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EFFECTS OF THINNING AND PRESCRIBED BURNING ON
BIRDS AND SMALL MAMMALS

Jennifer C. Woolf

B.S. Oregon State University, 1997

Presented in partial fulfillment of the requirements

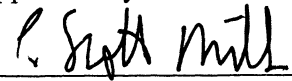
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Master of Science

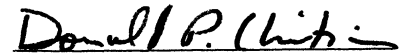
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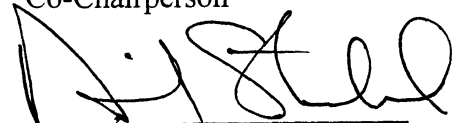
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The effects of thinning and prescribed burning on birds and small mammals.

Co-director: L. Scott Mills *LSM*

Co-director: Don Christian *DPC*

Land management agencies are restoring ponderosa pine forests and reducing fuel loads by thinning followed by prescribed burning. However, little is known about how this combination of treatments will affect local wildlife. In this study, I focus on the following short-term wildlife responses: 1) differences in avian and small-mammal community composition, 2) responses in the foraging patterns of bark-gleaning birds, 3) responses in small mammal abundance. I used three replicate 20-ha thinned/burned sites paired with three 20-ha control sites to examine these responses. I found minor differences in avian species composition. However, these differences involved sensitive species (USFS classification), indicating the need for further research on the quality of this habitat type. I encountered black-backed woodpeckers, hairy woodpeckers and white-breasted nuthatches foraging almost exclusively in thinned/burned sites. Additionally, the selection of large diameter, ponderosa pine trees as foraging substrates overlaps well with the treatment goals. Small mammal species composition differed slightly between treatments, with golden-mantled ground squirrels present in the thinned/burned areas only. Population responses were varied; deer mice were more abundant on thinned/burned sites in both years. Yellow-pine chipmunks showed a delayed response, being more abundant on thinned/burned sites during the second year of the study. Red-backed voles were more abundant on the control sites both years, but were uncommon on all sites. These diverse responses indicate that land managers must consider multi-level wildlife responses, both positive and negative, when implementing thinning followed by prescribed burning.

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hours of stress relief, stimulating conversations, and valuable critiques, in particular, my labmates: Mike Schwartz, Dave Tallmon, John Citta, Paul Griffin, Sue Cox, Reesa Yale, and Tammy Mildenstein. Most importantly, Brian Woolf has provided love and support through all of my struggles, has kept me well fed with his exceptional cooking, and has spent many an hour in the field helping set up study sites, trap small mammals and fixing field trucks. I would not be as successful without Brian at my side providing whatever it is I need at that moment. Thank you.

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TABLE OF CONTENTS

Abstract	ii
Acknowledgements	iii
List of Tables	viii
List of Figures	xii
Chapter 1: The effects of thinning and prescribed fire on birds and small mammals: an introduction	1
Background	1
Study goals	3
Literature Cited	5
Chapter II. The effects of thinning and prescribed fire in ponderosa pine forests on avian species composition	15
Abstract	15
Introduction	16
Study site and design	17
Methods	19
Results	19
Discussion	24
Literature Cited	26
Chapter III. Effects of thinning and prescribed fire on the foraging patterns of bark-gleaning birds	29
Abstract	29
Introduction	30
Study site and design	33
Methods	36

Analysis	39
Results	41
Behavior	41
Microhabitat selection	45
Red-breasted nuthatch	45
Mountain chickadee	48
White-breasted nuthatch	50
Black-backed woodpecker	53
Hairy woodpecker	57
Foraging and fire	60
Discussion	60
Literature Cited	65
Chapter IV. Small mammals responses to thinning and prescribed fire in ponderosa pine forests	74
Abstract	74
Introduction	75
Study site and design	78
Methods	80
Analysis	81
Results	82
Discussion	86
Abundance	86
Species composition	94
Management Implications	94

Literature Cited	95
Appendix I. Montana Department of Natural Resources Treatment Description as modified from DNRC 1995 contract	103
Appendix II. Wildlife Data collection conducted for National Fire/Fire Surrogate Study	106
Appendix III. Fire intensity/severity characterization	108
Appendix IV. Candidate model sets considered for selection of forage tree characteristics	119

LIST OF TABLES

Chapter II. The effects of thinning and prescribed fire in ponderosa pine forests on avian species composition

Table 1. Presence (X) or absence of bird species during the breeding season obtained with four replicate point counts at three to four points per site. C represents unmanipulated sites, B represents thinned/burned sites. (a) 2002 season (b) 2001 season	
Table 1a. 2002 season	20
Table 1b. 2001 season	21

Table 2. Species that displayed trends in presence/absence. There are 6 possible times (3 sites x 2 years) a bird could be present in a thinned/burned area or control area.	22
--	----

Chapter III. Effects of thinning and prescribed fire on the foraging patterns of bark-gleaning birds

Table 1. Behavioral information collected for each foraging observation	37
---	----

Table 2. Description of tree characteristics recorded on forage trees and random trees	38
--	----

Table 3. Logistic regression results for red-breasted nuthatches in treated areas. Best approximating models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio.	
(a) selection among any tree class	46
(b) selection within tree class	47

Table 4. Logistic regression results for red-breasted nuthatches in control sites. Best models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio.	
(a) selection among any tree class	49
(b) selection within tree class	49

Table 5. Logistic regression results for mountain chickadees in treatment areas. Best models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio.	
(a) selection among any tree class	51

(b) selection within tree class	51
Table 6. Logistic regression results for mountain chickadees in control areas. Best models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio.	
(a) selection among any tree class	52
(b) selection within tree class	52
Table 7. Logistic regression results for white-breasted nuthatches in treatment areas. Best models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio.	
(a) selection among any tree class	54
(b) selection within tree class	54
Table 8. Logistic regression results for black-backed woodpeckers in treated. Best models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio.	
(a) selection among any tree class	55
(b) selection within tree class	56
Table 9. Logistic regression results for hairy woodpeckers in treatment areas. Best models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio.	
(a) selection among any tree class	58
(b) selection within tree class	59
 Chapter IV. Small mammals responses to thinning and prescribed fire in ponderosa pine forests	
Table 1. Relative abundance (N_B/N_C), Population estimates (N), standard errors, 95 percent confidence intervals and daily capture probabilities (p) of deer mice, yellow-pine chipmunks, and southern red-backed voles. All estimates were calculated with the null model in program CAPTURE.	83
Table 2. Species composition for each study site, for both years of the study. Numbers in parenthesis are the total number of <i>Spermophilus lateralis</i> caught over both years.	88
 Appendix III. Fire intensity/severity characterization	
Table 3.1. Description of visual characteristics of ground char classes, as described in Ryan and Noste (1983)	110
Table 3.2. Adapted classification of ground char classes developed by Jenny Woolf and Mick Harrington to describe fire severity	111

Table 3.3 Flame length classes with the corresponding crown scorch heights and tree mortality classes (Ryan and Noste 1983)	112
Table 3.4. Average crown scorch height, maximum crown scorch height and the flame class associated with the average scorch height for the grid-points sampled in Burn 1	113
Table 3.5. Average crown scorch height, maximum crown scorch height and the flame class associated with the average scorch height for the grid-points sampled in Burn 2	114
Table 3.6. Average crown scorch height, maximum crown scorch height and the flame class associated with the average scorch height for the grid-points sampled in Burn 3	115
Table 3.7 Area within 10- meter radius circle of sampled grid-points in each category of char, the sum of these percentages multiplied by the appropriate value, the associated ground char class and fire severity rating for Burn 1	116
Table 3.8 Area within 10meter radius circle of sampled grid-points in each category of char, the sum of these percentages multiplied by the appropriate value, the associated ground char class and fire severity rating for Burn 2	117
Table 3.9. Area within 10meter radius circle of sampled grid-points in each category of char, the sum of these percentages multiplied by the appropriate value, the associated ground char class and fire severity rating for Burn 3	118
 Appendix IV. Candidate model sets considered for selection of forage tree characteristics	
Table 4.1 Candidate model set considered for red-breasted nuthatches for selection of forage tree characteristics among any tree class	119
Table 4.2. Candidate model set considered for red-breasted nuthatches for selection of forage tree characteristics within the same tree class	120
Table 4.3. Candidate model set considered for mountain chickadees for selection of forage tree characteristics among any tree class	121

Table 4.4. Candidate model set considered for mountain chickadees for selection of forage tree characteristics within the same tree class	122
Table 4.5. Candidate model set considered for white-breasted nuthatches for selection of forage tree characteristics among any tree class	123
Table 4.6. Candidate model set considered for white-breasted nuthatches for selection of forage tree characteristics within the same tree class	124
Table 4.7. Candidate model set considered for black-backed woodpeckers for selecting trees among any tree class	125
Table 4.8. Candidate model set considered for black-backed woodpeckers for selecting trees within the same tree class	126
Table 4.9. Candidate model set considered for hairy woodpeckers for selection of forage tree characteristics among any tree class	127
Table 4.10. Candidate model set considered for hairy woodpeckers for selection of forage tree characteristics within the same tree class	128

LIST OF FIGURES

Chapter II. The effects of thinning and prescribed fire in ponderosa pine forests on avian species composition

- Figure 1. Location of Lubrecht Experimental Forest in relation to climax vegetation in Montana, from Montana Natural Resource Information System Geographic Information System (<http://nris.state.mt.us/nsdi/nris/lu26.gif>). 18

Chapter III. Effects of thinning and prescribed fire on the foraging patterns of bark-gleaning birds

- Figure 1. Location of Lubrecht Experimental Forest in relation to climax vegetation in Montana, from Montana Natural Resource Information System Geographic Information System (<http://nris.state.mt.us/nsdi/nris/lu26.gif>). 34

- Figure 2. Schematic of control plots and treatment plots in relation to National Fire/Fire Surrogate Study blocks 35

- Figure 3. Distribution of foraging behaviors observed; A. = red-breasted nuthatches, B. = mountain chickadees, C. = white-breasted nuthatches, D. = black-backed woodpeckers, E. = hairy woodpeckers 42

- Figure 4. Distribution of horizontal tree stratum use by the bark-gleaning birds on study sites 43

- Figure 5. Distribution of vertical tree stratum use, divided into thirds: upper, middle, low, by the bark-gleaning birds on study sites. 44

Chapter IV. Small mammals responses to thinning and prescribed fire in ponderosa pine forests

- Figure 1. The configuration of trapping grids for each pair of 20-ha plots, grid had 25 m spacing. (a) Burn1/Control 1 (b) Burn2/Control 2 (c) Burn3/Control 3 79

- Figure 2. The estimated abundances, with standard error bars, of deer mice *Peromyscus maniculatus* for each paired treatment/control site in 2001 (top) and 2002 (bottom) 84

Figure 3. The estimated abundances, with standard error bars, of yellow-pine chipmunks *Tamias amoenus* for each paired treatment/control site in 2001 (top) and 2002 (bottom) 85

Figure 4. The estimated abundances, with standard error bars, of red-backed voles *Clethrionomys gapperi* for each paired treatment/control site in 2001 (top) and 2002 (bottom) 87

CHAPTER I. The effects of thinning and prescribed fire on birds and small mammals: an introduction

BACKGROUND

Before European settlement, many forest types were mosaics of uneven aged, moderately open, large-tree dominated stands that were maintained by fire, insect depredations and age-related mortality (Arno et. al. 1995, Fiedler 2000). Fire suppression in ponderosa pine (*Pinus ponderosa*) forests has resulted in an increase in Douglas-fir (*Pseudotsuga menziesii*), a shade-tolerant species, with a much denser understory (Covington et al. 1997). This shift in species composition has resulted in higher fuel loads, decreases in soil moisture and nutrient availability, increases in fire severity and size (Covington et al. 1997, Smith 2000) and increases in the scale of insect outbreaks such as Douglas-fir tussock moth (*Orgyia pseudotsugata* McDunnough) (Tiedemann et al. 2000).

Western Montana contains nearly five million acres of pine/fir forests that were historically maintained by frequent low-intensity fire (Smith and Arno 1999, Veblen et al. 2000). Fire suppression in western forests has changed the mosaic of successional stages. In the western United States, recent large-scale, high-intensity fires have been attributed to the lack of fire for the past century. On a national scale, the Bush administration is calling for a major change in land management practices. The 10-year Comprehensive Strategy Implementation Plan signed May 2002 calls for the active management of forests by reducing the accumulation of fuels (Department of Interior et al. 2001). The Forest Service and Interior Department planned to treat over 2.5 million acres of land in 2002 alone. Treatments include forest thinning, prescribed burns or the combination of

thinning followed by a prescribed burn. The treatment goal is to reduce the accumulation of hazardous fuels and restore forests to conditions before fire suppression. Agencies have increased the acreage treated with fuel reduction/restoration treatments by nearly 30 percent over last year (NFP website).

The effects of thinning followed by prescribed burning on wildlife populations is poorly understood (Tiedemann et al. 2000). Current forest management plans aim to reduce acreage of stand replacement fire, while increasing acreage of thinned and prescribed burned areas. These major shifts in landscape patterns will have large impacts on wildlife populations. Certain species may respond favorably to the treatment, while others may respond unfavorably (Smith 2000). Understanding the responses of different species to thinned and burned areas is imperative for wildlife managers to understand the impacts of these shifts in habitat type on the ecosystem.

Because returning fire directly may result in unwanted mortality of the desirable large trees, federal and state agencies are integrating ponderosa pine forest restoration into their timber harvest program with selective cuts, followed by prescribed burns. The management goal is open uneven-aged stands dominated by large ponderosa pine trees. The Montana Department of Natural Resources (DNRC) is integrating ponderosa pine forest restoration into its timber harvest program with a commercial thin that is combined with a selective cut, and followed by a prescribed burn (Appendix 1). The agency plans on selective removal and prescribed burns on a ~ 25 year rotation, which is within the historic fire interval (5-30 years, Arno 1996).

STUDY GOALS

In this study, I focus on the following short-term wildlife responses to thinning and prescribed burning in ponderosa pine forest: 1) shifts in community composition, both avian and small mammal communities, 2) responses in the foraging patterns of bark-gleaning birds, 3) responses in small mammals species composition and abundance.

Examining these responses will provide a broad overview of short-term responses from changes in both the forest floor and forest canopy. Changes in forest canopy may affect the breeding bird community, this treatment will open the canopy and change understory structure. Changes in forest structure as a result of vegetation management regularly lead to changes in avian communities (Franzreb and Ohmart 1978, Szaro and Balda 1979, Dellasala et al. 1996, Easton and Martin 1998, Hobson and Bayne 2000). Disturbance from natural fires causes shifts in avian communities (Hutto 1995, Hobson and Schieck 1999, Kriesel and Stein 1999), that can differ from shifts observed due to harvest-related disturbance (Schieck and Hobson 2000). The effects of thinning followed by prescribed fire in ponderosa pine forests has not been well studied (but see Bock and Bock 1983). In Chapter II, I examine short-term differences in avian species composition between the thinned and burned areas compared to areas that represent sites slated for fuel reduction treatments. This examination of differences in avian species composition will provide a coarse filter to direct future research on avian responses to this treatment.

For cavity nesting birds in the bark-gleaning guild, forest management practices are known to change nest availability (Weikel and Hayes 1999, Steeger and Hitchcock 1998, Li and Martin 1991), but little published information exists on effects on foraging patterns. It has been suggested that food availability may be the limiting factor for

woodpeckers (Gunn and Hagan 2000). Prey density has been suggested as an important predictor of woodpecker presence (Powell 2000). Many bark-gleaning birds forage on beetles (Otvos 1965; Otvos & Stark 1985), and fire often increases the level of beetle activity in a forest stand. Shifts in food resources will likely shift territory size, abundance, and density of nest sites. As primary cavity nesters, this subset of birds influences the available future nest habitat for a number of secondary cavity nesting vertebrates (Martin and Eadie 1999, Aitken et al. 2002). In Chapter III, I examine the foraging patterns of bark-gleaning birds in thinned and burned areas compared to areas that represent sites slated for fuel reduction treatments.

Small mammals may respond to management-induced changes in the forest floor, such as potential changes in small and large downed woody debris, areas of intense fire, and shifts in the understory vegetative community and structure. Although species abundance may not be a good indicator of habitat quality (Van Horne 1983), changes in small mammal abundance may have reverberating effects in the ecosystem. Small mammals are often strong interactors in the ecosystem. The most abundant species on my study sites are deer mice (*Peromyscus maniculatus*), yellow pine chipmunks (*Tamias amoenus*) and red-backed voles (*Clethrionomys gapperi*). Deer mice are important seed predators, and may negatively affect the plant community. Deer mice are the most common carrier of Hantavirus, of interest when fuel-reduced stands are at the urban interface (Kuenzi et al. 2001). Because chipmunks and deer mice are primary nest predators in forested systems (Martin 1993, Martin 1988a, Martin 1988b) shifts in abundance may affect nest survival rates of songbirds. Red-backed voles play an important role as dispersers of mycorrhizal fungi (Maser et al. 1978). Thus different

species may have strong interactions, as well as being important prey for forest carnivores and raptors. In Chapter IV, I examine short-term differences in small mammal species composition and abundance in thinned and burned areas compared to areas that represent sites slated for fuel reduction treatments.

As this major shift in land management practices moves forward, it is important to understand the way wildlife may respond. By examining these responses we gain broader knowledge into the overall response of wildlife to a forest treatment designed to emulate historic stand conditions.

My study was supported by the National Fire/Fire Surrogate study (FFS), a five-year inter-disciplinary study examining different fuel reduction methods. The treatments include control, selective tree removal, selective tree removal and prescribed fire, and prescribed fire. I have overlaid control plots on the National Study for efficiency when possible. Please refer to Appendix 2 for details of this research.

Each chapter is being written as a publication, therefore it is repetitious.

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Chapter II. The effects of thinning and prescribed fire in ponderosa pine forests on avian species composition

Abstract

In this study, I determined if there are differences in avian species composition between areas thinned and burned to restore ponderosa pine and comparable untreated areas. I used three replicate 20-ha thinned/burned plots paired with three 20-ha control plots, and compared avian species composition in the 2001 and 2002 breeding seasons. Overall, this treatment had minimal impacts on avian species composition on our sites. Black-backed woodpeckers and dusky flycatchers were consistently present in thinned/burned sites only. Several other species displayed weaker trends in exclusive presence/absence. However, two sensitive species (USFS classification), black-backed woodpeckers and olive-sided flycatchers, were observed in thinned/burned sites only. Differences in composition of abundant species, such as dusky flycatchers, may not be of immediate concern, but studies such as this can guide needs of further research on sensitive and rare species. Specifically, further research determining the demographic quality of thinned/burned areas for sensitive species is imperative.

INTRODUCTION

Historically, many ponderosa pine (*Pinus ponderosa*) forests were characterized by frequent, low-intensity fires that maintained them in an open, uneven-aged state. The lack of natural disturbance in ponderosa pine forests has resulted in an increase in Douglas-fir (*Pseudotsuga menziesii*), a shade-tolerant species, in the understory. Fire suppression during the past 75 years in the United States has resulted in dense understory conditions in many forest types that historically were maintained in a semi-open condition by fire. A change in tree species composition with multiple secondary and associated effects, combined with increased fire risks, have prompted land managers to seek ways to return natural disturbance regimes to the landscape. Western Montana contains nearly 5 million acres of pine/fir forests that were historically maintained by frequent low-intensity fire. Following national trends, The Montana Department of Natural Resources (DNRC) is integrating ponderosa pine forest restoration into its timber harvest program with a commercial thin that is combined with a selective cut, followed by a prescribed burn (Appendix 1).

The change in habitat components, including canopy and understory structure and density, that result from ponderosa pine forest restoration may affect avian species composition. Studies on changes in forest structure, resulting from timber harvest, have shown shifts in avian species composition (Franzreb and Ohmart 1978, Dellasala et al. 1996, Hobson and Bayne 2000, Schieck and Hobson 2000). The management of understory vegetation can influence changes in bird communities (Easton and Martin 1998, Rodewald and Smith 1998). Although numerous studies have been conducted on the effects of natural fire (Bock and Lynch 1970, Bock and Bock 1983, Schieck and

Hobson 2000) and more recently on prescribed fire (Artman et al. 2001), determining the short-term effects of a combination of thinning and prescribed burning on bird communities has been little investigated. In this project, I determined if there are differences in avian species composition between areas that have been managed to restore ponderosa pine forests compared to areas that would be candidates for treatment.

STUDY SITE AND DESIGN

Study sites were located within the boundaries of The University of Montana's Lubrecht Experimental Forest, 38 km NE of Missoula, MT at approximately 1200 – 1350 m elevation (Figure 1). The area was heavily logged in the early 1900s, with subsequent fire suppression. The second-growth ponderosa pine/Douglas-fir forests represent xeric, low-elevation forest conditions common in western Montana.

My study design consisted of three 20-ha control plots paired with three 20-ha treated plots. The treatment plots were located on Montana Department of Natural Resources (DNRC) managed land within the boundaries of Lubrecht Experimental Forest. The DNRC implemented a selective tree removal treatment in winter 1998/1999 (Appendix 1) and the sites were all subsequently burned in spring 2000. The size of treatments ranges from 60 – 250 ha, with 20-ha plots located within the treatment boundaries. Each control plot was paired with a treatment plot of the same size, shape and forest type. Each plot had a 75-m buffer from any defined habitat edge (road, habitat-type change). The control plots were reduced in size (remaining plots were 14 – 18 ha) following prescribed burning during the 2002 season.

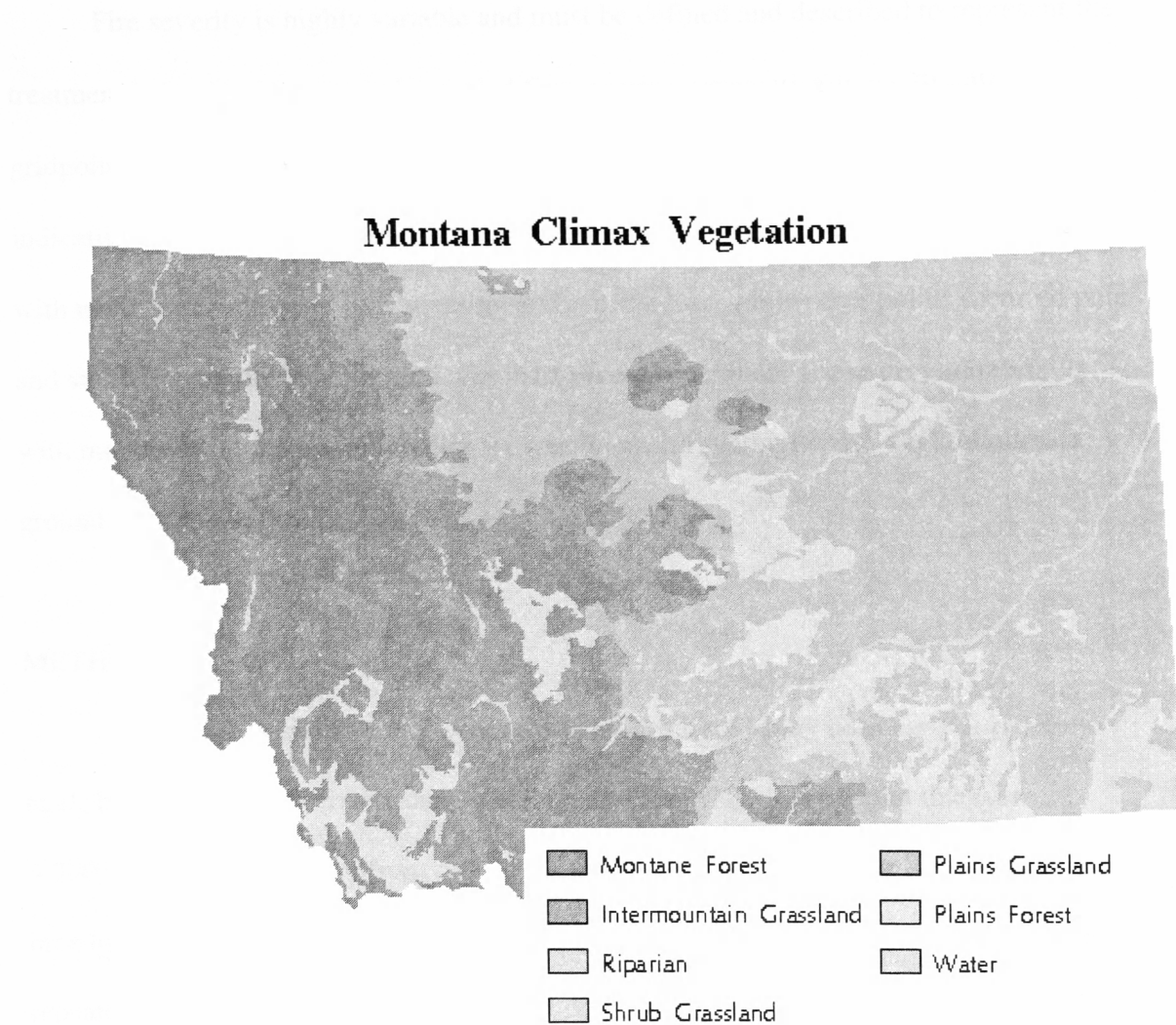


Figure 1. Location of Lubrecht Experimental Forest in relation to climax vegetation in Montana, from Montana Natural Resource Information System Geographic Information System (<http://nris.state.mt.us/nsdi/nris/lu26.gif>).

Fire severity is highly variable and must be defined and described to represent the treatment being implemented. I sampled fire severity systematically on 29 - 49 gridpoints per 20-ha plot. Burn 1 was dominated by flame length class (2) and (3), indicating high levels of sapling and pole-tree mortality. Burn 2 was highly variable, with many areas suffering only seedling and sapling loss, while other points incurred pole and small saw timber loss. Burn 3 was least severe in terms of above ground mortality, with most points indicating mortality for seedlings and saplings only. Light/moderate ground char dominated all sites (See Appendix 3).

METHODS

Fixed-radius point counts were conducted from mid-May until early July (Hutto et al. 1986). Surveys were conducted at three or four gridpoints per plot that were > 200 m apart and > 100 m from plot edge. Counts were repeated four times during the breeding season, with gridpoints and observers being rotated among visits. Counts were repeated four times to increase detection of rare species and of birds whose singing behaviors varied temporally. I was interested in species presence/absence, and did not compare species abundance. Species were considered present if observed once on a site.

RESULTS

I observed 37 species of birds over the course of the study, 34 in thinned/burned sites and 28 in unmanipulated sites. Several species were consistently observed in only one habitat type during both years of the study (Table 1, Table 2). Black-backed

Table 1. Presence (X) or absence of bird species during the breeding season obtained with four replicate point counts at three to four points per site. C represents unmanipulated sites, B represents thinned/burned sites. (a) 2002 season (b) 2001 season

Table 1a. 2002 season

	C1	B1	C2	B2	C3	B3
American Robin <i>Turdus migratorius</i>	X	X	X	X	X	X
Black-backed Woodpecker <i>Picoides arcticus</i>		X		X		X
Brown-headed Cowbird <i>Molothrus ater</i>	X	X	X	X	X	X
Cassin's Finch <i>Carpodacus cassinii</i>		X		X		X
Cassin's Vireo <i>Vireo cassinii</i>	X	X	X	X	X	X
Chipping Sparrow <i>Spizella passerina</i>	X	X	X	X	X	X
Clark's Nutcracker <i>Nucifraga columbiana</i>	X	X	X	X	X	X
Common Raven <i>Corvus corax</i>	X	X	X	X	X	X
Dark-eyed junco <i>Junco hyemalis</i>	X	X	X	X	X	X
Dusky flycatcher <i>Empidonax oberholseri</i>		X		X		X
Gray Jay <i>Perisoreus canadensis</i>		X	X	X	X	X
Hairy Woodpecker <i>Picoides villosus</i>		X		X	X	X
Hermit Thrush <i>Catharus guttatus</i>	X	X	X	X	X	X
Mountain Chickadee <i>Poecile gambeli</i>	X	X	X	X	X	X
Mourning Dove <i>Zenaida macroura</i>		X	X	X		
Northern Flicker <i>Colaptes chrysoides</i>	X	X		X		X
Orange-crowned Warbler <i>Vermivora celata</i>			X	X		
Pine Siskin <i>Carduelis pinus</i>	X	X	X	X	X	X
Pileated Woodpecker <i>Dryocopus pileatus</i>	X					
Red-breasted Nuthatch <i>Sitta canadensis</i>	X	X	X	X	X	X
Ruby-crowned Kinglet <i>Regulus calendula</i>	X	X	X	X	X	
Red Crossbill <i>Loxia curvirostra</i>	X	X	X	X	X	X
Sharp-shinned Hawk <i>Accipiter striatus</i>	X					
Swainson's Thrush <i>Catharus ustulatus</i>	X		X	X		
Townsend's Solitaire <i>Myadestes townsendii</i>	X	X	X	X		X
Warbling Vireo <i>Vireo gilvus</i>	X			X		
White-breasted Nuthatch <i>Sitta carolinensis</i>				X		X
Western Meadowlark <i>Sturnella neglecta</i>				X		
Western Tanager <i>Piranga ludoviciana</i>	X	X	X	X	X	X
Wild Turkey <i>Meleagris gallopavo</i>			X			
Western Wood-Pewee <i>Contopus sordidulus</i>			X			
Yellow-rumped Warbler <i>Dendroica coronata</i>	X	X	X	X	X	X

Table 1b. 2001 season

	C1	B1	C2	B2	C3	B3
American Crow <i>Corvus brachyrhynchos</i>				X	X	X
American Goldfinch <i>Carduelis tristis</i>				X		
American Robin <i>Turdus migratorius</i>		X		X		X
Black-backed Woodpecker <i>Picoides arcticus</i>		X				X
Brown-headed Cowbird <i>Molothrus ater</i>	X	X	X	X	X	X
Cassin's Finch <i>Carpodacus cassinii</i>	X					X
Cassin's Vireo <i>Vireo cassinii</i>	X	X	X	X	X	X
Chipping Sparrow <i>Spizella passerina</i>	X	X	X	X	X	X
Clark's Nutcracker <i>Nucifraga columbiana</i>				X		X
Common Raven <i>Corvus corax</i>	X	X		X	X	X
Dark-eyed junco <i>Junco hyemalis</i>	X	X	X	X	X	X
Dusky flycatcher <i>Empidonax oberholseri</i>				X		
Gray Jay <i>Perisoreus canadensis</i>						X
Hammond's Flycatcher <i>Empidonax hammondii</i>				X		
Hairy Woodpecker <i>Picoides villosus</i>	X	X				X
Hermit Thrush <i>Catharus guttatus</i>	X	X	X			X
Mountain Chickadee <i>Poecile gambeli</i>	X	X	X	X	X	X
Mourning Dove <i>Zenaida macroura</i>						X
Northern Flicker <i>Colaptes chrysoides</i>		X	X		X	X
Olive-sided Flycatcher <i>Contopus cooperi</i>						X
Pine Siskin <i>Carduelis pinus</i>	X	X	X	X	X	X
Pileated Woodpecker <i>Dryocopus pileatus</i>	X		X			X
Red-breasted Nuthatch <i>Sitta canadensis</i>	X	X	X	X	X	X
Ruby-crowned Kinglet <i>Regulus calendula</i>	X	X	X	X	X	
Red Crossbill <i>Loxia curvirostra</i>	X	X	X	X	X	X
Swainson's Thrush <i>Catharus ustulatus</i>				X	X	X
Townsend's Solitaire <i>Myadestes townsendii</i>	X	X	X	X	X	X
Townsend's Warbler <i>Dendroica townsendii</i>				X		
Three-toed Woodpecker <i>Picoides tridactylus</i>				X		
Western Tanager <i>Piranga ludoviciana</i>	X	X	X	X	X	X
Yellow-rumped Warbler <i>Dendroica coronata</i>	X	X	X	X	X	X

Table 2. Species that displayed trends in presence/absence. There are 6 possible times (3 sites x 2 years) a bird could be present in a thinned/burned area or control area.

Species	Thin/Burn	Control
Black-backed woodpecker <i>Picoides arcticus</i>	5/6	0/6
Dusky flycatcher <i>Empidonax oberholseri</i>	4/6	0/6
White-breasted nuthatch <i>Sitta carolinensis</i>	2/6	0/6
Cassin's Finch <i>Carpodacus cassinii</i>	4/6	1/6
American Robin <i>Turdus migratorius</i>	6/6	3/6
Pileated Woodpecker <i>Dryocopus pileatus</i>	1/6	4/6
Hairy Woodpecker <i>Picoides villosus</i>	5/6	2/6
Clark's Nutcracker <i>Nucifraga columbiana</i>	5/6	3/6
Olive-sided Flycatcher <i>Contopus cooperi</i>	1/6	0/6
Hammond's Flycatcher <i>Empidonax hammondii</i>	1/6	0/6
Three-toed Woodpecker <i>Picoides tridactylus</i>	1/6	0/6
Townsend's Warbler <i>Dendroica townsendii</i>	1/6	0/6
Western Wood-Pewee <i>Contopus sordidulus</i>	0/6	1/6
Additional 15 species	6/6	6/6

woodpeckers (*Picoides arcticus*) were recorded in all three thinned/burned sites in 2002, and in two of three thinned/burned sites in 2001; with no observations recorded in unmanipulated sites. Dusky flycatchers (*Empidonax oberholseri*) were recorded in all three thinned/burned sites in 2002 and in one of three thinned/burned sites in 2001, with no observations recorded in unmanipulated sites. White-breasted nuthatches (*Sitta carolinensis*), olive-sided flycatchers (*Contopus cooperi*), hammond's flycatchers (*Empidonax hammondi*), townsend's warblers (*Dendroica townsendi*), American goldfinches (*Carduelis tristis*), western meadowlarks (*Sturnella neglecta*) and three-toed woodpeckers (*Picoides tridactylus*) were not observed often, but were observed only in thinned/burned sites. Wild turkeys (*Meleagris gallopavo*) and western wood-pewees (*Contopus sordidulus*) were recorded in unmanipulated sites only.

Other species showed strong patterns in presence during only one year of the study (Table 1). Cassin's finches (*Carpodacus cassinii*) were recorded exclusively in thinned/burned sites in 2002, however in 2001, they were recorded in one of the unmanipulated plots. Clark's nutcrackers (*Nucifraga columbiana*) were recorded in thinned/burned sites only in 2001, but in all sites in 2002. Pileated woodpeckers (*Dryocopus pileatus*) were recorded exclusively in unmanipulated sites in 2002, and in two of three unmanipulated sites in 2001, compared to one of three thinned/burned site in 2001.

Hairy woodpeckers (*Picoides villosus*) and northern flicker (*Colaptes auratus*) were recorded in thinned/burned sites more consistently than in unmanipulated sites (Table 1, Table 2). Both species were recorded in all three thinned/burned sites in 2002, and only one unmanipulated site. Patterns were weaker in 2001.

DISCUSSION

Most differences resulted from birds rarely recorded in either thinned-burned or control areas (9 species, Table 2). However, black-backed woodpeckers and dusky-flycatchers commonly occurred only on thinned and burned sites.

Black-backed woodpeckers typically occupy naturally disturbed forested habitats that have been colonized by bark beetles (Scolytidae) and woodborer beetles (Buprestidae and Cerambycidae). Although this species typically shows a strong association with areas that have experienced stand-replacement fire, (Hutto 1995, Murphy and Lehnhausen 1998), they have been observed in unburned forests with beetle outbreaks (Bull et al. 1986, Goggans et al. 1989) and unburned boreal forests (Villard 1994). My study sites had been invaded by *Dendroctonus valens* (pers. obs.), and both Buprestids and Cerambycids were present. This readily available food source may explain black-backed woodpecker presence in a low-severity fire.

When in forests, dusky flycatchers typically occupy open coniferous forest. In western Montana, they have been found in ponderosa pine/Douglas-fir forests, thinned coniferous forests and logged areas (Sedgewick 1993). It has been speculated that dusky flycatchers may benefit from forestry practices that thin dense stands (Sedgewick 1993). Although dusky flycatchers were found in thinned and subsequently burned areas only, I suspect they are responding to the change in forest structure resulting from thinning (as opposed to fire), as found in previous studies.

Many other species varied considerably in their pattern of presence. Cassin's finch were observed consistently only in thinned/burned sites. Similar to dusky flycatchers, this species most likely responds to the opening up of the canopy (Ehrlich et

al. 1988). Pileated woodpeckers were observed consistently only in unmanipulated sites, yet they were uncommon on all sites. The Clark's nutcrackers exclusive presence in thinned-burned sites in 2001 may be explained by chance, or by a difference in seed availability during that year. Conifer seeds may have been plentiful in all areas in 2002, and plentiful only in thinned/burned sites in 2001.

Overall, treatment did not have major effects on avian species composition. This is not surprising, considering previous studies. Rutledge and Conner (2002) reported longleaf pine groundcover restoration treatments did not affect community composition. Fire is currently being reintroduced to restore mixed-oak forests in Ohio, with no changes in bird community composition yet detected (Artman et al. 2001). However, shifts in the bird community were observed between shelterwood logged and unmanaged (for past 40yr) ponderosa pine stands in the Black Hills of South Dakota (Anderson and Crompton 2002).

Of course this study is of limited spatial scale and examines only immediate effects (< 5 yr) of thinned/burned treatments. This leads me to recommend the impacts should be studied in a more in-depth manner. Forest treatments are becoming widespread for both ponderosa pine forest restoration and fuel reduction purposes. Black-backed woodpeckers and olive-sided flycatchers are sensitive species (USFS classification), and their presence on sites does not provide any insight into the quality of the sites. Currently, there is concern timber harvest could create ecological traps for olive-sided flycatchers (Robertson, unpub. data). Without more intensive research into the recruitment rates of both species, it is not possible to determine if the same concern is applicable. Changes in presence of sensitive or declining species should be of special

concern. Shifts in composition of abundant species may not be of concern, but studies such as this one provide guidance to direct further research into the mechanisms causing shifts and the impacts on sensitive and rare species of these shifts.

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Chapter III. Effects of thinning and prescribed fire on the foraging patterns of bark-gleaning birds

Abstract

This study focuses on short-term responses of thinning combined with prescribed fire on the foraging patterns of bark-gleaning birds. I determined tree characteristics important in the selection of foraging substrates and whether different species forage preferentially in thinned/burned or control sites. I conducted foraging surveys on three replicate 20-ha thinned/burned plots paired with three 20-ha control plots. Red-breasted nuthatches and mountain chickadees were encountered more often in control sites. Black-backed woodpeckers, hairy woodpeckers and white-breasted nuthatches were encountered almost exclusively in thinned/burned sites. Overall, birds selectively foraged on larger diameter trees, selecting ponderosa pine compared to Douglas-fir. Black-backed woodpeckers strongly selected trees with beetle evidence present. My results suggest thinning and burning is compatible with providing foraging substrates for species present. Indeed, the increase in the encounter rate of bark-gleaning birds on treated sites suggests the treatment has a positive effect on providing foraging substrates for these species.

INTRODUCTION

Historically, many ponderosa pine (*Pinus ponderosa*) forests were characterized by frequent, low-intensity fires that maintained them in an open, uneven-aged state. These stands were maintained by fire, insect depredations and age-related mortality (Arno et al. 1995, Fiedler 2000). Fire suppression in ponderosa pine (*Pinus ponderosa*) forests has resulted in an increase in Douglas-fir (*Pseudotsuga menziesii*), a shade-tolerant species, with a denser understory (Covington et al. 1997). This transition has produced higher fuel loads, reduced soil moisture and nutrient availability, increased fire severity and size (Harris and Covington 1983, Covington et al. 1997, Smith 2000) and increased scale of insect outbreaks such as Douglas-fir tussock moth (*Orgyia pseudotsugata* McDunnough) (Tiedemann et al. 2000).

Western Montana contains nearly five million acres of pine/fir forests that were historically maintained by frequent, low-intensity fire (Agee 1993, Smith and Arno 1999, Veblen et al. 2000). Following national trends, the Montana Department of Natural Resources (DNRC) is integrating ponderosa pine forest restoration into its timber harvest program with a commercial thin combined with a selective cut and followed by a prescribed burn (Appendix 1). A silvicultural treatment is implemented in dense stands prior to fire because of the build-up of fuels from years of fire suppression. Returning fire without thinning may result in high levels of unwanted mortality for the desired large trees, and may increase the challenge of containing a prescribed fire. The agency plans to thin and burn on a ~ 25 year rotation, which is within the historic fire interval (5-30 years, Arno 1996). Understanding different wildlife species responses to thinned/burned areas is necessary for wildlife managers to understand the effects of these shifts in habitat

type on ecosystem functioning. This study focuses on short-term responses in the foraging patterns of cavity nesting birds in the bark-gleaning guild.

Primary cavity nesting birds play a vital role in ecosystems by creating nest sites for a diverse array of secondary cavity nesting species (Martin and Eadie 1999, Aitken et al. 2002). Many studies have considered the effects of forest management practices and natural fires on nest availability for cavity nesting birds (Li and Martin 1991, Saab and Dudley 1998, Weikel and Hayes 1999, Saab et al. 2002). Little published information exists on how thinning followed by prescribed fire affects foraging patterns of these species.

A diversity of dead and diseased trees is required to provide nesting habitat for different primary cavity nesters. As weak primary cavity nesters, red-breasted nuthatches (*Sitta canadensis*) and mountain chickadees (*Poecile gambeli*) require soft snags to excavate their nests (Steeger and Hitchcock 1998). White-breasted nuthatches (*Sitta carolinensis*) rely on natural cavities for nest sites (McEllin 1979). Woodpeckers require anything from small-diameter hard snags (Black-backed woodpecker) to larger diameter snags (Lewis's woodpecker) (Saab et al. 2002). Brawn and Balda (1988) found that availability of nest sites only moderately affected mountain chickadee densities and had no effect on white-breasted nuthatch densities.

However, food availability may limit many cavity nesting species (Caton 1996). White-breasted nuthatches do not allow conspecifics into their nest territory during the breeding season (McEllin 1979), with territory sizes largely determined by resource availability. Food availability close to the nest is necessary and forest managers have historically assumed that leaving nest snags will provide such food. However, many

bark-gleaners feed on live trees as well (Weikel and Hayes 1999). Food resources for bark-gleaning birds will likely shift as a result of prescribed fire. Many bark-gleaning birds forage on beetles (Otvos 1965, Otvos and Stark 1985, Murphy and Lehnhausen 1998), with arboreal arthropods being more commonly eaten by smaller birds (Weikel and Hayes 1999). These prey sources may be influenced by fire. Shifts in food resources likely affect territory size, abundance, and density of nest sites.

In addition to being affected by prey sources, insectivorous birds may also help control insects thought of as pests. Insectivorous birds have been shown to be a major predator on Douglas-fir tussock moth and Western spruce budworm (Torgerson et al. 1990) and bark beetles. Limiting bark beetle densities after prescribed fire is a main directive of the national fire plan (NFP website). Considering the documented role of insectivorous birds in suppressing insect populations, and accelerating the decline of insect outbreaks (Otvos 1979), managers will benefit from understanding the foraging patterns of bark-gleaning birds in areas of potential insect outbreaks.

The objectives of this study are to examine the foraging patterns of several bird species in the bark-gleaning guild, focusing on characteristics of live and dead trees that birds select. I also determine if birds forage on beetle-infested trees preferentially compared to dead trees without beetles, and if birds forage on treated versus untreated sites preferentially.

STUDY SITE AND DESIGN

Study sites were located within the boundaries of The University of Montana's Lubrecht Experimental Forest, 38 km NE of Missoula, MT at approximately 1200 – 1350

m elevation (Figure 1). The area was heavily logged in the early 1900s, with subsequent fire suppression. The second-growth ponderosa pine/Douglas-fir forests represent xeric, low-elevation forest conditions common in western Montana.

My study design consisted of three 20-ha control plots paired with three 20-ha treated plots (Figure 2). The treatment plots were located on Montana Department of Natural Resources (DNRC) managed land within the boundaries of Lubrecht Experimental Forest. The DNRC selectively removed trees in winter of 1998/1999 (Appendix 1) and the sites were subsequently burned in the spring of 2000. The size of treatments ranges from 60 ha to 250 ha, with 20-ha plots located within the treatment boundaries. Although shapes of plots varied, each control plot paired with a treatment plot had the identical shape. Each plot had a 75-m buffer from any defined habitat edge (road, habitat-type change). The control plots were reduced in size (remaining plots were 14 – 18 ha) during the 2002 season when prescribed burning occurred on these sites.

As a process structuring communities, fire is incredibly variable and must be defined operationally to represent the treatment being implemented. I implemented a systematic sampling scheme, with a range of 29 - 49 grid-points per 20-ha plot. Site “Burn 1” was dominated by flame length class (2) and (3), indicating high levels of sapling and pole tree mortality. Site “Burn 2” was highly variable, with many areas suffering only seedling and sapling loss, while other points incurred pole and small saw timber loss. Site “Burn 3” was the least severe in terms of above ground mortality, with most points indicating mortality for seedlings and saplings only. Light/moderate ground char dominated all sites (See Appendix 3).

Montana Climax Vegetation

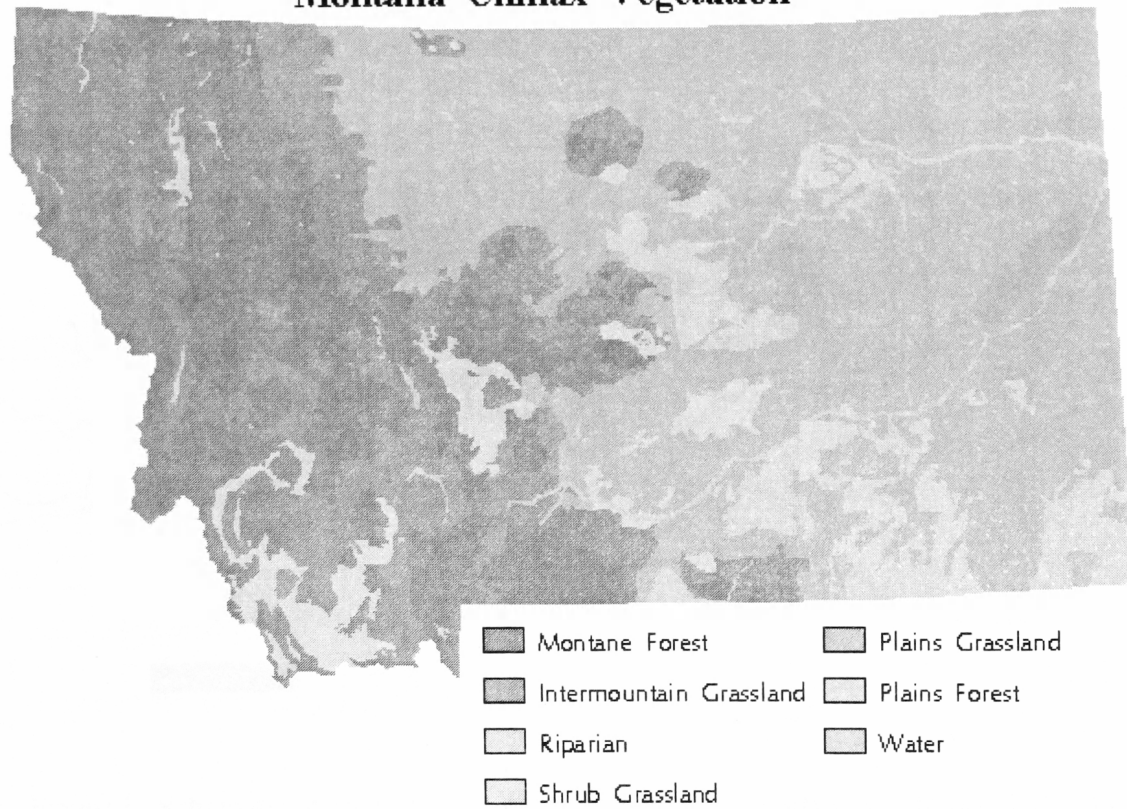


Figure 1. Location of Lubrecht Experimental Forest in relation to climax vegetation in Montana, from Montana Natural Resource Information System Geographic Information System (<http://nris.state.mt.us/nsdi/nris/lu26.gif>).

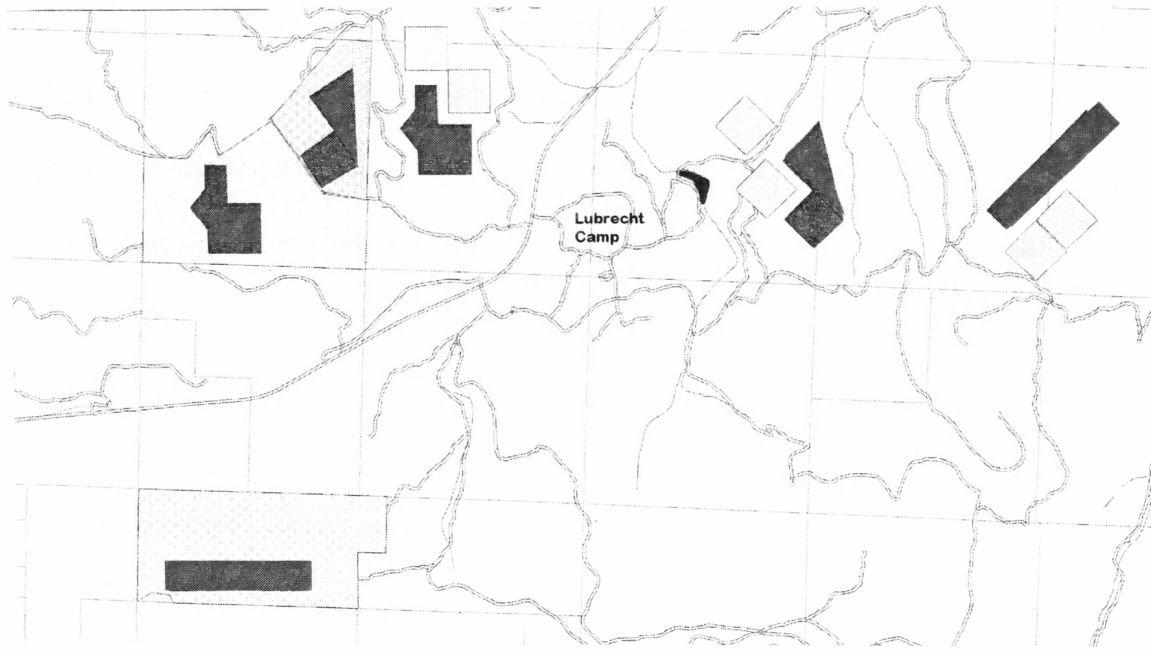


Figure 2. Schematic of control plots and treatment plots in relation to National Fire/Fire Surrogate Study blocks

FORAGING SURVEYS

Cavity nesting birds in the bark-gleaning guild present on the study site include red-breasted nuthatch, white-breasted nuthatch, black-backed woodpecker (*Picoides arcticus*), hairy woodpecker (*P. villosus*), downy woodpecker (*P. pubescens*), three-toed woodpecker (*P. tridactylus*) and pileated woodpecker (*Dryocopus pileatus*). Mountain chickadee is not necessarily in the bark-gleaning guild, but chickadees spend a good proportion of their foraging time on the bark of trees. We recorded forage information on chickadees only when they were bark-gleaning (as opposed to foliage-gleaning).

METHODS

Foraging surveys were conducted during summer 2001 and 2002. Surveys began in spring at the onset of nesting season and continued until the birds began to flock in late summer. A survey consisted of an observer walking a systematic, non-overlapping grid of 50 m spacing for one hour. Surveys were conducted from dawn through late morning/early afternoon. Observers were rotated among sites. Survey starting points were rotated to ensure equal coverage of the grid at different times of morning. When a bark-gleaning bird was seen or heard within 100 m, it was followed until a foraging bout was observed. Only the initial foraging bout was recorded (Hejl et al. 1990, Bell et al. 1990). Once a foraging bout was observed, the clock was stopped while observers recorded bird behavior (Table 1) and characteristics of the forage tree (Table 2). To increase the independence of samples, foraging bouts of nuthatches and chickadees were not recorded within 100 m of a previous bout on the same day. For woodpeckers, which are easily sexed at a distance, observations from different sexes were allowed within

Table 1. Behavioral information collected for each foraging observation

Bird behavior	description
forage behavior	GL: glean PR: probe in crevic PK: peck SC: scaling by driving bill into bark at an angle EX: excavating (leaving > 1cm hole)
horizontal strata	B: bole LP: proximal end of live branch LM: middle portion of live branch LD: distal end of live branch DP: proximal end of dead branch DM: middle of dead branch DD: distal end of live branch C: cone
vertical strata	L: lower third of tree or snag M: middle third of tree or snag H: upper third of tree or snag

Table 2. Description of tree characteristics recorded on forage trees and random trees.

Tree characteristic	description	variable description
sp	tree species: ponderosa pine, Douglas-fir, other species	categorical
dbh	tree diameter at breast height (cm)	continuous
bark	bark retention 0: 0% 1: 1-49% 2: 50-99% 3: 100%	categorical
can	canopy connections; obtained by an observer standing at the base of the tree and determines if there is a canopy connections at N, NE, E, SE, S, SW, W, NW, there are 0-8 possible per tree	continuous
fir	fire effects 0: no fire effects 1: bole scorch only 2: crown partially scorched 3: crown entirely scorched	categorical
btl	beetle evidence 0: no beetle evidence 1: beetle entrance or exit holes evident	categorical
folC	dominant foliage color G: green R: red NA: no foliage	categorical
folR	foliage retention 0: 0% 1: 1-49% 2: 50-99% 3: 100%	categorical

200 m on the same day, and within the same sex at > 200 m (Morrison et al.1987, Hejl et al. 1990).

During both seasons, sampling effort included 385 h in treatment sites and 233 h in control sites. The difference in effort was due to reduced effort in the control sites after prescription burns reduced the size of plots.

I evaluated selection of tree characteristics at two levels: within the same tree class (live or dead) and among any tree class. For each tree foraged on, two random trees were chosen within 50 m and within the plot. The first random tree was within the same class (live or dead) as the forage tree and the second tree was any (live or dead) random tree. I recorded all the same tree characteristics on each random tree as on each forage tree (Table 2). Random trees were located by randomly selecting a compass direction and distance (paces) to walk within 50 m and within the plot.

ANALYSIS

Selection of foraging trees was evaluated separately for each bird species using multiple logistic regression (Hosmer and Lemeshow 2002) in a model selection framework (Burnham and Anderson 2002). Logistic regression is a useful tool for microhabitat selection because the scale of analysis can be on the individual, availability can be estimated, both continuous and categorical variables can be included, and the experimental unit is each sample. An assumption of logistic regression is independent samples. Although many of our foraging observations may be on the same birds, I

attempted to increase the independence of samples through constraints on sequential observations of the same bird, as noted above.

I used AICc, a model selection criterion adjusted for small sample sizes (Burnham and Anderson 2002) to determine the most parsimonious model and best approximating model to the data. AICc weights measure the level of uncertainty in model selection, with weights less than 0.90 indicating that the current best model may not be the top ranked model with a different data set. Foraging observations from treatment sites and control sites were analyzed separately to determine if the same tree characteristics were selected. The same candidate model set was considered for both treatment and control (Appendix 4, tables 1-10). Selection within tree class was analyzed separately from among classes, with both sets of analyses having their own candidate model set (Appendix 4, tables 1-10). For each candidate model set, I used the Hosmer and Lemeshow goodness of fit test (Hosmer and Lemeshow 2002). A year effect was tested using the global model, and year was included in all models if the year increased the amount of variation explained while considering the addition of another parameter (lower AICc). The global model for each candidate set included all of the variables in the candidate model set (Appendix 4, tables 1-10).

The odds ratio was used to interpret logistic regression results. The dependent variable in binary logistic regression is 0 or 1. The odds ratio is the ratio of the odds of the independent variable = 1 to the odds of the independent variable = 0 and is calculated by e^{β} (Hosmer and Lemeshow 2002). The odds ratio (OR) can be interpreted as how much more likely (>1.0) or unlikely (<1.0) it is for the outcome to be present (dependent variable = 1) for every unit increase in the independent variable, while all other variables

in the model are held constant. If the 95 percent confidence interval for the odds ratio includes 1.0, then inference is limited.

RESULTS

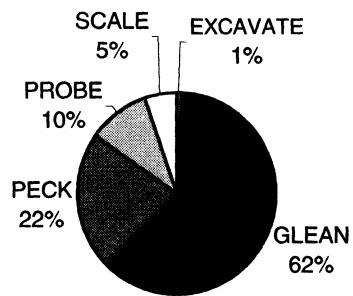
Behavior

Red-breasted nuthatches and mountain chickadees exhibited the same foraging behavior in control and treatment sites. Overall, red-breasted nuthatches spent the majority of observed foraging time gleaning from the surface of trees (62%, Figure 3). While the majority of the foraging observations were on the bole of the tree (31%), there was considerable time spent on live branches (42%); (Figure 4). They concentrated foraging efforts in the middle vertical stratum (47%) (Figure 5).

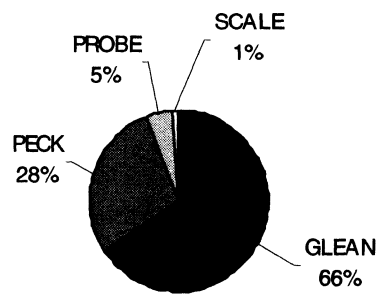
Mountain chickadees spent the majority of observed foraging time gleaning from the surface of live branches (66%); (Figure 3). The majority of the foraging observations were on live branches (63%), especially the middle portion. In fact, mountain chickadees were rarely observed foraging on the boles of trees (5%); (Figure 4). They concentrated foraging efforts in the highest vertical stratum (48%) of trees (Figure 5).

White-breasted nuthatches spent the majority of observed foraging time gleaning from the surface of the bark (54%); (Figure 3). The majority of the foraging observations were on the bole of the tree (50%); (Figure 4). Time not spent on the bole of the tree was evenly distributed between live and dead branches (Figure 4). They concentrated foraging efforts in the middle vertical stratum (62%); (Figure 5).

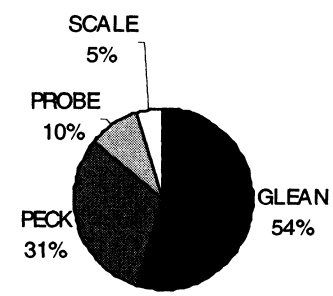
Black-backed woodpeckers spent an overwhelming majority of observed foraging time pecking into the bark surface (86%); (Figure 3). Most foraging observations were



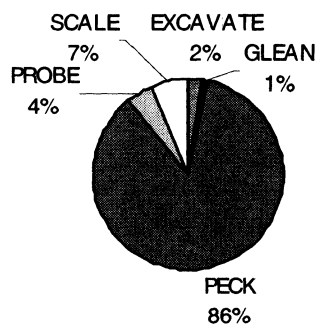
A.



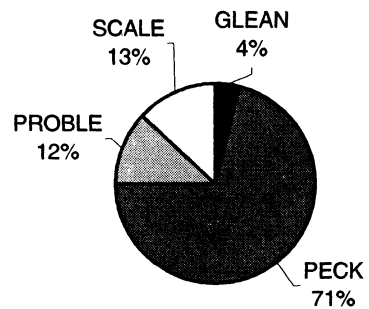
B.



C.



D.



E.

Figure 3. Distribution of foraging behaviors observed; A. = red-breasted nuthatches, B. = mountain chickadees, C. = white-breasted nuthatches, D. = black-backed woodpeckers, E. = hairy woodpeckers

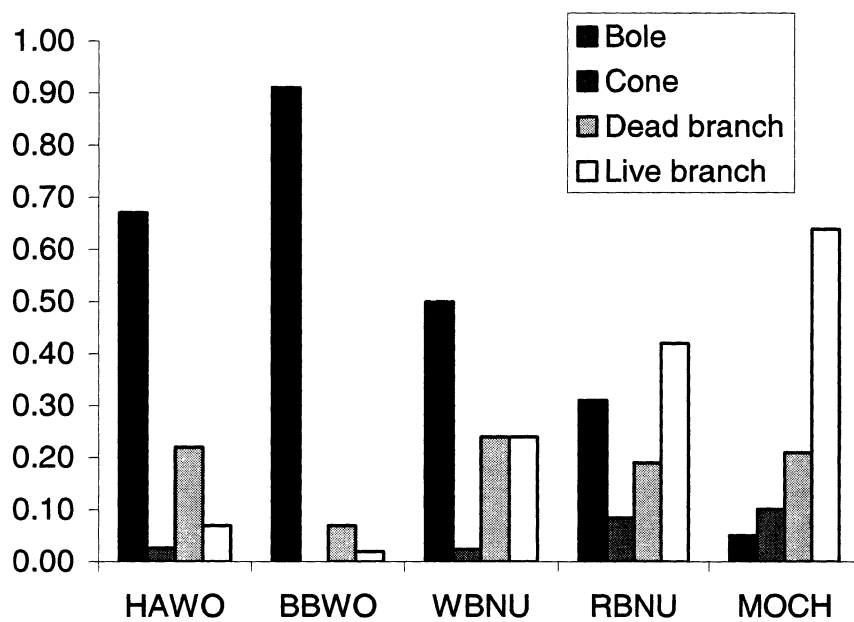


Figure 4. Distribution of horizontal tree stratum use by the bark-gleaning birds on study sites

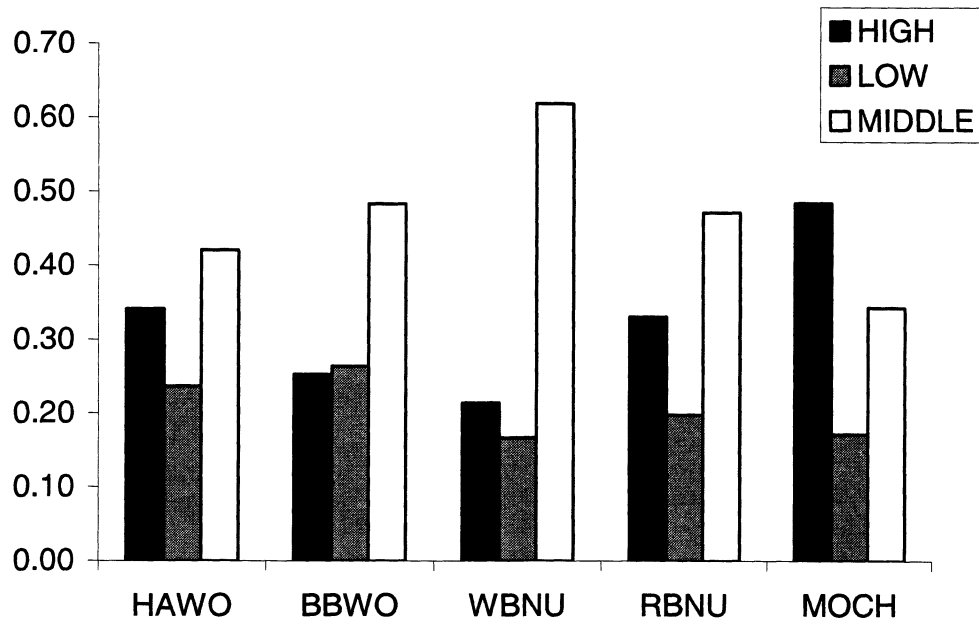


Figure 5. Distribution of vertical tree stratum use, divided into thirds: upper, middle, low, by the bark-gleaning birds on study sites.

on the bole of the tree (91%); (Figure 4). They concentrated foraging efforts in the middle vertical stratum (48%); (Figure 5). The 52% of time not spent on the middle vertical stratum of the tree was evenly distributed between the low and high strata (Figure 5).

Hairy woodpeckers spent a majority of observed foraging time pecking into the bark surface (71%); (Figure 3). A majority of foraging observations were on the bole of the tree (67%); (Figure 4). Foraging observations that were not on the bole were almost exclusively on dead branches (23%); (Figure 4). Although they foraged in the middle vertical strata most (42%), all vertical strata of the tree were used regularly (Figure 5).

Microhabitat selection

Red-breasted Nuthatch

I recorded 249 foraging bouts for red-breasted nuthatches: 125 in treatment sites and 124 in control sites. Red-breasted nuthatches were encountered more often in control sites, with 0.53 forages/hour compared to 0.32 forages/hour in treatment sites.

Selection among any tree class

Red-breasted nuthatches selected larger trees in both sites. In treatment sites, the likelihood of red-breasted nuthatches foraging on a tree increased 1.10 times for each 1 cm increase in tree diameter (Table 3a, odds ratio (OR) = 1.10), when all other variables in the model are held constant. Models including tree class and tree species were within two AICc values, AICc weights were less than 0.90 (Burnham and Anderson 2002) (Table 3a). In both models containing tree class, live trees were selected. Although tree

Table 3. Logistic regression results for red-breasted nuthatches in treated areas. Best approximating models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio. (a) selection among any tree class (b) selection within tree class.

Table 3a. Selection among any tree class; global model goodness of fit, Hosmer and Lemeshow $p = 0.80$.

Model	Δ AICc	AIC weight	Variable	Coefficient (β)	S.E.	Odds Ratio (Exp β)	95% CI for Odds ratio
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{can}$	0	0.35	dbh	.09	.01	1.10	(1.07, 1.12)
			can	.01	.09	1.01	(0.84, 1.21)
			constant	-2.68	.40	.07	
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{class}$	1.19	0.20	dbh	.08	.01	1.09	(1.06, 1.11)
			class	.75	.38	2.13	(1.01, 4.48)
			constant	-2.93	.42	.05	
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{ class} - \beta_3\text{can} + \beta_4\text{Douglas-fir} - \beta_5\text{other species}$	1.34	0.18	dbh	.09	.01	.94	(1.06, 1.12)
			class	.86	.41	1.16	(1.07, 5.27)
			Douglas-fir	.15	.39	2.37	(0.54, 2.50)
			other species	-.33	.85	.72	(0.14, 3.84)
			can	-.06	.10	1.09	(0.78, 1.15)
β_0 (null)	99.8		constant	-3.07	.48	.05	
Global model:							
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{Douglas-fir} + \beta_4\text{other species} + \beta_5\text{can} + \beta_6\text{btl} + \beta_7\text{fir1} + \beta_8\text{fir2} + \beta_9\text{fir3} + \beta_{10}\text{class*Douglas-fir} + \beta_{11}\text{class*other species} + \beta_{12}\text{class*dbh} + \beta_{13}\text{dbh*Douglas-fir} + \beta_{14}\text{dbh*other species} + \beta_{15}\text{fir1*btl} + \beta_{16}\text{fir2*btl} + \beta_{17}\text{fir3*btl}$							

Table 3b. Selection within tree class; global model goodness of fit, Hosmer and Lemeshow $p = 0.21$

Model	Δ AICc	AIC weight	Variable	Coefficient (β)	S.E.	Odds Ratio (Exp β)	95% CI for Odds ratio
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{btl}$	0	0.23	dbh	.07	.01	1.07	(1.05, 1.09)
			btl	.27	.33	1.31	(0.69, 2.50)
			constant	-2.15	.36	0.12	
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas-fir} + \beta_3\text{other species}$	1.14	0.13	dbh	.07	.01	1.07	(1.05, 1.09)
			Douglas-fir	-.03	.34	.97	(0.50, 1.88)
			other species	6.62	17.82	748.14	(0.00, 1.1e18)
			constant	-2.07	.38	.13	
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{can}$	1.37	0.11	dbh	.07	.01	1.07	(1.05, 1.09)
			can	-.09	.09	.91	(0.77, 1.08)
			constant	-1.93	.36	.15	
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas-fir} + \beta_3\text{other species} + \beta_4\text{can}$	1.99	0.083	dbh	.06	.01	1.07	(1.05, 1.09)
			Douglas-fir	.01	.34	1.01	(0.52, 1.96)
			other species	6.64	17.98	762.82	(0.00, 1.5e18)
			can	-.10	.09	.91	(0.77, 1.08)
			constant	-1.92	.40	.15	
β_0 (null)	60.17						
Global model:							
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas-fir} + \beta_3\text{other species} + \beta_4\text{fir1} + \beta_5\text{fir2} + \beta_6\text{fir3} + \beta_7\text{btl} + \beta_8\text{can} + \beta_9\text{dbh*Douglas-fir} + \beta_{10}\text{dbh*other species} + \beta_{12}\text{btl*Douglas-fir} + \beta_{13}\text{btl*other species} + \beta_{14}\text{fir1*btl} + \beta_{15}\text{fir2*btl} + \beta_{16}\text{fir3*btl}$							

species and canopy connections were included in the models, the 95% CI for the odds ratio included 1.0 (Table 3a).

In control sites, a tree was 1.05 times more likely to be foraged on for every 1cm increase in tree diameter (Table 4a, OR = 1.05) when all other variables in the model are held constant. Douglas-fir trees were selected against compared to ponderosa pine (Table 4a, OR = 0.12), however, large Douglas-fir trees were more likely to be foraged upon (Table 4a, OR = 1.06). Models including tree class and canopy connections were within two AICc values, AICc weights were less than 0.90 (Table 4a). The 95% CI for the odds ratio for both canopy connections and tree class included 1.0 (Table 4a).

Selection within tree class

Along with tree diameter (Table 3b, OR = 1.07) beetle evidence was important in tree selection in treatment sites, however, 1.0 is included in the 95% CI for the odds ratio (0.687, 2.497) (Table 3b). Models including tree species and canopy connections were within two AICc values, AICc weights were less than 0.90. The 95% CI for the odd ratio for both variables included 1.0.

The global model was a poor fit in control sites and was not evaluated further (Hosmer and Lemeshow goodness of fit, $p = 0.004$).

Mountain Chickadee

We recorded 99 foraging bouts for mountain chickadees, 55 in treatment sites and 44 in control sites. Mountain chickadees were encountered more often in control sites, with 0.19 forages/hour compared to 0.14 forages/hour in treatment sites.

Table 4. Logistic regression results for red-breasted nuthatches in control sites. Best models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio. (a) selection among any tree class (b) selection within tree class.

Table 4a. Selection among any tree class; global model goodness of fit, Hosmer and Lemeshow $p = 0.84$

Model	Δ AICc	AIC weight	Variable	Coefficient (β)	S.E.	Odds Ratio (Exp β)	95% CI for Odds ratio
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas-fir} + \beta_3\text{other species} + \beta_4\text{dbh}*\text{Douglas-fir} + \beta_5\text{dbh}*\text{other species}$	0	0.35	dbh	.05	.01	1.05	(1.02, 1.08)
			Douglas-fir	-2.15	.76	0.12	(0.03, 0.52)
			other species	8.39	112.62	4402.02	(0.00, 3.21e99)
			Douglas-fir *dbh	.05	.02	1.06	(1.01, 1.11)
			other species*dbh	-.05	2.54	.95	(0.01, 137.50)
			constant	-1.19	.49	.31	
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{class} \beta_3\text{Douglas-fir} + \beta_4\text{other species} + \beta_5\text{can}$	0.44	0.28	dbh	.08	.01	1.08	(1.06, 1.10)
			class	-0.24	0.55	0.78	(0.27, 2.29)
			Douglas-fir	-.62	.32	.54	(0.27, 1.01)
			other species	5.92	12.68	372.75	(0.00, 2.3e13)
			can	.12	.07	1.13	(0.99, 1.29)
			constant	-2.93	.42	.05	
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas-fir} + \beta_3\text{other species}$	1.21	0.19	dbh	.08	.01	1.08	(1.06, 1.10)
			Douglas-fir	-.58	.31	.56	(0.30, 1.02)
			other species	5.82	12.80	336.26	(0.00, 2.6e13)
			Constant	-2.93	.42	.05	
β_0 (null)	86.88						
Global model:							
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{Douglas-fir} + \beta_4\text{other species} + \beta_5\text{can} + \beta_6\text{btl} + \beta_7\text{fir1} + \beta_8\text{fir2} + \beta_9\text{fir3} + \beta_{10}\text{class}*\text{Douglas-fir} + \beta_{11}\text{class}*\text{other species} + \beta_{12}\text{class}*\text{dbh} + \beta_{13}\text{dbh}*\text{Douglas-fir} + \beta_{14}\text{dbh}*\text{other species} + \beta_{15}\text{fir1}*\text{btl} + \beta_{16}\text{fir2}*\text{btl} + \beta_{17}\text{fir3}*\text{btl}$							

Table 4b. Selection within same tree class; global model poor fit (Hosmer and Lemeshow goodness of fit, $p = 0.004$)

Microhabitat selection

Selection among any tree class

When bark gleaning, mountain chickadees selected larger trees (OR = 1.07, Table 5a) in treatment sites. Canopy connections is included in the best model, the 95% CI for the odds ratio includes 1.0. (Table 5a). There are no other models within two AICc values (Table 5a).

The global model was a poor fit in control sites and was not evaluated further (Hosmer and Lemeshow goodness of fit, $p = 0.05$).

Selection within any tree class

The same parameters, tree diameter and canopy connections were important in treatment sites (Table 5b). Larger trees were important (Table 5b, OR = 1.06); again for canopy connections, the 95% CI of the odds ratio includes 1.0 (Table 5b). There are no other models within two AICc values (Table 5b)

Tree diameter and canopy connections were also important in the control sites. Larger trees (OR = 1.07, Table 6b) with more canopy connections (OR = 1.30, Table 6b) were selected. A model including tree species was within two AICc values, AICc weights were less than 0.90. The 95% CI for the odds ratio includes 1.0 for both categorical variables describing tree species (Table 6b)

White-breasted nuthatch

We recorded 42 foraging bouts for white-breasted nuthatches, 41 in treatment sites and 1 in control sites. White-breasted nuthatches were encountered more often in treatment sites, with 0.11 forages/hour compared to 0.004 forages/hour in control sites.

Table 5. Logistic regression results for mountain chickadees in treatment areas. Best models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio. (a) selection among any tree class (b) selection within tree class.

Table 5a. Selection among any tree class; global model goodness of fit, Hosmer and Lemeshow $p = 0.59$

Model	Δ AICc	AIC weight	Variable	Coefficient (β)	S.E.	Odds Ratio (Exp β)	95% CI for Odds ratio
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{can}$	0	0.74	dbh	0.07	0.02	1.07	(1.04, 1.10)
			can	0.12	0.11	1.13	(0.90, 1.40)
			constant	-1.92	0.49	0.15	
β_0 (null)	31.00						
Global model:							
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{Douglas-fir} + \beta_4\text{other species} + \beta_5\text{fir1} + \beta_6\text{fir2} + \beta_7\text{fir3} + \beta_8\text{can} + \beta_9\text{class}*\text{Douglas-fir} + \beta_{10}\text{class}*\text{other species} + \beta_{11}\text{class}*\text{dbh} + \beta_{12}\text{dbh}*\text{Douglas-fir} + \beta_{13}\text{dbh}*\text{other}$							

Table 5b. Selection within tree class; global model goodness of fit, Hosmer and Lemeshow $p = 0.85$

Model	Δ AICc	AIC weight	Variable	Coefficient (β)	S.E.	Odds Ratio (Exp β)	95% CI for Odds ratio
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{can}$	0	0.60	dbh	.06	.02	1.06	(1.03, 1.10)
			can	.18	.12	1.20	(0.95, 1.51)
			constant	-1.99	.54	.14	
β_0 (null)	22.04						
Global Model:							
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas-fir} + \beta_3\text{other species} + \beta_4\text{fir1} + \beta_5\text{fir2} + \beta_6\text{fir3} + \beta_7\text{can} + \beta_8\text{dbh}*\text{Douglas-fir} + \beta_9\text{dbh}*\text{other species}$							

Table 6. Logistic regression results for mountain chickadees in control areas. Best models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio. (a) selection among any tree class (b) selection within tree class.

Table 6a. Selection among any tree class; global model goodness of fit, Hosmer and Lemeshow $p = 0.05$ indicating a poor fit

Table 6b. Selection within tree class; global model goodness of fit, Hosmer and Lemeshow $p = 0.71$

Model	Δ AICc	AIC weight	Variable	Coefficient (β)	S.E.	Odds Ratio (Exp β)	95% CI for Odds ratio
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{can}$	0	0.37	dbh	.07	.02	1.07	(1.04, 1.11)
			can	.26	.11	1.30	(1.04, 1.63)
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas-fir} + \beta_3\text{other species} + \beta_4\text{can}$	0.27	0.32	constant	-2.81	.76	.06	
			dbh	.08	.02	1.08	(1.04, 1.12)
			Douglas-fir	.77	.57	2.15	(0.70, 6.61)
			other species	-1.22	1.26	.29	(0.03, 3.46)
			can	.26	.12	1.29	(1.02, 1.64)
β_0 (null)	21.63		constant	-1.92	.40	.15	

Global Model:
 $\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas-fir} + \beta_3\text{other species} + \beta_4\text{fir1} + \beta_5\text{fir2} + \beta_6\text{fir3} + \beta_7\text{can} + \beta_8\text{dbh*Douglas-fir} + \beta_9\text{dbh*other species}$

Microhabitat selection

Selection among any tree class

Only treatment site data were analyzed due to a small sample size in control sites (N=1). Tree diameter was the only variable in the best model (OR = 1.11, Table 7a). Models including tree class, canopy connections and tree species were within two AICc values, AICc weights were less than 0.90. The 95% CI for the odds ratios for tree class, canopy connections and tree species included 1.0 (Table 7a).

Selection within same tree class

Again, tree diameter was the only variable in the best model (OR = 1.08 Table 10). A model including tree class was within two AICc values, AICc were less than 0.90. The 95% CI of the odds ratio for tree class included 1.0 (Table 7b).

Black-backed woodpecker

We recorded 92 foraging bouts for black-backed woodpeckers, 84 in treatment sites and 8 in control sites. Black-backed woodpeckers were encountered more often in treatment sites, with 0.22 forages/hour compared to 0.03 forages/hour in control sites

Selection among any tree class

Only treatment site data were analyzed due to a small sample size in control sites (N=8). Year was included in all candidate model sets (Appendix 4, Table 4.7). Black-backed woodpeckers selected larger trees (OR = 1.03 Table 8a) with beetle evidence present. Beetle evidence was extremely important; black-backed woodpeckers were 8.67 times more likely to forage on a tree if beetle evidence was present (Table 8a) when tree

Table 7. Logistic regression results for white-breasted nuthatches in treatment areas. Best models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio. (a) selection among any tree class (b) selection within tree class.

Table 7a. Selection among any tree class; Hosmer and Lemeshow goodness of fit $p = 0.76$

Model	Δ AICc	AIC weight	Variable	Coefficient (β)	S.E.	Odds Ratio (Exp β)	95% CI for Odds ratio
$\beta_0 + \beta_1 dbh$	0	0.38	dbh	.11	.03	1.11	(1.06, 1.17)
$\beta_0 + \beta_1 dbh + \beta_2 class$	1.76	0.16	constant	-2.91	.71	.05	
			dbh	.11	.03	1.12	(1.06, 1.18)
			class	-.40	.64	.67	(0.19, 2.37)
$\beta_0 + \beta_1 dbh + \beta_2 can$	1.87	0.15	constant	-2.78	.73	.06	
			dbh	.11	.03	1.11	(1.06, 1.17)
			can	.09	.16	1.09	(0.79, 1.50)
$\beta_0 + \beta_1 dbh + \beta_2 Douglas-fir + \beta_3 other\ species$	1.95	0.14	constant	-3.00	.74	.05	
			dbh	0.11	0.03	1.12	(1.06, 1.18)
			Douglas-fir	-0.12	0.70	0.89	(0.23, 3.49)
			other species	1.34	0.93	3.81	(0.62, 23.59)
β_0 (null)	35.34		constant	-3.22	0.85	0.04	
Global Model:							
$\beta_0 + \beta_1 class + \beta_2 Douglas-fir + \beta_3 other\ species + \beta_4 fir1 + \beta_5 fir2 + \beta_6 fir3 + \beta_7 can + \beta_8 btl$							

Table 7b. Selection within same tree class; global model goodness of fit, Hosmer and Lemeshow $p = 0.90$

Model	Δ AICc	AIC weight	Variable	Coefficient (β)	S.E.	Odds Ratio (Exp β)	95% CI for Odds ratio
$\beta_0 + \beta_1 dbh$	0	0.42	dbh	.08	.02	1.08	(1.04, 1.12)
$\beta_0 + \beta_1 dbh + \beta_1 class$	1.08	0.25	constant	-2.30	0.65	0.10	
			dbh	0.08	0.02	1.08	(1.04, 1.13)
			class	-0.61	0.60	0.54	(0.17, 1.74)
			constant	-1.99	0.71	0.14	
β_0 (null)	20.58						
Global Model:							
$\beta_0 + \beta_1 dbh + \beta_2 Douglas-fir + \beta_3 other\ species + \beta_4 can + \beta_5 fir1 + \beta_6 fir2 + \beta_7 fir3 + \beta_8 btl$							

Table 8. Logistic regression results for black-backed woodpeckers in treated. Best models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio. (a) selection among any tree class (b) selection within tree class.

Table 8a. Selection among any tree class; global model goodness of fit, Hosmer and Lemeshow $p = 0.93$

Model	Δ AICc	AIC weight	Variable	Coefficient (β)	S.E.	Odds Ratio (Exp β)	95% CI for Odds ratio
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{btl} + \beta_3\text{year}$	0	0.48	dbh	0.03	0.01	1.03	(1.01, 1.06)
			btl	2.16	0.39	8.67	(4.07, 18.49)
			year	0.15	0.47	1.16	(0.47, 2.90)
			constant	-2.12	0.58	0.12	
$\beta_0 + \beta_1\text{class} + \beta_2\text{btl} + \beta_3\text{fire} + \beta_4\text{btl*fire} + \beta_5\text{year}$	1.72	0.20	class	-1.02	.55	.36	(0.12, 1.06)
			btl	10.29	20.18	29426.06	(0.00, 4.4e21)
			fir1	1.34	0.9300	3.813	(0.62, 23.59)
			fir2	2.36	1.37	10.59	(0.73, 154.77)
			fir3	-.30	1.53	.75	(0.04, 14.79)
			btl*fir1	-9.33	20.18	>.00	(0.00, 1.3e13)
			btl*fir2	-9.15	20.20	>.00	(0.00, 1.6e14)
			btl*fir3	-7.03	20.21	>.00	(0.00, 1.4e14)
			year	.20	.50	1.23	(0.46, 3.25)
			constant	-2.30	1.11	.10	

β_0 (null) 46.57

Global Model:

$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{Douglas-fir} + \beta_4\text{other} + \beta_5\text{fir1} + \beta_6\text{fir2} + \beta_7\text{fir3} + \beta_8\text{bark1} + \beta_9\text{bark2} + \beta_{10}\text{bark3} + \beta_{11}\text{btl} + \beta_{12}\text{folR} + \beta_{13}\text{folNA} + \beta_{14}\text{fol1} + \beta_{15}\text{fol2} + \beta_{16}\text{fol3} + \beta_{17}\text{fir1*btl} + \beta_{18}\text{fir2*btl} + \beta_{19}\text{fir3*btl} + \beta_{20}\text{class*dbh} + \beta_{21}\text{class*Douglas-fir} + \beta_{22}\text{class*other species} + \beta_{23}\text{year}$

Table 8b. Selection within the same tree class; global model goodness of fit, Hosmer and Lemeshow $p = 0.85$

Model	Δ AICc	AIC weight	Variable	Coefficient (β)	S.E.	Odds Ratio (Exp β)	95% CI for Odds ratio
$\beta_0 + \beta_1 dbh + \beta_2 \text{Douglas-fir} + \beta_3 \text{other species} + \beta_4 \text{year}$	0	0.44	dbh	.04	.014	1.505	(1.01, 1.07)
			Douglas-fir	-1.43	.50	.24	(.09, 0.65)
			other species	.40	1.28	1.50	(0.12, 18.31)
			constant	-.91	.58	.40	
$\beta_0 + \beta_1 dbh + \beta_2 btl + \beta_3 \text{year}$	0.27	0.39	dbh	.047	.01	1.05	(1.02, 1.08)
			btl	1.00	.40	2.72	(1.25, 5.91)
			year	0.21	0.61	1.24	(0.51, 3.31)
			constant	-2.03	.61	.13	
β_0 (null)	21.80						
Global Model:							
$\beta_0 + \beta_1 dbh + \beta_2 \text{Douglas-fir} + \beta_3 \text{other species} + \beta_4 \text{fir1} + \beta_5 \text{fir2} + \beta_6 \text{fir3} + \beta_7 \text{bark1} + \beta_8 \text{bark2} + \beta_9 \text{bark3} + \beta_{10} \text{btl} + \beta_{11} \text{folR} + \beta_{12} \text{folNA} + \beta_{13} \text{fol1} + \beta_{14} \text{fol2} + \beta_{15} \text{fol3} + \beta_{16} \text{fir1} * \text{btl} + \beta_{17} \text{fir2} * \text{btl} + \beta_{18} \text{fir3} * \text{btl} + \beta_{19} \text{year}$							

diameter and year are held constant. A model including fire effects and the interaction between fire effects and beetle evidence was within two AICc values, AICc weights were less than 0.90. The 95% confidence intervals of the odds ratio included 1.0 for fire effects and the interaction term for fire effects and beetle evidence (Table 8a).

Selection within same tree class

Only treatment site data were analyzed due to a small sample size in control sites (N=8). Year was included in all candidate model sets (Appendix 4, Table 4.8). The best model included tree diameter (Table 8b, OR = 1.51) and tree species, however, both 95% CI of the OR for Douglas-fir and other species indicator variables included 1.0 (Table 8b). A model including beetle evidence was within two AICc values, AICc weights were less than 0.90, confirming the importance of beetle presence (OR = 2.72, Table 8b).

Hairy woodpecker

We recorded 76 foraging bouts for hairy woodpeckers, 64 in treatment sites and 12 in control sites. Hairy woodpeckers were encountered more often in treatment sites, with 0.17 forages/hour effort compared to 0.05 forages/hour effort in control sites.

Microhabitat selection

Selection among any tree class

Only treatment data were analyzed due to a small sample size in control sites (N=12). Both tree diameter (Table 9a, OR = 1.11) and tree class were important in treatment sites (Table 9a). A live tree was 0.15 times as likely to be foraged upon than a dead tree, that is dead trees were selected in comparison to live trees. Models including

Table 9. Logistic regression results for hairy woodpeckers in treatment areas. Best models, indicated by Δ AICc, as well as coefficients, odds ratio, and 95% CI for the odds ratio. (a) selection among any tree class (b) selection within tree class.

Table 9a. Selection among any tree class; global model goodness of fit, Hosmer and Lemeshow $p = 0.59$

Model	Δ AICc	AIC weight	Variable	Coefficient (β)	S.E.	Odds Ratio (Exp β)	95% CI for Odds ratio
$\beta_0 + \beta_1 \text{ dbh} + \beta_2 \text{ class}$	0	0.45	dbh	0.11	0.02	1.11	(1.07, 1.16)
			class	-1.88	0.62	0.15	(0.05, 0.51)
			constant	-1.93	0.45	0.14	
$\beta_0 + \beta_1 \text{ class} + \beta_2 \text{ dbh} + \beta_3 \text{ folR} + \beta_4 \text{ folNA} + \beta_5 \text{ fol1} + \beta_6 \text{ fol2} + \beta_7 \text{ fol3} + \beta_8 \text{ Douglas-fir} + \beta_9 \text{ other species}$	1.21	0.24	class	-2.16	1.43	.12	(0.01, 1.92)
			dbh	.09	.02	1.09	(1.04, 1.15)
			folR	-1.87	1.98	.15	(>0.00, 7.523)
			folNA	5.27	17.34	193.81	(0.00, 1.1e17)
			fol1	7.97	17.37	2898.51	(0.00, 1.8e18)
			fol2	7.93	17.38	2765.42	(0.00, 1.7e18)
			fol3	6.05	17.29	424.26	(0.00, 2.2e17)
			Douglas-fir	-1.87	.73	.15	(0.04, 0.649)
			other species	-.37	1.33	.69	(0.05, 9.32)
			constant	-7.02	17.36	>.00	
			$\beta_0 + \beta_1 \text{ dbh} + \beta_2 \text{ class} + \beta_3 \text{ dbh} * \text{class}$	2.04	0.16	dbh	-2.30
class	.10	.03				1.1	(1.05, 1.17)
class*dbh	.01	.05				1.01	(0.93, 1.11)
constant	-1.85	.52				.16	
β_0 (null)	39.68						
Global Model:							
$\beta_0 + \beta_1 \text{ class} + \beta_2 \text{ dbh} + \beta_3 \text{ Douglas-fir} + \beta_4 \text{ other species} + \beta_5 \text{ can} + \beta_6 \text{ fir1} + \beta_7 \text{ fir2} + \beta_8 \text{ fir3} + \beta_9 \text{ bark1} + \beta_{10} \text{ bark2} + \beta_{11} \text{ bark3} + \beta_{12} \text{ btl} + \beta_{13} \text{ folR} + \beta_{14} \text{ folNA} + \beta_{15} \text{ fol1} + \beta_{16} \text{ fol2} + \beta_{17} \text{ fol3} + \beta_{18} \text{ fir1} * \text{btl} + \beta_{19} \text{ fir2} * \text{btl} + \beta_{20} \text{ fir3} * \text{btl} + \beta_{21} \text{ class} * \text{Douglas-fir} + \beta_{22} \text{ class} * \text{other species} + \beta_{23} \text{ folR} * \text{fol1} + \beta_{24} \text{ folR} * \text{fol2} + \beta_{25} \text{ folR} * \text{fol3} + \beta_{26} \text{ folNA} * \text{fol1} + \beta_{27} \text{ folNA} * \text{fol2} + \beta_{28} \text{ folNA} * \text{fol3}$							

Table 9b. Selection within same tree class; global model goodness of fit, Hosmer and Lemeshow $p = 0.13$

Model	Δ AICc	AIC weight	Variable	Coefficient (β)	S.E.	Odds Ratio (Exp β)	95% CI for Odds ratio
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{folR} + \beta_3\text{folNA} + \beta_4\text{fol1} + \beta_5\text{fol2} + \beta_6\text{fol3} +$	0	0.61	dbh	0.11	0.02	1.115	(1.07, 1.16)
			foliage color red	-3.73	22.25	.024	(0.00, 2.1e17)
			foliage color none	-4.96	22.27	.007	(0.00, 6.3e16)
			foliage retention 1	-0.82	1.02	.441	(0.06, 3.27)
			foliage retention 2	-0.10	0.86	.902	(0.17, 4.90)
			foliage retention 3	-6.28	22.26	.002	(0.00, 1.7e16)
			constant	2.49	22.28	12.10	
β_0 (null)	27.48						
Global Model:							
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas-fir} + \beta_3\text{other species} + \beta_4\text{can} + \beta_5\text{fir1} + \beta_6\text{fir2} + \beta_7\text{fir3} + \beta_8\text{bark1} + \beta_9\text{bark2} + \beta_{10}\text{bark3} + \beta_{11}\text{btl} + \beta_{12}\text{folR} + \beta_{13}\text{folNA} + \beta_{14}\text{fol1} + \beta_{15}\text{fol2} + \beta_{16}\text{fol3} + \beta_{17}\text{fir1*btl} + \beta_{18}\text{fir2*btl} + \beta_{19}\text{fir3*btl} + \beta_{20}\text{dbh*Douglas-fir} + \beta_{21}\text{dbh*other species}$							

tree species, foliage color, and foliage retention were within two AICc values, AICc weights were less than 0.90. However all variables had very large 95% confidence intervals for the odds ratio (Table 9a).

Selection within same tree class

Only treatment site data were analyzed due to a small sample size in control sites (N=12). A large number of parameters are included in the best model (Table 9b), including tree diameter, tree species, foliage color and retention. However, tree diameter is the only variable without a 95% CI that includes 1.0 (OR = 1.11, Table 9b). The likelihood of a tree being selected increases as diameter increases.

Foraging and fire

All foraging bouts recorded were overlaid on the grid with fire severity ratings to determine if birds were concentrating on areas with different levels of severity. Black-backed and hairy woodpeckers both concentrated in higher severity areas in sites burn 1 and burn 2. In site burn 3, foraging bouts were not as associated with severity. This could be because the fire was less severe in burn 3, therefore there were fewer areas of higher severity. White-breasted nuthatches appear to concentrate in higher severity areas in burn 2. Red-breasted nuthatches and mountain chickadees foraged in areas displaying a variety of severity conditions.

DISCUSSION

Sympatric birds within sites often exploit different resources (Bull et al. 1986, (Morrison & With 1987, Lundquist and Manuwal 1990, Villard and Beninger 1993,

Murphy and Lehnhausen 1998). The five sympatric species on our sites exploited different sections of trees for resources. Among the smaller birds that mostly gleaned insects from close to bark surface, red-breasted nuthatches were generalists exploiting the entire tree fairly evenly. Mountain chickadees exploited mostly live branches, while white-breasted nuthatches concentrated on the tree bole. Woodpeckers tend to exploit insects deeper inside the bark by pecking (Harris 1982, Lundquist and Manuwal 1990, Powell 2000). Black-backed woodpeckers foraged almost exclusively on the tree bole. Hairy woodpeckers exploited other tree sections, especially dead branches.

Recent studies suggest that food availability may limit primary cavity nesting birds (Caton 1996, Weikel and Hayes 1999, Gunn and Hagan 2000) or at least influence bird density (Li and Martin 1991, Powell 2000). As primary cavity-nesters, this subset of birds influences the available future nest habitat for a number of secondary cavity nesting vertebrates (Martin and Eadie 1999, Aitken et al 2002). Examining foraging patterns can give insights into characteristics important as foraging substrates (Brawn et al. 1982), thereby allowing managers insight into what constitutes foraging habitat.

A large number of studies have been completed examining the foraging behavior of bark-gleaning birds. Franzreb (1985) described the general foraging ecology of brown creepers. Grundel and Dahlsten (1991) studied arthropod prey fed to nestling mountain chickadees. Conner et al. (1994) and Farris (2000) both describe woodpecker foraging patterns in relation to snag conditions. While Murphy and Lehnhausen (1998) examine woodpecker foraging patterns in a recent stand-replacement burn. We know foraging behavior of birds changes with seasonal variation (Brawn 1982, Morrison et al. 1985, Morrison and With 1987, Ford et al. 1990, Lundquist and Manuwal 1990), weather

(Grubb 1978, Dolby and Grubb 1999) presence of interspecifics (Villard 1994, Matthysen 1999, Weikel and Hayes 1999, Brennan et al. 2000) and between sexes in conspecifics (Grubb 1982, Morrison and With 1987).

While there seems to be a plethora of information on this topic, this is the first study to compare the foraging patterns of bark gleaning birds between this fuel reduction treatment (thinning-prescribed fire) and control sites. It is known that silvicultural manipulations alone can alter bark-gleaning birds' foraging patterns (Szaro and Balda 1979, Weikel 1997) and concerns over how thinning and burning may affect these ecosystem drivers have been expressed for more than a decade (Morrison et al. 1987, Brennan et al. 2000). I found that species usually encountered after fires, including black-backed woodpeckers, hairy woodpeckers and white-breasted nuthatches (Hutto 1995, Hoffman 1997, Murphy and Lehnhausen 1998, Kriesel and Stein 1999, Dixon and Saab 2000), were encountered primarily in our thinned and burned sites. These results indicate this particular treatment may enhance available foraging habitat for this guild.

All birds selected larger trees for foraging, with diameter having a large influence in some cases. For example, the probability of a red-breasted nuthatch foraging on a 12.7cm (5.0in.) diameter tree changes from 0.19 to 0.71 for a 38.1cm (15in.) diameter tree, all other things equal (treated areas, selection among any class). Black-backed woodpeckers displayed less sensitivity to increases in diameter. The probability of a black-backed woodpecker foraging on a 12.7cm (5.0in.) diameter tree changes from 0.18 to 0.33 for a 38.1cm (15in.) diameter tree, all other things equal. This finding is consistent with foraging patterns of nuthatches and woodpeckers in other habitat types

(Lundquist and Manuwal 1990, Villard and Beninger 1993, Villard 1994, Weikel and Hayes 1999, Gunn and Hagan 2000)

Fuel reduction treatments of this type typically reduce the available small diameter trees, while leaving larger diameter target species (i.e. ponderosa pine, western larch). Therefore, selection of larger diameter trees as foraging substrates overlaps well with treatment objectives. Although tree diameter was often the only variable that I could confidently conclude anything about, many other variables influence selection. Small sample sizes combined with a large amount of variation in the data caused many variables to have large confidence intervals that included 1.0 (95% CI for odds ratio). These variables should still be considered as being potentially important because they explained enough variation to be included in the best approximating model set.

Selection differences found between treatments involved differences in availability. Although red-breasted nuthatches selected against Douglas-fir trees in treatment and control sites, conclusions could only be made in control sites due to wide confidence intervals in treatment sites. This could be due to a small sample of Douglas-fir trees in treatment sites. Douglas-fir is selectively thinned as part of the treatment, so relatively few Douglas-fir trees remain on thinned-burned sites.

Beetle evidence may have been important only in thinned-burned sites as a result of low levels of beetle activity in control sites. Bark beetles respond to disturbance and often persist at high levels for the first few years post-disturbance. We observed this trend on our sites, with high levels of beetle attacks occurring through the 2002 season. The most common beetle evidence present was red turpentine beetles (*Dendroctonus valens* Lec.) and wood-boring beetles (Buprestidae and Cerambycidae). Red turpentine

beetles prefer trees injured by fire, logging operations, or other damage (Hagle et al. 1987). Buprestids and Cerambycids both attack recently cut trees or those killed by bark beetles (Hagle et al. 1987). This explains why these beetles would be found more often in thinned and burned sites than control sites.

Ponderosa pine was selected compared to Douglas-fir for most bird species, but red-breasted nuthatches selected large diameter Douglas-fir in control sites. This is based on measured use and availability, so availability discrepancies are accounted for. Hairy woodpeckers forage heavily on ponderosa pine where available (Morrison et al. 1985, Morrison et al. 1987, Morrison and With 1987). Fuel reduction treatments would not be contrary to this selection, as some large Douglas-firs may be left to fulfill basal area requirements (Appendix 1).

Within the same tree class (live or dead), red-breasted nuthatches selected trees with beetle evidence. Although red-breasted nuthatches are generalists (Adams and Morrison 1993, Ghalambor and Martin 1999), they selected for bark beetles where available. Beetle evidence was key to selection for black-backed woodpeckers. The probability of foraging a 12.7cm (5in) diameter tree increases from 0.18 without beetles to 0.65 with beetle evidence. Beetle presence has been suggested as a primary indicator of black-backed woodpecker density (Powell 2000). In contrast to a somewhat common view of some land managers that beetle presence is negative, my data indicate that beetle presence following prescribed fire is important for providing good foraging habitat.

As expected, red-breasted nuthatches selected live trees (Morrison et al. 1987, Weikel and Hayes 1999); woodpeckers selected dead trees (Bull et al. 1986, Lundquist Manuwal 1990, Villard 1994, Goggans 1989, Kriesel and Stein 1999). Both Gunn and

Hagan (2000) and Kriesel and Stein (1999) observed hairy woodpeckers selecting recently dead trees, a trend confirmed by our observations of foliage color and retention being important (variables describing time since tree death). White-breasted nuthatches selected dead trees, a trend not observed before.

Overall these trends suggest that fuel reduction treatments in ponderosa pine will not negatively affect the food resources of the bark-foraging community present before treatment. Indeed, the treatment may increase the availability of foraging substrates for black-backed woodpeckers, hairy woodpeckers and white-breasted nuthatches. The tendency of these birds to concentrate foraging in the higher severity burn areas suggests that foraging habitat will be enhanced if prescribed burns burn at higher intensities in pockets across the landscape.

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Chapter IV. Small mammals responses to thinning and prescribed fire in ponderosa pine forests.

Abstract

The objectives of this study were to determine if small mammal species composition and abundance are different on sites that have undergone a ponderosa pine forest restoration/fuel reduction treatment of thinning and burning compared to sites that are candidates for this treatment. I compared species composition and abundance on three replicate 20-ha thinned/burned plots paired with three 20-ha control plots. Paired sites were simultaneously live-trapped in July/August 2001 and 2002. I used mark-recapture techniques to estimate abundance. Golden-mantled ground squirrels were present exclusively on thinned/burned sites. Deer mice were more abundant in thinned/burned sites during both years of the study. Yellow-pine chipmunks became more abundant in thinned/burned sites during the second year only. Red-backed voles were less abundant on thinned/burned sites, but were uncommon on all sites. These results indicate changes in small mammal abundance and potentially composition as a result of this restoration treatment. Considering the strong role small mammals play in ecosystem interactions, such changes could have indirect effects on many aspects of the ecosystem.

INTRODUCTION

Before European settlement, many forest types in the western U.S were mosaics of uneven aged, moderately open stands dominated by large trees, such stands were maintained by fire, insect depredations and age-related mortality (Arno et. al. 1995, Fiedler 2000). Fire suppression in ponderosa pine (*Pinus ponderosa*) forests has resulted in an increase in shade-tolerant Douglas-fir (*Pseudotsuga menziesii*) and a denser understory (Covington et al. 1997). This transition has produced higher fuel loads, reduced soil moisture and nutrient availability, increased fire severity and size (Harris and Covington 1983, Covington et al. 1997, Smith 2000) and increased scale of insect outbreaks such as Douglas-fir tussock moth (*Orgyia pseudotsugata* McDunnough Tiedemann et al. 2000).

Following national trends, the Montana Department of Natural Resources (DNRC) is integrating ponderosa pine forest restoration into its timber harvest program with a commercial thin that is combined with a selective cut, and followed by a prescribed burn (Appendix 1). Thinning before burning removes accumulated fuel, allowing greater control of the prescribed burn and lower mortality risk to large residual trees. The agency plans on this prescription on a ~ 25 year rotation, which is within the historic fire interval (5-30 years, Arno 1996).

Because western Montana has nearly five million acres of pine/fir forests that were historically maintained by frequent low intensity fire (Agee 1993, Smith and Arno 1999, Veblen et al. 2000), and much of this will be restored using this thin-burn treatment, understanding different species responses to these treatments is imperative for

wildlife managers. In this study, I determined both numerical responses of small mammals as well as shifts in species composition.

Small mammals may respond to management-induced changes in the forest floor, such as potential increases in small downed woody debris, potential decreases in large downed woody debris, areas of intense fire, and shifts in the understory vegetative community and structure. Although abundance of individual species may not be a good indicator of habitat quality (Van Horne 1983), changes in small mammal abundance may have reverberating effects in the system.

The most abundant small mammal species in this region include deer mice (*Peromyscus maniculatus*), yellow-pine chipmunks (*Tamias amoenus*) and southern red-backed voles (*Clethrionomys gapperi*). Deer mice are the most common carrier of Hantavirus, of interest when fuel-reduced stands are at or near the urban interface, where rates of infected deer mice are highest (Kuenzi et al. 2001). Therefore, changes in deer mice populations may have direct effects on human health.

In addition to direct effects, changes in the small mammal community could reverberate through the system via indirect effects. Chipmunks and deer mice are well documented as primary nest predators in forest systems (Martin 1993, Martin 1988, Martin and Roper 1988), and play important roles as seed predators (e.g. Tallmon et al. in review). Red-backed voles play an important role as dispersers of mycorrhizal fungi (Maser et al. 1978). Furthermore, an increase in small mammal abundance would also provide increased prey for forest carnivores and raptors, which could potentially reduce predation on songbirds by providing alternative prey or increase incidental predation by attracting more predators to an area.

Determining the effects of these treatments on small mammal abundance will lend insight into possibly widespread effects on the ecosystem. These effects may be positive for some species (raptors) and negative for others (songbirds). Each species plays a different consumer role, as well as being important prey for forest carnivores and raptors. Each species may also respond differently to changes in the forest floor structure.

While many studies have been conducted on the responses of deer mice to logging practices (Clough 1987, Carey and Johnson 1995, Menzel et al. 1999, Sullivan et al. 2000) and fire (see Ream 1981), little information is available on response of this species to ponderosa pine restoration treatments (but see Douglass et al. 1999). Little is known about how yellow-pine chipmunks respond to any logging practices. Yellow-pine chipmunks prefer open habitats (Meredith 1976) and have been shown to increase in abundance due to pre-commercial thinning (Sullivan and Klenner 2000, Sullivan 2000), while deer mice are abundant in a variety of habitats (Carey and Johnson 1995, Sullivan 1979, Menzel et al. 1999). Red-backed voles are found most often in moist forests with downed woody debris (Foresman 2001, Pearson 1994), but their response to this treatment is unknown.

The objectives of this study were to determine if small mammal species composition and abundance differ on sites treated by thinning and burning compared to sites that are candidates for this treatment. I expected deer mice and yellow-pine chipmunks to be more abundant on thinned/burned sites and red-backed voles to be less abundant on thinned/burned sites, but expected species composition to be unaffected by treatment.

STUDY SITE AND DESIGN

Study sites were located within the boundaries of The University of Montana's Lubrecht Experimental Forest, 38 km NE of Missoula, MT at approximately 1200 – 1350 m elevation. The area was heavily logged in the early 1900s, with subsequent fire suppression. The second-growth ponderosa pine/Douglas-fir forests represent xeric, low-elevation forest conditions common in western Montana.

My study design is considered a quasi-experiment, meaning study investigators did not control the treatments, the treatments were planned and implemented by a land management agency (James and McCulloch 1995). The study began one year post-treatment, therefore, there are spatial but not temporal controls.

The quasi-experimental design consisted of three 20-ha control plots paired with three 20-ha treatment plots (Figure 1); paired plots were similar in shape, size and forest type. The treatment plots were located on Montana Department of Natural Resources (DNRC) land within the boundaries of Lubrecht Experimental Forest. The DNRC selectively thinned trees in winter of 1998/1999 (Appendix 1) and all three sites were subsequently broadcast burned in spring of 2000. The size of treatments was from 60-250 ha, with 20-ha sampling plots located within the treatment boundaries. Each plot had a 75-m buffer from any defined habitat edge (road, habitat-type change). Control plots were defined as areas that are candidates for the treatment, as opposed to pristine areas. Control plots were second growth stands dominated by ponderosa pine and had not been logged or burned since ~ 1930s, resulting in a dense understory of Douglas-fir.

Fire severity is highly variable and must be defined and described in order to represent the treatment being implemented. I sampled fire severity systematically on

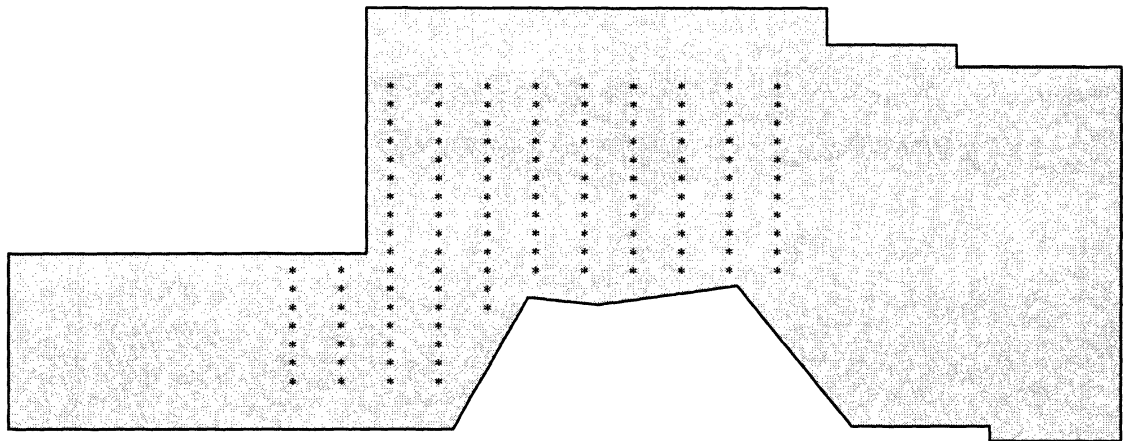


Figure 1a. Burn 1/Control 1 pair

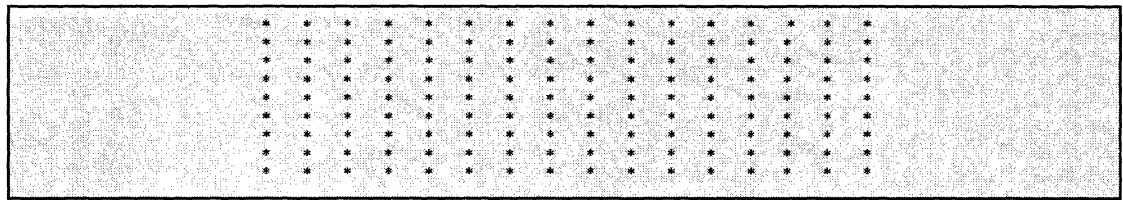


Figure 1b. Burn 2/Control 2 pair

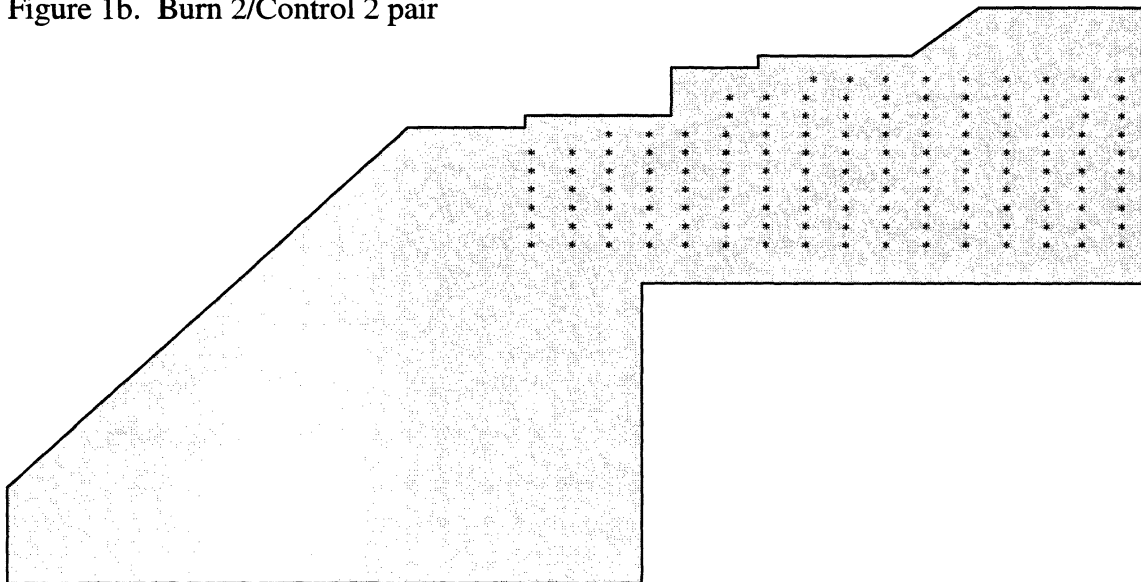


Figure 1c. Burn 3/Control 3 pair

Figure 1. The configuration of trapping grids for each pair of 20-ha plots, grid had 25 m spacing. (a) Burn1/Control 1 (b) Burn2/Control 2 (c) Burn3/Control 3

29 - 49 gridpoints per 20-ha plot. Flame length class (2) and (3) dominated Burn 1, indicating high levels of sapling and pole tree mortality. Burn 2 was highly variable, with many areas suffering only seedling and sapling loss, while other points incurred pole and small saw timber loss. Burn 3 was least severe in terms of above ground mortality, with most points indicating mortality for seedlings and saplings only. Light/moderate ground char dominated all sites (See Appendix 3).

METHODS

Each 20-ha pair had a unique trapping grid with 128 to 144 traps per paired plot (Figure 1). A large Sherman trap (7.5 cm x 8.75 cm x 22.5 cm) was located within 2 m of each grid-point. Traps were pre-baited with sunflower seed and oat groats 2 days before each session began. Polyester bedding and ~ 1cm³ piece of apple were added during the trapping session. Traps were placed inside an empty half-gallon milk container for insulation and protection from rain. Traps were opened early evening and checked and closed each morning. Each animal was sexed, weighed and individually marked, and its reproductive condition recorded. Deer mice and red-backed voles were individually marked by toe clipping, while larger animals were ear-tagged. Toe-clipping is a widely accepted form of marking small mammals and does not negatively affect survival (Pavone and Boonstra 1984). Traps were opened for 5 consecutive nights, to maximize detection probabilities while minimizing violations of assumed population closure violations (Williams et al. 2002). Paired plots (treatment and control) were

trapped simultaneously. Trapping occurred during late July and early August during summer 2001 and 2002.

ANALYSIS

I estimated abundance on each plot with program CAPTURE (Rexstad and Burnham 1991). Tests within CAPTURE indicated that the closure assumption was violated for both chipmunks and deer mice. Closure violations can result from deaths during the trap session, one time stops into the area (migratory birds), immigration, emigration, and random movement in and out of the trapping grid (Kendall 1999). Since I was not trapping a habitat island, it is not surprising that small levels of random movement in and out of the grid occurred.

As long as movement in and out of the study area is random, estimates using the closed population models in Otis et al. 1978 are still valid (Kendall 1999). However, the models that incorporate individual heterogeneity (Mh jackknife estimator, Burnham and Overton 1979) suffer increased bias when there is random movement in and out of the study area (Kendall 1999). Plots exhibited individual heterogeneity in capture history, with model Mh being selected by CAPTURE as the best model 75% of the time for deer mice, and 60% of the time for chipmunks. Red-backed voles occurred in small sample sizes causing CAPTURE to perform poorly in the model selection process. However, due to increased bias due to closure violation, I controlled for uncertainty in the model selection process by using only the null model (Mo) to estimate abundance, standard error and 95% confidence intervals. The Mo estimator, which assumes constant capture probabilities across time and individuals, is negatively biased in the presence of

individual heterogeneity, so estimates are conservative (Otis et al. 1978). I used non-overlapping 95 percent confidence intervals as evidence of significant differences between paired treatment/control plots (Johnson 1999). Known mortalities were removed from the capture histories and added to the abundance estimate, an approach that does not affect variance (Williams et al 2002). Because paired plots were the same shape and size, and had the same grid configurations and trapping dates, comparisons of abundance was made only between paired thinned/burned plots and unmanipulated (control) plots.

RESULTS

Deer mice were more abundant in thinned/burned plots than in unmanipulated plots during in both years (Table 1, Figure 2). In 2001, deer mice were 1.5 to 2.9 times more common in thinned/burned plots than in control plots. In 2002, deer mice were 1.8 to 4.5 times more common in thinned/burned plots than in control plots. The lack of overlap between the 95% confidence intervals for paired comparisons in all cases indicates that the differences are not only biologically meaningful, but also significant (Table 1, Figure 2). Consequently, there was no need to conduct formal significance tests.

Yellow-pine chipmunks were more abundant in thinned/burned plots in 2002 (Table 1, Figure 3), but not in 2001. In 2001, yellow-pine chipmunks were less abundant in two of three thinned/burned plots and more abundant in the third thinned/burned plot. In 2002, yellow-pine chipmunks were 1.6 to 2.4 (Table 1, Figure 3) times more abundant on thinned/burned plots than on unmanipulated sites. The lack of overlap between the

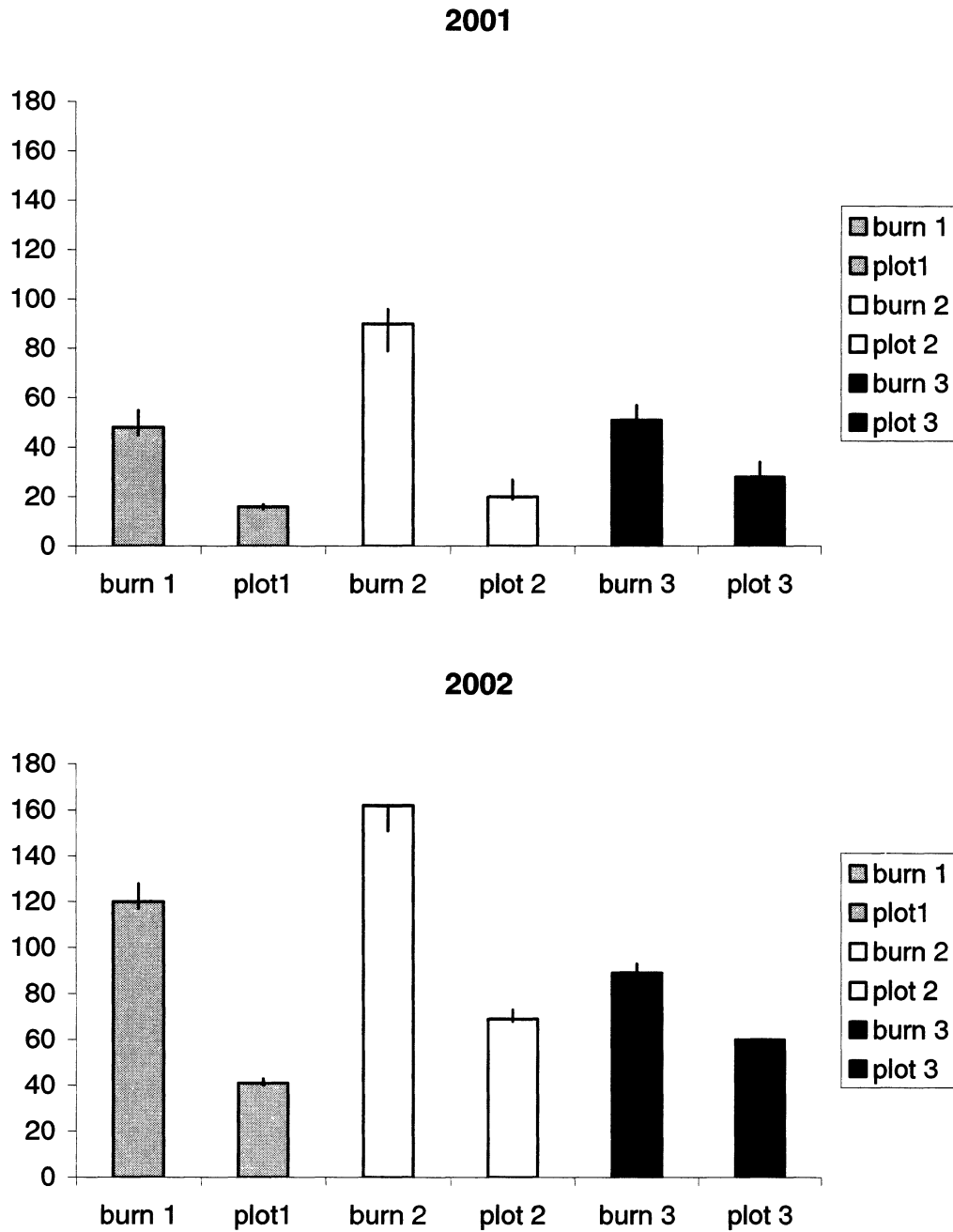


Figure 2. The estimated abundances, with standard error bars, of deer mice *Peromyscus maniculatus* for each paired treatment/control site in 2001 (top) and 2002 (bottom).

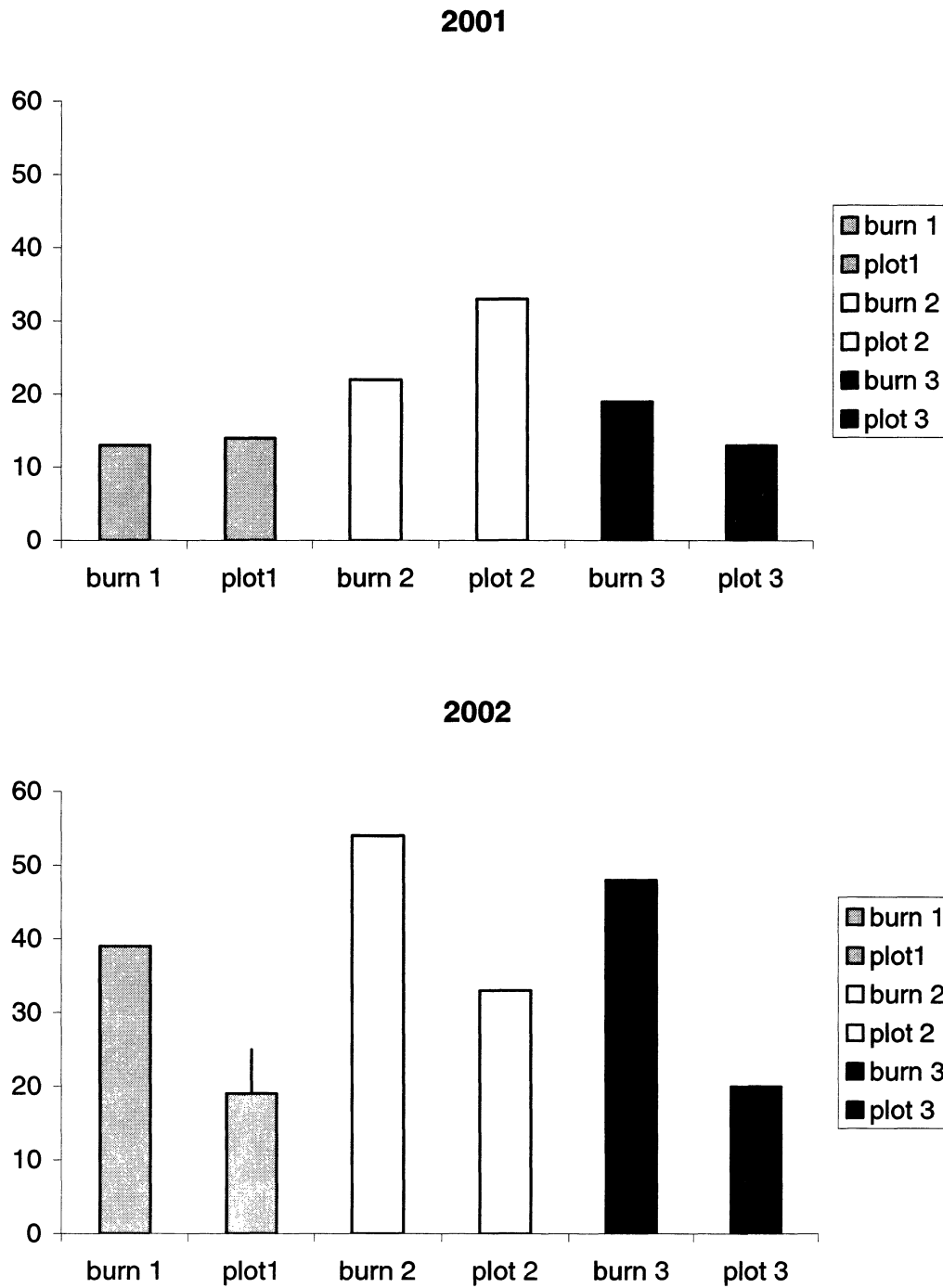


Figure 3. The estimated abundances, with standard error bars, of yellow-pine chipmunks *Tamias amoenus* for each paired treatment/control site in 2001 (top) and 2002 (bottom).

95% confidence intervals for paired comparisons in 2002, in all cases, indicates that the differences are significant and biologically meaningful (Table 1, Figure 3).

Red-backed voles were captured in small numbers on both sites, resulting in less precise estimates. Red-backed voles were less abundant in thinned/burned sites than in unmanipulated plots in both years (Figure 4). In 2001, I captured red-backed voles in burn 2 only, where they were 0.6 times as abundant as in unmanipulated sites. In 2002, red-backed voles were about 0.1 times as abundant in thinned/burned sites as compared to unmanipulated sites (Table 1). Due to small sample sizes, estimates are less precise. Confidence intervals for the burn1/plot 1 pair and burn3/plot3 pair do not overlap in either season, however the confidence intervals for the burn2/plot 2 pair overlap in both years. Therefore, statistically significant differences were only apparent on 2 of 3 pairs of plots.

Species composition differed between the thinned/burned plots and the unmanipulated plots (Table 2). Golden-mantled ground squirrels (*Spermophilus lateralis*) were captured on all three thinned/burned plots both years, but were not captured on unmanipulated plots. *Microtus* spp. were captured on one of the thinned/burned sites in 2002, whereas red-backed voles were the only voles captured on other plots.

DISCUSSION

Abundance

As expected, deer mice were consistently more abundant on thinned/burned sites. Over the two years, deer mice were at least 1.5 times as abundant, and as much as 4.5

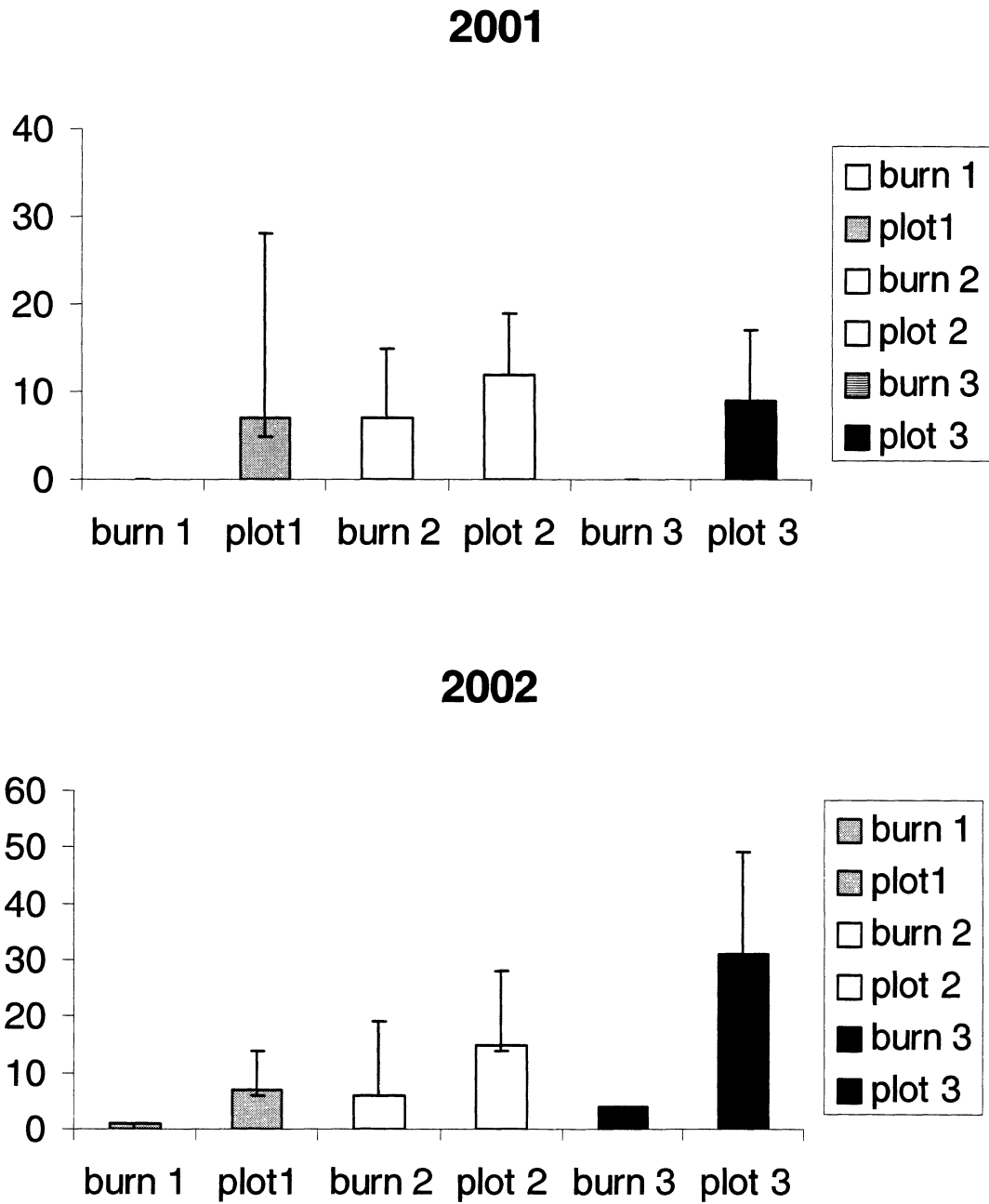


Figure 4. The estimated abundances, with standard error bars, of red-backed voles *Clethrionomys gapperi* for each paired treatment/control site in 2001 (top) and 2002 (bottom).

Table 2. Species composition for each study site, for both years of the study. Numbers in parenthesis are the total number of *Spermophilus lateralis* caught over both years.

	BURN	CONTROL	BURN	CONTROL	BURN	CONTROL
	1	1	2	2	3	3
<i>Peromyscus maniculatus</i>	X	X	X	X	X	X
<i>Tamias amoenus</i>	X	X	X	X	X	X
<i>Clethrionomys gapperi</i>	X	X	X	X	X	X
<i>Microtus longicaudus</i>					X	
<i>Spermophilus lateralis</i>	X (5)		X (2)		X (1)	
<i>Sorex species</i>	X	X	X	X	X	X

times as abundant (Table 1). I did not collect recruitment or survival information, therefore my inference is limited to numerical responses, and the effects of such responses on the system. Abundance of deer mice often increases following timber harvesting (Waters and Zabel 1998, Gunther et al. 1983). Sullivan (1979) and Sullivan et al. (2000) reported no differences in density or demographic attributes among timber-harvested areas, but Tallmon and Mills (in review) show strong changes in both density and survival. Martell (1984) examined black spruce sites that had been clearcut or selectively harvested. Deer mice increased in abundance post-fire in both types of timber harvest.

Response of small mammal populations to fire is well documented (Ream 1981). Deer mice generally are more abundant following fire. In a spruce/fire forest, deer mice were more abundant five years post burn compared to stand that had undergone harvest and herbicide treatment (Clough 1987). Positive numerical responses to fire in tall grass prairie and shrub steppe shadscale communities have also been documented (Kaufman et al. 1988, Clark and Kaufman 1990, Groves and Steenhof 1988).

In ponderosa pine forests in South Dakota, deer mouse abundance increased one year post-fire (Bock and Bock 1983), but no consistent difference in abundance two years post-fire. The difference could be due to the short-term nature of both studies; perhaps if Bock and Bock had measured abundance three and four years post fire, a consistent pattern would appear. Conversely, there could be ecological differences in the forest floor in ponderosa pine forests in South Dakota versus Montana resulting in different responses.

In a similar study in western Montana, Douglass et al. (1999) found an immediate increase in deer mouse abundance examining small mammal abundance one year after prescribed burning/two years post-thinning. My results supplement this study by examining years three and four post-treatment, indicating that deer mice abundance is sustained for numerous years after thinning and prescribed fire. Masters et al. (1998) examined small mammal responses to a very similar treatment in shortleaf pine forests of Arkansas. These forests are similar in that they were historically dominated by frequent fires and are currently being restored to an open pine-grassland forest to protect red-cockaded woodpeckers. *Peromyscus* sp. (dominated by *Peromyscus leucopus*) were relatively more abundant in stands that had been restored.

Deer mice have a large impact of forest ecosystems as primary seed predators. Large numbers of deer mice can translate into significant impacts on the plant community (Tallmon and Mills in press). Additionally, deer mice are insect predators and can act as control agents on certain insect populations. A good example of this involves gall flies: deer mice are often in greater numbers in the winter where spotted knapweed occurs due to the presence of gall flies, and they can have a negative impact on the control of knapweed with gall flies (Pearson et al. 2000). Deer mice are also important prey species for both mammalian and avian predators. Therefore, an increase in deer mouse abundance after thinning-burning may affect the plant community, insect community and predator community.

Yellow-pine chipmunks showed a more complex pattern, showing no response in 2001. However there was a positive, significant treatment effect in 2002; they were 1.6 to 2.4 times as abundant on thinned/burned sites (Table 1). This pattern is generally

consistent with studies showing an immediate decrease in chipmunks after fire in conifer stands, followed by a gradual increase (Ahlgren 1966, Gashwiler 1959, Gashwiler 1970).

Although we do not know the mechanism underlying deer mouse and (to a lesser extent) chipmunk increases on treated sites, previous hypotheses have focused on seed availability. As deer mice were more abundant during both years and depend heavily on seeds as a food source, it is unlikely that a lack of seeds as a food source explains the pattern observed for yellow-pine chipmunks. Seeds are often thought to be the most important food source for chipmunks, but a variety of food items are consumed including: fungi, fruits, bulbs, insects, bird's eggs, flowers, green foliage, roots, and "small animal life" (Maser and Maser 1987, Sutton 1992). Some of these foods, such as hypogeous fungi, may not be readily available until a few years post-fire. Soil scarification and understory reduction may reduce sporocarp production for the first few years after a disturbance (McIntire 1984). Soil humus and decayed wood are important substrates for the formation of ectomycorrhizae in western Montana Douglas-fir/larch forests (Harvey et al. 1976). McIntire (1984) hypothesized "a significant increase in bare mineral soil and a decrease in duff depth corresponds to a decrease in the necessary organic matter for mycorrhizal formation and subsequent sporocarps". Therefore, it may be that yellow-pine chipmunks may require hypogeous fungi for moisture and thinning/burning reduces the available fungi due to increases in exposed mineral soil and decreased duff depth for the first few years.

In addition, yellow-pine chipmunks often respond positively, in terms of abundance, to disturbances that open the forest canopy. Sullivan and Klenner (1999) reported increases in abundance in heavily thinned lodgepole pine stands as compared to

moderately thinned and old growth. McKeever (1961) captured yellow-pine chipmunks frequently in open ponderosa pine stands, but less often in a stand of old-growth fir.

Yellow-pine chipmunks were more common in shelterwood logged fir forests compared to mature and old growth in the Sierra Nevada range (Waters and Zabel 1998).

Contrary to my results, Martell (1984) and Douglass et al. (1999) found yellow-pine chipmunks to be more abundant in areas that had been logged and burned one year post fire. I would expect the study conducted by Douglass et al. (1999) to have similar results due to the similarity of study sites (western Montana ponderosa pine stands). The differences could be attributable to different time scales, as their study looked at abundance the season immediately after fire, whereas we began our study three years after fire. However, this study did not observe an increase until three years after fire, indicating a more delayed response. Potential differences in prescribed fire severity could be a reason for this difference: all three of the prescribed fires on my sites resulted in light/moderate ground char.

An increase in abundance of yellow-pine chipmunks has a diverse effect on the ecosystem. They are important dispersers of conifer seeds through the regular caching of conifer seeds, increasing the dispersal distance from the source tree as compared to wind (Vander Wall 1993, Vander Wall and Joyner 1998). Chipmunks are the primary nest predator in many forested systems (Martin 1998, Martin 1988, Martin and Roper 1988), so significant increases in chipmunk numbers could have a negative effect on the nest success of songbirds. Since they are consistently mycophagous, they could play an important role in fungi dispersal in open, dry forests, where more traditional dispersers such as red-backed voles are rare. Finally, yellow-pine chipmunks are important prey

species to a number of predators, including mustelids, bobcats (*Lynx rufus*), coyotes (*Canis latrans*) and most diurnal raptors.

As expected, southern red-backed voles were less abundant and less consistently present on thinned-burned sites than unmanipulated sites. Red-backed voles were only present on one of three thinned/burned site in 2001, and were significantly less abundant throughout. Southern red-backed voles in Montana are well documented as preferring moist, dense forests (Foresman 2001, Pearson 1994). Consequently, abundance of southern red-backed voles often declines following disturbances that open the forest canopy and create more xeric conditions. Southern red-backed voles were more common in old-growth Douglas-fir/lodgepole pine forests than in young pine and seed tree stands (Sullivan et al. 2000). Alternately, Carey and Johnson (1995) and Gunther et al. (1983) did not find significant numerical differences between unmanaged and managed forests.

Burning may have negative effects in addition to timber harvest (Martell 1984). He compared clearcut black spruce to selectively logged black spruce before and after fire. Southern red-backed voles were found almost exclusively in non-burned stands. In northern Maine, the same pattern was observed; southern red-backed voles were recorded in various managed and unmanaged forest stands, but were absent in the burned site (Clough 1987).

My results coincide with patterns in these previous studies. Although my effect sizes are significant in two of three paired comparisons, southern red-backed voles are not common on the unmanipulated (control) sites. The unmanipulated sites are dry forests dominated by ponderosa pine, contain relatively low levels of downed woody debris, and downed debris present decays slowly. Although these sites have a dense

overstory, this is an unnatural condition for this forest type that typically burned frequently. Under natural conditions (with fire as a process), I would not expect high numbers of southern red-backed voles in this forest type.

Species composition

A minor shift in species composition was observed (Table 2). Deer mice, yellow-pine chipmunks and red-backed voles were observed in both thinned/burned sites. Golden-mantled ground squirrels were consistently observed exclusively in thinned/burned sites. *Microtus* spp. were observed exclusively in only one thinned/burned site. This suggests that the presence of golden-mantled ground squirrels is likely a treatment effect. Conversely, the presence of *Microtus* spp. is likely a site-specific phenomenon.

Golden-mantled ground squirrels are much more abundant in open ponderosa pine forests than closed canopy lodgepole pine and fir forests (McKeever 1964). They typically avoid areas with little herbaceous vegetation and direct sunlight (McKeever 1964). My findings are not surprising considering the thinned/burned sites are being restored to an open ponderosa pine forest stand. This species may continue to increase in abundance as the time post-fire increases, thereby increasing potential ecosystem impacts.

MANAGEMENT IMPLICATIONS

Treatments to restore ponderosa pine forest and to reduce fuel often involve selective thinning followed by prescribed burning. These treatments are becoming more common, and encompass more acreage every year (NFP website). This study indicates

there will be major impacts on the small mammal community as a result of widespread application of these prescriptions. These impacts are diverse, including some species composition changes and strongly increased abundance of deer mice and chipmunks. Such effects on small mammals could in turn affect seed predation, conifer seed dispersal, nest predation and prey availability to both nocturnal and diurnal mammalian and avian predators.

Increasingly, fuel reduction treatments are advocated at the “wildland-urban interface”. An important consideration in this instance is the prevalence of Hantavirus in deer mice found in this same interface. Kuenzi et al. (2001) reported deer mice in semi-domestic settings (rural with outbuildings) have higher rates of the antibody. This evidence, combined with an up to 4.5 fold increase in deer mouse abundance should be considered when advocating this treatment on a widespread basis in the “wildland-urban interface”. Doing so may inflate levels of deer mice with Hantavirus in regular contact with human populations.

Overall, this thinning and burning in ponderosa pine forests will not have a negative effect on small mammals. However, the changes in small mammal abundance and potentially in species composition may have major effects on many aspects of the ecosystem.

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Appendix I. Montana Department of Natural Resources Treatment Description as modified from DNRC 1995 contract

Silvicultural Prescription

Sale Name: West Lubrecht Date: 1-10-95
TWP: 13N RG: 14 W SEC: 10 Unit: Missoula Prepared by: Bob Rich
 12N 14 W 22
Aspect: varies Stand: All Ac: 3600 Unit #: All Ac: 3600
Slope: 0 – 40%
Average Elevation: 4400 ft.
 Range: 4000-5200 ft.
Soils/Parent Material: Tertiary Clays, Glacial Outwash, and Colluviums
Habitat type (s): PSME/PHMA-CARU, PSME/VACA, PSME/SYAL-CARU,
 PSME/CARU-CARU
Productivity: Class II – III

MANAGEMENT OBJECTIVES:

Description of Existing Stand:

The entire sale area was logged between 1905 and 1934. Portions of the area have been logged a second time between 1962 and 1982. The majority of the stands are overstocked second growth ponderosa pine, western larch, Douglas fir and very limited amounts of lodgepole pine. Stands are mainly poles to small sawlogs with some scattered patches of large diameter trees from the previous stand, these are mainly Douglas fir. There are scattered patches of regeneration mainly Douglas fir. Pine beetle mortality is common throughout the area. Potential crop trees are capable of good release after thinning.

Target Stand and Silvicultural Plan:

Target stand description: 120 square feet of basal area per acre, scattered patches of ponderosa pine and western larch

Structure: UNEVEN-AGED species composition: 60% PP, 30% WL, 10% DF

Silvicultural Objectives: Commercially thin the stand to 70 square feet of basal area per acre in areas of overstocked immature timber of desirable species mix and capable of release. In areas of uneven-aged stand structure or areas where regeneration is desired, employ an individual tree selection system; reduce basal area in these areas to 50 square feet basal area/acre. Leave dominant trees as leave trees, favoring ponderosa pine and western larch over Douglas fir. Harvest Douglas fir over 120 years old, but retain the majority of ponderosa pine and western larch over 20 inches in diameter. Retain all trees that are cull due to rot or have good potential as nest trees for cavity nesters. Small openings may be made if no suitable leave trees are present in order to establish areas of regeneration for the future uneven-aged stand. Following harvest the stands will be evaluated for prescribed burning on an individual basis. Burning will reduce Douglas fir in the understory, prepare a seedbed for western larch regeneration and reduce fire hazard

resulting from retaining 10 –15 tons per acre of coarse down woody material after harvest.

Regeneration Discussion: Natural regeneration as part of a selection cut

Management Plan: The current harvest is predominantly a commercial thin due to the fairly even-age nature of the stand. However, some regeneration will become established as a result of this cutting and begin to develop an uneven-aged stand. Enter the stands again in 25 years with a selection cut and continue a 25-year cutting cycle. Areas of primarily immature larch and ponderosa pine will generally be commercially thinned. Areas of poor trees incapable of release or areas of mature Douglas fir will receive a selection cut with the goal of establishing regeneration of seral species. Longer-term goal is an uneven age stand with the following prescription:

Q factor	= 1.2
Residual Density	= 60 sq. ft. ba/ac regulated 10 sq. ft. ba/ac unregulated (old growth component)
Maximum tree size	= 20 inches
Cutting cycle	= 25 years

Calendar Rotation

1997	Commercial thin/selection cut
2022	Selection cut

Prescribed Treatments

1999	Under burn
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Implementation Notes: The planned harvest with some prescribed burning should result in a stand more similar to the pre-settlement era stand than the one currently on the site. In the future, the stands will be open-grown, uneven-aged with patchy regeneration. They will be dominated by 16" + diameter trees. Seral species, ponderosa pine and western larch, will be the major stand components with lesser amounts of Douglas fir present.

Contract Period

The contract may start following the formal bid award and a pre-work conference. All work must be completed by October 10, 1999

Technical Specifications, Inspection, and Acceptance

A. Timber Marking

1. Leave tree cut as a selection cut
2. Leave basal area as follows:
 - Burn 1: 47 ft./acre
 - Burn 2: 44 ft./acre
 - Burn 3: 35 ft./acre
3. Trees shall be marked with at least a one-inch wide horizontal blue paint band. Paint band shall be placed at approximately five feet above ground level and shall extend around 90% of the circumference of the tree.
4. Tree Selection
 - a. Leave trees should be dominant and co-dominant trees at least 6 inches in DBH
 - b. Mark only healthy trees with good form except as noted below in 4c. Forked or crooked trees may be left to provide wildlife habitat.
 - c. Leave all trees over 20" DBH unless otherwise instructed.
 - d. Leave all trees that are cull due to rot.
 - e. Leave tree species preference starting with most favorable is: ponderosa pine, western larch, lodgepole pine, Douglas-fir.
 - f. Trees forked at the base should either both be cut or both left; do not take one and leave one
 - g. Trees may be left in a somewhat clumpy pattern. Species and dominance should take precedence over a perfectly equal spacing between trees.

Appendix II. Wildlife Data collection conducted for National Fire/Fire Surrogate Study

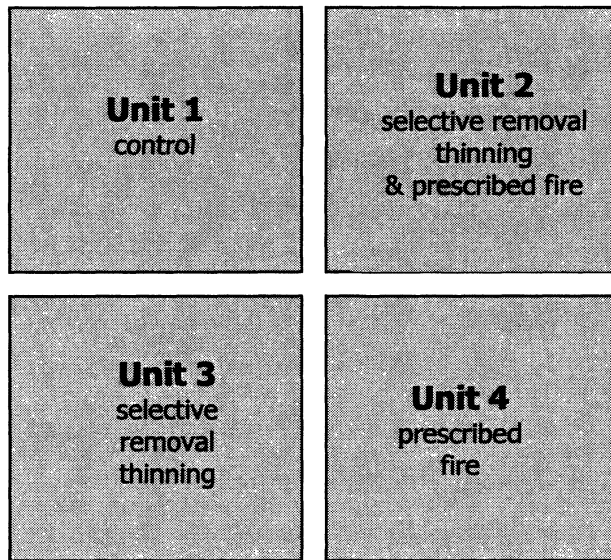
As part of the interdisciplinary team of scientists collecting data on the National Fire/Fire Surrogate study (FFS), we will conduct the following surveys starting in the summer of 2000 and continuing until the study is complete. The FFS uses a block design, with four units in each block (Appendix Figure 1). Each unit will receive one of four treatments:

- 1) control
- 2) prescribed fire
- 3) selective tree removal
- 4) selective tree removal and prescribed fire

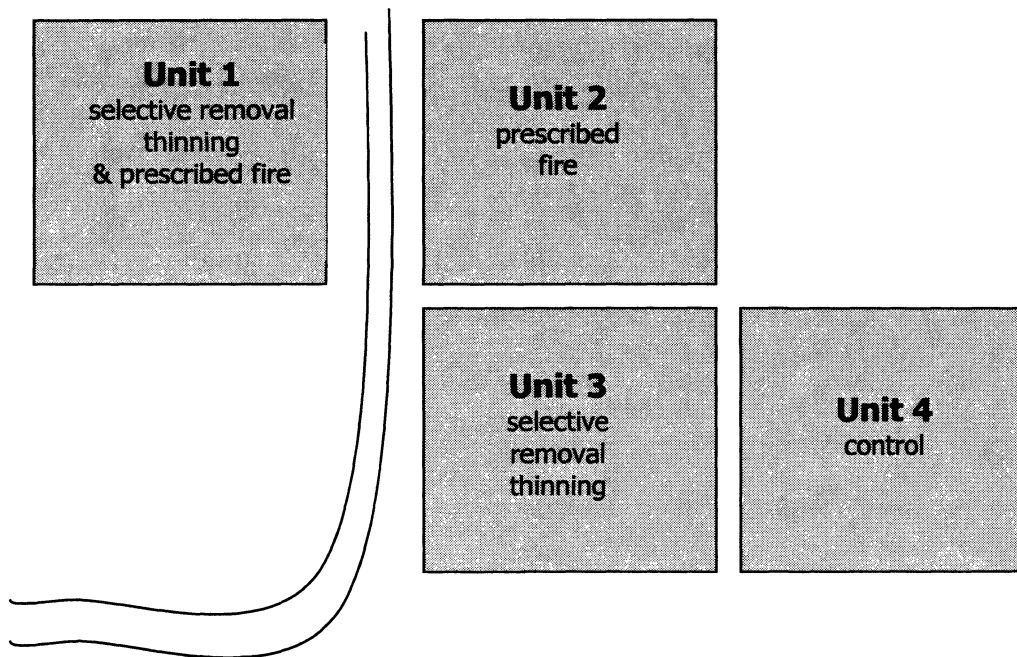
1. Small mammal trapping is conducted pre-treatment and post-treatment. Trapping was conducted in the summer of 2000 before any treatments were implemented (Table 1) and will be conducted for one season after all treatments have been completed. A 7x7 grid with 25-meter spacing will be used (Figure 2) with one Sherman trap within two meters of every grid point. Traps are pre-baited for two days with sunflower seed and oat groat, with apple and poly bedding added during the trapping period. Traps will be set for five consecutive nights, checked in the morning and closed during the day. Animals will be processed at the trap sight and individually marked. One block will be trapped simultaneously, and blocks will be trapped consecutively.
2. Tomahawk trapping was conducted during the summer 2000 season and will not continue due to low capture numbers (Table 2).
3. Songbird nest searching is conducted every season on eight selected units, two of each treatment. Our selected treatments are units one – four in block 1 and units one – four in block 2. We included all songbirds present in our surveys in the summer of 2000 and found this to be inefficient due to the labor intensity of finding and monitoring nests. Beginning in the 2001 season, we focus on dark-eyed juncos (*Junco hyemalis*; a ground nester), chipping sparrows (*Spizella passerina*; tree nester) and cavity nesters in our surveys so that our efforts will be more productive. Other species nests will be recorded and monitored if found. Nests will be monitored every three days until success (one nestling successfully fledged) or failure is observed. Nest vegetation data will be collected at each site. This includes describing the nest substrate, aspect, height, and cover of nest. An 11.3-meter radius circle is then delineated and all trees within the circle are counted.
4. Songbird point counts are conducted four times in each unit during the breeding season.
5. Bark gleaner forage surveys are conducted in all units during the season; see earlier description of forage surveys.
6. Pitfall trapping for amphibians is conducted pre-treatment and post-treatment. Traps were installed every 100 meters in block 3 in the fall of 2000 and opened for ten consecutive nights. A large number of long-toed salamanders (*Ambystoma macrodactylum*) were captured during this session, however, no recaptures were recorded. This is not surprising due to the layout of the traps and the fact that the salamanders were most likely engaged in a one way migration out of their breeding

pond. On a national level, pitfall trapping has become optional, so we will have to decide whether to continue this effort on our site. While finding a treatment effect with the current design is not likely, it is interesting to note the distance from water we have documented the salamanders. Our efforts may be refocused into determining how far from water we can document them.

Appendix Figure 1a. Configuration of Blocks 1 and 2; each block consists of four 9-ha units that receive a different treatment



Appendix Figure 1b. Configuration of Block 3



Appendix III. Fire intensity/severity characterization

Fire is incredibly variable and must be defined and described in order to represent the treatment being implemented. Fire intensity is the energy output at the time of the fire and can be indirectly measured from flame length (Agee 1993). Crown scorch can be assessed post-fire and classified into a flame length class (Ryan and Noste 1985, Swezy and Agee 1991; see Table 1). Fire severity is the effect of the fire on the landscape, as it affects the forest floor, tree canopy and other parts of the ecosystem and can be measured by tree mortality and ground fire severity ratings (Ryan and Noste 1985). A protocol for measuring fire severity on the sites was developed in collaboration with Mick Harrington, PhD., a fire ecologist at the Rocky Mountain Research Station Fire Sciences Lab, located in Missoula, Montana.

Methods

I implemented a systematic sampling scheme, with a range of 29 - 49 grid-points per 20-ha plot. At each selected grid-point, a 10-m radius circle was delineated. For all trees greater than 12.5 cm in diameter, a crown scorch height and bole scorch height was recorded. Scorch height plot averages and maximums can be used to estimate flame length, which is a direct indicator of fire intensity. Crown scorch height is converted into a flame length class (Ryan and Noste 1985). A tree mortality record is obtained by counting the number of trees that survived the fire and the number of trees killed by the fire within the 10-m circle. I estimated ground fire severity using ocular estimates of percent cover of ground char following Ryan and Noste (1985). Ground fire severity indicates the fire's effect on forest floor resources such as microbial biomass (Tiedemann 2000) and the seed bank. Flame length classes combined with ground char estimates are a good quantitative measurement of fire severity at that point. By using a systematic sampling system, I can describe the variability observed in fire behavior across the sites.

I adapted the methodology recommended by Ryan and Noste (1985). I used the maximum crown scorch height at each grid-point, as opposed to the average, to be conservative in reporting severity. The standard ground char classes did not accurately describe our data. For example, "light ground char: < 2% severe char, < 15% moderate char"; did not allow for a case of 5% severe char and 10% moderate char. Therefore, Mick Harrington and I developed an adapted classification system. The percentage of ground within each ground char class (unburned (1), light (2), moderate (3), severe (4); see Table 1 for description) was multiplied by the corresponding number (i.e. 25% light = 0.25×2) and summed. This summed value was then assigned a descriptive classification (Table 2.).

Characterization

The use of average crown scorch height to obtain a flame length class may have underestimated the severity of the fire, as can be seen in the large number of different classifications when using average versus maximum crown scorch height (Table 3). Flame length class can be interpreted practically by the corresponding tree mortality size class (Table 4). For example, a flame length class of (1) indicates that most seedlings will die. Burn 1 was dominated by flame length class (2) and (3), indicating high levels of sapling and pole tree mortality. Burn 2 was highly variable, with many areas suffering only seedling and sapling loss, while other points incurred pole and small saw timber

loss. Burn 3 was the least severe burn in terms of above ground mortality, with most points indicating mortality for seedlings and saplings only (Table 3).

Light/moderate ground char dominated all sites. On Burn 1, 68% of the plots were classified as light/moderate, 23% light, 7% moderate, and 3% unburned /light (N = 31 subsamples). Burn 2 was highly variable in ground char classifications, consistent with the variability in flame length classes. The plots were classified as 50% light/moderate, 30% light, 13 % moderate, and 7% unburned/light. Burn 3 exhibited the most constant ground char measurements, with 76% light/moderate, 21% light and 3% unburned.

Table 3.1. Description of visual characteristics of ground char classes, as described in Ryan and Noste (1983).

Ground char class	Timber/Slash
Unburned	The fire did not burn on the forest floor. Some damage may occur to vegetation due to radiated or convected heat from adjacent areas
Light	Leaf litter is charred or consumed. Upper duff may be charred, but the duff layer is not altered over the entire depth. Woody debris is partially burned. Some small twigs and much of the branch wood remain. Logs are scorched or blackened, but not charred. Crumbled, rotten wood is scorched to partially burned.
Moderate	Litter is consumed. Duff is deeply charred or consumed but the underlying mineral soil is not visibly altered. Woody debris is largely consumed. Some branch wood is present, but no foliage or twigs remain. Logs are deeply charred. Burned-out stump holes are common
Severe	Litter and duff are completely consumed, and the top layer of mineral soil is visibly altered, often reddish. Structure of surface soil may be altered. Twigs and small branches are completely consumed. Few large branches remain, but those that do are deeply charred. Sound logs are deeply charred, rotten logs are completely consumed.

Table 3.2. Adapted classification of ground char classes developed by Jenny Woolf and Mick Harrington to describe fire severity.

Summed value	Description	Classification
1.0	unburned	U
1.0 - 1.4	unburned to lightly charred	UL
1.5 – 1.9	lightly charred	L
2.0 – 2.4	lightly to moderately charred	LM
2.5 – 2.9	moderately charred	M
3.0 – 3.4	moderately to severely charred	MS
3.5 – 4.0	severely charred	S

Table 3.3 Flame length classes with the corresponding crown scorch heights and tree mortality classes (Ryan and Noste 1983).

Flame length Class	Flame length Range	Crown scorch height	Tree mortality size class	
	meters	meters	Dbh in cm	
1	0 – 0.6	0 - 2.74	< 2.5	Seedling
2	0.7 – 1.2	2.75 - 7.32	2.6 – 12.5	Sapling
3	1.3 – 2.4	7.33 - 19.5	12.6 – 22.6	Poles
4	2.5 – 3.7	19.6 - 35.4	22.7 – 33.0	Small saw timber
5	> 3.7	> 35.4	> 33.0	Large saw timber

Table 3.4. Average crown scorch height, maximum crown scorch height and the flame class associated with the average scorch height for the grid-points sampled in Burn 1.

Point	Avg. flame length (m)	Max. flame length (m)	Avg. flame length class	Max. flame length class	N
10	8.7	11.0	3	3	3
104	8.7	10.0	3	3	5
112	5.1	6.0	2	2	7
123	5.3	6.0	2	2	9
13	5.3	11.0	2	3	8
20	4.8	6.5	2	2	5
23	1.5	3.0	1	2	2
27	5.4	8.0	2	3	4
33	8.0	8.0	3	3	3
34	3.1	5.0	2	2	7
4	12.0	12.0	3	3	6
41	0.0	0.0	1	1	4
48	0.5	2.0	1	1	6
50	14.0	14.0	3	3	3
55	8.5	12.0	3	3	2
6	3.1	4.0	2	2	6
62	1.3	4.0	1	2	6
69	2.0	4.0	1	2	2
72	8.0	8.0	3	3	2
78	16.0	16.0	3	3	6
92	8.0	12.0	3	3	3
B5	0.0	0.0	1	1	1
B9	11.5	11.5	3	3	4
C12	0.0	0.0	1	1	4
C2	1.4	4.0	1	2	13
J12	6.0	6.0	2	2	5
J2	0.9	3.0	1	2	6
M10	15.5	15.5	3	3	6
M2	6.9	15.0	2	3	23
M20	9.0	9.0	3	3	1
P5	1.7	4.0	1	2	7
P9	11.5	11.5	3	3	6

Table 3.5. Average crown scorch height, maximum crown scorch height and the flame class associated with the average scorch height for the grid-points sampled in Burn 2.

Point	Avg. flame length (m)	Max. flame length (m)	Avg. flame length class	Max. flame length class	N
100	1.29	4.5	1	2	7
101	0.5	4.0	1	2	12
106	1.56	10.0	1	3	9
107	3.4	5.0	2	2	7
114	7.0	14.0	2	3	5
12	0.0	0.0	1	1	7
120	5.0	8.0	2	3	7
126	7.7	15.5	3	3	14
129	13.25	20.0	3	4	4
144	0.0	0.0	1	1	3
18	3.5	8.0	2	3	8
212	20.9	22.0	4	4	8
218	6.3	9.5	2	3	6
224	0.0	0.0	1	1	4
23	0.6	2.5	1	1	7
230	8.25	16.5	2	3	2
236	15.0	15.0	3	3	5
242	0.0	0.0	1	1	7
248	10.0	11.0	3	3	2
254	19.3	20.0	3	4	7
26	2.4	7.0	1	2	9
260	0.3	2.0	1	1	6
266	4.9	6.5	2	2	4
272	4.0	8.0	2	3	4
278	2.6	6.0	1	3	5
28	3.0	3.0	2	2	1
29	0.0	0.0	1	1	4
29b	0.0	0.0	1	1	2
35	1.7	3.5	1	2	8
40	2.5	6.0	1	2	8
41	1.6	4.5	1	2	10
47	0.5	5.0	1	2	18
53	1.9	4.5	1	2	5
54	3.2	5.5	2	2	6
57	2.6	6.5	1	2	6
59	0.0	0.0	1	1	1
64	0.6	3.0	1	2	5
65	0.2	2.5	1	1	27
70	1.0	8.0	1	3	23
71	0.0	0.0	1	1	3
77	1.1	6.0	1	2	22
79	1.5	6.0	1	2	19
83	1.3	8.0	1	3	13
87	0.0	0.0	1	1	1
89	2.3	6.5	1	2	7
9	5.7	12.0	2	3	8
90	0.0	0.0	1	1	2
95	0.9	10.0	1	3	31
98	0.9	4.0	1	2	8

Table 3.6. Average crown scorch height, maximum crown scorch height and the flame class associated with the average scorch height for the grid-points sampled in Burn 3.

Point	Avg. flame length (m)	Max. flame length(m)	Avg. flame length class	Max. flame length class	N
108	0.4	1.5	1	1	4
116	4.3	6.0	2	2	6
127	2.8	8.5	2	3	9
139	0.0	0.0	1	1	5
30	1.0	6.0	1	2	6
37	2.0	10.0	1	3	5
4	0.8	3.0	1	2	8
49	1.3	5.0	1	2	6
66	0.3	1.8	1	1	6
94	1.6	6.5	1	2	4
B19	0.0	0.0	1	1	3
BA22	0.0	0.0	1	1	2
BU24	0.0	0.0	1	1	5
I24	0.6	4.5	1	2	7
K21	0.0	0.0	1	1	5
L20	2.0	6.0	1	2	5
M24	0	0	1	1	5
MA20	0.5	5.0	1	2	5
MH14	4.0	6.0	2	2	4
MH24	1.6	5.0	1	2	10
MO17	2.0	4.5	1	2	16
N18	0.3	2.0	1	1	8
O18	1.1	4.5	1	2	6
P17	1.25	5.0	1	2	4
S20	0.0	0.0	1	1	6
SB21	2.56	5.0	2	2	8
SL20	1.88	4.5	2	2	4
SM20	0.0	0.0	1	1	2

Table 3.7 Area within 10- meter radius circle of sampled grid-points in each category of char, the sum of these percentages multiplied by the appropriate value, the associated ground char class and fire severity rating for Burn 1.

Point	% unburned	%light	% moderate	% severe	Sum % * value	Ground char class	Fire severity rating
10	0	70	25	5	2.35	LM	3LM
104	0	88	10	2	2.14	LM	3LM
112	35	60	5	0	1.7	L	2L
123	20	77	2	1	1.84	L	2L
13	10	70	15	5	2.15	LM	3LM
20	25	73	1	1	1.78	L	2L
23	60	30	5	5	1.55	L	2L
27	10	87	2	1	1.94	L	3L
33	10	45	35	10	2.45	LM	3LM
34	10	75	10	5	2.1	LM	2LM
4	0	80	15	5	2.25	LM	3LM
41	0	85	10	5	2.2	LM	1LM
48	5	80	15	0	2.1	LM	1LM
50	15	70	10	5	2.05	LM	3LM
55	20	35	30	15	2.4	LM	3LM
6	30	63	5	2	1.79	L	2L
62	7	60	30	3	2.29	LM	2LM
69	15	53	25	7	2.24	LM	2LM
72	0	42	55	3	2.61	M	3M
78	0	77	20	3	2.26	LM	3LM
92	10	82	5	3	2.01	LM	3LM
B5	35	45	20	0	1.85	L	1L
B9	0	65	30	5	2.4	LM	3LM
C12	90	5	5	0	1.15	UL	1UL
C2	0	70	25	5	2.35	LM	2LM
J12	0	55	30	15	2.6	M	2M
J2	0	82	15	3	2.21	LM	2LM
M10	0	75	15	10	2.35	LM	3LM
M2	0	65	30	5	2.4	LM	3LM
P5	0	97	2	1	2.04	LM	2LM
P9	0	85	10	5	2.2	LM	3LM

Table 3.8 Area within 10meter radius circle of sampled grid-points in each category of char, the sum of these percentages multiplied by the appropriate value, the associated ground char class and fire severity rating for Burn 2.

Point	% unburned	%light	% moderate	% severe	Sum % * value	Ground char Class	Fire severity rating
100	60	30	5	5	1.55	L	2L
101	65	35	0	0	1.35	UL	2UL
106	15	75	5	5	2	L	3L
107	0	85	10	5	2.2	LM	2LM
114	5	70	15	10	2.3	LM	3LM
12	40	55	5	0	1.65	L	1L
120	5	75	15	5	2.2	LM	3LM
126	0	87	10	3	2.16	LM	3LM
129	0	75	20	5	2.3	LM	4LM
136	30	62	5	3	1.81	L	L
144	0	90	5	5	2.15	LM	1LM
18	0	85	10	5	2.2	LM	3LM
212	0	45	50	5	2.6	M	4M
218	0	60	30	10	2.5	M	3M
224	20	65	10	5	2	L	1L
23	0	88	10	2	2.14	LM	1LM
230	0	15	75	10	2.95	M	3M
236	0	25	75	0	2.75	M	3M
242	0	75	20	5	2.3	LM	1LM
248	0	85	10	5	2.2	LM	3LM
254	0	50	35	15	2.65	M	4M
26	15	80	5	0	1.9	L	2L
260	0	90	5	5	2.15	LM	1LM
266	0	80	10	10	2.3	LM	2LM
272	0	85	10	5	2.2	LM	3LM
278	10	85	5	0	1.95	L	3L
29	30	60	10	0	1.8	L	1L
29B	0	88	10	2	2.14	LM	1LM
35	10	75	10	5	2.1	LM	2LM
40	15	72	10	3	2.01	LM	2LM
41	0	55	40	5	2.5	M	2M
47	10	75	10	5	2.1	LM	2LM
53	0	78	20	2	2.24	LM	2LM
54	0	98	2	0	2.02	LM	2LM
57	40	48	10	2	1.74	L	2L
59	40	55	5	0	1.65	L	11L
64	90	5	5	0	1.15	UL	2UL
65	0	80	20	0	2.2	LM	1LM
70	5	83	10	2	2.09	LM	3LM
71	20	79	1	0	1.81	L	1L
77	35	53	10	2	1.79	L	2L
79	15	75	5	5	2	L	2L
83	0	50	45	5	2.55	M	3M
87	10	45	42	3	2.38	LM	1LM
89	0	98	0	2	2.04	LM	2LM
9	0	55	40	5	2.5	M	3M
90	20	68	10	2	1.94	L	1L
95	5	90	5	0	2	L	3L
98	65	23	10	2	1.49	UL	2UL

Table 3.9. Area within 10meter radius circle of sampled grid-points in each category of char, the sum of these percentages multiplied by the appropriate value, the associated ground char class and fire severity rating for Burn 3.

Point	% unburned	%light	% moderate	% severe	Sum % * value	Ground char class	Fire severity rating
108	15	64	20	1	2.07	LM	1LM
116	10	60	27	3	2.23	LM	2LM
127	7	90	2	1	1.97	L	3L
139	15	80	5	0	1.9	L	1L
30	20	60	15	5	2.05	LM	2LM
37	20	55	20	5	2.1	LM	3LM
4	25	40	30	5	2.15	LM	2LM
49	0	95	4	1	2.06	LM	2LM
66	0	80	15	5	2.25	LM	1LM
94	5	82	10	3	2.11	LM	2LM
B19	0	89	10	1	2.12	LM	1LM
BA22	0	84	15	1	2.17	LM	1LM
BU24	5	77	10	8	2.21	LM	1LM
I24	5	75	10	10	2.25	LM	2LM
K21	30	60	10	0	1.8	L	1L
L20	10	68	20	2	2.14	LM	2LM
M4	0	80	15	5	2.25	LM	1LM
MA20	0	88	10	2	2.14	LM	2LM
MH14	0	85	10	5	2.2	LM	2LM
MH24	5	63	30	2	2.29	LM	2LM
MO17	5	80	10	5	2.15	LM	2LM
N18	0	94	5	1	2.07	LM	1LM
O18	0	0	0	0	0	U	2U
P S17	10	86	2	2	1.96	L	2L
SC20	35	60	5	0	1.7	L	1L
SB 21	0	93	5	2	2.09	LM	2LM
SL20	0	83	10	7	2.24	LM	2LM
SM20	20	69	10	1	1.92	L	1L

Appendix IV. Candidate model sets considered for selection of forage tree characteristics

Table 4.1 Candidate model set considered for red-breasted nuthatches for selection of forage tree characteristics among any tree class.

Logit
$\beta_0 + \beta_1 \text{class}$
$\beta_0 + \beta_1 \text{dbh}$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species}$
$\beta_0 + \beta_1 \text{fir1} + \beta_2 \text{fir2} + \beta_3 \text{fir3}$
$\beta_0 + \beta_1 \text{btl}$
$\beta_0 + \beta_1 \text{can}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{dbh}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{btl}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{fir1} + \beta_3 \text{fir2} + \beta_4 \text{fir3}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{can}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{btl}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{fir1} + \beta_3 \text{fir2} + \beta_4 \text{fir3}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{can}$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species} + \beta_3 \text{btl}$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species} + \beta_3 \text{fir1} + \beta_4 \text{fir2} + \beta_5 \text{fir3}$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species} + \beta_3 \text{can}$
$\beta_0 + \beta_1 \text{btl} + \beta_2 \text{fir1} + \beta_3 \text{fir2} + \beta_4 \text{fir3}$
$\beta_0 + \beta_1 \text{btl} + \beta_2 \text{can}$
$\beta_0 + \beta_1 \text{fir1} + \beta_2 \text{fir2} + \beta_3 \text{fir3} + \beta_4 \text{can}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{btl} + \beta_3 \text{btl} * \text{class}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{dbh} + \beta_3 \text{class} * \text{dbh}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 \text{class} * \text{Douglas fir} + \beta_5 \text{class} * \text{other species}$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species} + \beta_3 \text{btl} + \beta_4 \text{Douglas fir} * \text{btl} + \beta_5 \text{other species} * \text{btl}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 \text{dbh} * \text{Douglas fir} + \beta_5 \text{dbh} * \text{other species}$
$\beta_0 + \beta_1 \text{btl} + \beta_2 \text{fir1} + \beta_3 \text{fir2} + \beta_4 \text{fir3} + \beta_5 \text{fir1} * \text{btl} + \beta_6 \text{fir2} * \text{btl} + \beta_7 \text{fir3} * \text{btl}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 \text{can}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{dbh} + \beta_3 \text{Douglas fir} + \beta_4 \text{other species} + \beta_5 \text{class} * \text{Douglas fir} + \beta_6 \text{class} * \text{other species}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{dbh} + \beta_3 \text{Douglas fir} + \beta_4 \text{other species} + \beta_5 \text{class} * \text{dbh}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{dbh} + \beta_3 \text{Douglas fir} + \beta_4 \text{other species} + \beta_5 \text{can}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{dbh} + \beta_3 \text{Douglas fir} + \beta_4 \text{other species} + \beta_5 \text{can} + \beta_6 \text{class} * \text{Douglas fir} + \beta_7 \text{class} * \text{other species} + \beta_8 \text{class} * \text{dbh}$

Table 4.2. Candidate model set considered for red-breasted nuthatches for selection of forage tree characteristics within the same tree class.

Logit
$\beta_0 + \beta_1 dbh$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species}$
$\beta_0 + \beta_1 \text{fir1} + \beta_2 \text{fir2} + \beta_3 \text{fir3}$
$\beta_0 + \beta_1 btl$
$\beta_0 + \beta_1 can$
$\beta_0 + \beta_1 dbh + \beta_2 \text{Douglas fir} + \beta_3 \text{other species}$
$\beta_0 + \beta_1 dbh + \beta_2 btl$
$\beta_0 + \beta_1 dbh + \beta_2 \text{fir1} + \beta_3 \text{fir2} + \beta_4 \text{fir3}$
$\beta_0 + \beta_1 dbh + \beta_2 can$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species} + \beta_3 btl$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species} + \beta_3 \text{fir1} + \beta_4 \text{fir2} + \beta_5 \text{fir3}$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species} + \beta_3 can$
$\beta_0 + \beta_1 btl + \beta_2 \text{fir1} + \beta_3 \text{fir2} + \beta_4 \text{fir3}$
$\beta_0 + \beta_1 btl + \beta_2 can$
$\beta_0 + \beta_1 \text{fir1} + \beta_2 \text{fir2} + \beta_3 \text{fir3} + \beta_4 can$
$\beta_0 + \beta_1 btl + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 btl * \text{Douglas fir} + \beta_5 btl * \text{other species}$
$\beta_0 + \beta_1 dbh + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 dbh * \text{Douglas fir} + \beta_5 dbh * \text{other species}$
$\beta_0 + \beta_1 btl + \beta_2 \text{fir1} + \beta_3 \text{fir2} + \beta_4 \text{fir3} + \beta_5 \text{fir1} * btl + \beta_6 \text{fir2} * btl + \beta_7 \text{fir3} * btl$
$\beta_0 + \beta_1 dbh + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 can$
$\beta_0 + \beta_1 dbh + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 can + \beta_5 dbh * \text{Douglas fir} + \beta_6 dbh * \text{other species}$
Global model:
$\beta_0 + \beta_1 dbh + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 \text{fir1} + \beta_5 \text{fir2} + \beta_6 \text{fir3} + \beta_7 btl + \beta_8 can + \beta_9 dbh * \text{Douglas fir} + \beta_{10} dbh * \text{other species} + \beta_{12} btl * \text{Douglas fir} + \beta_{13} btl * \text{other species} + \beta_{14} \text{fir1} * btl + \beta_{15} \text{fir2} * btl + \beta_{16} \text{fir3} * btl$

Table 4.3. Candidate model set considered for mountain chickadees for selection of forage tree characteristics among any tree class.

Logit
$\beta_0 + \beta_1\text{class}$
$\beta_0 + \beta_1\text{dbh}$
$\beta_0 + \beta_1\text{Douglas fir} + \beta_2\text{other species}$
$\beta_0 + \beta_1\text{fir1} + \beta_2\text{fir2} + \beta_3\text{fir3}$
$\beta_0 + \beta_1\text{can}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{Douglas fir} + \beta_3\text{other species}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{can}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas fir} + \beta_3\text{other species}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{can}$
$\beta_0 + \beta_1\text{Douglas fir} + \beta_2\text{other species} + \beta_3\text{fir1} + \beta_4\text{fir2} + \beta_5\text{fir3}$
$\beta_0 + \beta_1\text{Douglas fir} + \beta_2\text{other species} + \beta_3\text{can}$
$\beta_0 + \beta_1\text{fir1} + \beta_2\text{fir2} + \beta_3\text{fir3} + \beta_4\text{can}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{class*dbh}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{Douglas fir} + \beta_3\text{other species} + \beta_4\text{class*Douglas fir} + \beta_5\text{class*other species}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas fir} + \beta_3\text{other species} + \beta_4\text{dbh*Douglas fir} + \beta_5\text{dbh*other species}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{Douglas fir} + \beta_3\text{other species} + \beta_4\text{can}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{Douglas fir} + \beta_4\text{other species} + \beta_5\text{class*Douglas fir} + \beta_6\text{class*other species}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{Douglas fir} + \beta_4\text{other species} + \beta_5\text{class*dbh}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{Douglas fir} + \beta_4\text{other species} + \beta_5\text{can}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{Douglas fir} + \beta_4\text{other species} + \beta_5\text{can} + \beta_6\text{class*Douglas fir} + \beta_7\text{class*other species} + \beta_8\text{class*dbh}$
Global model:
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{Douglas fir} + \beta_4\text{other species} + \beta_5\text{fir1} + \beta_6\text{fir2} + \beta_7\text{fir3} + \beta_8\text{can} + \beta_9\text{class*Douglas fir} + \beta_{10}\text{class*other species} + \beta_{11}\text{class*dbh} + \beta_{12}\text{dbh*Douglas fir} + \beta_{13}\text{dbh*other}$

Table 4.4. Candidate model set considered for mountain chickadees for selection of forage tree characteristics within the same tree class.

Logit
$\beta_0 + \beta_1 \text{dbh}$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species}$
$\beta_0 + \beta_1 \text{fir1} + \beta_2 \text{fir2} + \beta_3 \text{fir3}$
$\beta_0 + \beta_1 \text{can}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{fir1} + \beta_3 \text{fir2} + \beta_4 \text{fir3}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{can}$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species} + \beta_3 \text{fir1} + \beta_4 \text{fir2} + \beta_5 \text{fir3}$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species} + \beta_3 \text{can}$
$\beta_0 + \beta_1 \text{fir1} + \beta_2 \text{fir2} + \beta_3 \text{fir3} + \beta_4 \text{can}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 \text{can}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 \text{dbh*Douglas fir} + \beta_5 \text{dbh*other species}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 \text{can} + \beta_5 \text{dbh*Douglas fir} + \beta_6 \text{dbh*other species}$
Global Model:
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 \text{fir1} + \beta_5 \text{fir2} + \beta_6 \text{fir3} + \beta_7 \text{can} + \beta_8 \text{dbh*Douglas fir} + \beta_9 \text{dbh*other species}$

Table 4.5. Candidate model set considered for white-breasted nuthatches for selection of forage tree characteristics among any tree class.

Logit
$\beta_0 + \beta_1\text{class}$
$\beta_0 + \beta_1\text{dbh}$
$\beta_0 + \beta_1\text{Douglas fir} + \beta_2\text{other species}$
$\beta_0 + \beta_1\text{fir1} + \beta_2\text{fir2} + \beta_3\text{fir3}$
$\beta_0 + \beta_1\text{can}$
$\beta_0 + \beta_1\text{btl}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{Douglas fir} + \beta_3\text{other species}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{can}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas fir} + \beta_3\text{other species}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{can}$
$\beta_0 + \beta_1\text{fir1} + \beta_2\text{fir2} + \beta_3\text{fir3} + \beta_4\text{btl}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{Douglas fir} + \beta_4\text{other species}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{can}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{Douglas fir} + \beta_3\text{other species} + \beta_4\text{can}$
Global Model:
$\beta_0 + \beta_1\text{class} + \beta_2\text{Douglas fir} + \beta_3\text{other species} + \beta_4\text{fir1} + \beta_5\text{fir2} + \beta_6\text{fir3} + \beta_7\text{can} + \beta_8\text{btl}$

Table 4.6 Candidate model set considered for white-breasted nuthatches for selection of forage tree characteristics within the same tree class.

Logit
$\beta_0 + \beta_1 \text{dbh}$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species}$
$\beta_0 + \beta_1 \text{fir1} + \beta_2 \text{fir2} + \beta_3 \text{fir3}$
$\beta_0 + \beta_1 \text{can}$
$\beta_0 + \beta_1 \text{btl}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{can}$
$\beta_0 + \beta_1 \text{fir1} + \beta_2 \text{fir2} + \beta_3 \text{fir3} + \beta_4 \text{btl}$
Global Model:
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 \text{can} + \beta_5 \text{fir1} + \beta_6 \text{fir2} + \beta_7 \text{fir3} + \beta_8 \text{btl}$

Table 4.7. Candidate model set considered for black-backed woodpeckers for selecting trees among any tree class.

Logit
$\beta_0 + \beta_1\text{class} + \beta_2\text{year}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{year}$
$\beta_0 + \beta_1\text{Douglas fir} + \beta_2\text{other species} + \beta_3\text{year}$
$\beta_0 + \beta_1\text{fir1} + \beta_2\text{fir2} + \beta_3\text{fir3} + \beta_4\text{year}$
$\beta_0 + \beta_1\text{bark1} + \beta_2\text{bark2} + \beta_3\text{bark3} + \beta_4\text{year}$
$\beta_0 + \beta_1\text{btl} + \beta_2\text{year}$
$\beta_0 + \beta_1\text{folR} + \beta_2\text{folNA} + \beta_3\text{fol1} + \beta_4\text{fol2} + \beta_5\text{fol3} + \beta_6\text{year}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{year}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{Douglas fir} + \beta_3\text{other species} + \beta_4\text{year}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{btl} + \beta_3\text{year}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{year}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{folR} + \beta_3\text{folNA} + \beta_4\text{fol1} + \beta_5\text{fol2} + \beta_6\text{fol3} + \beta_7\text{year}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{bark1} + \beta_3\text{bark2} + \beta_4\text{bark3} + \beta_5\text{year}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas fir} + \beta_3\text{other species} + \beta_4\text{year}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{btl} + \beta_3\text{year}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{year}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{folR} + \beta_3\text{folNA} + \beta_4\text{fol1} + \beta_5\text{fol2} + \beta_6\text{fol3} + \beta_7\text{year}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{bark1} + \beta_3\text{bark2} + \beta_4\text{bark3} + \beta_4\text{year}$
$\beta_0 + \beta_1\text{btl} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{year}$
$\beta_0 + \beta_1\text{btl} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{fir1*btl} + \beta_6\text{fir2*btl} + \beta_7\text{fir3*btl} + \beta_8\text{year}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{class*dbh} + \beta_4\text{year}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{Douglas fir} + \beta_3\text{other species} + \beta_4\text{class*Douglas fir} + \beta_5\text{class*other species} + \beta_6\text{year}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{btl} + \beta_6\text{fir1*btl} + \beta_7\text{fir2*btl} + \beta_8\text{fir3*btl} + \beta_9\text{year}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{btl} + \beta_6\text{folR} + \beta_7\text{folNA} + \beta_8\text{fol1} + \beta_9\text{fol2} + \beta_{10}\text{fol3} + \beta_{11}\text{bark1} + \beta_{12}\text{bark2} + \beta_{13}\text{bark3} + \beta_{14}\text{year}$
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{Douglas fir} + \beta_4\text{other species} + \beta_5\text{folR} + \beta_6\text{folNA} + \beta_7\text{fol1} + \beta_8\text{fol2} + \beta_9\text{fol3} + \beta_{10}\text{year}$
$\beta_0 + \beta_1\text{btl} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{folR} + \beta_6\text{folNA} + \beta_7\text{fol1} + \beta_8\text{fol2} + \beta_9\text{fol3} + \beta_{10}\text{year}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{folR} + \beta_3\text{folNA} + \beta_4\text{fol1} + \beta_5\text{fol2} + \beta_6\text{fol3} + \beta_7\text{Douglas fir} + \beta_8\text{other species} + \beta_9\text{year}$
Global Model:
$\beta_0 + \beta_1\text{class} + \beta_2\text{dbh} + \beta_3\text{Douglas fir} + \beta_4\text{other species} + \beta_5\text{fir1} + \beta_6\text{fir2} + \beta_7\text{fir3} + \beta_8\text{bark1} + \beta_9\text{bark2} + \beta_{10}\text{bark3} + \beta_{11}\text{btl} + \beta_{12}\text{folR} + \beta_{13}\text{folNA} + \beta_{14}\text{fol1} + \beta_{15}\text{fol2} + \beta_{16}\text{fol3} + \beta_{17}\text{fir1*btl} + \beta_{18}\text{fir2*btl} + \beta_{19}\text{fir3*btl} + \beta_{20}\text{class*dbh} + \beta_{21}\text{class*Douglas fir} + \beta_{22}\text{class*other species} + \beta_{23}\text{year}$

Table 4.8. Candidate model set considered for black-backed woodpeckers for selecting trees within the same tree class.

Logit
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{year}$
$\beta_0 + \beta_1\text{Douglas fir} + \beta_2\text{other species} + \beta_3\text{year}$
$\beta_0 + \beta_1\text{fir1} + \beta_2\text{fir2} + \beta_3\text{fir3} + \beta_4\text{year}$
$\beta_0 + \beta_1\text{bark1} + \beta_2\text{bark2} + \beta_3\text{bark3} + \beta_4\text{year}$
$\beta_0 + \beta_1\text{btl} + \beta_2\text{year}$
$\beta_0 + \beta_1\text{folR} + \beta_2\text{folNA} + \beta_3\text{fol1} + \beta_4\text{fol2} + \beta_5\text{fol3} + \beta_6\text{year}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas fir} + \beta_3\text{other species} + \beta_4\text{year}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{btl} + \beta_3\text{year}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{year}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{folR} + \beta_3\text{folNA} + \beta_4\text{fol1} + \beta_5\text{fol2} + \beta_6\text{fol3} + \beta_7\text{year}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{bark1} + \beta_3\text{bark2} + \beta_4\text{bark3} + \beta_5\text{year}$
$\beta_0 + \beta_1\text{btl} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{year}$
$\beta_0 + \beta_1\text{btl} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{fir1*btl} + \beta_6\text{fir2*btl} + \beta_7\text{fir3*btl} + \beta_8\text{year}$
$\beta_0 + \beta_1\text{btl} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{folR} + \beta_6\text{folNA} + \beta_7\text{fol1} + \beta_8\text{fol2} + \beta_9\text{fol3} + \beta_{10}\text{bark1} + \beta_{11}\text{bark2} + \beta_{12}\text{bark3} + \beta_{13}\text{year}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{folR} + \beta_3\text{folNA} + \beta_4\text{fol1} + \beta_5\text{fol2} + \beta_6\text{fol3} + \beta_7\text{Douglas fir} + \beta_8\text{other species} + \beta_9\text{year}$
$\beta_0 + \beta_1\text{btl} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{folR} + \beta_6\text{folNA} + \beta_7\text{fol1} + \beta_8\text{fol2} + \beta_9\text{fol3} + \beta_{10}\text{year}$
Global Model:
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas fir} + \beta_3\text{other species} + \beta_4\text{fir1} + \beta_5\text{fir2} + \beta_6\text{fir3} + \beta_7\text{bark1} + \beta_8\text{bark2} + \beta_9\text{bark3} + \beta_{10}\text{btl} + \beta_{11}\text{folR} + \beta_{12}\text{folNA} + \beta_{13}\text{fol1} + \beta_{14}\text{fol2} + \beta_{15}\text{fol3} + \beta_{16}\text{fir1*btl} + \beta_{17}\text{fir2*btl} + \beta_{18}\text{fir3*btl} + \beta_{19}\text{year}$

Table 4.9. Candidate model set considered for hairy woodpeckers for selection of forage tree characteristics among any tree class.

Logit
$\beta_0 + \beta_1 \text{class}$
$\beta_0 + \beta_1 \text{dbh}$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species}$
$\beta_0 + \beta_1 \text{can}$
$\beta_0 + \beta_1 \text{fir1} + \beta_2 \text{fir2} + \beta_3 \text{fir3}$
$\beta_0 + \beta_1 \text{bark1} + \beta_2 \text{bark2} + \beta_3 \text{bark3}$
$\beta_0 + \beta_1 \text{btl}$
$\beta_0 + \beta_1 \text{folR} + \beta_2 \text{folNA} + \beta_3 \text{fol1} + \beta_4 \text{fol2} + \beta_5 \text{fol3}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{dbh}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{folR} + \beta_3 \text{folNA} + \beta_4 \text{fol1} + \beta_5 \text{fol2} + \beta_6 \text{fol3}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species}$
$\beta_0 + \beta_1 \text{dbh} + \beta_2 \text{folR} + \beta_3 \text{folNA} + \beta_4 \text{fol1} + \beta_5 \text{fol2} + \beta_6 \text{fol3}$
$\beta_0 + \beta_1 \text{Douglas fir} + \beta_2 \text{other species} + \beta_3 \text{folR} + \beta_4 \text{folNA} + \beta_5 \text{fol1} + \beta_6 \text{fol2} + \beta_7 \text{fol3}$
$\beta_0 + \beta_1 \text{btl} + \beta_2 \text{fir1} + \beta_3 \text{fir2} + \beta_4 \text{fir3}$
$\beta_0 + \beta_1 \text{btl} + \beta_2 \text{fir1} + \beta_3 \text{fir2} + \beta_4 \text{fir3} + \beta_5 \text{fir1} * \text{btl} + \beta_6 \text{fir2} * \text{btl} + \beta_7 \text{fir3} * \text{btl}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{dbh} + \beta_3 \text{class} * \text{dbh}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{Douglas fir} + \beta_3 \text{other species} + \beta_4 \text{class} * \text{Douglas fir} + \beta_5 \text{class} * \text{other species}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{folR} + \beta_3 \text{folNA} + \beta_4 \text{fol1} + \beta_5 \text{fol2} + \beta_6 \text{fol3} + \beta_7 \text{folR} * \text{fol1} + \beta_8 \text{folR} * \text{fol2} + \beta_9 \text{folR} * \text{fol3} + \beta_{10} \text{folNA} * \text{fol1} + \beta_{11} \text{folNA} * \text{fol2} + \beta_{12} \text{folNA} * \text{fol3}$
$\beta_0 + \beta_1 \text{btl} + \beta_2 \text{fir1} + \beta_3 \text{fir2} + \beta_4 \text{fir3} + \beta_5 \text{folR} + \beta_6 \text{folNA} + \beta_7 \text{fol1} + \beta_8 \text{fol2} + \beta_9 \text{fol3} + \beta_{10} \text{bark1} + \beta_{11} \text{bark2} + \beta_{12} \text{bark3}$
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{dbh} + \beta_3 \text{folR} + \beta_4 \text{folNA} + \beta_5 \text{fol1} + \beta_6 \text{fol2} + \beta_7 \text{fol3} + \beta_8 \text{Douglas fir} + \beta_9 \text{other species}$
Global Model:
$\beta_0 + \beta_1 \text{class} + \beta_2 \text{dbh} + \beta_3 \text{Douglas fir} + \beta_4 \text{other species} + \beta_5 \text{can} + \beta_6 \text{fir1} + \beta_7 \text{fir2} + \beta_8 \text{fir3} + \beta_9 \text{bark1} + \beta_{10} \text{bark2} + \beta_{11} \text{bark3} + \beta_{12} \text{btl} + \beta_{13} \text{folR} + \beta_{14} \text{folNA} + \beta_{15} \text{fol1} + \beta_{16} \text{fol2} + \beta_{17} \text{fol3} + \beta_{18} \text{fir1} * \text{btl} + \beta_{19} \text{fir2} * \text{btl} + \beta_{20} \text{fir3} * \text{btl} + \beta_{21} \text{class} * \text{Douglas fir} + \beta_{22} \text{class} * \text{other species} + \beta_{23} \text{folR} * \text{fol1} + \beta_{24} \text{folR} * \text{fol2} + \beta_{25} \text{folR} * \text{fol3} + \beta_{26} \text{folNA} * \text{fol1} + \beta_{27} \text{folNA} * \text{fol2} + \beta_{28} \text{folNA} * \text{fol3}$

Table 4.10. Candidate model set considered for hairy woodpeckers for selection of forage tree characteristics within the same tree class.

Logit
$\beta_0 + \beta_1\text{dbh}$
$\beta_0 + \beta_1\text{Douglas fir} + \beta_2\text{other species}$
$\beta_0 + \beta_1\text{can}$
$\beta_0 + \beta_1\text{fir1} + \beta_2\text{fir2} + \beta_3\text{fir3}$
$\beta_0 + \beta_1\text{bark1} + \beta_2\text{bark2} + \beta_3\text{bark3}$
$\beta_0 + \beta_1\text{btl}$
$\beta_0 + \beta_1\text{folR} + \beta_2\text{folNA} + \beta_3\text{fol1} + \beta_4\text{fol2} + \beta_5\text{fol3}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas fir} + \beta_3\text{other species}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{folR} + \beta_3\text{folNA} + \beta_4\text{fol1} + \beta_5\text{fol2} + \beta_6\text{fol3}$
$\beta_0 + \beta_1\text{Douglas fir} + \beta_2\text{other species} + \beta_3\text{folR} + \beta_4\text{folNA} + \beta_5\text{fol1} + \beta_6\text{fol2} + \beta_7\text{fol3}$
$\beta_0 + \beta_1\text{btl} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3}$
$\beta_0 + \beta_1\text{btl} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{fir1*btl} + \beta_6\text{fir2*btl} + \beta_7\text{fir3*btl}$
$\beta_0 + \beta_1\text{folR} + \beta_2\text{folNA} + \beta_3\text{fol1} + \beta_4\text{fol2} + \beta_5\text{fol3} + \beta_6\text{folR*fol1} + \beta_7\text{folR*fol2} + \beta_8\text{folR*fol3} + \beta_9\text{folNA*fol1} + \beta_{10}\text{folNA*fol2} + \beta_{11}\text{folNA*fol3}$
$\beta_0 + \beta_1\text{btl} + \beta_2\text{fir1} + \beta_3\text{fir2} + \beta_4\text{fir3} + \beta_5\text{folR} + \beta_6\text{folNA} + \beta_7\text{fol1} + \beta_8\text{fol2} + \beta_9\text{fol3} + \beta_{10}\text{bark1} + \beta_{11}\text{bark2} + \beta_{12}\text{bark3}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{folR} + \beta_3\text{folNA} + \beta_4\text{fol1} + \beta_5\text{fol2} + \beta_6\text{fol3} + \beta_7\text{Douglas fir} + \beta_8\text{other species}$
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas fir} + \beta_3\text{other species} + \beta_4\text{dbh*Douglas fir} + \beta_5\text{dbh*other species}$
Global Model:
$\beta_0 + \beta_1\text{dbh} + \beta_2\text{Douglas fir} + \beta_3\text{other species} + \beta_4\text{can} + \beta_5\text{fir1} + \beta_6\text{fir2} + \beta_7\text{fir3} + \beta_8\text{bark1} + \beta_9\text{bark2} + \beta_{10}\text{bark3} + \beta_{11}\text{btl} + \beta_{12}\text{folR} + \beta_{13}\text{folNA} + \beta_{14}\text{fol1} + \beta_{15}\text{fol2} + \beta_{16}\text{fol3} + \beta_{17}\text{fir1*btl} + \beta_{18}\text{fir2*btl} + \beta_{19}\text{fir3*btl} + \beta_{20}\text{dbh*Douglas fir} + \beta_{21}\text{dbh*other species}$