting birds, compared to a random selection of available trees, in the northeastern Cascades study site, WA, following implementation of Fire–Fire Surrogate Treatments, 2004–2005. (b) Height of trees selected as foraging substrate by cavity-nesting birds, compared to a random selection of available trees, in the northeastern Cascades study site, WA, following implementation of Fire–Fire Surrogate Treatments, 2004–2005.

Table 6
Observation rates (mean ± S.E.) of cavity-nesting birds within each treatment-type in the northeastern Cascades study site, WA, following implementation of Fire–Fire Surrogate Treatments, 2004–2005.

	Number of foraging observations per hour			
	Control	Burn only	Thin only	Thin–burn
Chickadee	0.25 ± 0.11	0.42 ± 0.09	0.25 ± 0.08	0.22 ± 0.09
Nuthatch	0.29 ± 0.08	0.42 ± 0.17	0.57 ± 0.10	0.72 ± 0.08
Woodpecker	0.07 ± 0.03	0.08 ± 0.03	0.14 ± 0.05	0.44 ± 0.16

Model results suggested burning and thinning activities impacted foraging observation probabilities. Chickadees and nuthatches, were more likely to forage in burned stands, thinned stands, and thinned–burned stands compared to control stands, although all treatment 95% confidence intervals for chickadees included 0, and the burn only 95% confidence interval for nuthatches included 0 (Table 5). Woodpeckers were less likely to forage in the burn only stands and more likely to forage in thin only and thin–burn stands, although the burn only and thin only 95% confidence intervals included 0 (Table 5). For all bird groups, the effect size (β treatment) was greatest for the thin–burn treatment. All bird groups selected for larger diameter trees in treated stands, relative to availability (Fig. 3a).

All bird groups were observed foraging more frequently in treatment stands than in control stands, with one exception (Table 6). Chickadees were observed less often in thin–burn stands. Only nuthatches exhibited a significantly different rate of detection (F value = 3.67, d.f. = 3, $P = 0.035$) and that difference occurred between the control and thin–burn stands. The rate of nuthatch foraging observations in thin–burn stands was more than twice the rate of observations in the control stands.

4. Discussion

Chickadees, nuthatches and woodpeckers, foraged on large trees and snags in dry conifer forests within the northeastern Cascades study area and foraging tree selection was positively associated with FFS treatments. Model-averaged parameter estimates and 95% confidence intervals suggest diameter and treatment were the most influential aspects of foraging tree selection. All three bird groups selected for large diameter live trees or snags relative to availability in all treatments. The importance of diameter in habitat selection of cavity-nesting birds is well documented (Thomas et al., 1979; Lundquist, 1988; Lundquist and Manuwal, 1990; Adams and Morrison, 1993; Weikel and Hayes, 1999; Bevis and Martin, 2002; Bunnell et al., 2002a; Dickson et al., 2004). Cavity-nesting birds, especially woodpeckers, need large diameter trees for nesting, in order to have cavities capable of housing large birds (Thomas et al., 1979). Selection for foraging tree diameters may not depend entirely on bird size, but is also likely related to prey availability and use. Woodpeckers, nuthatches and chickadees all forage primarily on arthropods (Torgersen et al., 1990; Ghalambor and Martin, 1999; McCallum et al., 1999; Jackson et al., 2002). In spring a large prey base is readily available and arthropod abundance and distribution is influenced by bark characteristics (Lundquist and Manuwal, 1990; Adams and Morrison, 1993). Older trees usually have a greater diameter, which provides for greater surface area, deeper furrows in the bark and greater likelihood of decay, all of which increase the likelihood to be inhabited by insects and exploited by birds (Adams and Morrison, 1993; Bull et al., 1997). Increasing diameter of the available substrate or number of snags through prescribed burning or thinning should increase the prey volume for cavity-nesting birds.

Although tree size appears to be influential in foraging selection, tree height only improved foraging models when included as a negative interaction term (dbh × ht) for nuthatches and woodpeckers. This would suggest birds are selecting for shorter and wider trees. Older trees with decay may also have broken tops, offering a possible explanation for the negative height interaction. Several other studies also found tree height was not a consistent factor in habitat selection and can be highly variable (Conner, 1980; Bunnell et al., 2002b; Jackson et al., 2002). Detecting birds in the tops of trees was limited by our sampling procedure, although the impact was likely diminished by the open structure and steep terrain of the stands.

Although our confidence intervals suggest tree status and FFS treatment are not consistently important factors in determining foraging selection, there is likely a sound biological reason for their inclusion in the various models (Hollenbeck, 2007). Our study stands were composed primarily of live trees interspersed with few large snags and we could not distinguish foraging selection for one or the other. The importance of snags to woodpeckers is well documented in the northwest United States (Thomas et al., 1979; Lundquist, 1988; Lundquist and Manuwal, 1990; Weikel and Hayes, 1999). However, as in other regions (Conner, 1980; Woolf, 2003), the woodpeckers in our study did not strictly limit foraging to snags but also foraged on live trees.

Information on the effects of fire and thinning on bird foraging is limited. A review of the available literature indicates that bark gleaners as a group have very mixed responses to fire that may depend on fire severity (Huff et al., 2005; Kotliar et al., 2007). Since the bulk of available information related to fire deals with high severity-stand replacement wildfire and bird abundance (see Saab and Powell, 2005 for review), we must use caution in our comparisons as our fire treatments were low-intensity prescribed burns. As such, one might assume a relationship exists between abundance and foraging. However, how do birds change their foraging behavior in response to these disturbances? Our results suggest implementation of burning and thinning treatments positively impacts foraging tree selection and model selection showed nuthatches and woodpeckers were more likely to be observed foraging in treated stands, while tree diameter was far more influential on chickadees regardless of treatment. The combination of mechanical thinning and burning had the greatest positive correlation with foraging tree selection. Since fire and thinning can increase the proportion of available large trees, we might expect to see more birds foraging in these areas. Artman (2003) found an increase in red-breasted nuthatches in stands that had been recently thinned to reduce the density of small trees and snags (<30 cm). In contrast, studies indicate nuthatches and creepers were less abundant in intensely burned areas of Arizona, and the Pacific Northwest (Bock and Block, 2005; Huff et al., 2005) or showed no response in the Rocky Mountains (Saab et al., 2005). Chickadees, generally exhibit a negative or neutral response in post-high severity-stand replacement fire stands (Kotliar et al., 2002; Huff et al., 2005). Woodpeckers in our study area were more likely to select for trees in thinned–burned stands. Gaines et al. (2007) also found white-headed woodpeckers were only detected in thinned stands. In contrast, other studies have concluded that black-backed woodpeckers are generally more abundant following high-intensity fires (Hutto, 1995; Kotliar et al., 2002). Woolf (2003) also found woodpeckers were more likely to forage in higher severity burned areas. Our results for the burn only treatment may be a reflection of the very low severity fire that resulted in a cool spring burn (Agee and Lolley, 2006), that did not affect habitat enough to encourage increased woodpecker foraging through the creation of snags and removal of small trees. The lower intensity burns may have also left enough foliage to sustain the foraging needs of chickadees.

5. Conclusions

In this study we tested a small number of possible habitat variables, to develop a suite of models to assist habitat managers when making decisions regarding cavity-nesting birds and potential impacts of forest management activities. The effect of fuel reduction treatments on foraging was documented for the short-term, while long-term effects are unknown at this point. We grouped bird species to increase sample size which may have masked results for individual species. However, our results indicate activities such as thinning and burning may best enhance foraging habitat for bark gleaning species as a whole.

Previous studies have shown short-term (1–3 years) neutral to positive responses of avian communities and many species to fire and fire surrogate treatments in dry forest (Germaine and Germaine, 2002; Zebehazy et al., 2004; Wightman and Germaine, 2006; Gaines et al., 2007). Our study contributes to this knowledge base by providing managers with information on the foraging response of bark gleaners to these treatments. Results from these studies can be used by managers to (1) evaluate the effects of fire and fire surrogate treatments on avian species and (2) better design treatments to have neutral to positive responses on key avian species of management interest. Our data and other fire and fire surrogate research suggest that some important treatment design considerations include the removal of small trees (present due to fire exclusion), opening of the canopy to provide increased herbaceous and bare ground cover resulting in improved invertebrate assemblages and thus improved forage abundance (Wightman and Germaine, 2006; Gaines et al., 2007), and the retention of large trees and snags (>40 cm dbh) that provide important foraging substrate and nesting habitat. As Germaine and Germaine (2002) point out, the effects of fire and fire surrogate treatments on wildlife need to be understood because it is imperative that forest restoration not focus solely on forest structural attributes without consideration of impacts to native wildlife. Future research should focus on the long-term implications of fire and fire surrogate treatments.

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