

## AN ABSTRACT OF THE THESIS OF

Maureen V. Duane for the degree of Master of Science in Forest Science presented on September 4, 2001. Title: Response of Wood-Boring Beetles (Coleoptera: Buprestidae, Cerambycidae) to Prescribed Understory Burning in Mixed-Conifer Stands of Southwestern Oregon.

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Abstract approved: \_\_\_\_\_

Darrell W. Ross

Prescribed burning is increasingly being used as a management tool to reduce potential fuels on the forest floor and promote stand vigor through removal of dense, crowded vegetation. Because fire affects both the standing vegetation and the amount of downed wood in the ecosystem, it is imperative to examine how organisms dwelling in woody debris are responding to this alteration of habitat.

Woody debris chewing arthropods are important to nutrient cycling and decomposition and serve as an important food source for wildlife. This study focuses on two families of wood-boring beetles, (Coleoptera: Buprestidae and Cerambycidae), which utilize woody debris for food and habitat. Most species of buprestids and cerambycids do not attack live, vigorous trees but are usually associated with stressed, fire-killed or recently downed trees.

Two studies were conducted examining the response of wood-boring beetles to prescribed burning. First, an experimental study monitored the response of wood-boring beetles (both adults and larvae) to various levels of burn severity on logs placed in a designated prescribed understory burn site. However, treatments were not applied evenly or as intended. Several logs

designated to be burned were not burned at all. Logs which did burn were only slightly charred, with no bark consumption. Adult beetles flying to the logs were monitored using flight intercept traps. Bark samples were taken to determine percent utilization by beetle larvae. Results were compared across percent of charring. No relationships between attraction or utilization and percent char could be detected. The burned and unburned logs were equally attractive to wood-boring beetles.

Second, a retrospective study was conducted, surveying adult wood-boring beetle populations in several prescribed burn sites, 1 to 15 years after burning. Overall abundance, abundance of individual species, richness and diversity were compared to adjacent control plots. While no significant relationships existed between time since burn and abundance, numbers of adult wood-boring beetles peaked in the first year after burning and remained significantly higher on previously burned sites when compared to unburned, control plots.

The goal of these two studies was to determine the effect of prescribed burning on the habitat of wood-boring beetles and to aid in the development of woody debris and fire management programs. While no causal inferences could be made, wood-boring beetle populations appear to be responding positively to prescribed burning in southwestern Oregon.

Response of Wood-Boring Beetles (Coleoptera: Buprestidae, Cerambycidae)  
to Prescribed Understory Burning in Mixed-Conifer Stands of Southwestern  
Oregon

by

Maureen V. Duane

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## Dedication

This thesis is dedicated to my mom and dad, Pat and Jim Duane, and to my closest friends, my second family - you know who you are. Thanks to all of you for your patience, faith, insanity and love.

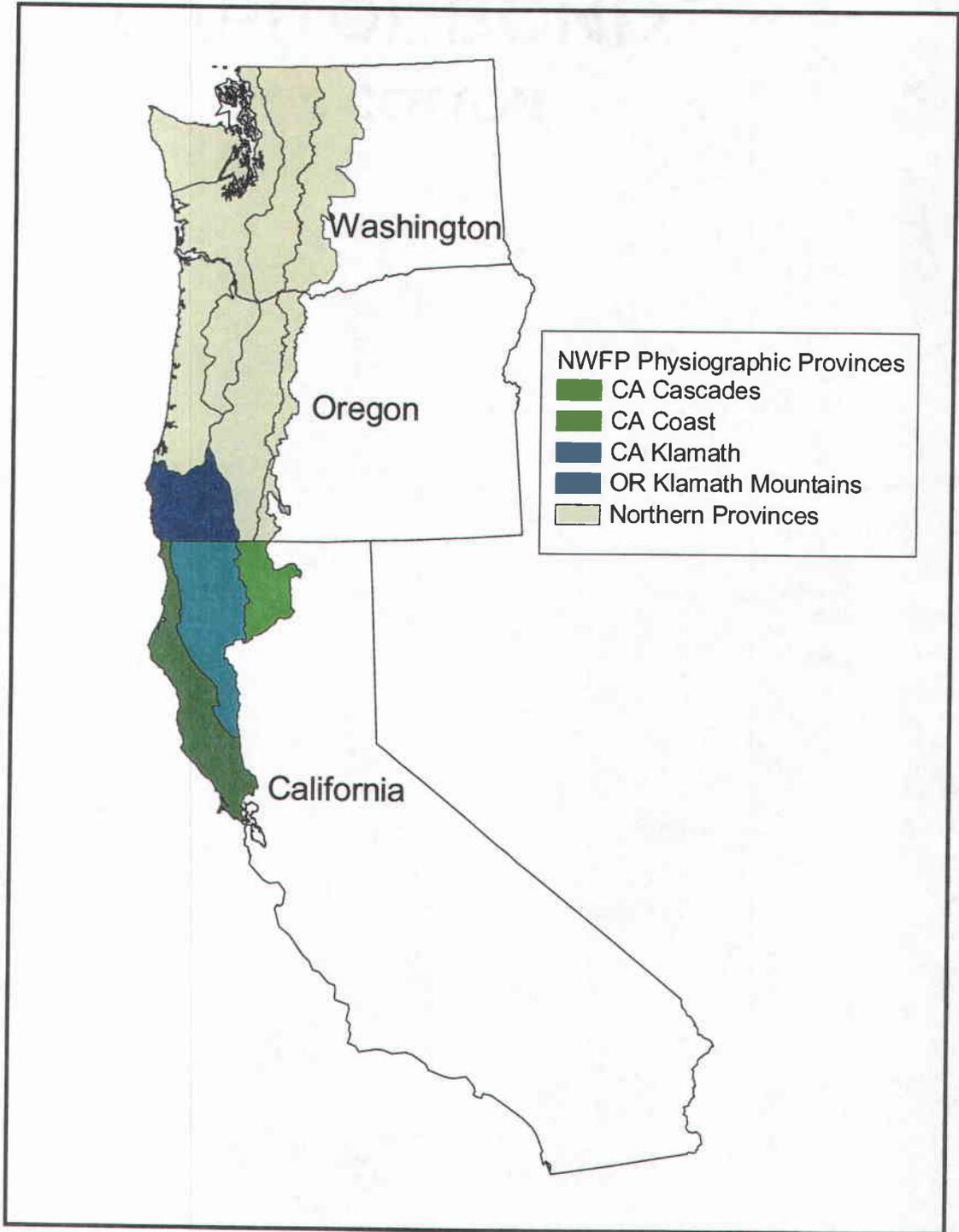
# **Response of Wood-Boring Beetles (Coleoptera: Buprestidae, Cerambycidae) to Prescribed Understory Burning in Mixed-Conifer Stands of Southwestern Oregon**

## **1. Introduction**

In recent years, there has been a shift in the focus of forest management on federal lands from primarily that of maximizing timber production to a more complete, ecosystem approach. There is a need for understanding all the components of the forest ecosystem and how management practices and natural disturbances affect flora and fauna, their functions, and recovery.

This study focuses on one specific functional group of arthropods within the range of the northern spotted owl, as directed by the Northwest Forest Plan (NWFP) (Holthausen et al. 1994). The species analysis team for the NWFP identified coarse woody debris (CWD) chewing arthropods, as one of four functional groups of arthropods, requiring further study and analysis based on general lack of knowledge and limited range of this group, as well as expected high sensitivity to various management practices (Holthausen et al. 1994). Canopy herbivores, gap and understory herbivores, and soil and litter-dwelling arthropods were the other three functional groups identified for further study.

All groups are of particular interest in the southern physiographic provinces of the NWFP, which encompasses northern California and southwestern Oregon (Fig. 1.1). Managers in these regions need to know how these groups will respond to various management practices or natural disturbances. The main concern is whether NWFP land allocations and management practices to be conducted within them still allow for the continued existence and function of these four groups of arthropods.



**Figure 1.1** Physiographic provinces designated by the Northwest Forest Plan.

## **1.1 Coarse Woody Debris and Associated Arthropods**

Different studies define CWD in a variety of ways, including material such as logs, snags, dead branches and roots. Minimum diameters used to define "coarse" also vary widely, depending on the study, from > 2.5 cm to > 7.5 – 15 cm (Harmon et al. 1986). In literature related to the NWFP, the USDA Forest Service (1994) considers CWD to be much larger material typically > 50 cm in diameter. Downed woody debris can also be divided into fuel size classes which correspond to the rate at which the material gains or loses moisture (Table 1.1) (Agee 1993). Further references to CWD here will include downed woody material > 2.5 cm in diameter.

**Table 1.1** Fuel size classes for downed woody material (Agee 1993).

Downed Woody Material Diameter (cm)	Fuel Size Class (hour)
0 - 0.6	1
0.6 - 2.5	10
2.5 - 7.6	100
7.6 - 20.3	1000
> 20.3	> 1000

Despite the fact that CWD and its inhabitants are vital components in most ecosystems, very little is known about species distribution and habitat dynamics of CWD chewers in general (Harmon et al. 1986). Ecologists and entomologists have a general understanding of arthropods that utilize CWD. Bark beetles, wood-boring beetles, termites, ants, wood wasps and carpenter bees are the most common insects utilizing this habitat (Edmonds and Eglitis 1989, Harmon et al. 1986, Holthausen et al. 1994, Schowalter 1994), but studies of CWD arthropods are limited.

Holthausen et al. (1994) cited the general scarcity of information about this functional group as the main reason for further investigation into CWD arthropod habitat associations. Schowalter (1994), in surveying the Columbia River Basin of Oregon, also repeatedly remarked how information on this functional group was lacking in both this area and across Oregon. Schowalter (1994) mentioned that recent surveys of CWD associated arthropods at the intensively studied H.J. Andrews Experimental Forest in western Oregon resulted in a doubling of known species. Because CWD and its associated fauna have not been thoroughly studied, accurate and complete species lists do not exist, and relatively little information is available to predict population viabilities, habitat dynamics or responses to various management practices.

CWD arthropod diversity is predicted to be highest in late successional and old growth areas (Harmon et al. 1986, Shaw et al. 1991, Schowalter 1994). Most forests of this type occur on federal lands (Schowalter 1994). Therefore, Forest Service and BLM land managers are responsible for accomplishing their management goals while maintaining the function of CWD chewing arthropods. However, more biological information is needed to develop sound management policies and prescriptions (Shaw et al. 1991, Schowalter 1994, McCullough et al. 1998).

## **1.2 Wood-Boring Beetles**

Within the large functional group of CWD chewers, this study focuses on wood-boring beetles, specifically flatheaded and roundheaded wood-borers (Coleoptera: Buprestidae, Cerambycidae). Many families of CWD chewing arthropods are identified in Holthausen et al. (1994) which require further study. Because buprestids and cerambycids are relatively well studied and abundant throughout the West, and because time and resources were limited, I chose to focus my studies on these families.

### **1.2.1 *Biology and Impact of Wood-Boring Beetles***

Wood-boring beetles get their common name from the fact that larvae, hatched from eggs laid on or under the bark of trees or logs, will feed throughout the phloem and sapwood, and sometimes into the heartwood (Furniss and Carolin 1977). They generally do not cause economic damage since very few attack healthy trees. They are more often associated with utilization of dead trees or those live trees predisposed to secondary attack after injury (fire, lightning, mechanical), drought, pathogen or insect infestations, or other environmental stressors (Harmon et al. 1986). However, some species are considered economically important for their role in attacking material that is designated for salvage, or untreated lumber at mills (Duncan 1981, Furniss and Carolin 1977, Kimmey 1955, White 1983). Their tunneling in these logs or lumber can significantly reduce the value of the wood products derived from them.

Most of the information in the literature regarding wood-borers relates to these species of economic importance (Duncan 1981, Kimmey 1955, Kimmey and Furniss 1943, Lowell et al. 1992, Parmelee 1941). Typical larval mining and emergence holes can cause damage, sometimes only cosmetic in nature. However, if numbers of larvae are high and feeding is extensive enough, the wood can be rendered useless (Duncan 1981, White 1983). Adults have been known to emerge from treated wood in buildings almost fifty years after their construction (Duncan 1981).

### **1.2.2 *Wood-Boring Beetles and Nutrient Cycling***

The role of insects in breaking down CWD has been the subject of several studies, mainly on the progression of decomposition in fallen trees (Edmonds and Eglitis 1989, Grier 1978, Seastedt et al. 1989, Zhong and Schowalter 1989). While some arthropods degrade the structural integrity of

the log by excavating living and breeding chambers, others feed on the CWD and its fungal and bacterial associates (Harmon et al. 1986). Almost all CWD arthropods are associated with microorganisms (fungi, bacteria, and microarthropods), which are responsible for further breakdown of the tree and release of stored nutrients (Maser and Trappe 1984).

The tunneling habit that designates some wood-borers as pests, also makes this functional group vital in nutrient cycling (Edmonds and Eglitis 1989, Furniss and Carolin 1977, Harmon et al. 1986, Zhong and Schowalter 1989). Wood-borer larvae feed not only in the phloem, but also mine the sapwood and even the heartwood of dead or dying trees where few other wood dwellers occur (Furniss and Carolin 1977). Larval mining begins the process of structural breakdown of a fallen tree. Their entry and exit holes serve as infection courts for decomposing fungi and bacteria (Berry 1978, Furniss and Carolin 1977, Harmon et al. 1986, Shaw et al. 1991). Overall, the feeding activity of wood-borers is viewed as the single most important factor contributing to decomposition of fallen or dying trees, expediting the release of bound nutrients to the forest floor (Hickin 1963, Maser and Trappe 1984).

### **1.2.3 Wood-Boring Beetles as a Food Source for Wildlife**

Birds (especially woodpeckers), amphibians and smaller mammals, themselves vital to the structure and diversity of Pacific Northwest forest ecosystems, depend on coarse woody debris not only for shelter but also for food. These animals consume both wood-boring beetle larvae and adults. Larvae can be quite large, as in the case of *Ergates spiculatus* (LeConte) sometimes reaching 60-70 mm long, and make substantial meals for many wildlife species.

Birds are the primary feeders on wood-boring beetles. Hanula and Franzreb (1997) report wood-borers as potentially important components of

the endangered red-cockaded woodpecker (*Picoides borealis*) diet. Linsley (1959) reviewed several studies citing wood-boring beetle larvae as a large part of the diets of woodpeckers, creepers, flycatchers, nighthawks, and warblers. Otvos and Stark (1985) conducted an extensive study of 25 species of forest inhabiting birds and found that beetles made up the largest part of their diets. More specifically, buprestids and cerambycids were largely represented in the diets of hairy woodpeckers (*Picoides villosus*), downy woodpeckers (*Picoides pubescens*), three-toed woodpeckers (*Picoides tridactylus*), and pileated woodpeckers (*Dryocopus pileatus*).

Amphibians and mammals also feed on wood-borers in rotting logs. The Oregon slender salamander (*Batrachoseps wrighti*) and clouded salamander (*Aneides ferreus*) use their small, slender bodies to exploit narrow larval galleries for food (Maser and Trappe 1984). The Trowbridge shrew (*Sorex trowbridgii*) also feeds on the internal organs of beetles found in or around logs (Maser and Trappe 1984).

### **1.3 Cerambycid Wood-borers**

Members of beetle family Cerambycidae are often referred to as long-horned wood-borers because of the adult antennae, which are at least half as long as their bodies (White 1983). Larvae are often rounded at the head, hence the other common name for the family, the roundheaded wood-borers. Adults rarely feed on anything more than pollen, needles or fungi (White 1983). Larvae can mine phloem so extensively at times that they compete with bark beetles for food (Furniss and Carolin 1977). The presence of bark is almost always required for brood development (i.e. CWD decay classes I and II) as pupation often takes place in the outer bark (White 1983).

The family consists of seven subfamilies. Furniss and Carolin (1977) thoroughly reviewed those occurring in the western United States. Linsley

and Chemsak (1997) also comprehensively list all North American species and known host plants for their larvae.

Most information in the literature relates to Cerambycids that are economically important (Berry 1978, Galford 1980, Johnson and Lyon 1991, Solomon 1995). Most recently, infestations of the exotic Asian long-horned beetle, *Anoplophora glabripennis* Motschulsky, have been confirmed in several locations across the United States. This particular species threatens serious ecological and economical damage because of its ability to attack and kill common hardwoods such as maple, poplar, ash, willow, and elm as well as a variety of ornamentals. Cerambycids in the genus *Monochamus* (sawyer beetles) can cause serious degradation in conifer logs, but more importantly serve as vectors for pinewood nematode, a pathogen that causes tree death by blocking the sapwood as its numbers multiply (Hiratsuka et al. 1995). Adult sawyer beetles are especially attracted to fire-killed or scorched conifers (Cerezke and Volney 1995).

#### **1.4 Buprestid Wood-borers**

Wood-boring beetles in the family Buprestidae are commonly called flat-headed or metallic wood-borers, due to the flattened shape of the larvae's head and the often colorful gold, green or bronze metallic sheen of the adult exoskeleton. Adults are known to feed on pollen, needles or bark flakes (White 1983). Some adults in the genus *Melanophila* are thought to feed on dead insects, especially abundant in freshly burned areas (Evans 1962). Adults frequent sunny areas on trunks and logs and are known to bask in the sunlight (Scott 1979). In fact, Scott (1974) found that his catch of *Melanophila* was lower for traps in partial or full shade, as opposed to full sun.

The family is represented in the United States by over 700 species, most of them in the West. Furniss and Carolin (1977) provide a thorough list of buprestids in western forests.

Most buprestids attack only dead or dying trees, but a few species can be aggressive and/or cause economic damage. The golden buprestid, (*Buprestis aurulenta* L.), attacks weakened or recently felled trees. Its larval mining can be extensive and causes degrade of untreated lumber at mills or in wood products used in construction. Larval feeding can sometimes span 50 or more years. Exit holes from emerging adults create cosmetic damage in building materials (Duncan 1981).

The flatheaded fir borer, *Melanophila drummondi* (Kirby), is considered a serious pest of conifers in southwestern Oregon, especially on dry sites. Although it is typically associated with attack of weakened hosts, severe outbreaks have been recorded, resulting in thousands of hectares of Douglas-fir mortality (Overhulser 1986).

### **1.5 Wood-borer Attraction to Fire**

Insects and fire are interdependent disturbance forces acting to shape forest structure and succession (McCullough et al. 1998). Fires can directly kill standing vegetation, making it suitable and even attractive as wood-borer habitat (Furniss and Carolin 1977). In addition, fire damage weakens live trees, predisposing them to attack by more aggressive insects like bark beetles. Wood-borer attraction to trees weakened or killed by fire and subsequent bark beetle attacks are well documented (Duncan 1981, Furniss and Carolin 1977, Lowell et al. 1992, Wickman 1964).

Many wood-borers are attracted to smoke and volatile compounds released from burning trees (Scott 1974). This adaptation allows them to take advantage of this freshly created habitat. Wood-borers have been observed to appear at wildfires, prescribed burns, or other sources of smoke

in great numbers (Evans 1962, Linsley 1943, Parmelee 1941, Scott 1974, Wickman 1964). Further investigations found that one subgenus of Buprestidae actually possess infrared receptors to locate the heat of a blazing fire (Evans 1964).

Populations of insects utilizing the wood made available by fire can increase to high densities. Consequently, surrounding healthy trees are successfully attacked and killed, creating not only suitable habitat for wood-boring beetles, but also increasing the potential severity of wildfires.

Fire is essential in the creation of wood-borer habitat because of its pronounced and cyclical effect on CWD (Harmon et al. 1986). It is therefore relevant to examine the characteristics of fire regimes in southwestern Oregon, how these regimes have changed, and the effect on buprestid and cerambycid populations.

## **1.6 Fire Ecology of Southwestern Oregon**

Agee (1993) characterized the ponderosa pine (*Pinus ponderosa*) and mixed-conifer forests of southwestern Oregon as having frequent, low-intensity, low-severity fires with return intervals of 1-25 years. Frequent surface fires removed most young vegetation and debris, leaving mostly large, older and sparsely distributed ponderosa pine (*Pinus ponderosae*) and Douglas-fir (*Pseudotsuga menziesii*) (Agee 1993, Pyne et al. 1996).

Wildfire can result in the loss of valuable timber resources and real estate. To prevent loss, fire suppression has been practiced since the early 1900's (Hagle and Schmitz 1993). Fire suppression has resulted in overcrowded vegetation susceptible to dwarf mistletoe or other pathogen and insect infestations, which then leads to more abundant and continuous fuels on the forest floor and ladder fuels into the canopy (Hagle and Schmitz 1993). As a result of past fire suppression, forests in southwestern Oregon

are at a huge risk of large, high intensity wildfires otherwise uncharacteristic of this area.

Data from a NOAA remote weather station in Ashland, Oregon indicate only 7% of annual precipitation falls in summer months and temperatures average near 20 °C ([www.wrh.noaa.gov/Medford/quick/ashland.html](http://www.wrh.noaa.gov/Medford/quick/ashland.html)).

Summers in southwestern Oregon are hot, dry and drought periods are common (Overhulser 1986). These climate conditions and increasing fuel loads make fire management a concern.

The Ashland watershed in the Rogue River National Forest is of particular concern due to its high ecological and recreational value. In addition, rapidly expanding towns like Ashland represent the problem with growing urban/wildland interfaces. High value properties, roads and recreational trails being built near and within forests mean increased ignition sources from people, campfires, and cars (Agee 1993). Prescribed burning and other hazard reduction measures are more difficult to carry out close to urban populations because of air quality concerns and public dislike for these silvicultural activities. However, unhealthy forest conditions and high risk of wildfires, pose serious threats to people and property alike.

Today prescribed burning is increasingly being used to decrease fuels, remove competing vegetation, and gradually return stands to pre-suppression conditions. Because prescribed burning can alter CWD habitat by not only removing existing CWD but also by creating new CWD (either directly or indirectly), more information is needed to give natural resource managers and the public a better idea of what to expect if prescribed burning is to be used with increasing frequency.

### **1.7 Summary and Objectives**

A common theme throughout the literature is the lack of information about CWD chewers in general and how they react to management activities and

natural disturbances (Schowalter 1994, Harmon et al. 1986). Fire suppression has changed forest stand composition in southwestern Oregon and, in turn, may have also altered the role wood-borers play in these forests. Downed woody debris, once consumed by frequent, low-intensity, low-severity wildfires, may now be more abundant due to fire suppression. Subsequently, wood-borer populations may be larger than they were historically. Given their importance ecologically and their complex relationship with fire, it is important to determine how wood-boring beetles are affected by the increased use of prescribed burning.

The overall objective of this research was to determine how metallic and long-horned wood-boring beetles respond to prescribed understory burning in the ponderosa pine/mixed-conifer forests of southwestern Oregon. This was studied in two ways. First, an experimental study was conducted to determine the response of wood-boring beetles, both larvae and adults, to various levels of burn severity on logs placed in a designated prescribed burn site. Second, a retrospective study was conducted, surveying adult wood-boring beetle populations in several prescribed burn sites, 1 to 15 years after burning. The response in adult beetles was measured by estimating overall abundance as well as abundance of individual species in burned and unburned logs or sites. In addition to adult beetle collection, bark samples were used to estimate percentage larval utilization on experimental logs and to compare utilization to burn severity.

## 2. Experimental Log Study

### 2.1 Introduction

In recent years, forest management practices on federal lands have shifted from primarily timber production to more diverse objectives focused on ecosystem health. Coarse woody debris (CWD), its creation, distribution and dynamics, is one important component of the ecosystem. CWD is vital to soil stabilization, nutrient cycling and as habitat for various plants, animals and fungi (Hagan and Grove 1999, Harmon et al. 1986). Management efforts today almost always incorporate some consideration of the type and amount of CWD volumes to be left on site.

Wood-boring beetles (Coleoptera: Cerambycidae, Buprestidae) play an important role in the decomposition and nutrient cycling of CWD in forest ecosystems (Harmon et al. 1986). Adults deposit eggs on or under the bark of dead or dying trees, and larvae extensively mine the phloem, sapwood and sometimes even heartwood of host trees (Furniss and Carolin 1977). Their actions not only breakdown the structural integrity of the tree, but introduce fungi and bacteria which further advance the decay process (Maser and Trappe 1984).

Most wood-borers are associated with the attack of weakened or dead trees (Furniss and Carolin 1977). Fire or lightning injury, drought, other insect or fungal infestations, or an abundance of breeding material such as windthrow or logging slash, can predispose a tree or stand to attack by secondary invaders such as wood-borers (Furniss and Carolin 1977). Previous studies have determined rates of infestation by wood-borers following forest fires, primarily to assess the feasibility of salvage logging (Kimmey 1955, Kimmey and Furniss 1943, Lowell et al. 1992, Richmond and LeJeune 1945). The same actions that make wood-borers so important to

CWD decomposition can also cause significant damage to otherwise marketable but fire-damaged timber.

Prescribed burning, a fire management tool being used with increasing frequency to remove excessive fuel loads and help reduce overcrowded or unhealthy vegetation, can have significant effects on CWD and its invertebrate inhabitants. Prescribed fires or wildfires can consume debris on the forest floor, as well as cause standing tree mortality directly or indirectly by predisposing fire-injured trees to subsequent insect and fungal attack (Agee 1993, Harmon et al. 1986, McCullough et al. 1998). It is imperative to determine how prescribed burning programs affect important functional groups such as wood-boring beetles.

The objective of this study was to determine the response of wood-boring beetles (Buprestidae and Cerambycidae), both larvae and adults, to different degrees of burn severity on logs placed in a prescribed understory burn. This was accomplished by comparing the abundance of adult wood-borers collected at logs burned to various degrees, as well as comparison of larval utilization in those same experimental logs.

## **2.2 Methods and Materials**

### ***2.2.1 Site Description***

This study was conducted in a 66 ha mixed-conifer stand at approximately 1100 m elevation, just above the east fork of Ashland Creek in the Ashland Ranger District of the Rogue River National Forest, OR. The Ashland watershed is located at approximately 122.7° W longitude and 42.2° N latitude. This site has a south/southwest aspect and an average slope of 55% (SD=8.41). Mean annual temperature, from a NOAA remote weather station in Ashland, OR ([www.wrh.noaa.gov/Medford/quick/ashland.html](http://www.wrh.noaa.gov/Medford/quick/ashland.html)) is

approximately 11.2 °C, with January mean temperatures of 3.3 °C and July mean temperatures of 20.7 °C. Mean annual precipitation from the NOAA station is 48.7 cm (19.2 inches), with only 7.0 cm (2.8 inches) falling between June and September, and the remainder from October to May. Summers are dry and hot, and extended summer drought periods are common (Overhulser 1986). Franklin and Dyrness (1988) classify this area as predominantly ponderosa pine (*Pinus ponderosae*), often in association with Douglas-fir (*Pseudotsuga menziesii*), Pacific madrone (*Arbutus menziesii*), white fir (*Abies concolor*) at higher elevations, and several oak (*Quercus*) and manzanita (*Arctostaphylos*) species.

The Ashland watershed is an area of environmental concern due to its high recreational value and proximity to a rapidly growing wildland/urban interface. Previous policies of fire suppression have resulted in a shift in vegetation from more open ponderosa pine/ Douglas-fir forests with sparse understory, to crowded, mixed-conifer stands (Agee 1993). These stands tend to be susceptible to dwarf mistletoe and insect infestations, creating high fuel loads and increasing the risk for severe wildfires (Figure 2.1). Prescribed understory burning was used on this site as part of a long-term plan to reduce fuel loads and competition among dense vegetation.

The site was prescription burned in mid-June 1998. The burn was ignited by drip torches and conducted by Forest Service personnel from the Ashland and Applegate Ranger Districts of the Rogue River National Forest. The low-intensity, prescribed understory burn was conducted to reduce forest floor debris and remove some smaller, understory vegetation.



**Figure 2.1** Dwarf mistletoe infests many trees throughout the Ashland watershed, causing massive brooms like these. Brooms which break off become ground fuels for wildfires, while those remaining on the tree serve as aerial ladders shuttling understory fires to the canopy.

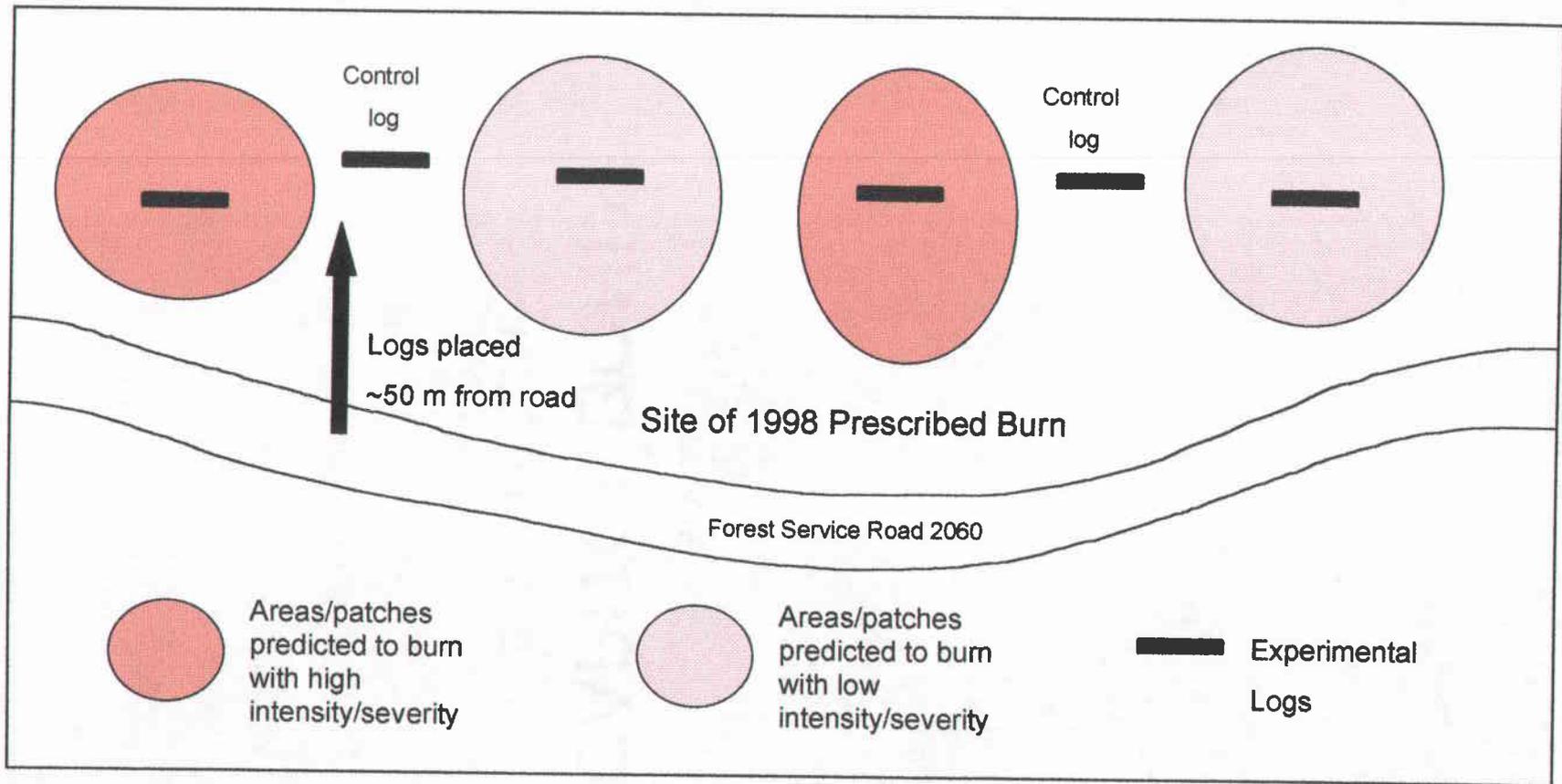
### **2.2.2 Experimental Design**

Eighteen Douglas-fir logs were placed within the study site either before or after the burn was conducted. Logs were approximately 1.5 m in length with an average diameter of 25 cm, representative of the larger class of CWD (1000+ hour fuels) but still able to be moved by hand (see Table 2.1 for log dimensions and characteristics.) Logs were cut from six trees (3 logs per tree) which had been windthrown the previous fall/winter (1997/1998). Recently fallen trees were used to minimize the amount of insect and fungal infestation already present and treatments were blocked by tree of origin to control for current infestations. Logs were tagged and length and diameter measured to estimate volume.

The study design was a randomized complete block. The three logs from each tree (block) were randomly selected to receive one of three treatments. One log from each tree was placed within areas predicted to burn with high intensity, based on fuel loading and lack of overstory (i.e. first areas to dry out). Intensity is defined as a physical characteristic of the fire, usually the rate of heat released per unit length (kW/m) (Agee 1993). This placement assumed the severity, or effect, of the fire on the log would also be high. In some cases, small debris was piled around the logs to ensure a higher severity of burn on the log. Another log from each tree was placed in areas predicted to burn with a low intensity, based on light fuel loads and a more closed canopy (i.e. slower to dry out), thereby assuming the impact of the burn on these logs would be lower in severity. A third log from each tree was left outside the burn area and placed on site after the burn was completed to act as an unburned control (Fig. 2.2).

**Table 2.1** Characteristics of logs used in the experimental burn study examining the response of wood-boring beetles to prescribed burning.

Block (Tree)	Log	Log Volume (cm <sup>2</sup> )	Date Burned	Date Trapped (or controls put in place)	Percent Char	Species Richness	Simpson's Diversity Index (1/C)
1	1	97,588.5	6/8,9/98	6/11/1998	100	3	2.3
1	2	90,895.4	control	6/11/1998	0	7	3.1
1	3	82,449.3	6/8,9/98	6/11/1998	10	7	5.5
2	1	98,403.9	not burned	6/22/1998	0	2	1.4
2	2	82,506.9	not burned	6/22/1998	0	5	2.6
2	3	117,781.9	control	6/23/1998	0	2	2.0
3	1	110,821.9	6/8,9/98	6/11/1998	85.6	5	4.5
3	2	90,700.0	6/8,9/98	6/11/1998	64.4	10	4.5
3	3	76,414.3	control	6/11/1998	0	5	3.5
4	1	96,276.0	6/19/1998	6/22/1998	85.4	3	3.0
4	2	107,626.1	control	6/23/1998	0	3	2.6
4	3	73,748.6	not burned	6/22/1998	0	1	1.0
5	1	81,875.2	6/8,9/98	6/11/1998	66.9	6	2.6
5	2	70,751.6	control	6/11/1998	0	6	4.6
5	3	62,050.7	not burned	6/22/1998	0	5	2.2
6	1	66,020.3	not burned	6/22/1998	0	0	0
6	2	63,009.9	6/8,9/98	6/11/1998	1.9	3	2.1
6	3	69,071.4	control	6/23/1998	0	3	3.0



**Figure 2.2** Placement of experimental logs in 1998 prescribed burn site. Two logs from each tree were placed in areas to be burned, either with high or low severity, based on vegetation cover and fuel availability. Control logs were placed on the site after burning.

### 2.2.3 Post-Fire Observations

No observations were made before or during the burn from which to calculate fire intensity or severity. Therefore, the prescribed burn was categorized two ways using post-burn observations.

First, three parallel transects 50 m apart and running lengthwise across the burned area, each approximately 1160 m in length, were surveyed. Every 20 m, the ground char class at that point was visually estimated as one of four categories (Ryan and Noste 1985):

- UNBURNED – no burn detected
- LIGHT GROUND CHAR – leaf litter only charred or consumed, duff layer not altered
- MODERATE GROUND CHAR – litter layer is consumed, duff is charred or consumed but mineral soil is unaltered
- DEEP GROUND CHAR – litter and duff completely consumed, top of mineral soil visibly altered (change of color), white ash present, fallen tree or roots burned out completely

Percentage of total sampling points for each category is then given as a relative measure of fire severity and coverage.

Second, crown scorch heights on 20 randomly selected Douglas-firs or ponderosa pines within the site were recorded. Heights were then translated into a measure of fire line intensity utilizing the following equation from Agee (1993):

$$h_s = 0.1483(I)^{2/3}$$

where  $h_s$  is each scorch height observation (m) and  $I$  represents fire line intensity in kW/m. Measures of fire line intensity are widely used in categorizing fires – both natural and prescribed – and can be used for future comparisons to other burns.

Once the burn was completed, each log was divided lengthwise into quarter sections and percentage char on each quarter was visually

estimated. Using these observations, each log was assigned a total percentage charring.

#### **2.2.4 Adult Beetle Collection**

Adult wood-boring beetles (Cerambycidae, Buprestidae) flying into the burn and presumably attempting to land on the logs were monitored with flight intercept traps. Traps were constructed of lightweight corrugated plastic material and plastic collection cups with an intercept surface measuring 30 cm x 43 cm. Two traps were nailed onto each log with one on each side (Fig. 2.3). Traps and control logs were placed as quickly as possible after the burn was completed.

The prescribed burn was conducted in two phases. One burn took place on 8 and 9 June 1998. In this phase, traps and control logs were placed in the stand on 11 June 1998. A second burn was conducted on 18 June 1998 because burn objectives were not met in the first burn. Traps and controls for logs burned in this phase were placed on 22 June 1998.

Traps were emptied approximately every 20 days from July to early October. Samples were transported to the laboratory and stored at  $-17.8\text{ }^{\circ}\text{C}$  until beetles could be counted and identified. All cerambycids and buprestids were identified to species, with the exception of one subgenus of Buprestidae, *Melanthaxia*, which is currently under revision. All individuals identified as belonging to subgenus *Melanthaxia* were grouped as *Anthaxia* (sub:*Melanthaxia*) spp., and represented primarily two species: *Anthaxia* (sub:*Melanthaxia*) *confusa* and *californica*. Abundance of beetles for each family was estimated for both the first collection period and for the whole summer for each experimental log.



**Figure 2.3** Flight intercept traps used to collect flying adult wood-borers in the experimental log study.

### ***2.2.5 Larval Gallery Survey***

In addition to surveying flying adult wood-borers, 12 bark samples of roughly 100 cm<sup>2</sup> were collected from each log (3 from the top, 3 from each side, 3 from the bottom) with a hole saw on 15 November 1998. Bark samples were transported to the laboratory and stored at -3.3 °C until they could be processed. The phloem side of the bark samples was traced onto clear transparency film. Larval galleries were traced and identified as cerambycid, buprestid or unidentifiable but belonging to either family, based on general shape and frass patterns (when possible). Both families have characteristically wide, winding galleries packed with frass. Buprestid galleries are typically packed with frass arranged in overlapping semicircles

while cerambycid frass has no pattern (Furniss and Carolin 1977).

Transparencies were then copied and digitized. An image analysis computer program (SigmaScan/Image™) was used to estimate areas of polygons (galleries). Percentage of total sample area utilized by each family was then calculated. Percent utilization by the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins) was also recorded because of its high occurrence in the samples and importance as a competitor for the same food source as wood-boring beetles (Edmonds and Eglitis 1989).

### 2.2.6 Data Analysis

Abundance of adult cerambycids and buprestids collected at each log for both the first collection period following burning (i.e. presumably the highest activity time for wood-borers attracted to the fire) and for the entire summer combined was calculated per ten trap days per log by dividing each collection count by the number of days the traps were open (since the last collection) and then multiplying by ten. Any species identified as having only non-conifer hosts were not included in this study. Abundance was regressed on percent char, using block (tree) as a classification variable only. This regression analysis was chosen due to the fact that the prescribed burn resulted in a continuous scale of burns on the experimental logs rather than the burn "treatments" which were planned. A log+1 transformation of all abundance data was used to correct for non-normal distribution and to stabilize unequal variance. Because approximately half of the logs designated for burn treatment remained unburned (Table 2.1), further regressions were run ignoring unburned log data. A two sample t-test was conducted comparing abundance on burned and unburned logs.

A measure of species richness and Simpson's diversity index was also assigned to each experimental log and regressed on percent char (as above). Simpson's diversity index is calculated as follows:

$$C = \sum_{i=1}^s (p_i)^2$$

where:  $s$  = total number of species in sample and

$p_i$  = proportion of all individuals in the sample belonging to species  $i$ .

The reciprocal ( $1/C$ ) is then used as the species diversity index value. Simpson's diversity index was selected as the measure of diversity because it weights abundant species more heavily. Values tend to vary less from sample to sample with introduction of one or two rare species (Barbour et al. 1987, Magurran 1988). This was an important strength given that several species collected in the study were represented by only one or two individuals all summer. Diversity indices, such as the Shannon-Wiener's index, are more sensitive to these rare collections and values can vary greatly from site to site (Magurran 1988).

Percent utilization was calculated for both wood-borer families separately, for total utilization by wood-borer larvae (including unidentifiable galleries belonging to either family), and for the Douglas-fir beetle, as a percentage of total area sampled per log. Percent utilization was then regressed on percent char, using block (tree) as a classification variable only. The regression analysis was performed on untransformed data with unburned log data both included and excluded. A two sample t-test was performed, on  $\log+1$  transformed data, to compare utilization in burned and unburned logs.

## **2.3 Results**

### **2.3.1 Post-fire Observations**

Average fire line intensity was calculated as 111.5 kW/m (95%CI: 96.7 – 126.2). Ground char observations were 44.3% unburned, 29.9% light ground char, 22.4% moderate ground char and 3.5% deep ground char.

Seven of the 18 logs were burned, with a percent char ranging from 2 to 100 percent (Table 2.1). The percent of burn was either very low (10% or less) or relatively high (64-100%), with no logs burned in the mid-range of 11-60% char. Because logs were windthrown the previous winter and had high moisture content, we saw no bark consumption except on the log charred 100%. Five logs designated to be burned did not receive any treatment at all. As a result, 11 of the 18 logs were completely unburned.

### 2.3.2 Adult Beetle Collection

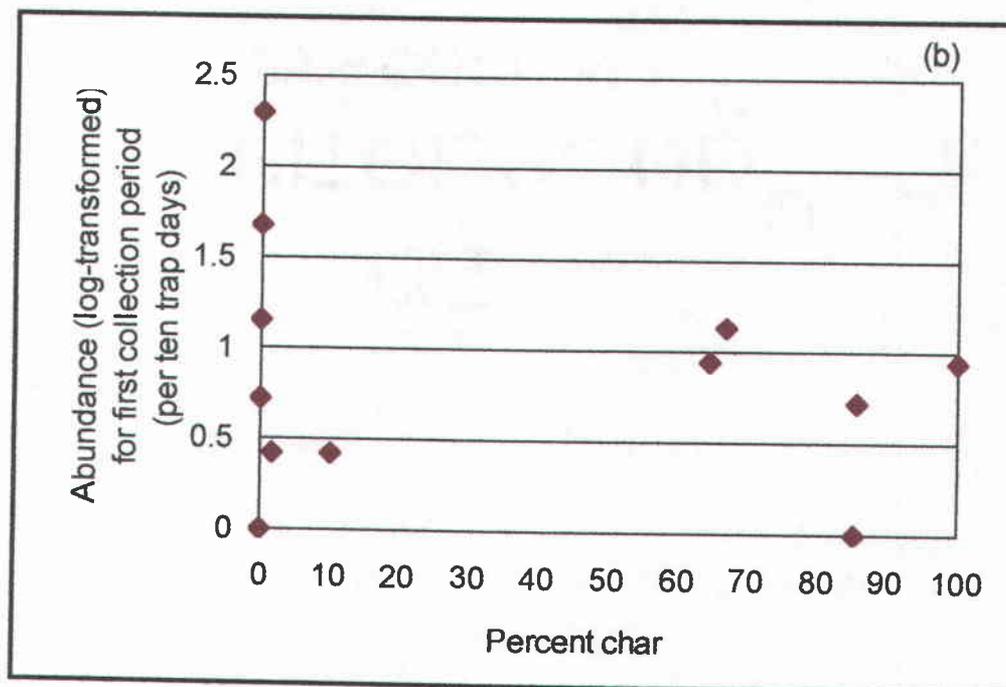
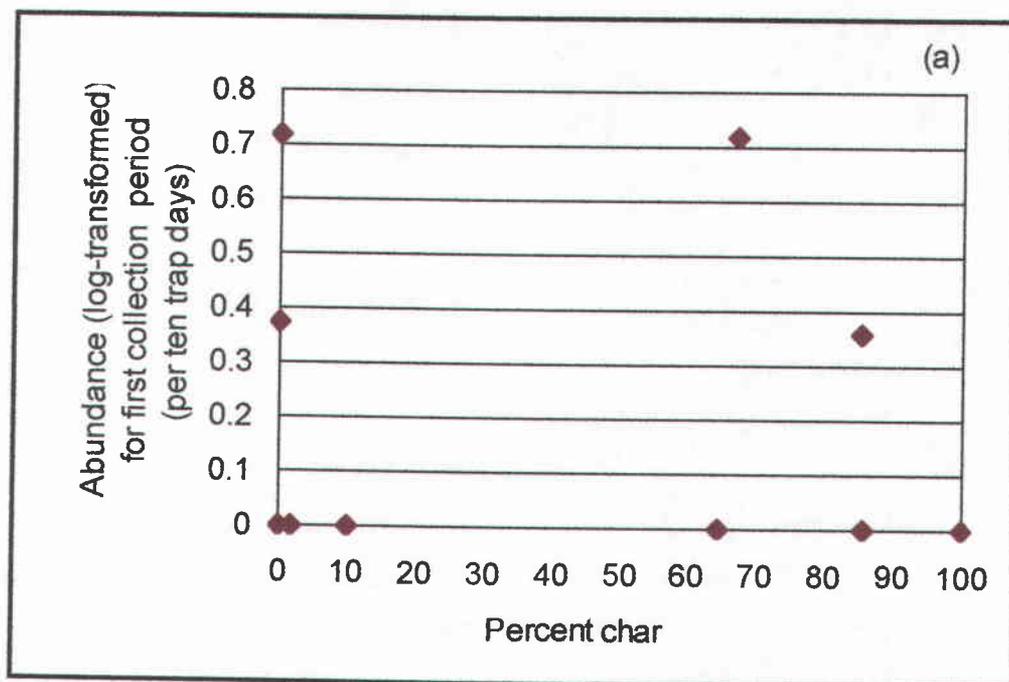
A total of 32 cerambycids and 176 buprestids were collected at all experimental logs combined, represented by 7 and 10 species respectively (Table 2.2). Two cerambycid species, *Phymatodes decussatus posticus* VanDyke and *Xylotrechus nauticus* (Mannerheim), were excluded from the analyses. *P. decussatus* feeds primarily on *Quercus* while *X. nauticus* feeds on *Quercus*, *Arbutus* and other hardwoods (Linsley and Chemsak 1997). One buprestid species, *Polycesta californica* LeConte, was excluded from the analyses. Its primary hosts are *Arbutus menziesii*, *Quercus*, *Populus*, and *Acer* (Furniss and Carolin 1977).

There was no significant relationship between median cerambycid or median buprestid abundance from the first collection period and percent char ( $R^2=0.21$ ,  $P=0.70$  and  $R^2=0.48$ ,  $P=0.88$ , respectively) (Fig. 2.4). Results from the entire summer's data were similar, with neither total cerambycid or buprestid abundance significantly correlated with percentage char on the logs ( $R^2=0.44$ ,  $P=0.44$  and  $R^2=0.43$ ,  $P=0.55$  respectively)(Fig. 2.5).

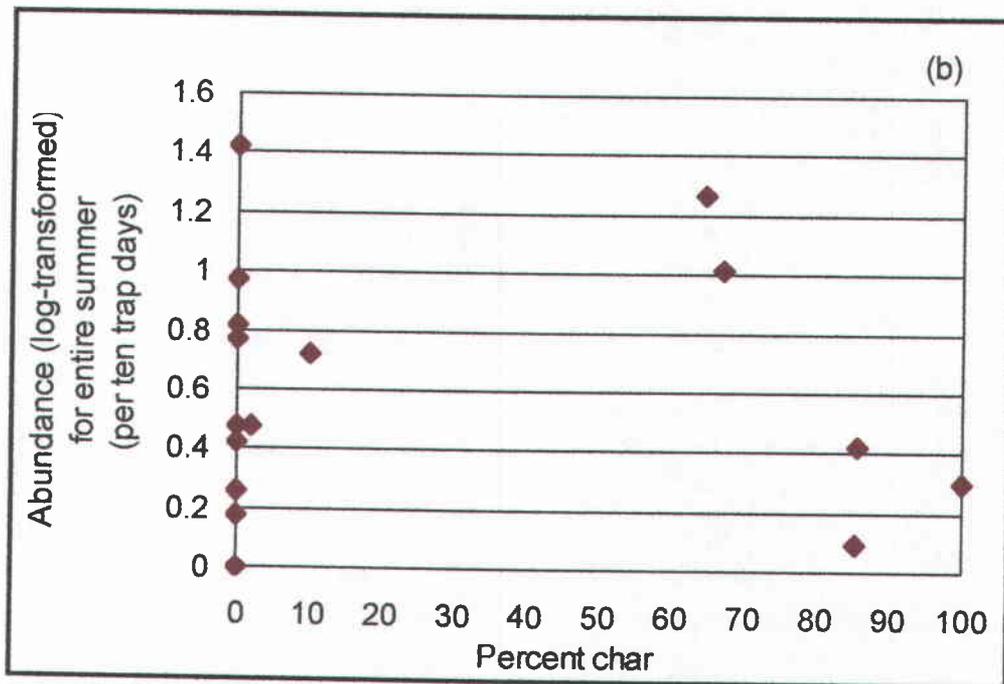
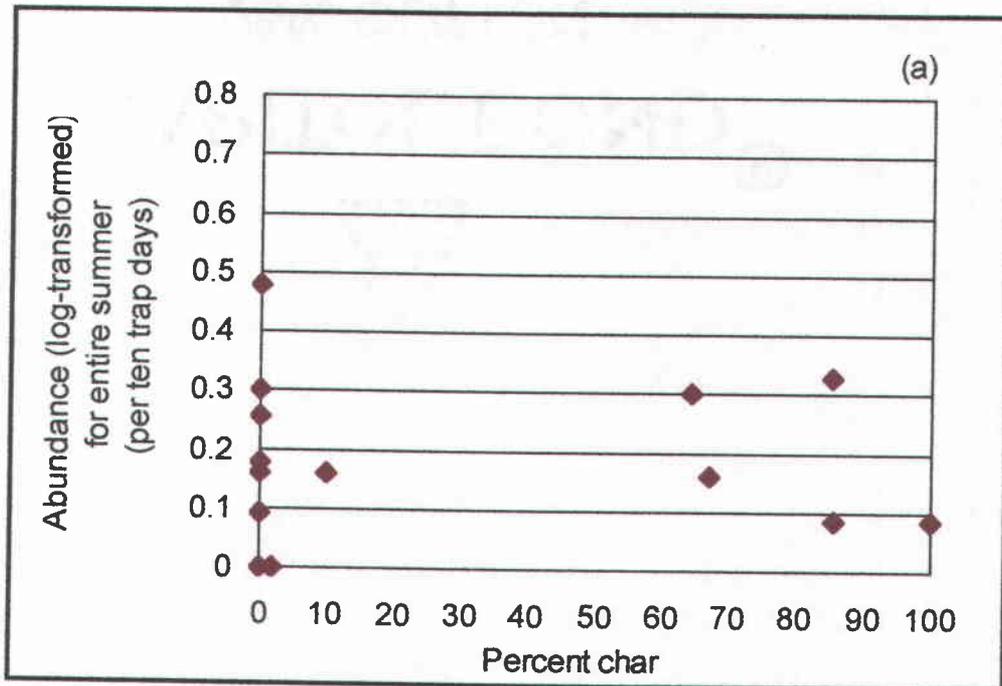
When data from unburned logs was excluded from analysis, there was still no significant relationship between severity of char on the logs and cerambycid ( $R^2=0.11$ ,  $P=0.47$ ) or buprestid ( $R^2=0.06$ ,  $P=0.61$ ) abundance. Second-degree polynomial regression analysis did not reveal any significant

**Table 2.2** Wood-borer species collected by flight traps in the experimental log study. AC=*Abies concolor*, PM=*Pseudotsuga menziesii*, PP=*Pinus ponderosae*, TH=*Tsuga heterophylla*. Host plants from <sup>1</sup>Bright (1986), <sup>2</sup>Chamberlain (1924), <sup>3</sup>Furniss and Carolin (1977), <sup>4</sup>Linsley and Chemsak (1997), <sup>5</sup>Yanega (1996).

Species:	Total:	Percent of total caught:	Associated Hosts:
<u>Cerambycidae</u>			
<i>Arhopalus asperatus</i> (LeConte)	5	15.6	AC, PP, PM <sup>4</sup>
<i>Leptura oblitterata</i> Halderman	1	3.1	<i>Abies</i> , <i>Picea</i> , <i>Pinus</i> , PM, <i>Tsuga</i> <sup>4</sup>
<i>Phymatodes decussatus</i> (LeConte)	1	3.1	<i>Quercus</i> <sup>4</sup>
<i>Phymatodes dimidiatus</i> (Kirby)	9	28.1	<i>Picea</i> , <i>Pinus</i> , PM, <i>Tsuga</i> <sup>4</sup>
<i>Trachysida aspera</i> (LeConte)	1	3.1	<i>Abies</i> <sup>5</sup> ; <i>Betula</i> , <i>Picea</i> , <i>Pinus</i> , <i>Populus deltoides</i> , PM, <i>Salix</i> <sup>4</sup>
<i>Ulochaetes leoninus</i> LeConte	13	40.6	AG, <i>Picea</i> , <i>Pinus</i> , PM, <i>Tsuga</i> <sup>4</sup>
<i>Xylotrechus nauticus</i> (Mannerheim)	2	6.3	<i>Arbutus menziesii</i> , <i>Quercus</i> , <i>Salix</i> <sup>4</sup>
Total	32	100	
<u>Buprestidae</u>			
<i>Anthaxia</i> (sub: <i>Melanthaxia</i> ) spp.	54	30.7	<i>Abies</i> <sup>3</sup> , <i>Quercus</i> <sup>2</sup> , <i>Pinus</i> <sup>3</sup> , PM <sup>3</sup> , <i>Rhododendron</i> <sup>2</sup> , <i>Salix</i> <sup>2</sup> , <i>Sequoia</i> <sup>3</sup>
<i>Buprestis aurulenta</i> L.	57	32.4	AG, <i>Pinus</i> , PM, <i>Thuja plicata</i> <sup>1</sup>
<i>Buprestis laeviventris</i> (LeConte)	1	0.6	<i>Larix</i> <sup>1</sup> ; <i>Pinus</i> , PM <sup>3</sup>
<i>Buprestis lyrata</i> Casey	14	8.0	AG, PP, PM <sup>1</sup>
<i>Buprestis subornata</i> (LeConte)	3	1.7	<i>Larix</i> <sup>1</sup> ; <i>Pinus</i> , PM <sup>3</sup>
<i>Chalcophora angulicollis</i> (LeConte)	3	1.7	<i>Abies</i> , <i>Pinus</i> , PM <sup>3</sup>
<i>Chrysophana placida</i> (LeConte)	1	0.6	<i>Abies</i> , <i>Pinus</i> , PM, <i>Tsuga</i> <sup>3</sup> ; <i>Thuja plicata</i> <sup>1</sup>
<i>Dicerca crassicollis</i> (LeConte)	22	12.5	<i>Abies magnifica</i> , PM, PP <sup>1</sup>
<i>Phaenops drummondi</i> (Kirby)	20	11.4	<i>Abies</i> , <i>Larix</i> , <i>Picea</i> , PM, TH <sup>3</sup> ; (rarely on <i>Pinus</i> ) <sup>1</sup>
<i>Polycesta californica</i> LeConte	1	0.6	<i>Arbutus menziesii</i> , <i>Quercus</i> , <i>Populus</i> , <i>Acer</i> <sup>3</sup>
Total	176	100	



**Figure 2.4.** Cerambycid (a) and buprestid (b) abundance (log-transformed) from first collection period against percent char on experimental logs.



**Figure 2.5.** Cerambycid (a) and buprestid (b) abundance (log-transformed) for entire summer against percent char on experimental logs.

relationships between charring and cerambycid ( $R^2=0.47$ ,  $P=0.25$ ) or buprestid ( $R^2=0.65$ ,  $P=0.12$ ) abundance (Fig. 2.6).

T-tests revealed no difference between burned (ignoring percent char) and unburned logs for cerambycid or buprestid abundance ( $P=0.49$  and  $P=0.64$ , respectively) (Fig. 2.7).

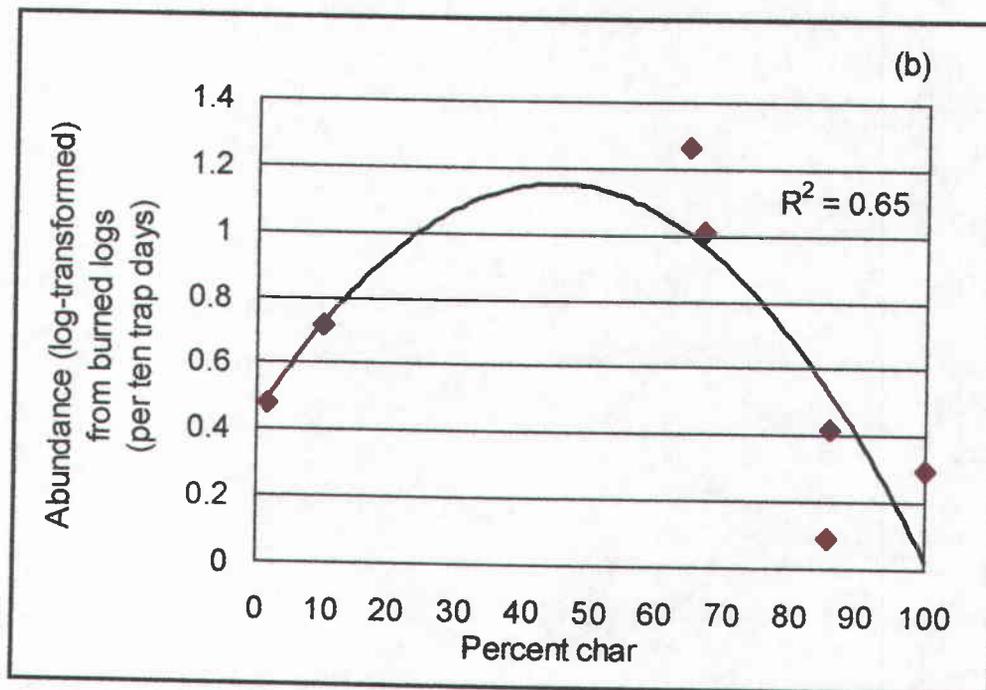
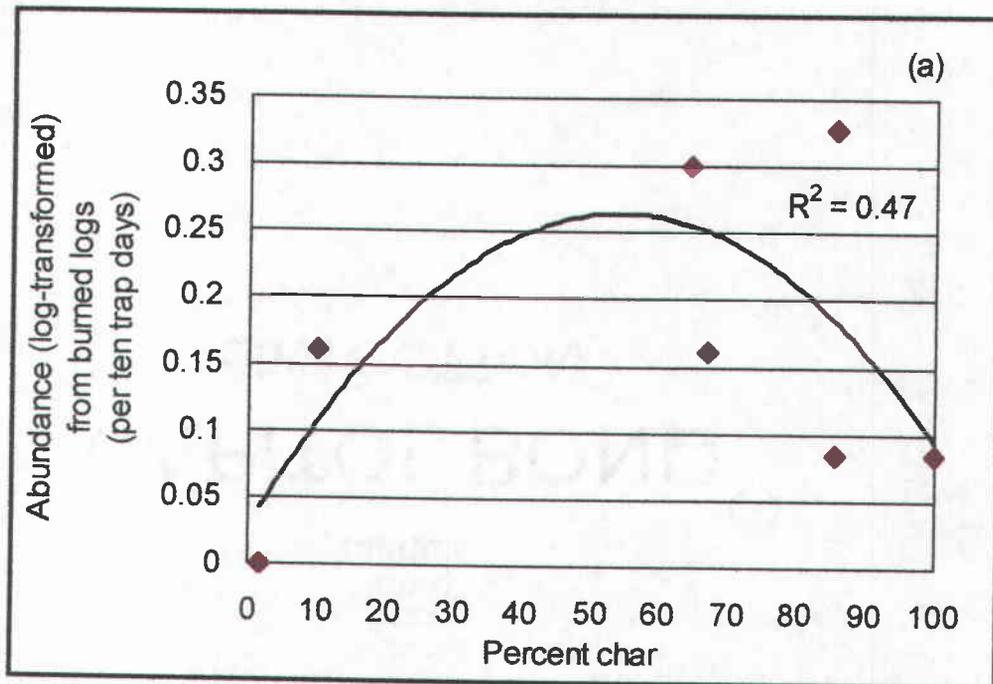
Neither species richness nor Simpson's diversity index were significantly correlated to percentage charring on the logs ( $P=0.71$  and  $P=0.86$ , respectively) (Figs. 2.8 and 2.9).

### **2.3.2 Larval Gallery Survey**

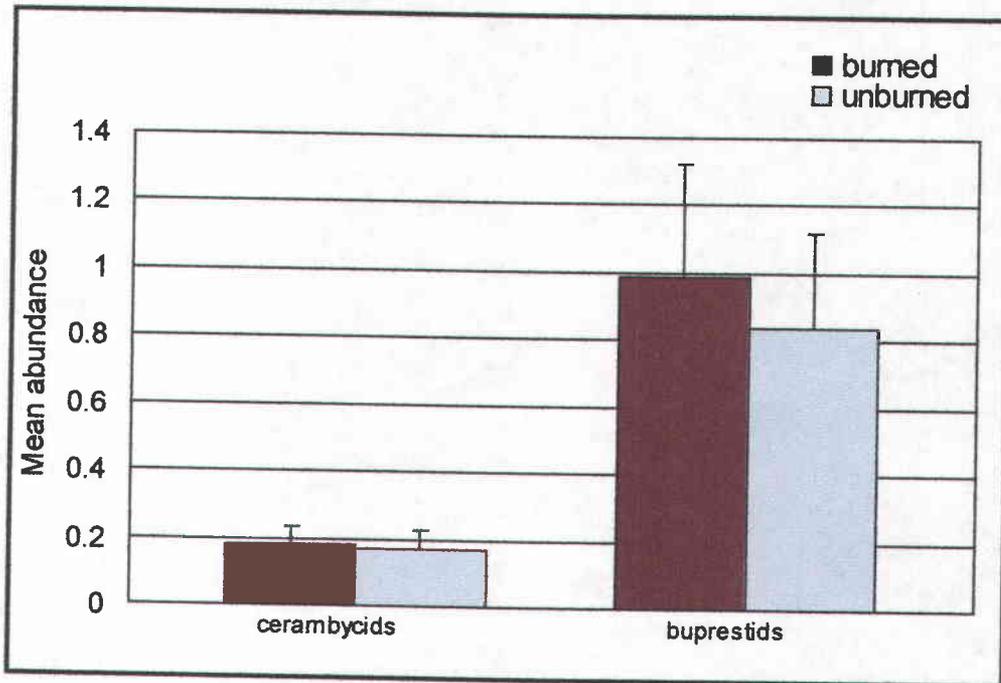
A total of 23,881.08 cm<sup>2</sup> of bark was sampled from the 18 experimental logs. Cerambycid and buprestid larvae utilized 9.27% of the total area sampled (4.38% identified as cerambycid galleries and 2.88% as buprestid galleries). Neither percent utilization by cerambycid nor buprestid larvae was significantly correlated to percent charring on the logs ( $R^2=0.52$ ,  $P=0.85$  and  $R^2=0.65$ ,  $P=0.10$ , respectively) (Fig 2.10 a and b). Total percent utilization by both wood-borer families combined was not significantly correlated to percent char ( $R^2=0.73$ ,  $P=0.80$ ) (Fig. 2.10c). Percentage utilization by the Douglas-fir beetle, which represented 4.28% of total area sampled, was not significantly correlated to percent charring on the logs ( $R^2=0.68$ ,  $P=0.17$ ) (Fig. 2.11).

When data from unburned logs was excluded, there was still no significant relationship between severity of burn and utilization by cerambycids ( $R^2=0.01$ ,  $P=0.80$ ), buprestids ( $R^2=0.001$ ,  $P=0.94$ ), both families combined ( $R^2=0.02$ ,  $P=0.75$ ), or the Douglas-fir beetle ( $R^2=0.42$ ,  $P=0.11$ ).

Two-sample t-tests revealed no difference in percent utilization by cerambycids ( $P=0.38$ ), buprestids ( $P=0.23$ ), both wood-borer families combined ( $P=0.69$ ), or the Douglas-fir beetle ( $P=0.41$ ) between burned and unburned logs (Fig. 2.12).



**Figure 2.6.** Cerambycid (a) and buprestid (b) abundance (log-transformed) from burned logs only against percent char on experimental logs (with second degree polynomial trend lines and  $R^2$  values).



**Figure 2.7.** Mean (SE) abundance of cerambycids and buprestids from burned and unburned experimental logs.

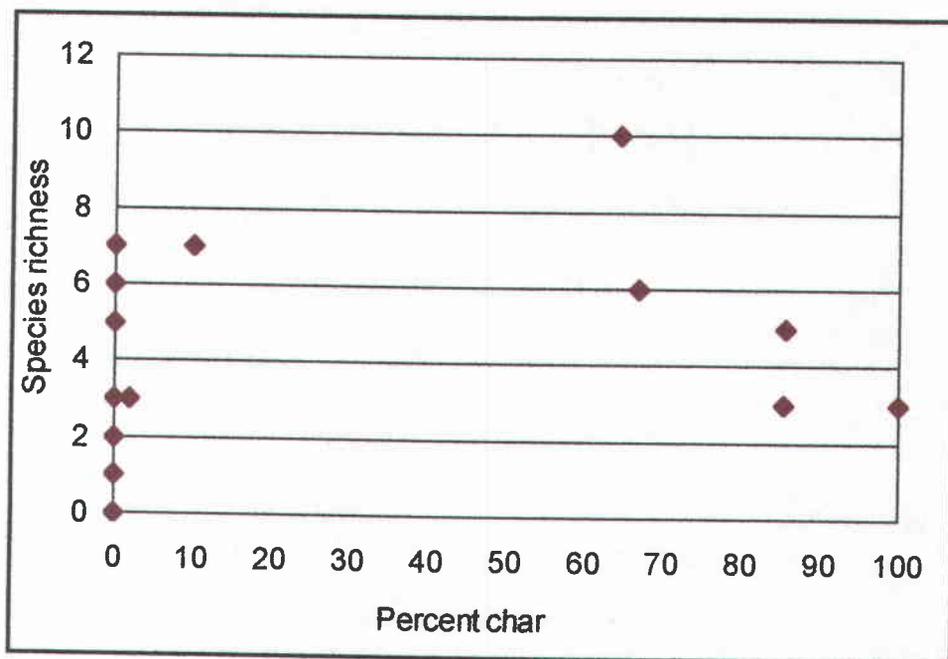


Figure 2.8. Species richness against percent char on experimental logs.

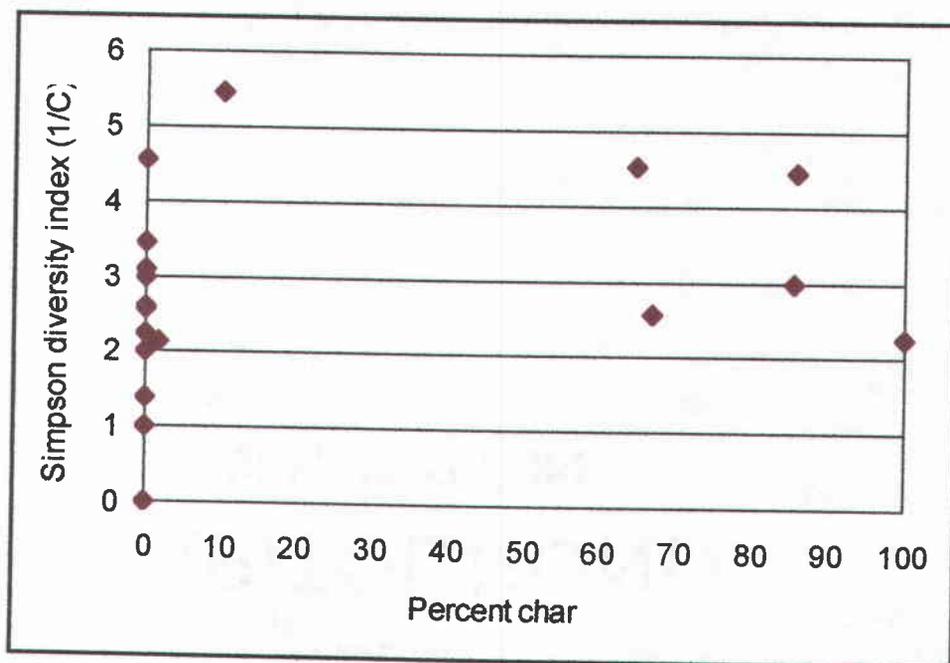
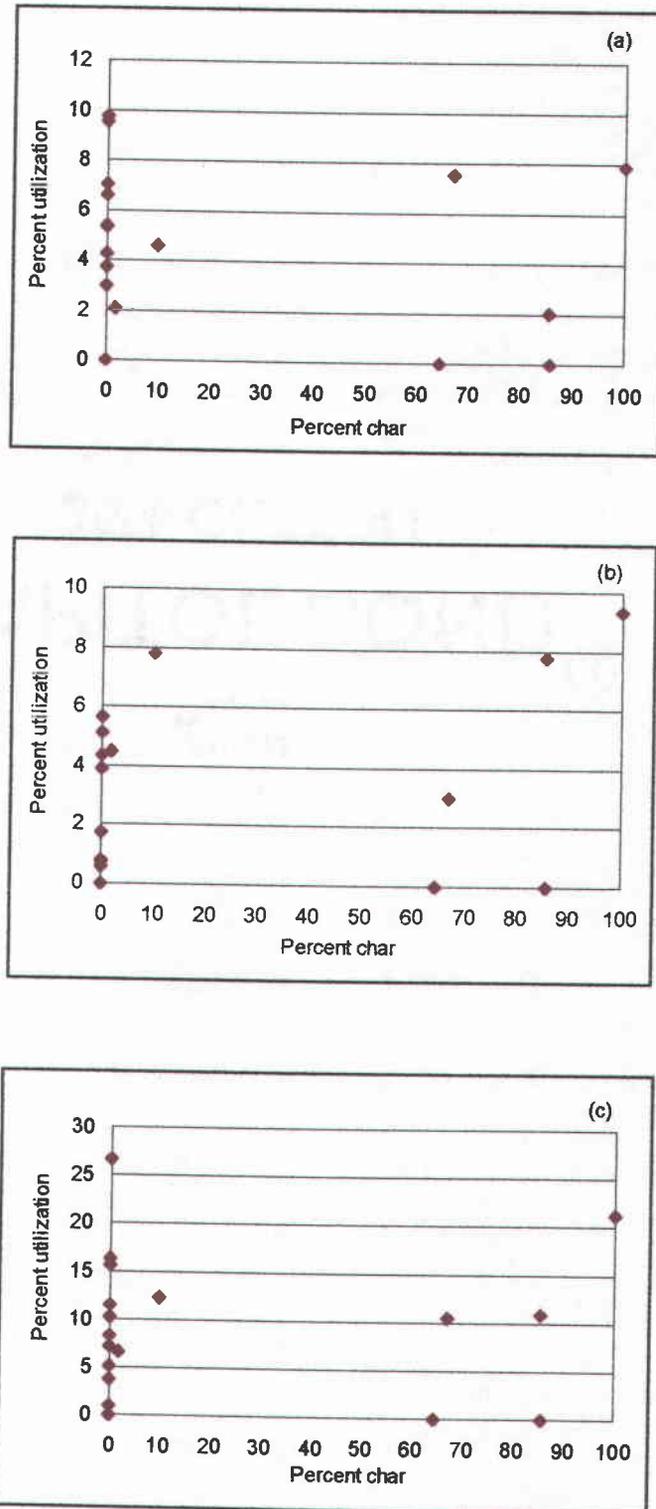
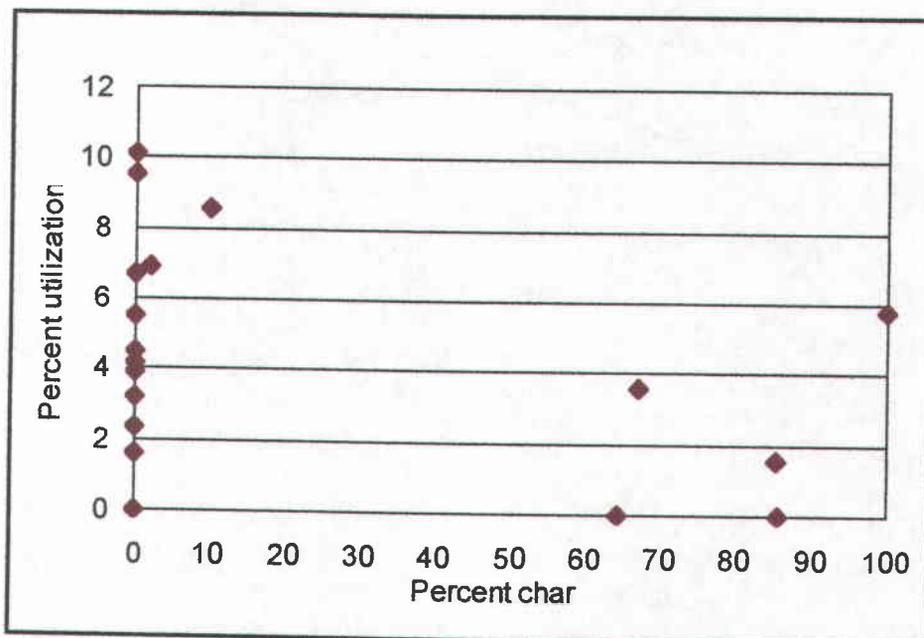


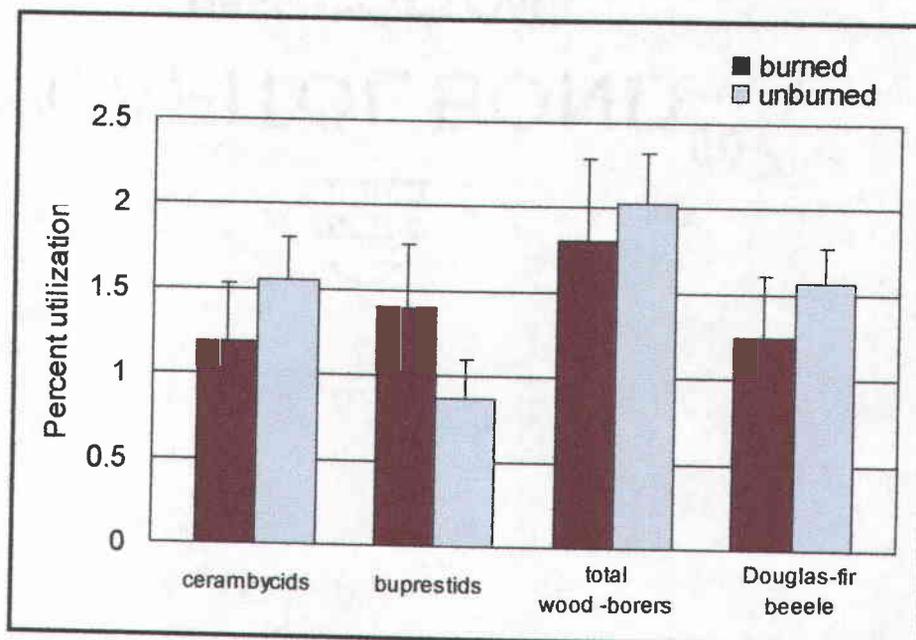
Figure 2.9. Simpson diversity index values against percent char on experimental logs.



**Figure 2.10.** Percent utilization by cerambycid larvae (a), buprestid larvae (b) and both wood-borer families combined (c) against percent char on experimental logs.



**Figures 2.11.** Percent utilization by the Douglas-fir beetle against percent char on experimental logs.



**Figure 2.12.** Mean (SE) percent utilization (log-transformed) by cerambycids, buprestids, both wood-borer families combined and the Douglas-fir beetle for burned and unburned experimental logs.

## **2.4 Discussion**

Overall, results from this study do not suggest a statistically significant relationship between severity of charring on the experimental logs and their attractiveness or suitability as hosts. However, it is important to recognize that treatments were not applied evenly or in the manner originally planned. Five of the twelve logs designated to be burned never received treatment. The severity, or impact, of the prescribed burn on the seven logs that did receive treatment was very low. These logs were charred to various extents, but there was little to no bark consumption. The severity of char varied greatly and did not represent a continuous scale. A large gap in data existed between 10 and 60 percent charring, with very few data points representing the rest of the scale. Given the low levels of scorch and the inconsistency of the treatment it is difficult to establish or quantify patterns in abundance or utilization as related to severity of burning.

Family abundance, both for the first collection period and for the whole summer, was not statistically correlated to percent charring (Figs. 2.4 and 2.5). Instead, abundance of cerambycids and buprestids seems to have no relationship with severity of charring or even with the burned or unburned state of the logs. Two sample t-tests confirmed the latter assertion that no difference existed between the two groups (Fig. 2.7).

When unburned log data were excluded (Fig. 2.6), there was no statistical evidence of a relationship. There appears to be a trend of increasing abundance with increasing char, which decreases again approaching 100% charring. It is difficult to make any conclusions about these patterns because data from 10-60% char are absent. However, Richmond and LeJeune (1945) found similar results when they charred logs by hand and monitored attack of wood-borers. They found logs that were burned with the highest degree of severity became unattractive as hosts. While second degree polynomial regression was still not significant in my study, trends consistent with Richmond and LeJeune's findings are apparent. Decreasing

attractiveness could be due to consumption of bark in higher severity burns. Many species of both cerambycids and buprestids lay eggs in crevices on or under the bark for protection, while many cerambycids require intact outer bark for pupation (Furniss and Carolin 1977). High severity of charring could have also resulted in drying out of the phloem, making logs less suitable, and therefore less attractive, as host material.

Because most cerambycids and buprestids are associated with the attack of recently killed or dying trees, it is possible the freshly cut logs placed in the prescribed burn site made attractive and suitable hosts, regardless of being burned. More specifically, Scott (1974) studied two species of Buprestidae, *Melanophila acuminata* DeGeer and *Phaenops drummondi* Kirby. He found that while the former species possess sensory pits which direct adults towards the infrared radiation of a fire, both species use primarily olfactory cues to select a suitable host. Olfactory perception of host volatiles probably plays the biggest role in attraction of other adult cerambycids and buprestids as well. So while it is possible that the prescribed burn attracted adult beetles to the site, any available food source such as freshly cut Douglas-fir logs would be equally utilized.

Comparison of species richness and Simpson's diversity index across percent charring did not reveal any correlation, nor did any large differences between burned and unburned logs exist (Figs. 2.8 and 2.9). Placement of the traps on the logs near the ground probably resulted in collection of several incidental species flying through the site. In addition, differences in microclimatic conditions around each experimental log, such as percent cover, slope and aspect might also have influenced trap catch and caused great variation in species collected. Both Scott (1974) and White (1983) remark on buprestid affinity for warmer, sunnier areas. Large variation in percent cover from log to log could have affected species and numbers caught.

While flight traps are a measure of adult attraction, both to the individual logs and to the burned area in general, larval gallery sampling is a measure of the suitability of individual logs for wood-borer development. Levels of percent utilization in general were comparable to those recorded for wood-borers and the Douglas-fir beetle in a study of unburned log decomposition (Zhong and Schowalter 1989). No relationships could be shown between percent utilization by buprestids, cerambycids or the Douglas-fir beetle and percent char (Figs. 2.10 and 2.11). Even when unburned log data was excluded, no significant patterns or relationships were apparent. Consistent with Parmelee (1945), all of the freshly cut logs seemed equally suitable as host material. Larval utilization did not decrease when percent charring approached 100%, as with adult capture in flight traps.

### 3. Retrospective Study

#### 3.1 Introduction

Prescribed burning is increasingly being used as a management tool throughout Northwest forests to reduce fuel loads, remove crowded and unhealthy vegetation, and help restore pre-suppression fire regimes (Agee 1993, Norris 1990). Fire, however carefully prescribed and controlled, has far reaching effects on the ecosystem. While it can consume fuels on the ground, it also creates coarse woody debris (CWD) through either direct killing of vegetation or predisposing live vegetation to other mortality agents such as insects and pathogens (Harmon et al. 1986). Much attention has focused on the rate at which insects and pathogens attack trees or downed wood after fire occurs on a site, but primarily for developing protocols for salvage logging operations (Kimmey and Furniss 1943, Kimmey 1955, Lowell et al. 1992, Ragenovich 1988, Rasmussen et al. 1996).

Wood-boring beetles (Coleoptera: Buprestidae, Cerambycidae) are some of the insects associated with utilization and excavation of fire killed or injured trees. Most wood-borers are known to be attracted to fire or smoke (Furniss and Carolin 1977). They can cause extensive wood deterioration and decay, not only by the larval mining of phloem, sapwood and sometimes even heartwood of a dead or dying tree, but by creation of infection courts for bacteria and fungi, which they often carry on their bodies (Berry 1978, Edmonds and Eglitis 1989, Furniss and Carolin 1977, Zhong and Schowalter 1989).

For this reason, wood-borers play a major role in decomposition and nutrient cycling of CWD in forested ecosystems. Because fire of any kind, including prescribed burning, affects CWD volume and input, it is important to understand how this management tool is affecting wood-borer habitat. This retrospective study was designed to determine the effect prescribed burning

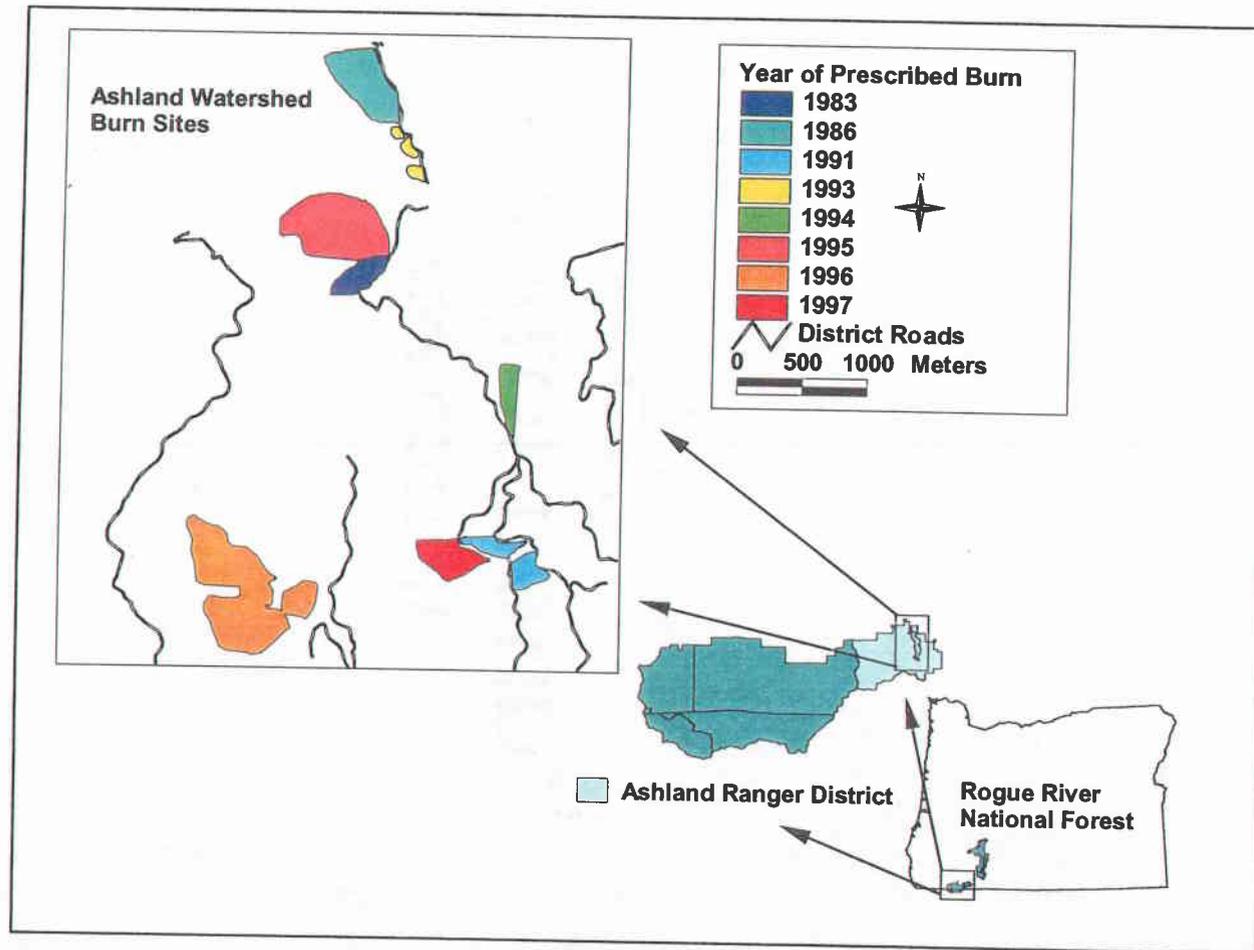
has on wood-boring beetles over time. Buprestid and cerambycid abundance (both at family and individual species level), from burned plots and adjacent, unburned control plots, was compared over a scale of time since burning.

## **3.2 Materials and Methods**

### ***3.2.1 Experimental Design and Site Description***

This study involved a survey of adult wood-boring beetles (Coleoptera: Cerambycidae, Buprestidae) on sites of past prescribed burns and on adjacent, unburned control plots in a paired plot design. All plots were located in the Ashland watershed of the Rogue River National Forest in the eastern Siskiyou Mountains of southwestern Oregon, approximately 122.7° W longitude and 42.2° N latitude (Fig. 3.1).

The eastern Siskiyou are characterized by loose, granitic soils on steep slopes. Mean annual temperature, from a NOAA remote weather station in Ashland, OR ([www.wrh.noaa.gov/Medford/quick/ashland.html](http://www.wrh.noaa.gov/Medford/quick/ashland.html)) is approximately 11.3 °C, with January mean temperatures of 3.3 °C and July mean temperatures of 20.7 °C. Mean annual precipitation is 48.7 cm (19.2 inches), with approximately 7.0 cm (2.8 inches) falling between June and September, and the remainder from October to May. Summers are dry and hot, and extended summer drought periods are common (Overhulser 1986). Franklin and Dyrness (1988) classify this area as predominantly ponderosa pine (*Pinus ponderosae*), often in association with Douglas-fir (*Pseudotsuga menziesii*), Pacific madrone (*Arbutus menziesii*), white fir (*Abies concolor*) at higher elevations, and several oak (*Quercus*) and manzanita (*Arctostaphylos*) species.



**Figure 3.1** Map of burn sites used in the retrospective study of the effects of burning on wood-boring insect populations. All sites are located in the Ashland Watershed of the Rogue River National Forest in southwestern Oregon.

Criteria used in selecting study sites included a mixed-conifer (ponderosa pine/Douglas-fir) stand composition, little to no silvicultural activities on the site in the past 50 years or through the summer of 1998, and the use of low severity prescribed underburns on the site performed for purposes of fuel reduction, vegetation removal and/or ecological restoration. Paired control plots were located as near as possible to burn study plots to reflect similar vegetation, elevation and aspect. Overall, 8 study plots were selected, covering a range of 1-15 years since prescribed burning, along with 8 unburned, control plots. Site characteristics are summarized in Table 3.1.

### 3.2.2 Adult Beetle Collection

Adult beetles were sampled with flight intercept traps constructed of lightweight corrugated, black plastic material and plastic collection cups. The intercept surface measured 30 cm x 43 cm (Fig. 3.2). Traps were placed a minimum distance of 50 m apart throughout each plot to evenly sample the burn and control plots, with six traps per plot. The 1995 burn site and its control were the only exceptions containing only 4 and 5 traps respectively, due to limited space. Traps were at an average height of 0.9 – 1.5 m off the ground. Traps were baited with a weak ethanol lure (270 $\mu$ L) in plastic centrifuge tubes. Release rates for these lures at a constant 25.6 °C (SE = 0.003) averaged  $1.52 \times 10^{-2}$  mg/day (SE =  $1.20 \times 10^{-3}$ ).

Traps were installed 22 – 29 June, 1998 and emptied every 20 days between July and September 1998. Insects collected were stored at -17.8 °C until they could be counted and identified. All buprestids and cerambycids were identified to species, with the exception of one subgenus of Buprestidae, *Melanthaxia*, which is currently under revision. All individuals identified as belonging to subgenus *Melanthaxia* were grouped as *Anthaxia* (sub:*Melanthaxia*) spp., and represented two species, *Anthaxia* (sub:*Melanthaxia*) *confusa* and *californica*.

**Table 3.1** Characteristics of plots used in retrospective study of the effects of burning on wood-boring insect populations. <sup>1</sup>Mass of woody debris measured using Brown's planar-intersect method for surveying downed woody material (Brown 1974).

Site	Average slope (%)	Aspect	Elevation(m)	Downed woody debris (kg/ha) <sup>1</sup>			Total
				2.5-7.6 cm (100 hr fuels)	7.6+cm sound (1000+ hr fuels)	7.6+cm rotten (1000+ hr fuels)	
1983 control	57.3	W/NW	1,100	2,251	1,915	5,759	9,926
1983 burn	64.8	W/NW	1,100	609	3,470	14,352	18,431
1986 control	36.3	W/SW	850	1,082	743	2,411	4,236
1986 burn	42.8	W/SW	850	1,169	853	974	2,996
1991 control	41.5	E/NE	1,340	1,760	6,958	5,647	14,365
1991 burn	52.8	E/NE	1,340	2,332	27,833	2,048	32,213
1993 control	48.0	SE/E/SW	920	2,683	4,028	14,269	20,979
1993 burn	39.2	W/NW	920	2,283	1,903	1,955	6,141
1994 control	56.5	E/NE	1,220	1,772	1,247	3,586	6,606
1994 burn	43.2	E/NE	1,220	3,731	3,319	321	7,371
1995 control	53.6	S/SE	1,000	2,494	6,512	8,006	17,012
1995 burn	53.5	S/SE	1,000	1,623	2,281	4,841	8,745
1996 control	40.7	N/NE	1,400	2,675	10,020	1,775	14,470
1996 burn	42.5	W/NW	1,400	1,711	1,964	2,157	5,832
1997 control	40.3	W/NW/N	1,280	2,313	7,074	9,095	18,482
1997 burn	72.2	S/SW	1,280	1,783	23,381	857	26,021



**Figure 3.2** Flight intercept trap used to collect flying adult wood-borers in the retrospective study of the effects of burning on wood-boring insect populations.

### **3.2.3 Downed Woody Debris Survey**

Downed woody debris was measured using Brown's planar-intersect method for surveying downed woody material (Brown 1974). Sixteen sampling transects were surveyed per plot, spaced 20 m apart. Because this study is primarily concerned with CWD chewing arthropods, only woody debris over 2.5 cm in diameter was surveyed. Presence of downed woody debris between 2.5 and 7.6 cm (1-3 in) in diameter was recorded using 3.66 m transects. For all downed woody material over 7.6 cm (3 in) in diameter, species and diameter were recorded as well as decay state (sound or rotten) using 15.25 m transects. Sound wood corresponded to decay classes I and II, while rotten wood corresponded to decay classes III and IV.

### **3.2.4 Site Characteristics**

For each plot, average slope was estimated from measurements taken at each trap location. Aspect was determined in the field for each plot. Average elevation was read from topographic maps.

### **3.2.5 Data Analysis**

Beetle abundance was calculated by dividing the total of each family or species collected on each plot by the number of traps in the plot (undamaged) multiplied by the number of days in the trapping period:

**Total caught (in one trapping period)**

**Number of open (undamaged) traps x Number of days in trapping period**

This value was then multiplied by ten to give abundance per ten trap days. Log transformations were taken for family abundance data to stabilize

unequal variance and non-normal distribution. Differences in abundance of adult beetles collected on burned and control plots were calculated for both families and the two most commonly collected species in each family and regressed against time. Log-transformed family abundance and individual species abundance was compared in one-sided paired t-test analyses to determine if abundance was higher in burned sites compared to unburned sites (regardless of time since burning).

Species richness (number of unique species collected) and Simpson's diversity index were calculated for all plots and compared in two-sided paired t-tests to determine if values differed between burned and unburned plots.

Simpson's diversity index is calculated as follows:

$$C = \sum_{i=1}^s (p_i)^2$$

where:  $s$  = total number of species in sample

$p_i$  = proportion of all individuals in the sample belonging to species  $i$

The reciprocal ( $1/C$ ) is then used as the species diversity index value. Simpson's diversity index was selected as the measure of diversity because it weights abundant species more heavily, therefore values tend to vary less from site to site with introduction of one or two rare species (Barbour et al. 1987, Magurran 1988). This was important given that several species collected in the study were represented by only one or two individuals all summer. Diversity indices, such as the Shannon-Wiener's index, are more sensitive to these rare collections and values can vary greatly from site to site (Magurran 1988).

Because woody debris in decay classes I and II compose the primary cerambycid and buprestid larval habitat, totals of sound woody debris (greater than 2.5 cm) were compared between burned and control plots in a two-sided paired t-test to determine if differences existed. Paired t-tests were used to compare cerambycid and buprestid abundance between burned and unburned plots, after adjusting for total amount of sound woody

debris as a covariate. Cerambycid and buprestid abundance was also regressed on sound woody debris, to determine if any relation existed, despite the presence or absence of prescribed burning.

### **3.3 Results**

#### **3.3.1 Adult Beetle Collection**

A total of 115 cerambycids and 984 buprestids were collected during the summer of 1998. Twenty species of Cerambycidae and 7 species of Buprestidae were identified (Table 3.2 and 3.3). *Trachysida aspera* LeConte and *Anastrangalia laetifica* (LeConte) comprised over half of all cerambycid species caught. *Anthaxia* (sub:*Melanthaxia*) spp. made up over 90% of all buprestids caught, with *Buprestis aurulenta* L. as the only other species found in relatively high abundance (6.5%).

There were no significant correlations between differences in either median cerambycid or buprestid abundance and time since burning ( $R^2=0.05$ ,  $P=0.60$ , and  $R^2=0.04$ ,  $P=0.65$ , respectively) (Fig. 3.3). Abundance for both families was highest the first year after burning.

For all four species analyzed, no significant correlations with time since burn existed (Figs. 3.4 and 3.5). All four species were in highest abundance in the most recently burned site.

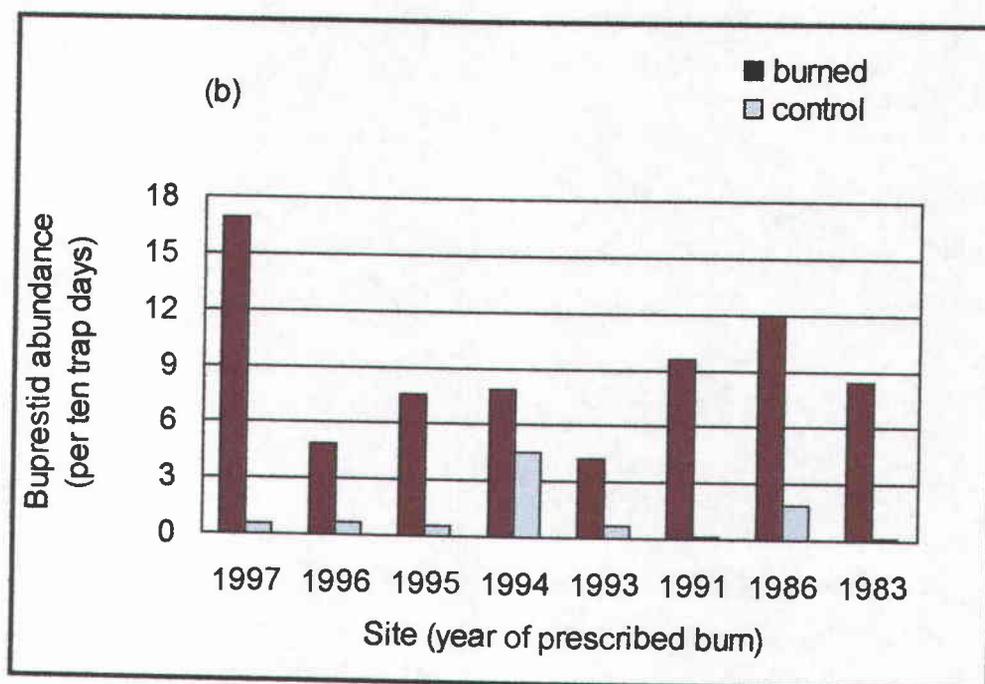
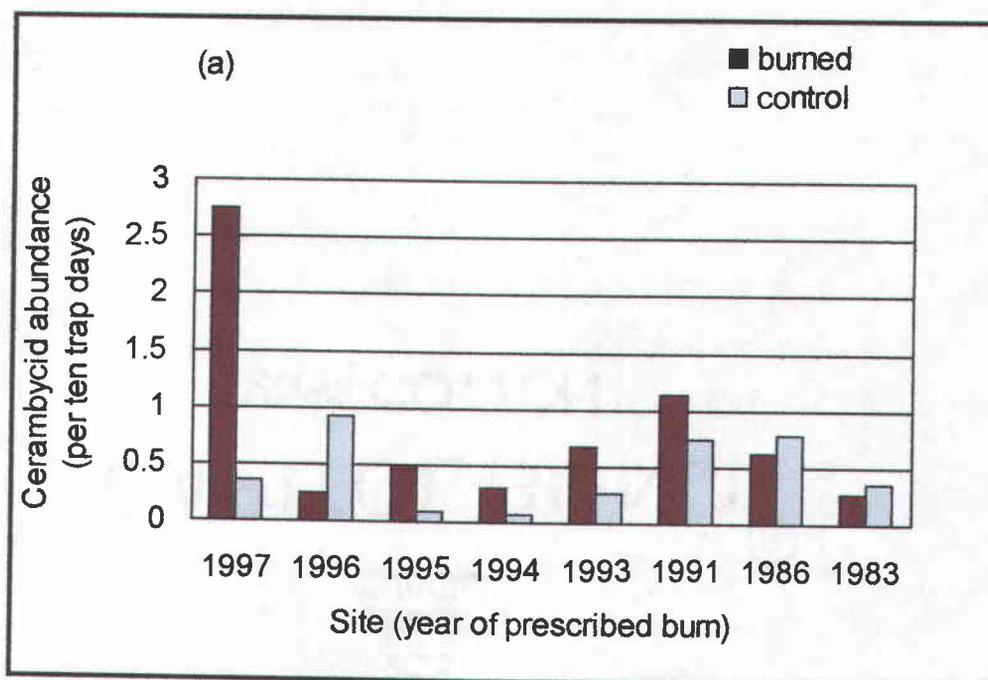
Median cerambycid abundance in burned plots was 1.8 times higher (95% CI: 0.68-4.70) than in control plots, however, a paired t-test showed no statistically significant difference ( $P=0.10$ ) (Fig. 3.6a). Buprestid abundance was significantly higher in the burned plots ( $P=0.0004$ ) (Fig. 3.6b), with median buprestid abundance 13.8 times higher (95%CI: 4.54-42.01) in burned than in control plots.

**Table 3.2** Cerambycid species collected by flight traps in the retrospective study. AC=*Abies concolor*, PM=*Pseudotsuga menziesii*, PP=*Pinus ponderosae*, TH=*Tsuga heterophylla*. Host plants from <sup>1</sup>Linsley and Chemsak (1997) , <sup>2</sup>Yanega (1996).

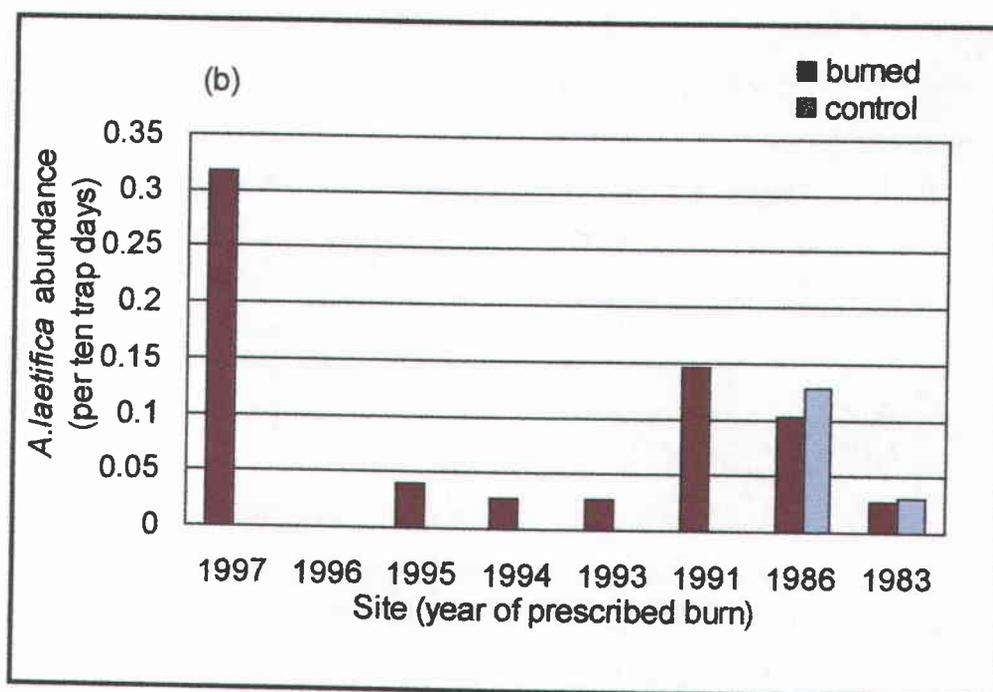
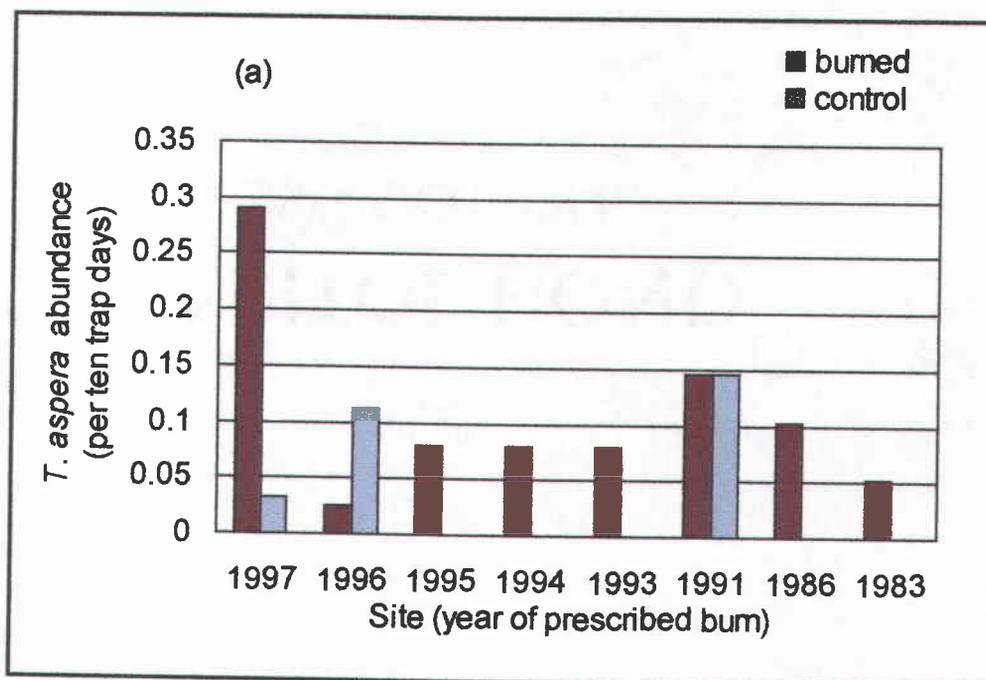
Cerambycidae Species:	Percent of		Associated Hosts:
	Total:	total caught:	
<i>Neolosterna rubida</i> (LeConte)	1	0.9	<i>Tsuga, Abies</i> <sup>1</sup>
<i>Anastrangalia laetifica</i> (LeConte)	31	27.0	<i>Pinus</i> <sup>1</sup>
<i>Anastrangalia sanguinea</i> (LeConte)	1	0.9	<i>Pinus</i> <sup>1</sup>
<i>Arhopalus asperatus</i> (LeConte)	6	5.2	AC, PP, PM <sup>1</sup>
<i>Asemum nitidum</i> LeConte	3	2.6	<i>Abies, Pinus, PM</i> <sup>1</sup>
<i>Brachyleptura dehiscens</i> (LeConte)	1	0.9	<i>Pinus, PM</i> <sup>1</sup>
<i>Brachyleptura vexatrix</i> Mannerheim	3	2.6	relatives found on <i>Quercus, Tsuga, Pinus</i> <sup>1</sup>
<i>Clytus pacificus</i> VanDyke	4	3.5	PM <sup>1</sup>
<i>Cosmosalia chrysocoma</i> (Kirby)	4	3.5	<i>Alnus, Picea, Pinus, Populus</i> <sup>1</sup>
<i>Dicentrus bluthneri</i> LeConte	1	0.9	AC, PM <sup>1</sup>
<i>Evodinus monticola vancouveri</i> Casey	5	4.3	<i>Abies, PM</i> <sup>1</sup>
<i>Leptura oblitterata</i> Halderman	1	0.9	<i>Abies, Picea, Pinus, PM, Tsuga</i> <sup>1</sup>
<i>Megasemum asperum</i> (LeConte)	1	0.9	<i>Abies, PM</i> <sup>1</sup>
<i>Molorchus bimaculatus californicus</i> Linsley	2	1.7	<i>Rhododendron occidentale</i> <sup>1</sup> ; most hardwoods <sup>2</sup>
<i>Ortholeptura valida</i> LeConte	3	2.6	AC, PP, PM, <i>Tsuga</i> <sup>1</sup>
<i>Phymatodes aeneus</i> LeConte	2	1.7	PM, TH <sup>1</sup>
<i>Phymatodes dimidiatus</i> (Kirby)	1	0.9	<i>Picea, Pinus, PM, Tsuga</i> <sup>1</sup>
<i>Trachysida aspera</i> (LeConte)	41	35.7	<i>Abies</i> <sup>2</sup> ; <i>Betula, Picea, Pinus, Populus deltoides, PM, Salix</i> <sup>1</sup>
<i>Xestoleptura crassipes</i> (LeConte)	1	0.9	<i>Pinus, PM, Thuja plicata, Tsuga</i> <sup>1</sup>
<i>Xylotrechus longitarsus</i> Casey	3	2.6	PM <sup>1</sup>
Total	115	100	

**Table 3.3** Buprestid species collected by flight traps in the retrospective study. AC=*Abies concolor*, PM=*Pseudotsuga menziesii*, PP=*Pinus ponderosae*, TH=*Tsuga heterophylla*. Host plants from <sup>1</sup>Bright (1986), <sup>2</sup>Chamberlain (1924), <sup>3</sup>Furniss and Carolin (1977).

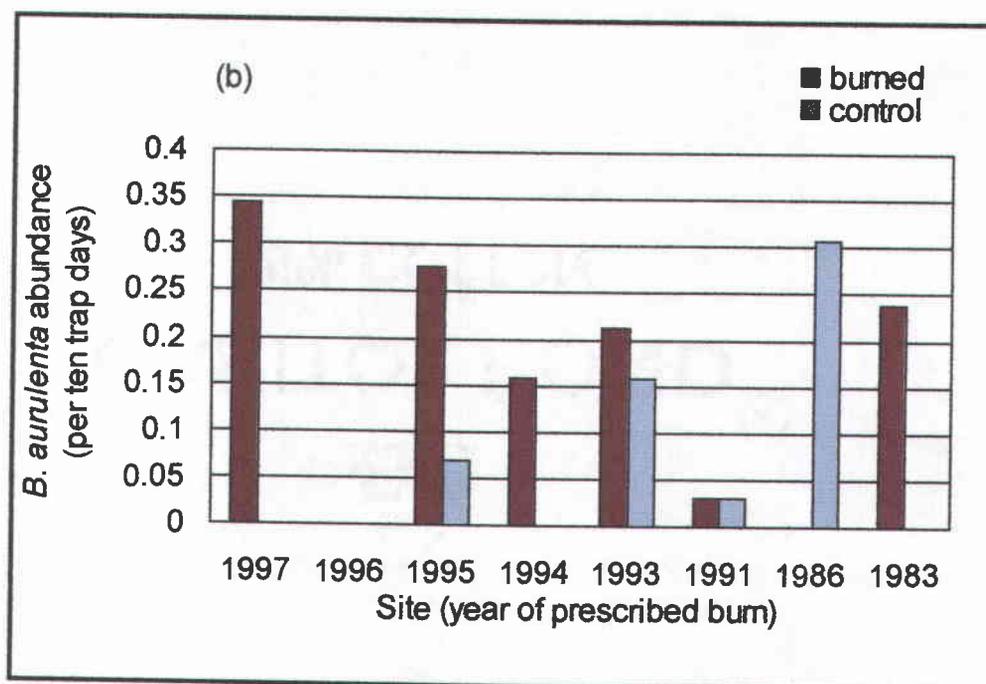
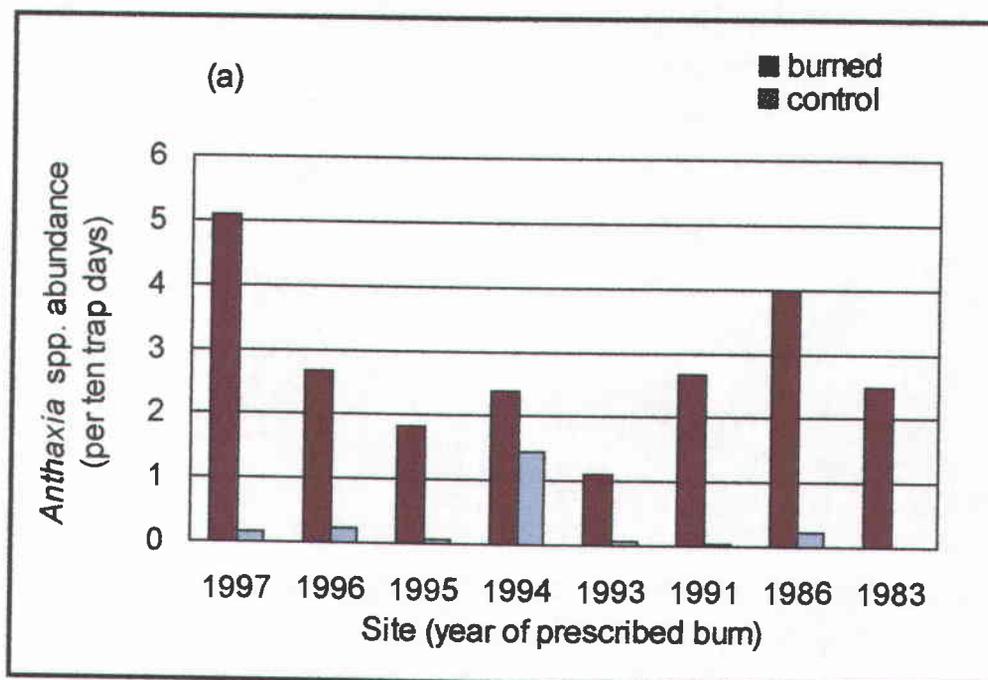
Buprestidae species:	Total:	Percent of total caught:	Associated Hosts:
<i>Anthaxia</i> (sub: <i>Melanthaxia</i> ) spp.	894	90.9	<i>Abies</i> <sup>3</sup> , <i>Quercus</i> <sup>2</sup> , <i>Pinus</i> <sup>3</sup> , PM <sup>3</sup> , <i>Rhododendron</i> <sup>2</sup> , <i>Salix</i> <sup>2</sup> , <i>Sequoia</i> <sup>3</sup>
<i>Buprestis aurulenta</i> L.	64	6.5	AG, <i>Pinus</i> , PM, <i>Thuja plicata</i> <sup>1</sup>
<i>Buprestis lyrata</i> Casey	3	0.3	AG, PP, PM <sup>1</sup>
<i>Chalcophora angulicollis</i> (LeConte)	9	0.9	<i>Abies</i> , <i>Pinus</i> , PM <sup>3</sup>
<i>Chrysophana placida</i> (LeConte)	3	0.3	<i>Abies</i> , <i>Pinus</i> , PM, <i>Tsuga</i> <sup>3</sup> ; <i>Thuja plicata</i> <sup>1</sup>
<i>Dicerca crassicolis</i> (LeConte)	9	0.9	<i>Abies magnifica</i> , PM, PP <sup>1</sup>
<i>Phaenops drummondi</i> (Kirby)	2	0.2	<i>Abies</i> , <i>Larix</i> , <i>Picea</i> , PM, TH <sup>3</sup> ; (rarely on <i>Pinus</i> ) <sup>1</sup>
Total	984	100	



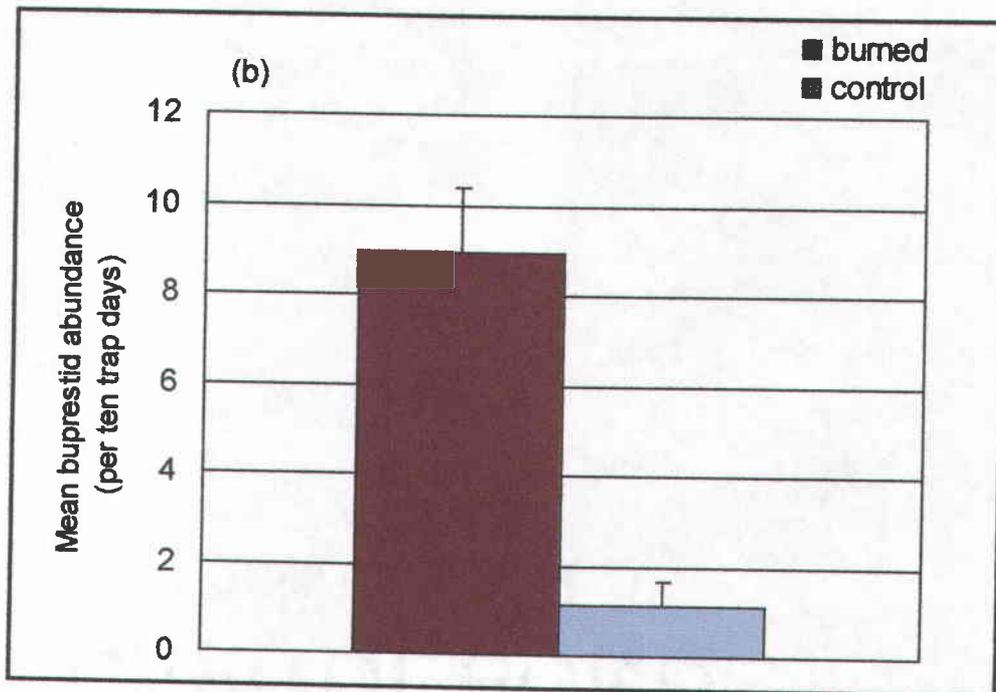
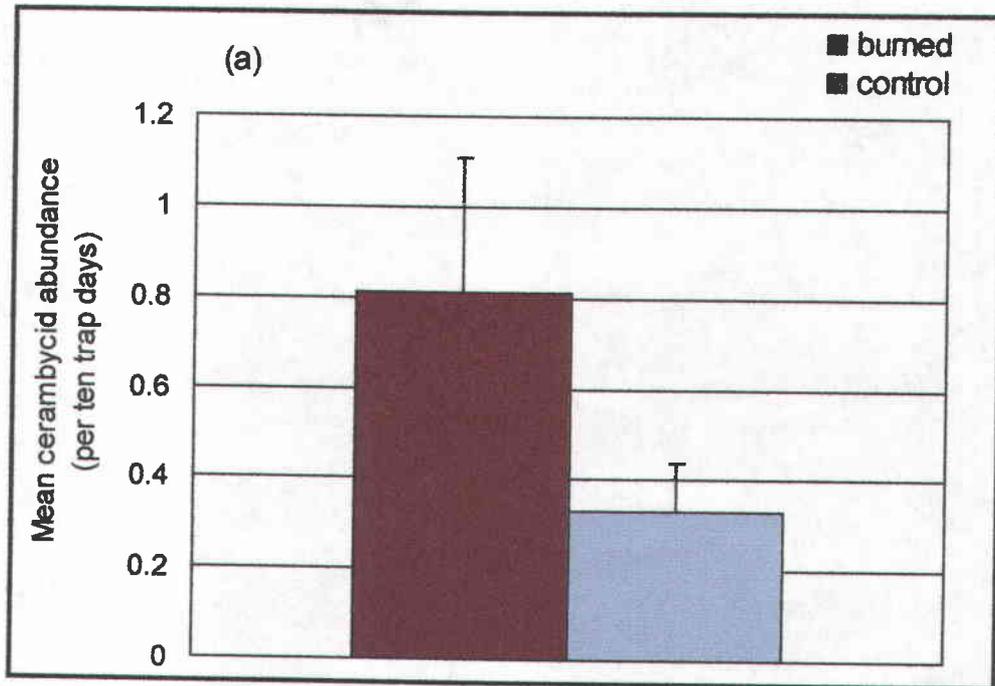
**Figure 3.3.** Differences in cerambycid (a) and buprestid (b) abundance between burned and control sites.



**Figure 3.4.** Difference in abundance between burned and control sites for the two most commonly collected cerambycid species, *Trachysida aspera* (a) and *Anastrangalia laetifica* (b).



**Figure 3.5.** Difference in abundance between burned and control sites for the two most commonly collected buprestid species, *Anthaxia* (sub:*Melanthaxia*) spp. (a) and *Buprestis aurulenta* (b).



**Figure 3.6.** Mean abundance of cerambycids (a) and buprestids (b) in burned and control sites.

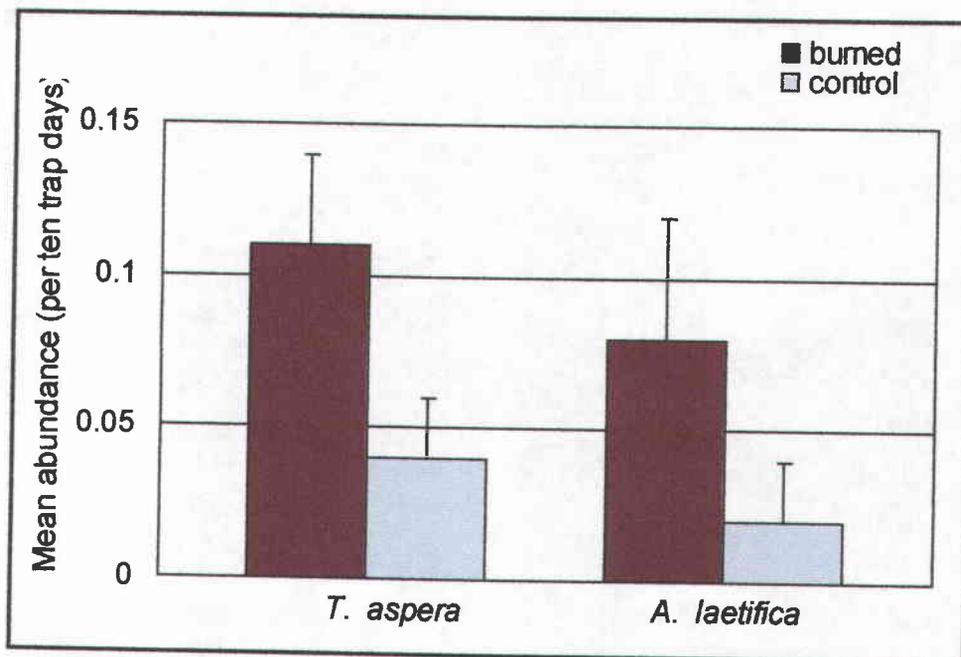
Of the two most numerous cerambycid species analyzed, *T. aspera* abundance was significantly higher in burned than in control sites ( $P=0.04$ ), but *A. laetifica* was not ( $P=0.07$ ) (Fig. 3.7). The buprestid species *Anthaxia* (sub: *Melanthaxia*) spp. was significantly more abundant in burned sites ( $P=0.0006$ ), but there was no difference in abundance of *B. aurulenta* between burned and unburned sites ( $P=0.13$ ) (Fig. 3.8)

Neither species richness nor Simpson's indices were significantly different for burned and control sites ( $P=0.24$  and  $P=0.25$ , respectively) (Fig. 3.9).

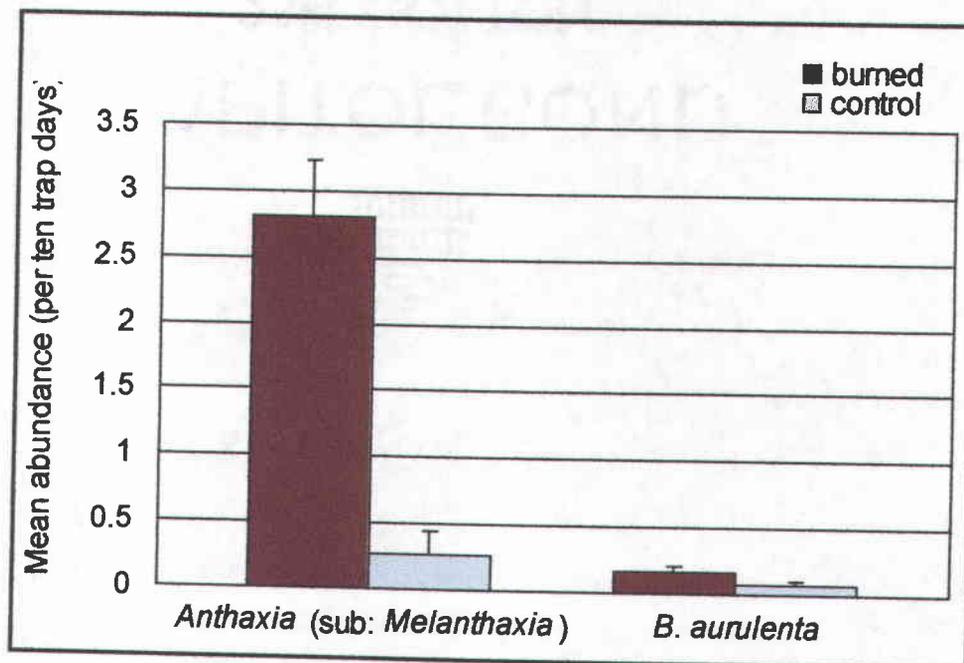
### 3.3.2 Downed Woody Debris Survey

Amounts of downed woody debris for all plots are listed in Table 3.1. There was no difference between burned and control plots in sound woody debris mass ( $P=0.43$ ) (Fig. 3.10). Precision in estimating abundance of cerambycids and buprestids was not significantly improved by including sound woody debris as a covariate. The covariate did not explain a significant portion of the variation in paired comparisons of cerambycid ( $P=0.33$ ) or buprestid abundance ( $P=0.25$ ) between burned and unburned plots.

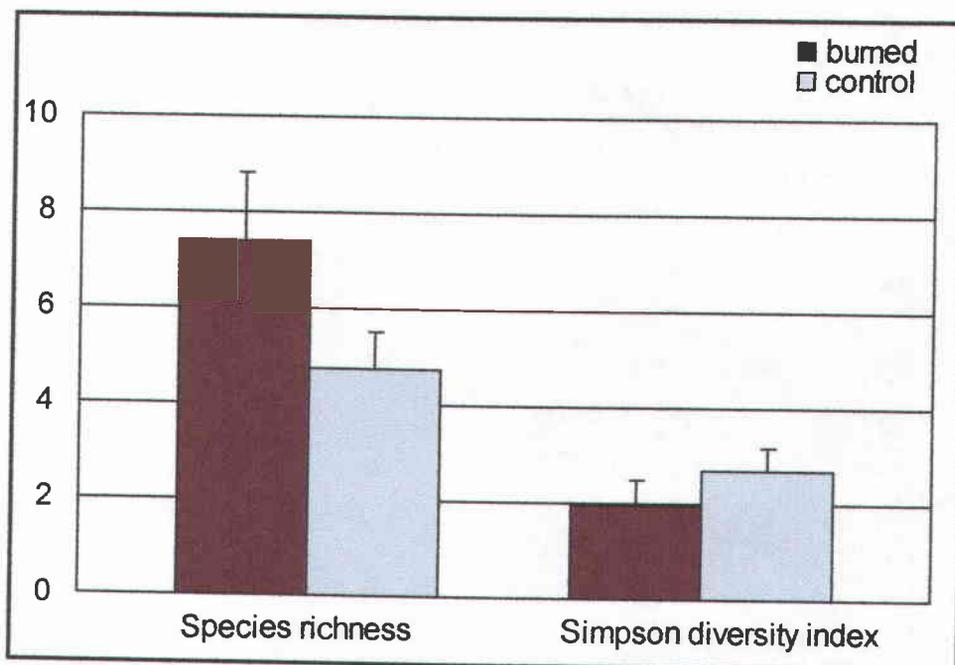
When cerambycid and buprestid abundance was regressed on amount of sound woody debris, regardless of burning, there was a significant relationship between sound woody debris and cerambycid abundance ( $R^2=0.50$ ,  $P=0.002$ ) (Fig. 3.11a). Buprestid abundance was not significantly correlated to sound woody debris ( $R^2=0.17$ ,  $P=0.11$ ) (Fig. 3.11b).



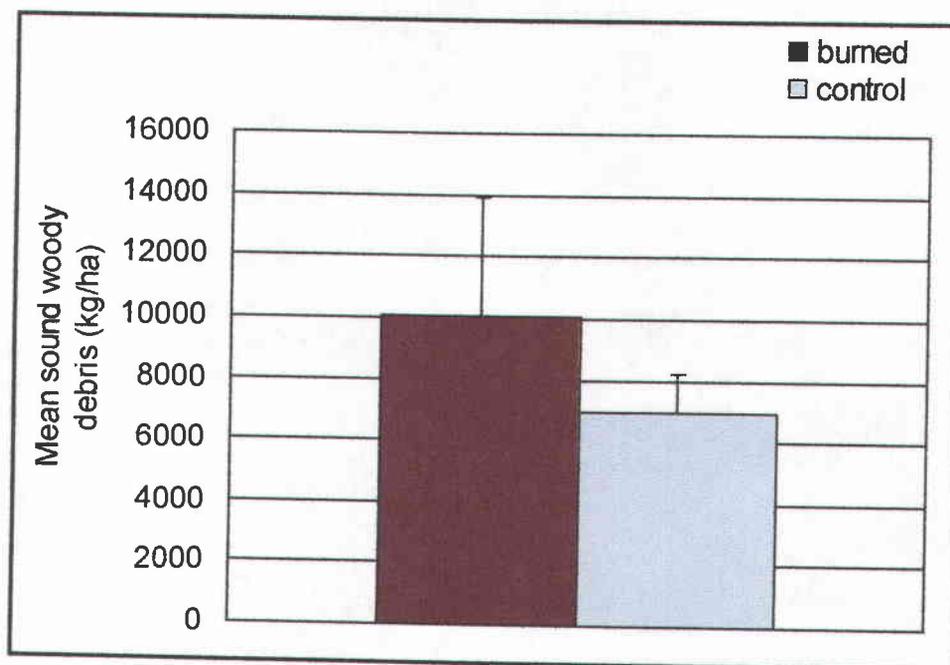
**Figure 3.7.** Mean abundance (SE) of cerambycid species *T. aspera* and *A. laetifica* in burned and control sites.



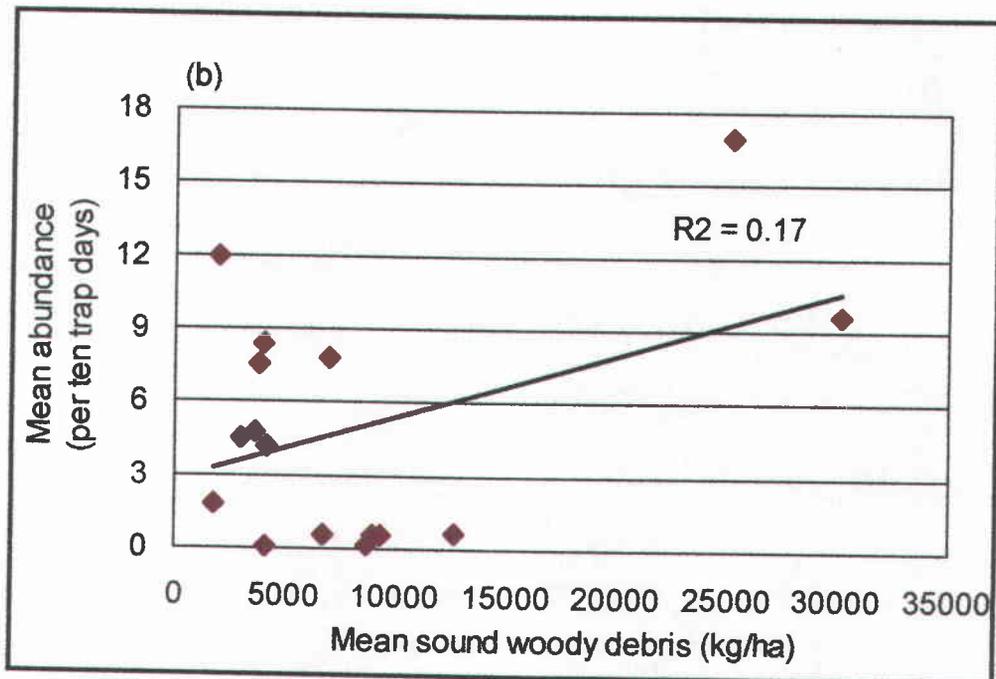
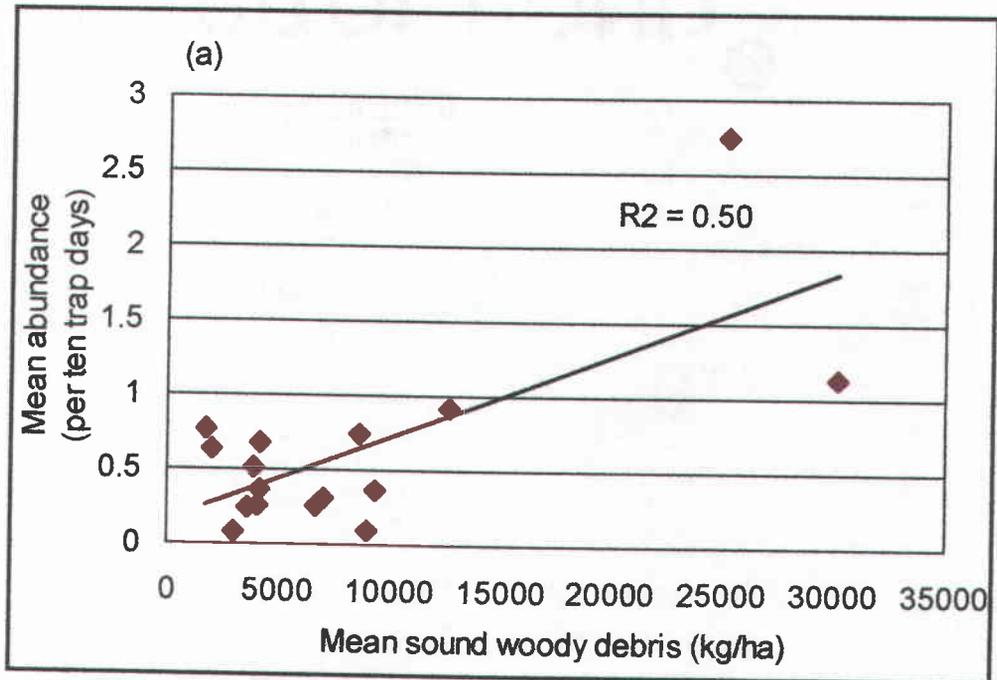
**Figures 3.8.** Mean abundance (SE) of buprestid species *Anthaxia* (sub: *Melanthaxia*) spp. and *B. aurulenta* in burned and control sites.



**Figure 3.9.** Species richness and Simpson diversity index values for burned and control sites.



**Figure 3.10.** Mean (SE) sound woody debris in burned and control sites.



**Figure 3.11.** Mean abundance of cerambycids (a) and buprestids (b) against mean sound woody debris from all sites (burned and control).

### 3.4 Discussion

Difference in family abundance, between burned and control plots, for both cerambycids and buprestids was not shown to be correlated with time since burning. This could be due to several factors. First, the life cycles of wood-boring beetles are known to vary greatly, both from species to species and within species themselves, depending on the nutritional quality of the host material (Eaton and Hale 1993, Furniss and Carolin 1977, Maser and Trappe 1984). While some beetles require only one year or less for larval development, other species feed in the phloem, sapwood, and heartwood for several years (Furniss and Carolin 1977). Traps could be sampling both adult beetles arriving at the site to capitalize on new food sources and those beetles emerging a year to several years after the prescribed burn. One way to correct for this would be to examine only trees killed by the burn, or monitor areas immediately following burning and for several years afterwards, for subsequent attack. Rasmussen et al. (1996) did this to some extent following the Yellowstone fires of 1988 monitoring attack of fire-killed or injured trees by both bark beetles and wood-borers. However, most studies monitoring arrival of wood-borers to fire-killed or injured timber has been conducted to determine rates of deterioration in order to implement salvage efforts after fire (Kimmey 1955, Kimmey and Furniss 1943, Lowell et al. 1992).

Background "noise" due to variations in site characteristics and treatment applications may have contributed to the study's inability to detect any relationship in abundance over time. Powers (1989) discusses limitations of retrospective studies, such as limited choice of controls and lack of control over treatment applications. However, due to the limited number of study sites available, accounting for numerous site characteristics as covariates, such as percent cover, slope, aspect, area of burn, and fire intensity or severity, was not possible.

Despite lack of statistically significant correlations, it is apparent that family abundance follows a distinct trend (Fig. 3.3). Both families are highest in abundance on the most recently burned site. Several sources note that wood-borer attack is highest in the first few years post-fire, especially directly after burning (Kimmey 1955, Rasmussen et al. 1996, McCullough et al. 1998). This peak in abundance could be reflecting both individuals with one year life cycles attracted to the fresh burn and emerging the following summer, as well as other species attracted to new woody debris created by delayed mortality from the burn.

The results of the paired t-tests indicate both families tend to be higher in abundance in burned sites, buprestids more so than cerambycids. Both families are often associated with the attack of fire-killed and injured trees or fire scars on standing trees (Furniss and Carolin 1977, Duncan 1981, Lowell et al. 1992, McCullough et al. 1998, Rasmussen et al. 1996). Some cerambycids have been observed to be attracted to fires, such as Wickman's (1964) observation of *Arhopalus asperatus* swarming to burning pines, but the family is equally associated with attack of trees killed by other agents such as insects, pathogens, windthrow or logging slash (Parmelee 1941).

Several buprestid species are attracted to smoke and fire, particularly in the genus *Melanophila*, now subdivided into *Melanophila* and *Phaenops*. Several sources refer to *Melanophila* flying distances over 50 miles to smoke and fire (Champion 1909, Evans 1962, Linsley 1933, Linsley 1943). The genus *Buprestis*, which is represented in this study by two species, is also attracted to fire-damaged timber (Duncan 1981). Buprestids were higher in abundance in burned sites and while no causal inferences can be made, it can be inferred that they are responding positively to prescribed burning.

A comparison of sound woody debris revealed no differences between burned plots and their controls, so differences in abundance noted above were not due to a difference in food resources. Cerambycid abundance was positively correlated with increasing sound woody debris (Fig. 3.11a). This

would be expected as a larger food source would promote larger populations of wood-borers in general. However, the correlation was not significant when buprestid abundance was regressed on sound woody debris (Fig. 3.11b). While cerambycids may be more closely linked to amount of woody debris alone, buprestids seem to respond more favorably to burning, as discussed above. Sound woody debris mass however was not a significant covariate and did not account for any extra variation.

*Trachysida aspera* comprised 27% of all cerambycids caught (Table 3.2). Linsley and Chemsak (1997) list its primary hosts as *Picea*, *Pinus*, *P. menziesii* and *Salix*. It was a fairly common species throughout all sites, but was significantly higher in abundance on burned sites (Fig. 3.7). Furniss and Carolin (1977) associate *T. aspera* with attack of fire-scorched trees, as well as those hit by drought or other insect infestation. Little else could be found regarding its biology and behavior. As with most of the cerambycids collected, *T. aspera* was most abundant in the most recently burned site (Fig. 3.4a). Furniss and Carolin (1977) report one generation annually, which corresponds to my findings that brood resulting from adults attracted to the burn the previous year would be emerging and collected in high abundance in the first post-fire year.

*Anastrangalia laetifica* comprised almost 36% of cerambycids caught (Table 3.2). Linsley and Chemsak (1997) list its primary host as *Pinus*. Very little of this species' biology or behavior could be found in the literature. There was suggestive but inconclusive evidence that *A. laetifica* was more abundant in burned sites, suggesting it might respond somewhat favorably to prescribed burning (Fig. 3.7). *A. laetifica* was also most abundant in the most recently burned site (Fig. 3.4b).

*Anthaxia* (sub:*Melanthaxia*) spp. made up 91% of all buprestids caught (Table 3.2). The small size of *Anthaxia* probably played the largest role in why so many were collected. While most species of Buprestidae and Cerambycidae collected are over several centimeters in size, *Anthaxia* spp.

are no more than 3-5mm in length and were more likely to fall directly into the trap's funnel. Larger species may have bounced away from the trap's intercept surface, missing the funnel completely.

More information was found in the literature regarding *Anthaxia* spp. Furniss and Carolin (1977) list its primary hosts as *Abies*, *Pinus*, *Pseudotsuga* and *Sequoia*, while Chamberlain (1924) also gives *Salix*, *Quercus*, *Rhododendron* and other broad-leaved trees and shrubs as host species. Larvae feed mostly in branches and twigs. *Anthaxia* abundance was significantly higher in burned plots (Fig. 3.8). While no sources could be found referring to *Anthaxia* attraction specifically to burned trees or areas, it is likely they are attracted to downed woody debris made available directly or indirectly by burning.

*Buprestis aurulenta*, or the golden buprestid, made up about 7% of all buprestids caught and was the only other buprestid species collected in great numbers throughout the summer (Table 3.3). Much more is known about *B. aurulenta* because it is considered a species of economic importance. Furniss and Carolin (1977) list *Pinus* and *Pseudotsuga* as its major hosts, where it is known to mine near fire scars, in fire-killed or injured trees, as well as salvaged and untreated wood in lumber yards (Duncan 1981). Even though it is often associated with mining of fire killed trees, there was no significant difference in its abundance on burned and unburned sites (Fig. 3.8).

*B. aurulenta* is also highest in abundance on the most recently burned site (Fig. 3.5b). However, its abundance in both the burned and control plots fluctuates greatly. *B. aurulenta* is noted for extreme variation in its life cycle. While normal development usually takes from 2-4 years, some sources note *B. aurulenta* emergence from treated timber or wood low in nutritional value as many as 15-55 years later (Duncan 1981). The pattern of abundance, or lack thereof, could be due to these life cycle variations.

Other cerambycid and buprestid species collected are listed in Tables 3.2 and 3.3, but very few were in high enough abundance to warrant further examination. Several species are quite common, such as *Arhopalus asperatus*, *Evodinus monticola vancouveri*, *Chalcophora angulicollis* and *Dicerca crassicollis*, but perhaps our traps were not best suited to capture all species evenly and abundantly. While no one trap is best suited to capture all types of wood-borers, future research might benefit by using several sampling methods, such as sweepnetting or vegetation beating, as most adults tend to feed on conifer needles or understory flowers (Furniss and Carolin 1977, Linsley and Chemsak 1997, Scott 1979, White 1983). Combining sampling methods, perhaps with multiple funnel traps, could increase numbers of individuals caught and give a better picture how each species is responding.

While species richness did not differ significantly from burned to unburned plots, mean species richness was approximately 1.5 times higher in the burned plots (Fig. 3.9). The highest measure of richness was found in the most recent burn. These results are possibly due to the immediate attraction of a larger number of species to the newly burned areas.

Simpson's diversity index was also not significantly different between burned and unburned plots (Fig. 3.9). However, sample sizes in this study were too small to give an accurate picture of species diversity. Often, only a few individuals represented many of the species collected.

#### 4. Conclusions

Fire, both natural and prescribed, has a profound effect on the dynamics of downed woody debris and organisms dwelling within it. The objective of this study was to examine the response of wood-boring beetles to disturbance by prescribed burning. Because the effects of burning can vary greatly, even within one burned area, it was important to examine these effects at both the individual log and stand levels.

It is difficult to draw any conclusions or inferences from the experimental log study, given that the treatments were not applied as planned. The prescribed understory burn was of very low intensity. The impact of the fire on the 7 logs which did burn was very low, represented by only external charring and no bark consumption. Results in the log study did not suggest that logs charred in the prescribed burn were more attractive or utilized by wood-borers. Yet, utilization of logs for habitat did not seem to be hindered by burning, as levels of consumption were similar to that of unburned logs in my study and other studies found in the literature. However, results (here and in the literature) suggest that logs approaching 100% scorching become less suitable habitat for wood-borers, as bark is consumed and phloem dries out. A higher degree of burn severity might be expected, on a broader scale, in severe wildfires. The goal of prescribed burning is to reduce the risk of these severe wildfires, a risk which has grown with the practice of fire suppression and subsequent fuel accumulation. Smaller, low-severity prescribed burns may be able to reduce these risks while not rendering coarse woody debris habitat unsuitable for wood-boring beetles.

At the stand level, the retrospective study showed the response of wood-boring beetles to prescribed burning to be significantly more favorable. Adult wood-boring beetles were almost always higher in abundance in burned sites, up to fifteen years later. These results support the idea that insects and fire are interdependent disturbance forces. While prescribed burning

consumes some downed woody debris, it also kills or damages live vegetation, producing additional habitat material immediately and indirectly for years afterward. Wood-borers, initially attracted to the site by smoke and fire, then capitalize on the newly available food sources.

The results of my studies suggest that prescribed burning in the Ashland watershed is generating favorable habitat for wood-boring beetles, particularly when the goal of these prescribed burns is to reduce the incidence of more severe wildfires previously uncharacteristic of this region. While currently no wood-boring beetles are threatened or endangered, they play a vital role in nutrient cycling and decomposition and are central to the diet of important wildlife species. Continuing to create suitable habitat for wood-boring beetles may be essential to maintaining forest ecosystem health in mixed-conifer forests of Southwestern Oregon.

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