AN ABSTRACT OF THE THESIS OF

Kathy L. (Connelly) Pendergrass for the degree of Master of Science in Rangeland Resources presented on May 4, 1995.

Title: Vegetation Composition and Response to Fire of Native Willamette Valley Wetland Prairies.

Abstract approved:

J. Boone Kauffman

Fires set by Native Americans were important in shaping and maintaining Willamette Valley prairie plant communities. With fire exclusion after Euro-American settlement in the 1840's, composition of the remaining prairies shifted toward shrub and tree dominance with a concomitant decline in endemic prairie plant populations. I hypothesize that by restoring fire as an ecosystem process native prairie flora would be enhanced by invigorating vegetative growth of natives, by controlling exotic species, and by controlling successional invasion of woody species. Additionally, I hypothesize that native prairie composition might be better enhanced by multiple burns compared to a single burn.

Initial vegetation composition, fuels, fire behavior, and subsequent changes in plant composition following fire were quantified in a total of five plant communities at Rose Prairie and Fisher Butte study sites near Eugene, Oregon. Three treatments were assessed over three years (unburned control, and once burned, and twice burned).

A total of 205 species were observed. Species richness was dominated by native forbs in all five plant communities. In contrast, vegetative cover was dominated by native perennial graminoids in all communities except one where exotic perennial graminoids dominated. *Rosa nutkana* was the most prevalent woody species in all communities. Initial preburn *R. nutkana* densities ranged from 30,519 to 50,963 plants ha$^{-1}$ at Rose Prairie and from 17,156 to 53,067 ha$^{-1}$ at Fisher Butte.

Fisher Butte had more tree encroachment relative to Rose Prairie. Most trees at both sites were seedlings and saplings, ranging between 3 to 70 cm in height. Total tree density initially ranged from 0 to 568 trees ha$^{-1}$ and from 430 to 1,071 ha$^{-1}$ at Fisher Butte where *Fraxinus latifolia* was invading the wet *Rosa/Juncus* community.

Total above ground biomass of Willamette Valley wetland prairies was greater than that of many other North American grasslands ranging from 6,958 to 12,038 kg ha$^{-1}$. The first season following one burn, above ground biomass decreased significantly in one community (-25.4%) and increased significantly in another (+68%).

Response to burning was often inconsistent and varied greatly by species among plant communities. Native as well as exotic species increased in frequency or cover with burning. Eight native perennials and three native annuals established or significantly increased frequency (p = 0.1) in burned areas in two or more plant communities. Four exotic perennials and one exotic annual increased significantly in frequency following fire. Although frequency of *Deschampsia cespitosa* increased in burn treatments, cover declined significantly in the first postfire year following one burn, indicating a shift from fewer large plants to a greater number of smaller plants immediately following burning.

Significant increases in vegetative cover occurred in burned areas in two Rose Prairie communities and in one Fisher Butte community, due primarily to changes in cover of perennial graminoids. Total cover of exotic species increased following one or two burns in all but one community. Significant increases in exotic forb cover occurred in two communities.

After two burns, relative frequency of native perennial forbs increased significantly in three communities. Relative frequency of exotic perennial graminoids declined significantly in burn treatments in all but one community where they increased in the control treatment. Native annual forbs increased in burns in all but one community.

Increases of woody biomass, frequency, and cover following burning suggest that Willamette Valley wetland prairie woody plants are highly resilient to burning and quickly recover and increase following fire. However, height of woody plants significantly declined following burning leading to an improved prairie structure. In addition, the number of *Fraxinus latifolia* seedlings and saplings were significantly reduced in burn treatments in the *Rosa/Juncus* community.

Fire behavior and fuel conditions in relation to vegetation response are required to develop optimal frequency and intensity of burn prescriptions. Information on the response of native, woody, exotic plants, and aboriginal food plants will assist land managers in determining optimal fire frequency for burning Willamette Valley wetland prairies to maintain and enhance desired species. This research initiates a long-term assessment of fire effects on Willamette Valley vegetation to determine optimal burn prescriptions for wetland prairies.

# VEGETATION COMPOSITION AND RESPONSE TO FIRE OF NATIVE WILLAMETTE VALLEY WETLAND PRAIRIES

by

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Kathy L. Pendergrass

Kathy L. (Connelly) Pendergrass, Author

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Dr. J. Boone Kauffman was involved in the design, analysis, and writing of each manuscript. Dr. Patsy M. Miller contributed invaluable assistance in the analysis and writing of Chapters 1, 4 and 5. Dr. Robert Frenkel, Dr. Patsy Miller, David P. Pilz all contributed invaluable editorial advise on all chapters.

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# DEDICATION

I dedicate this thesis effort to the spirit of my father, William Paul Pendergrass, to the spirit of my loyal dog-companion, Mocha, and to all the positive forces in my life that kept me going when I wanted to leave this planet.

Feet planted on earth,
 stretch high,
  touch the sky,
   feel the sun!!

**A Prayer to Gaia** by Sedonia Cahill

Great Mother, I am your daughter and I call to you
Teach me courage and kindness and how to love myself
Help my heart be pure and my vision clear
Show me how to live without bitterness and blame
Let me know nature which is always true
Fill me with your silence as I learn the art of patience
Teach me of my own power and purpose
Send me your light as you guide me into your dark cave
Hold me when I am afraid
Help me to see there is no fault in the Universe - only life dancing
Reveal to me that timeless space inside where the dance has no beginning
  and no end
Fill me with wonder as I touch once again the delicate magic that is life
In my heart there is much longing
I am ready to face whatever your Mystery may unveil.

# VEGETATION COMPOSITION AND RESPONSE TO FIRE OF NATIVE WILLAMETTE VALLEY WETLAND PRAIRIES

## CHAPTER 1

## INTRODUCTION

Fires are an important ecological process in maintaining prairie and grassland ecosystems throughout the world (Daubenmire 1968, Vogl 1974, Kucera 1981, Hulbert 1988, Collins and Wallace 1990). They influence ecosystem functions including plant regeneration, nutrient cycling, successional development, and vertebrate habitat alterations (Kilgore 1981, Volland and Dell 1981, Boerner 1982, Martin 1982, Wright and Bailey 1982). However, few studies have focused on the response of Willamette Valley prairie plant communities to burning (Streatfeild 1995).

The first human inhabitants in the Willamette Valley, the Kalapuya, arrived during a period of warmer and drier climate when this region presumably supported an extensive prairie ecosystem (11,500 to 8,000 BP) (Hansen 1947, Hansen 1967, Aikens 1993). As the climate cooled and precipitation increased, trees and shrubs were able to invade and establish from seed sources at the prairie edge (Thilenius 1968). Kalapuya burning maintained these prairies until Euroamerican settlement.

Prairie fires were extensive throughout the Willamette Valley during initial Euroamerican settlement. Early trappers and explorers described burned regions extending the entirety of the Willamette Valley (Habeck 1961, Johannesen et. al

1971). The Kalapuyas ignited most fires from late summer into early fall (August-September) (Clarke 1905, Sprague and Hansen 1946, Habeck 1961, Johannesen et al. 1971). The fire return interval (the number of years between two successive fires) at a particular site is unknown. Different Willamette Valley habitat types were perhaps burned at specific frequencies to attain desired plant response such as to maintain low underbrush in woodlands or to maximize *Camassia* spp. or *Madia* spp. production. Prairies may have been burned biennially, however, specifics on burning frequencies were not recorded in journal accounts of early explorers and pioneers (Atrozut 1955 in Boyd 1986).

At the onset of Euroamerican settlement the Willamette Valley consisted of an expansive prairie with occasional solitary oaks, scattered tracts of open-grown oak woodlands, and dense floodplain forests associated with rivers and streams (Habeck 1961, Johannesen et. al 1971). With the extirpation of Kalapuyans through disease and displacement, fire exclusion on these native ecosystems began in the 1840's and has largely continued since that time. Fire exclusion has resulted in succession to woodlands and forests of many former prairie areas (Clarke 1905, Sprague and Hansen 1946, Thilenius 1968). Prairies were maintained in some places by continued use of fire by settlers and by grazing (Boag 1992, Frenkel and Heinitz 1987, Streatfeild 1995). However, most prairies have been lost to forest succession, urbanization, and intense agricultural and pastoral practices (Johannesen et. al 1971, Sprague and Hansen 1946 Towle 1982, Christy and Alverson 1994). Native Willamette Valley grasslands are considered one of the rarest and most endangered of all natural ecosystems in Oregon (The Oregon Natural Heritage Program 1983). Less than 1% of the former extent of Willamette Valley prairies remain today.

Prairies of the Willamette Valley include dry, upland and wet, bottomland (wetland) prairies. This study was located in wetland prairie plant communities. With fire exclusion, wetland prairies may succeed to a dominance of willow (*Salix* spp.), cottonwood (*Populus trichocarpa*), hawthorn (*Crataegus* spp.) and ash (*Fraxinus latifolia*) woodlands and forests (Franklin and Dyrness 1973, Johannessen et. al 1971, Sprague and Hansen 1946, Thilenius 1968, Frenkel and Heinitz 1987).

An appreciation has developed in the scientific community for the important role that disturbance plays in ecosystem dynamics (Mooney and Godron 1983). The resilience of an ecosystem to a particular type of disturbance depends upon the frequency or regularity of the disturbance (Sousa 1984). After thousands of years of annual fall-season fires, Willamette Valley vegetation has evolved adaptations to survive that disturbance regime.

Fire removes accumulated litter and causes mortality of some plant individuals thus reducing competition and opening spaces for seedling establishment. Periodic burning in the tallgrass prairie consumed litter and increased biomass and species diversity compared to unburned prairie (Hopkins 1954, Hulbert 1969 and 1988, Risser 1988).

Remnant wetland prairies provide habitat to many rare and endemic plant species. State and federal laws mandate that publicly owned lands be managed to perpetuate these species (Rohlf 1989). In recent years, federal agencies have also been directed to sustain biological diversity on publically owned lands. Currently, reintroduction of fire may facilitate improved health in these disappearing communities.

Remnant prairies currently contain many exotic plant species (Towle 1982). Management practices that enhance exotics might further reduce native and rare plant species in prairie landscapes. The response of exotic species to burning is uncertain. Initial and sometimes unanalyzed, tentative results from other studies in Willamette Valley prairies suggest that exotic species may increase in response to burning (Macdonald - undated, Magee 1986, Frenkel and McEvoy 1983, Acker 1990, Frenkel and Streatfeild 1994, Streatfeild 1995). However, these same studies indicate that native species have also increased in percent cover or frequency following burning.

Little is known on the community ecology or the species life histories within prairie communities of the Willamette Valley. Observations of a positive response of native plant species to fire and some reduction of shrub and tree densities have been made by a number of investigators (Frenkel and McEvoy 1983, Acker 1986, Acker 1990, Streatfeild 1995). However, increases in exotic species have also been observed.

Optimal fire frequency of wetland prairies should be based upon responses of exotics, woody, and rare species as well as species which were important staple food sources of Native Americans (e.g. *Camassia spp.*, *Madia* spp., etc.). Optimal burns should (1) control woody species, (2) control exotic plants, (3) maximize cover and frequency of native plants, (4) increase density of aboriginal food plants, and/or (5) increase density and/or vigor of rare plants.

The operational hypotheses are:

1) prescribed burns enhance native wetland prairie flora by controlling successional invasion of woody species and by invigorating vegetative and reproductive growth of fire-adapted native plant communities;

2) fire controls or reduces composition of exotic species, thus leading to a greater level of health for the native system;

3) multiple burns facilitate successional retrogression and enhancement of native prairie species relative to a one-time burn.

Different fire intensities will result in different plant responses and succession trajectories. Therefore, fire behavior and fuel conditions in relation to vegetation response are important for developing optimal burn prescriptions.

To test these hypotheses and to assist in determining optimal long-term burn prescriptions, the following objectives of research were addressed:

(1) document fuel characteristics and fire behavior associated with experimental prescribed burns in wetland Willamette Valley prairie communities (Chapter 3).

(2) quantify preburn vegetative composition and response to two burn treatments in different plant communities at two Willamette Valley wetland prairies (Chapter 4); and

(3) quantify preburn shrub and tree composition and response to burn treatments in different plant communities at two Willamette Valley wetland prairies (Chapter 5).

This research initiates a long-term assessment of fire effects on Willamette Valley vegetation to determine optimal burn prescriptions for wetland prairies.

# CHAPTER 2
# A LITERATURE REVIEW: HISTORY OF WILLAMETTE VALLEY VEGETATION AND IMPORTANCE OF FIRE IN GRASSLANDS/PRAIRIES

## Introduction

The Willamette Valley is a linear lowland in western Oregon ranging from 40-65 km wide and extending 210 km from the Willamette River's southern headwaters to its northern confluence with the Columbia River (Orr et al. 1992). The Valley is delimited by the Coast Range to the west, the Cascade Mountains to the east, and the Calapooia Mountains to the south. During the Cretaceous Period (~130-62 million years before present - mBP), this region was part of a broad, flat continental shelf extending into the Pacific ocean from the Cascade Mountains (Orr et al. 1992).

During the Eocene Epoch (55-38 mBP), plate shifting resulted in uplifting, tilting and folding of the Coast Range and further uplifting of the Cascade Mountains; the Willamette Valley formed as a trough or depression between the two mountain ranges. This lowland trough was at first covered by an inland sea. With continued plate uplifting, this inland sea eventually drained to the Pacific ocean. The southern end of the Willamette Valley became terrestrial as early as the Eocene Epoch (55-38 mBP), although the northern portion of the Valley was not entirely terrestrial until the Miocene Epoch (5.3-2 mBP) (Detling 1968, Orr et al. 1992).

The Willamette Valley trough was filled with successive deposits of fluvial materials especially during a 2500 year interval (post 18,000 BP) in the Pleistocene Epoch (~2 mBP to present) as the climate warmed and glaciers receded (Alt and Hyndman 1978, Orr et al. 1992). Flooding during this interval resulted in successive back flows of floodwaters from the Columbia River into the Willamette Valley which extended up to elevations of about 120 m (Alt and Hyndman 1978). These flood events left behind sediments of varying depth, composition, and texture (sands and fine silts). This fluvial material is characteristic of current Willamette Valley soils (Orr et al. 1992). Other soil deposits have been carried into the Willamette Valley by flooding events and fluvial outwashes from Cascade Mountain rivers and streams.

Plant communities of the Willamette Valley have changed continuously over time in response to changes in landscape and climate (Detling 1968). The climate of the Pacific Northwest region has varied from periods of near arctic conditions to more tropical regimes. In addition to climatic and geologic influences, plant communities in the Willamette Valley have changed in response to disturbance processes. Most notably, vegetation in the Willamette Valley has recently developed with the presence of frequent natural and anthropomorphic fires (Sprague and Hansen 1946, Habeck 1961, Johannessen et al. 1971). In a region with climatic conditions that would currently support forested plant communities, it's apparent that fires ignited by Native Americans were important to the continued existence and maintenance of Willamette Valley prairies (Franklin and Dyrness 1973).

Specific effects of fire in Willamette Valley ecosystems have not been studied, however, fire effects have been documented in other grassland and forested ecosystems. We can formulate hypotheses to test fire effects in Willamette Valley prairies with a knowledge of the environmental history of the Willamette Valley and the effects of fire in other ecosystems. Thus, we may more quickly understand how best to maintain, enhance and/or restore the biodiversity of these unique prairie landscapes.

## History of Willamette Valley Vegetation

### Prehistoric changes

During the **Cretaceous Period** (130-62 million years before present - mBP), western Oregon was generally covered by ocean (Orr et al. 1992) (Table 2.1). Vegetation bordering this ocean (presently parts of eastern Oregon) consisted predominantly of hardwood trees (Detling 1968). Important species of that era that are still present within the Pacific Northwest today are referred to as the West American Element of the early flora. These species included; *Abies, Acer, Alnus, Betula, Cornus, Corylus, Crataegus, Fraxinus, Gaultheria, Juglans, Larix, Lithocarpus, Mahonia, Malus, Myrica, Philadelphus, Picea, Pinus, Populus,*

Table 2.1. Geologic, climatic and biological events in the Willamette Valley (WV) since the Createaceous Peroid (the last 130 million years).

| Geologic Epoch, Period, or Era | Years BP (m = million) | Geologic and Climatic Events | Biological Events |
|---|---|---|---|
| Late Holocene Era | 5,000 - 0 | Cooler temperatures and greater precipitation than previous climate. | Increase in *Pseudotsuga*, *Tsuga* and *Abies*; *Quercus* declines. Extensive settlement of region by euro-americans in 1840's; Indian-burning ceased. |
| Early Holocene Era | 10,000 - 5,000 | Hotter summers, colder winters, and less ppt. than present; driest postglacial climate at 9,000 BP; Larentide ice sheet disappears; xerothermic maximum ~6,000 BP; | *Pseudotsuga*, *Tsuga*, *Picea* and *Abies* decline from ~8,000 BP; peak range and expression of *Quercus* forests ~6-8,000 BP; peak expression of prairies and xerophytic species; megafauna present ~6,000 BP. |
| | 12,000 - 10,000 | Glacial retreat; wetter climate than present; much of WV inudated by glacial melt-waters. | Coniferous forest predominantly *Pinus contorta* ~11,000 BP; increase in *Pseudotsuga*, *Tsuga*, *Abies* and *Picea* ~11-8,000 BP. |
| Pleistocene Epoch | ~2.0 m - 0 | Early Pleistocene-less precipitation and much cooler than present; maximum extent of glaciation ~18,000 BP. | Temperate, coniferous forest in Pacific Northwest; Charcoal abundant in soil layers. First human occupation WV ~11,500-8,000 BP. |
| Pliocene Epoch | 5.3 m | Much uplift and tilting of Coastal Range. Early Pliocene-warmer and drier than present; Late Pliocene-increasing ppt. and decreasing temps.; summer ppt. drops sharply. | Appearance and expansion of Madro-Tertiary Geoflora in PNW; Loss of species dependent on summer precipitation. |

Table 2.1., Continued.

| | | | |
|---|---|---|---|
| Miocene Epoch | 24 m | Epoch began with a warm, rainy climate (?), ppt. evenly distributed through the year; lateritic soils formed; general cooling and drying trend. Much volcanism building Cascades. | Evidence of subtropical-temperate floral elements in WV; increase in Pinaceae; appearance and increase of herbaceous plant families in Pacific Northwest. |
| Oligocene Epoch | 37 m | Progressively cooling and drying trend. | Subtropical forests revert to a temperate forest similar to Cretaceous Period. |
| Eocene Epoch | 58 m | Increase in temperatures to subtropical climate; WV becoming terrestial with slow uplift and sedimentation of ocean floor. | Broadleaf forest develops with elements from now-common warm-temperate N.A. and flora now largely found in tropical and subtropical Central and S. America. |
| Cretaceous Period | 130 m | WV covered by ocean; temperate and humid climate with abundant summer precipitation. | Temperate forest at margin of inland sea (eastern Oregon)consists predominantly of hardwood genera. |

*Pseudotsuga, Quercus, Rhamnus, Salix, Sambucus, Sequoia, Smilax, Sorbus, Stipa, Torreya, Tsuga, Umbellularia, Viburnum,* and *Vitis.* Detling (1968) described two additional groups of genera that were present during the Cretaceous but are now generally absent from the Pacific Northwest. One of these groups, the East America Element, consisted of genera still present in eastern North America including: *Aristolochia, Asimina, Carpinus, Carya, Cassia, Castanea, Celastrus, Comptonia, Cotinus, Diospyros, Fagus, Ilex, Lindera, Liquidambar Liriodendron, Magnolia, Myrsine, Nelumbo, Nyssa, Ostrya, Piper, Sapindus, Sassafras, Taxodium, Tilia,* and *Ulmus.* A second group consisted of genera that are now extinct, or restricted to Asia or other tropical and subtropical regions of the New World. This group included: *Ailanthus, Cercidiphyllum, Cinnamomum, Ficus, Ginkgo, Glyptostrobus, Grewia, Hedera, Keteleeria, Laurus, Metasequoia, Paulinia, Persea, Pistachia, Pterocarya, Sabal, Sterculia, Zelkova,* and *Zizyphus.* The presence of genera in these groups now absent from the Pacific Northwest indicate a warmer, more humid climate. Many of these genera also occur today in locales with abundant summer rainfall suggesting that summer precipitation was probably greater in the Pacific Northwest during that period than currently.

During the **Eocene Epoch** (55-38 mBP), the ocean covering the Willamette Valley slowly turned into an inland sea through uplift of Coast and Cascade mountain ranges (Detling 1968). Toward the later part of the Eocene Epoch this inland sea began to disappear through further uplift and through sedimentation

(Detling 1968). As a result, a layer of Eocene silts and sands over a mile deep now extends under Eugene, Oregon (Orr et al. 1992).

Temperatures were elevated from those of the Cretaceous Period. Chaney and Sanborn (1933 in Detling 1968) postulated a mean annual temperature of ~20°C and an annual precipitation of ~178 cm. Eocene silts from this period contained fossil evidence of marine mollusks, crabs, and sharks of a tropical environment (Orr et al. 1992). Eocene sediments dated to ~42-38 mBP near Cottage Grove, Oregon, contained fossilized, broadleaf plants such as *Aralia*, which further suggested a warm, moist sub-tropical to tropical climate (Orr et al. 1992). These fossil plants located near Cottage Grove also indicated that portions of the southern Willamette Valley were terrestrial by the later part of the Eocene Epoch.

The new lowland plain formed by the retreating inland sea was occupied by a broadleaf forest from two floristic origins; (1) genera represented in the temperate Cretaceous floras of Alaska and central Rocky Mountains, now common to warm-temperate North America, and (2) a new group of genera now largely found in tropical or subtropical regions of Central or South America. The former group included; *Aralia, Aristolochia, Celastrus, Cinnamomum, Diospyros, Ficus, Magnolia, Persea, Platanus, Quercus, Rhamnus, Smilax* and *Viburnum*. The later group included; *Anona, Aporosa, Astronium, Calyptranthes, Cordia, Cupania, Inga, Lucuma, Mallotus, Meliosma, Nectrandra, Ocotea, Sapium, Siparuna, Strychnos, Symplocos,* and *Tetracera* (Detling 1968).

With progressive cooling and drying during the **Oligocene Epoch** (38-25 mBP), subtropical forest was replaced by a temperate forest similar to that displayed in upland regions during the earlier Cretaceous Period (Detling 1968). The inland sea covering the Willamette Valley reached as far south as Salem during a portion of this Epoch (Orr et al. 1992). Evidence of conifer genera such as *Sequoia, Metasequoia* and *Taxodium* were common in Oligocene sediments while *Abies, Pinus, Picea, Pseudotsuga* and *Tsuga* were present and widespread though not abundant.

Soil and plant evidence have lead to conflicting theories of the climatic regime during the **Miocene Epoch** (25-5.3 mBP). Bauxitic lateritic soils, which generally form in hot climates, are present in Willamette Valley sediments that formed during the Miocene (Alt and Hyndman 1978). Also, abundant evidence of fossil flora such as *Liquidambar, Platanus, Carya, Ginkgo* and *Metasequoia* were found in Willamette Valley sediment formed during the Miocene Epoch that further suggest a warm, rainy climate (Orr et al. 1992).

In contrast, Axelrod (1950 <u>in</u> Detling 1968) postulated cooler, drier conditions in the Pacific Northwest. Pinaceae increased during this period in Pacific Northwest locations with the appearance and increase of herbaceous families, including: Malvaceae, Onagraceae, Polemoniaceae, Umbelliferae, Gramineae, Cyperaceae and Compositae (Detling (1968). Detling (1968) postulated that an adverse climate for trees and shrubs (i.e drought and cold winters) may have facilitated increases in herbaceous species.

Thus, the Miocene Epoch likely began with a warm, rainy climate and became progressively cooler and drier with time. Volcanic activity was rapidly building the Cascade Range during this Epoch and the ocean finally withdrew from the region of the Willamette Valley (Orr et al 1992).

The **Pliocene Epoch** (5.3-2 mBP) was a period of continued uplift and tilting of the Coastal Range and folding of northern Willamette Valley rocks (Orr et al. 1992). Temperatures increased and precipitation decreased early in the period (Detling 1968). By the middle Pliocene, floras indicated that western United States was semiarid with a warmer climate than present (Detling 1968). The flora included: *Abies, Acer, Amelanchier, Mahonia, Picea, Pinus, Populus, Pseudotsuga* and *Sorbus*. During this warm, dry period, a number of plants included in the "Madro-Tertiary Geoflora" migrated from the south and flourished in the Willamette Valley region. This flora evolved in the more arid, hotter and continental portions of southwestern North America. A number of these genera are still present and in cases, abundant, in the Willamette Valley today, including; *Amelanchier, Arbutus, Arctostaphylos, Baccharis, Ceanothus, Fraxinus, Holodiscus, Mahonia, Myrica, Philadelphus, Pinus, Populus, Prunus, Quercus, Rhus, Ribes, Symphoricarpos,* and *Umbellularia* (Detling 1968).

Several xerophytic "islands" remain today in Lane County as evidence of this period of Madro-Tertiary Geoflora expansion, including; Bohemia-Fairview Mountain, Rebel Peak, Horsepasture Mountain, Spencer Butte and the Coburg Hills (Detling 1968). Further range extensions of these species were halted by the change toward a cooler, moister climate with the advent of the Pleistocene. Although there was a general trend toward a cooler and moister climate during the late Pliocene, a sharp drop in summer rainfall resulted in the loss of East American and East Asian Elements which were dependent upon summer precipitation (Detling 1968).

During the early **Pleistocene** (~2 mBP), Pacific Northwest forest taxa included *Pseudotsuga, Tsuga, Larix, Thuja, Alnus, Acer macrophyllum, Cornus nuttallii,* and *Populus,* while understory vegetation included *Corylus, Acer circinatum, Mahonia nervosa, Philadelphus, Rhamnus purshiana, Sambucus glauca* and *Vaccinium parviflorum (*Detling 1968). Alpine glaciation was extensive in the Pacific Northwest between 20-16,000 BP, although there was little glaciation in lowland regions. Precipitation was lower and temperatures were as much as 10°C cooler in western Washington (Whitlock 1992, Thompson et al. 1993).

The maximum extent of the Laurentide ice sheet over northeastern North America during this time period (~18,000 BP) significantly affected the climate of the northwest United States in three ways: (1) it caused a general cooling of the climate; (2) it split the North American jet stream - shifting winter storms to the south, resulting in a winter drying of the climate; and (3) it changed surface wind circulation and created stronger easterly winds that enhanced cold and arid conditions (Whitlock 1992).

Between 20,000 and 16,000 BP, the Puget Trough supported tundra and subalpine parkland; dominant plants included grasses, sedges, *Artemisia* spp. and tundra herbs (Whitlock 1992). A period of warming and overall glacial retreat occurred at ~12,000 BP, when the Willamette Valley was inundated with glacial meltwaters (Hansen 1947, Whitlock 1992, Thompson et al. 1993). *Pinus contorta* was likely the pioneer invader as glacial waters subsided from the Willamette Valley (Hansen 1947).

Pollen analysis suggested that the Willamette Valley was dominated by *P. contorta* with lesser amounts of *Picea sitchensis* and *Abies grandis* at ~11,000 BP (Hansen 1942, 1947, 1967). A period of warming and drying between 11,000 and 8,000 BP resulted in the decline of *P. contorta* and increases in *Pseudotsuga menziesii, Tsuga heterophylla, P. sitchensis* and *A. grandis* (Hansen 1947 and 1967).

Several sources report evidence for warm, dry conditions during the **early Holocene** (~10,000-5,000 BP) (Hansen 1947, 1967, Whitlock 1992, Thompson et al. 1993). During this time, the tilt of the earth was greater, and the northern hemisphere was closest to the sun during summer, rather than in winter as it is now. Therefore, summers were warmer and drier, and winters cooler than today. Total annual precipitation was 40-50% lower and the average annual temperature was 1-3°C higher in southwestern Washington during the early Holocene than at present (Whitlock et al. 1990 in Whitlock 1992).

At ~9,000 BP the Pacific Northwest was at its driest since the glacial maximum and far drier than at present as indicated by climatic simulations, pollen, and lake-level data (Thompson et al. 1993). Species shifts also indicated an extended drought period between ~10,000 to 6,000 BP with *P. menziesii, Alnus* *rubra*, and *Pteridium* appearing in great abundance in western Washington and prairies expanding in the central Puget Trough (Whitlock 1992). Pollen studies in the Willamette Valley also document a warming, drying trend between 8,000 and 6,000 BP as *P. menziesii, T. heterophylla, P. sitchensis,* and *A. grandis* declined in composition and as *Quercus* and other xerophytic species reached their maximum extents (Hansen 1947, 1967). Modelling indicated a thermic maximum but increasing moisture levels at ~6,000 BP, although precipitation remained below present values (Thompson et al. 1993). Stands of *Pinus ponderosa* remaining in the valley attest to a former warmer, drier climate (Hansen 1947).

The Laurentide ice sheet covering eastern North America disappeared between 9,000 and 6,000 BP, ending its distant influence over climate in the Pacific Northwest (Thompson et al. 1993). Bones of ice age mammals such as mammoths, mastodon, giant sloth, and bison (eight foot at the shoulder) were found in buried organic layers of Willamette Valley soils (particularly at Lake Labish, near Salem) and dated to ~6,000 BP (Hansen 1967, Orr et al. 1992). Megafaunal grazers and browsers likely had a significant impact upon the compositional direction of plant species in the Willamette Valley during this time period.

During the **late Holocene** (5,000 BP to present), summer drought lessened, temperatures declined and precipitation increased compared to the early Holocene (Whitlock 1992). Some mesophytic taxa such as *Thuja plicata, T. heterophylla* and *P. sitchensis* increased, while grasses, composites and chenopodes declined in the Puget Trough of Washington. Pollen analysis showing increases of *P. menziesii, Tsuga* and *Abies* at Willamette Valley sites also indicate a pattern of increasing moisture and cooler temperatures during the last 4,000 (Hansen 1947, 1967).

## Human habitation, subsistence, and burning practices

Human occupancy of the Willamette Valley probably began some 11,500 years ago, with firm evidence of occupancy for at least 8,000 years (Aikens 1993). Indigenous people of the Willamette Valley formed a series of geographically independent living groups and all spoke a language variation belonging to the Kalapuya family (Mackey 1974, Minor et al. 1981, Boyd 1986, Toepel 1991, Aikens 1993). Harvest and processing of camas bulbs (*Camassia* spp.) and a variety of other plant foods were of particular importance in Kalapuya subsistence; the harvest of deer meat (*Odocoileus* spp.) was secondary (Aikens 1993).

Subsistence revolved around a pattern of hunting and gathering seasonally available foods. In the spring, multi-family camps would divide into small, mobile family groups to begin harvesting the abundant plant and animal resources found throughout the Valley's wetlands, prairies and woodlands. From spring and through summer, a variety of staple foods including; waterfowl, deer, fish, camas, hazel nuts (*Corylus cornuta* var. *californica*), acorns (*Quercus* spp.), and various seeds and berries were gathered and processed for winter storage. In mid- to late- summer, family groups moved to Coastal and Cascade upland areas to fish, hunt, and harvest large quantities of berries. In Autumn, family units remained dispersed across the landscape and continued to gather acorns, various seeds, fruits, and roots. Fires were started intentionally in the dry late summer months for a variety of reasons discussed in the next section. By late fall and early winter, family units would regroup at village locations and inhabit semi-subterranean wooden lodges at permanent winter sites.

### Kalapuya fire use and frequency

The Kalapuya presumably utilized fire for a variety of purposes. Fires increased the production of bulbs, roots, rhizomes, seeds, and berries of many staple food plants including camas, onions (*Allium* spp.), bracken fern (*Pteridium aquilinum*), salal (*Gaultheria shallon*), huckleberries (*Vaccinium* spp.), blackcaps (*Rubus leucodermis*), strawberries (*Fragaria* spp.), thimble berries (*R. parviflora*), salmonberries (*R. spectabilis*) and blackberries (*R. ursinus*) (Mackey 1974, Minor et al. 1981, Boyd 1986, Aikens 1993). Underburning in oak and hazel woodlands reduced brush and thick herbaceous ground covers, making acorns and nuts easier to find (Boyd 1986). Burning encouraged production of suckers from the base of hazel trees and growth of various reeds; both important materials in basketry. Fire assisted in the collection of tarweed seed (Mackey 1974, Minor et al. 1981, Boyd 1986). Burning removed the sticky exterior plant residue of tarweed and facilitated ripening and opening of seed pods. Following fire, the plant skeleton, with the attached seed pods, remained standing. Immediately following burning, Kalapuya women used racket-like sticks to dislodge tarweed seeds from seed pods, knocking them into baskets. Most of the seed was ground into a meal and used like flour. Tarweed was valued so highly by the Kalapuya, that patches were the "property" of particular family groups.

The fertilizing effect of burning was also well-understood and utilized by the Kalapuya in the cultivation of tobacco (*Nicotiana quadrivalvus*) (Boyd 1986). An area with accumulated woody debris was burned to produce ash and to prepare a seed bed prior to sowing tobacco seeds.

Burning was also used to collect grasshoppers and other insects as they fled fire. Dead insects were also gathered from areas following burning (Mackey 1974, Dicken and Dicken 1979, Boyd 1986).

Fire was used to assist in game hunting and management. Game animals included a variety of waterfowl, dove, quail, elk (*Cervis elaphus*), white-tailed deer (*Odocoileus virginianus leucurus*), and black-tailed deer (*Odocoileus hemions columbianus*) (Boyd 1986). Two elderly Kalapuya Indians at the Grande Ronde reservation told a story of "the great fall hunt" of deer (Clark 1905). They described a highly organized burning pattern requiring a head chieftain and a great force of men. At a given signal, men spread over the landscape, began burning the prairie and driving deer toward a determined area where the animals became easy prey. A sufficient number of deer were killed to provide meat for the coming winter months.

The Kalapuyas not only used fire directly as a tool to drive-hunt deer, but indirectly as a plant manipulation tool to attract and concentrate game animals (Mackey 1974, Minor et al. 1981, Boyd 1986, Aikens 1993). Unburned patches would purposefully be left within a matrix of burned-over land. Game species would naturally concentrate in these unburned areas immediately following burning and were thus more easily hunted. The Kalapuya also underburned woodlands to reduce brush, facilitating better visibility and easier movement through areas during hunting. In some cases, the Kalapuya may have burned to subsequently attract game animals to areas of more palatable regrowth (Minor et al. 1981, Boyd 1986).

Fire might also have acted as a tool for tribal defense. Approaching enemies could easily be seen by maintaining open prairie and open-understory woodlands adjacent to long term camps (Clark 1905, Habeck 1961, Boyd 1986).

Numerous journal accounts by explorers and settlers indicated that prairie fires were common every year in the Willamette Valley during the summer and fall months (Sprague and Hansen 1946, Habeck 1961, Johannessen et al. 1971, Thilenius 1968). However, the return interval of fire (the number of years between successive fires) at each particular site within the valley is unknown. One journal account by Lewis Judson (Atrozut 1955 in Boyd 1986) indicates that the prairies may have been burned biennially.

These journal records raise a number of questions. Was the prairie in Judson's account a wet prairie or a dry prairie? Were different habitat types such as oak woodlands, riparian forest, dry prairie and wet prairie sites burned at different frequencies to meet specific objectives? For example, were tarweed patches burned more frequently, e.g., every year, than huckleberry patches, e.g., every seven years? Journal accounts do not provide precise insight into these questions.

The Kalapuya probably burned particular habitat types and/or specific plants on a frequency that resulted in desired plant responses, e.g. burn frequencies that maintained low brush density or increased desirable plants and/or their fruits. Little anthropological field work was gathered on the specifics of burn frequencies in different Willamette Valley habitats; therefore, the entire story of Kalapuya burning practices may never be known (Boyd 1986).

## European exploration and devastation of the Kalapuya culture

The maritime fur trade began along the Pacific Northwest coast around the 1780's, and marked the first contact of the Kalapuyas with European trade goods and diseases (Minor et al. 1981). Lewis and Clark explored in the area during their 1805-1806 expedition. Although no direct contact with the Kalapuya was documented, expedition accounts referenced the existence of the Kalapuya and estimated their population. The first recorded meeting between whites and the Kalapuya was during 1812 when fur traders from Astoria visited the Willamette Valley (Zenk 1976 <u>in</u> Minor et al. 1981). During the 1820's and 1830's, a number of fur trappers settled in the Willamette Valley; however, the region remained largely unsettled until the 1840's (Minor et al. 1981).

Initial contacts with Europeans and their virulent diseases lead to a number of epidemics that dramatically reduced the populations of the Kalapuya (Mackey 1974, Boyd 1986). The first of these epidemics was small-pox which spread from Missouri during 1782-1783 and may have destroyed half of the Kalapuya population. Malaria raged from 1830 to 1833, further reducing the Kalapuya population 90% and eliminating entire villages in some places. The pre-contact population of the Kalapuya was estimated as 14,000 in 1806 (even after the smallpox epidemic); by 1841 the population numbered approximately 600. The devastation of the Kalapuyas and their culture allowed the subsequent uncontested occupation of the Willamette Valley by European settlers (Mackey 1974). The remainder of the Kalapuya Indians were placed on the Grande Ronde Indian reservation in 1855.

## Fire and its exclusion from the Willamette Valley

Charcoal is abundant in soil layers deposited during the Pleistocene Epoch (2 mBP to present) indicating fire's importance as a force in shaping species compositions during this era (Cwynar 1987). Humans arrived during a warmer and drier period when the climate and environmental conditions may have supported an extensive prairie landscape (Whitlock 1992). With a trend toward a cool, moist climate, the Willamette Valley should have been largely a forested landscape at the time of European settlement. However, shrub and tree expansion was suppressed by the burning activities of the Kalapuya Indians (Hansen 1947, Hansen 1967, Clarke 1905, Morris 1934, Sprague and Hansen 1946, Habeck 1961, Johannessen et al. 1971, Dicken and Dicken 1979, Thilenius 1968). Fire scars in tree growth rings show evidence of a high frequency of fire in the Willamette Valley extending back to 1647 (Sprague and Hansen 1946). This is as far back into history as the tree record extends in the Willamette Valley, where few trees are older than 350 years.

The Willamette Valley was not a close-forested landscape when European settlement began. Journal accounts from explorers and early settlers (1830-1840's) describe the Willamette Valley as an expansive prairie with occasional solitary oaks, scattered tracts of open-grown oak woodlands, and a dense riparian forest "gallery" along perennial stream and river channels (Habeck 1962, Johannessen et. al 1971). An account from the journal of an early pioneer on June 2, 1834, described the area near the confluence of the Long Tom and the Willamette River, (near the present city of Eugene and close to research sites used in this thesis) as generally extensive plains of grasslands with seasonal wetlands and swampy areas "and to the (W)est extends the chain of mountains, the first range of rising hills with little wood on them" (Munford 1982). An historical cadastral survey map prepared in 1854 of the vicinity of Fern Ridge Reservoir indicates the general area around the Fisher Butte and Rose Prairie study sites (research sites in Chapters 3 - 5) as open, flat prairies (Finley 1994).

Prairie fires were extensive throughout the Willamette Valley at the time of European settlement (Sprague and Hansen 1946, Habeck 1961, Johannessen et al. 1971). Early trappers and explorers described burned regions extending from Oregon City, at the north end of the valley, to areas south of Eugene, a distance of approximately 210 km (Johannessen et al. 1971). Journal accounts indicate that the Kalapuyas ignited fires from late summer into early fall (August-September) on a regular, almost yearly basis (Clarke 1905. Sprague and Hansen 1946, Habeck 1961, Johannessen et al. 1971). However, fires were also reported from mid-summer (July 1) and into late fall (October 18) (Boyd 1986).

With increased pressure from settlers to control fire and the extirpation of Kalapuyans through disease and displacement, inadvertent fire exclusion in the Valley generally began in the late 1840's and has largely continued to the present. Fire exclusion has resulted in encroachment of woodlands and forests into former prairies (Clarke 1905, Sprague and Hansen 1946, Thilenius 1968, Cole 1977). However, heavy grazing has stemmed woody growth in places (Frenkel and Heinitz 1987). With fire exclusion, wet prairies succeed to willow, cottonwood, hawthorn and ash woodlands and forests, and drier grasslands succeed to oak and maple woodlands and ultimately to Douglas fir forests (Franklin and Dyrness 1973, Johannessen et. al 1971, Sprague and Hansen 1946, Thileius 1968, Frenkel and Heinitz 1987).

## European settlement and changes in the landscape

Large-scale settlement of the Willamette Valley progressed swiftly during the mid 1840's; by 1850 there were 11,873 people residing south of the Columbia River (Minor et al. 1981). Rapid settlement continued with passage of the Donation Land Act. Each American citizen who settled in the Oregon territory by 1850 was entitled to a 320 acre-claim of free land. With settlement, came the replacement (via the plow) of many prairie plant communities with agricultural crops. Indeed, prairies fringed by forest were the preferred locations to settle during the middle to late 1800's (Minor et al. 1981). This pattern of settlement in the Willamette Valley probably lead to the decline of dryland prairies early in the history of settlement. Prairies not plowed and cropped were heavily grazed by various livestock. Numerous horses, hogs and sheep, and large herds of cattle were already ranging the Willamette Valley by 1844 (Towle 1982). Livestock grazing increased and peaked in 1899; open-ranging of livestock became illegal in the Willamette Valley ~1900 (Towle 1982). Between 1890 and 1930's, hill lands not heavily grazed were often occupied by fruit orchards. After 1930, tree crops became concentrated on the coarser-textured floodplains (Towle 1982). Subsequently, a number of orchard crop species have naturalized in the Willamette Valley.

Large and small-scale flood control projects have also altered the Willamette Valley landscape and its hydrology in recent years (Habeck 1961, Towle 1982). Various channels and reservoirs for flood control were constructed throughout the 20th century. The Fern Ridge Dam was completed in 1942 (Towle 1982). Thus, there are far fewer natural ponds, marshes and other wetlands in the Willamette Valley today compared to the presettlement era (Franklin and Dyrness 1973). The areal extent of wetlands in Oregon decrease 38% between 1780 and 1980 (Dahl 1990).

## Introduction of exotic plants

Numerous authors described the general pre-settlement natural vegetation patterns, e.g., prairie, marsh, fir forest, woodland thickets, gallery forests along rivers, of the Willamette Valley (Smith 1949, Habeck 1961, Johannessen et al. 1971). However, complete historical species lists were never compiled for these landscape types. The species composition of Willamette Valley prairies has been significantly modified by accidental and deliberate introduction of exotic plant species. A number of exotic species that are now naturalized in the Willamette Valley landscape were intentionally introduced as orchard, food-crop, hedgerow and ornamental plants (e.g. *Pyrus communis, Prunus avium, Pyrus malus, Crataegus monogyna, Rosa eglanteria*). Other exotic species arrived in association with livestock, various types of cargo, ballast and in imported agricultural seed mixes. A species list of grasses in Salem and vicinity in 1919 indicated that 52% of the plants were introduced (Nelson 1919). Exotic and now-naturalized plant species form ~11% of the vascular plant flora of California (Mooney and Drake 1987). Most of the exotic flora are annuals. Although no data are available for Oregon or the Willamette Valley, we may assume a somewhat lower composition of exotics to that of California which had been heavily grazed by livestock since 1800 and agriculturally exploited in the mid 19th century.

## Summary of vegetation history

Present patterns of natural plant species diversity expressed in the Willamette Valley "represent a culmination of ecological, climatological, and geological processes spanning several time scales" (Whitlock 1992). Clearly, species composition and diversity has varied across the Willamette Valley landscape throughout its geological history. Human populations have also exerted a tremendous influence upon the dynamics and composition of Willamette Valley vegetation. Within a century and a half, prairie, savanna, and open woodland ecosystems that were once extensive throughout the Willamette Valley are today close to extinction. Closed-canopy forest has increased. Agricultural and urbanized landscapes have replaced natural landscapes. Today, less than 0.1% of presettlement prairies are thought to exist in fragmented, disjunct and degraded conditions throughout the valley (Christy and Alverson 1994). Even the remaining fragments of natural vegetation have changed radically in composition as exotics have replaced natives, as native taxa have gone extinct and as new assemblages have developed.

Remnant wetland prairies host several narrowly endemic, rare and potentially endangered plant species, including *Lomatium bradshawii*, a federally listed endangered plant species. State and federal laws now mandate that any publicly owned lands containing endangered or threatened plant species be managed in such a way as to perpetuate the existence of these species. Successful techniques for the conservation of biological diversity, maintenance of a prairie structure, and native composition requires a set of management practices especially adapted for these plant communities. At this stage, recovery and improvement of remnant prairies includes the reintroduction of fire as an ecosystem process.

Prairies of the Willamette Valley are somewhat arbitrarily separated into dryland and wetland prairie plant communities. The current study focussed on vegetation responses to burn treatments in two wetland prairie remnants.

## Importance of Disturbance and Fire in Grasslands/Prairies

Contemporary information on plant responses to burning in Willamette Valley prairies is limited (Frenkel and McEvoy 1983, Magee 1986, Acker 1986, Acker 1990, Connelly and Kauffman 1991, Frenkel and Streatfeild 1994, Streatfield 1995). Data on fuels and fire behavior are lacking. Information can, however, be gained through review of fuels, fire behaviors and plant responses in other ecosystem types, especially in other grassland/prairie communities. The most comparable ecosystem to wetland prairies of the Willamette Valley in terms of biomass and structure, is the mesic, tallgrass prairie of the Central and

Northern Great Plains. Like the tallgrass prairie, Willamette Valley prairie is highly productive with aboveground standing crops ranging from 3,230 kg ha-1 to ~12,000 kg ha-1 (Moir and Mika 1972, Kucera 1981, Frenkel and McEvoy 1983, Chapter 3). Also, like tallgrass prairies, Willamette Valley prairies contain high species diversity within small geographic areas. Two-hundred- thirty-seven species occurred within a single square mile of tallgrass prairie in Nebraska (McNaughton et al. 1982). Similar high levels of species richness occur in Willamette Valley prairies (Chapter 3). But unlike tallgrass prairie, Willamette Valley prairie has a marked dry summer and moist spring.

Grassland ecosystems have generally evolved with varying intensities and frequencies of disturbance, both spatially and temporally (Sousa 1984). Contrary to the traditional concept that disturbances disrupt ecosystem equilibrium, equilibrium in natural ecosystems is currently perceived as a special case, rather than the rule (Zedler et. al 1983). Vegetation composition is in a continuous state of flux due to environmental perturbations and cycles. Disturbance events, such as fire, may play as great a role in community dynamics as do biological interactions of competition and predation (White 1979).

The historic and current prevalence of fire in grassland ecosystems of the world indicates its functional importance in community dynamics (Daubenmire 1968, Vogl 1974, Kucera 1981, Risser et al. 1981, and Wright and Bailey 1982). Fires facilitate plant regeneration, nutrient cycling, reproductive responses, successional trajectory, and vertebrate habitat alterations (Daubenmire 1968, Kucera 1981, Hulbert 1988).

## Fuel and fire characteristics of grassland fires

Grassland fuels typically have a rapid rate of ignition, rapid spread, high fireline intensity, and a relatively short residence time (Vogl 1974). Most grassland fuels burn readily; they are usually very dry, loosely and contiguously arranged, and finely divided and thus provide a base for sustained ignition (Daubenmire 1968, Vogl 1974, Kucera 1981). Due to these fuel characteristics, the occurrence of extremely high temperature for long time periods at the plant and soil surface, which result in damage to the basal portions of plants and rootstalks, is uncommon during grassland fires (Volland and Dell 1981, Vogl 1974).

Due to differences in weather, fuel quality and quantity, and fuel moisture content at the time of burning, no two fires are identical in terms of fire behavior and resulting plant responses (Martin 1982). Fuel quality and quantity generally depend on soil nutrient status, plant species composition and climatic and other biotic factors (e.g. wildlife grazing) (Rundel 1981).

## Fire regimes

To understand the natural history of a site and its plant composition, it is particularly helpful to know the site's fire regime, that is, the historical frequency and intensity of fire. A grassland fire regime may be classified as a regime of frequent/low intensity fire if one equates intensity with plant mortality and not with rate of energy release (Kilgore 1981). Most aboveground biomass is generally consumed in a grassland fire while individual plants usually survive (Volland and Dell 1981, Kucera 1981). This regime is also characterized by a short number of years between successive burns.

Fire interval is the number of years between two successive fires, and the mean fire return interval is the average of all fire intervals and is determined in a specific area during a designated time period (Kilgore 1981). The natural fire return interval in any ecosystem relates to climate, ignition source and probability of fire, fuel accumulation, and fuel quality available to sustain and carry a fire. Wetter climate grasslands with rapid fuel accumulations may have a shorter fire return interval and fires of a higher caloric output than drier climate grasslands (Kucera 1981).

The natural fire frequency for many prairies/grasslands of North America is estimated as 5-10 years (Wright and Bailey 1982). Prescriptions for burning tallgrass prairies, typically specify a 2-3 year interval to maximize grass production and species diversity (Kucera 1981). Annual burning of tallgrass prairie resulted in a uniform sward of prairie grasses with a reduced presence of broad-leaved species and reduced diversity; biennial burning maintained both grass and broad-leaved species (Kucera and Koelling 1964). In contrast, a 4-7 year burn interval is deemed appropriate for drier grasslands in Texas and much longer burn intervals may be characteristic of the arid, shortgrass mixed prairies of western Kansas (Kucera 1981, Wright and Bailey 1982). Because fire effects differ by species, an optimal overall fire frequency may be difficult to determine (Curtis and Partch 1948). Plant compositional effects of a specific fire treatment should be evaluated against objectives for the site to be burned. For example, an objective for a particular burn treatment might be to increase the density of a rare plant species of concern. The density of rare plant individuals should be measured prior to and following burning and in comparison with control/unburned densities (Connelly and Kauffman 1991). Characteristics of the burn treatment should also be measured including such variables as weather, fuel moistures, maximum temperatures reached at the soil surface, flame characteristics, and fuel consumption.

By evaluating changes in plant density and the parameters of different burns and different fire frequencies, managers and researchers will be able to establish cause and effect of burning and to eventually determine an optimal fire frequency that meets the parameters of a specific objective.

## Plant survival/responses to fire and plant regeneration

The meristematic regions of perennial grassland species are generally located at or below the soil surface, increasing the probability of survival from intense fire temperatures (Volland and Dell 1981). Invading woody species have meristems that are held aloft and are vulnerable to mortal damage during fires. Most of the current literature supports the tenant that fire reduces or discourages the growth of shrubs and trees (Bragg and Hulbert 1976, Daubenmire 1968, Kucera 1981, Wright and Bailey 1982). Many shrub and tree species have, however, evolved adaptations to rapidly sprout following fire, particularly in shrubland and forest ecosystems (Ahlgren and Ahlgren 1960, Wright and Bailey 1982, Keeley 1984, Keeley 1987, Kauffman and Martin 1990).

Plant tolerance to heat from fires depends upon the type of tissue being affected; seeds are the most tolerant and roots are the most susceptible of plant tissues (Volland and Dell 1981). Seeds of some grass species will tolerate temperatures ranging from 82°C to 127°C for up to a five minute duration (Wright 1931, Sampson 1944). Similarly, temperatures in excess of 120°C are required to destroy shrub and tree seeds of chaparral and Sierra forests (Wright 1931, Christensen and Muller 1975, Kauffman and Martin 1990). Leaf tissue is killed by temperatures of ~60°C for durations ranging from 2 to 60 minutes (Wright and Bailey 1982). Although the root system is the most heat sensitive plant structure, the soil layer can act as an effective insulator (especially when moist) to protect root tissues from extreme temperatures (Volland and Dell 1981). Some plants possess morphological adaptations that increase their heat tolerance or fire resistance, e.g., thick bark on tree species (Kauffman 1990).

In general, species of grassland communities reproduce after fire by using two life history strategies: 1) sexual reproduction via seed and 2) vegetative reproduction via stem and root budding, underground rhizomes, bulbs and corms (Wells 1969, Voland and Dell 1981, Keeley 1984, Barbour et. al 1987, Keeley and Keeley 1987, and Keeley 1988).

Seedlings may originate on-site from the soil seed bank or from seeds held aloft on the plant and not consumed by fire (i.e. plant-held seed bank). Seedlings may also originate from off-site seed sources via wind and animal dispersal following fire. The effect of fire on the soil, plant-held seed banks, and postfire seedbed conditions depends upon the particular plant species, season of burn, position of seed in the soil or aboveground, and, most importantly, the severity (consumption) of the fire (Kauffman 1990). As maximum temperatures below the soil surface during grassland fires seldom reach levels that destroy seeds, seed production, germination and seedling establishment may be promoted by fire (Vogl 1974). Previous research has shown that fire affects germination of seeds and seedling establishment (Martin and Cushwa 1966, Mallik and Gimingham 1985, Rasmussen and Wright 1988). Germination may be stimulated directly by fire heat effects or indirectly due to changes in the postfire environment. Enhanced germination in the postfire environment may be due to increased light, temperature, or nutrients, decreased allelopathic compounds in litter or soil, or due to a leachate/charate stimulus (Christensen and Muller 1975, Sharrow and Wright 1977, Keeley 1984, Keeley and Keeley 1987, Hulbert 1988, Keeley 1988).

## Plant composition in response to fire

Surface fires generally remove accumulated aboveground biomass while little affecting the below ground perrenating buds (Volland and Dell 1981). Thus, plant species composition may be little changed from the pre-fire composition. Conversely, ground or high intensity fires oxidize part or all of the root mat and accumulated organic deposits and may result in drastic changes in species composition from the pre-fire plant composition. Typically, a fire burns as a combination of fire types, skipping over some areas, moving quickly as a surface fire in some areas, while in other areas persisting as glowing combustion removing peat and organic fuels down to mineral soils. This variable fire behavior creates a mosaic of fire intensity over a landscape. This mosaic of fire intensity generally creates much heterogeneity in vegetation response and greater community diversity in the postfire environment (Sousa 1984). The size, shape, and timing of fire all influence the pattern of recolonization and ultimately, patch diversity of a landscape (Sheldon 1986).

Fire removes accumulated litter and causes mortality of some plant individuals thus reducing immediate competition for the surviving species and opening spaces for seedling establishment. Periodic burning in the tallgrass prairie consumes excessive accumulations of litter leading to increases in species diversity above that found on unburned prairie (Hopkins 1954, Hulbert 1969 and 1988, Risser 1988).

The three most important fire factors determining vegetation composition following fire are burn interval, season of burn, and consumption level of the burn (Volland and Dell 1981). Depending upon a species morphological characteristics and seed ecology, various plant species have been observed to increase or decrease following fire (Daubenmire 1968, Vogl 1974, Kucera 1981, Wright and Bailey 1982). For example, mortality of rhizomatous grass species may be lower than that of bunchgrasses due to the below ground location of rhizome tissues (Conrad and Poulton 1966). Nitrogen-fixing legumes may increase in the post-fire plant community (Daubenmire 1968, Mallik and Gimingham 1985). In some cases, fire has favored graminoid plants, while in other cases fire has favored broad-leaved herbs (Curtis and Partch 1948, Hervey 1949, Daubenmire 1968, Young and Miller 1985, Kucera 1981). Fire is very instrumental in eliminating or controlling invading woody species in grassland environments (Bragg and Hulbert 1976, Vogl 1974, Kucera 1981).

Some natural communities become more vulnerable to exotic plant invasion when natural disturbances, such as fire, are eliminated (Mooney and Drake 1987). Fires characteristic of tallgrass prairies helped to exclude invading species not adapted to periodic fires. Therefore, judicious timing and prescription of fire may help reduce exotic plant compositions in native prairies. Spring burns in tallgrass prairies reduced cover of an introduced bluegrass species and improved conditions for native plants (Curtis and Partch 1948, Hill and Platt 1975). Prescribed burning in the sagebrush/steppe region reduced cheatgrass (*Bromus tectorum*, an introduced annual) density in favor native plant species (Young and Miller 1985, Sapsis 1990). Litter accumulations may perpetuate the dominance of annual weed species on unburned western rangelands (Glendening 1942, Evans and Young 1970). However, composition of exotic species may increase following burning particularly when the fire frequency is increased (Zedler et al. 1983).

## Biomass, flowering and fruiting in response to fire

Increased vegetative, flowering, and seed production have commonly been observed following fire, indicating alterations in species allocation patterns in response to fire (summaries in Daubenmire 1968, Vogl 1974, Kucera 1981, Wright and Bailey 1982).

The darkened soil surface after fire and removal of litter layers may effectively extend the growing season of a site by earlier solar warming of soils which facilitates earlier growth initiation (Hulbert 1969 and 1988, Vogl 1973, Sharrow and Wright 1977). Aboveground productivity often increased for two to three years following fire in mesic grasslands with adequate soil moisture, but aboveground productivity declined in arid grasslands and in grasslands burned annually (Risser et al. 1981). In tallgrass prairies, excessive accumulation of litter after fire exclusion leads to lowered primary plant productivity (Weaver and

Rowland 1952, Hopkins 1954, Kucera et al. 1967, Hill and Platt 1975, Hulbert 1969). In more arid regions, litter buildup following fire may favor increased biomass production through conservation of moisture (Hervey 1949, Willms et al. 1986, Kucera 1981).

Plant phenology may also be affected by burning. Plants in burned areas may flower and/or fruit earlier during postfire growing seasons and may stay green longer when compared to plants on adjacent unburned areas (Blaisdel 1953, Daubenmire 1968). Flower and seed production of various species may increase, decrease, or be unaffected following fire (Stone 1951, Blaisdel 1953, Dix and Butler 1954, Young and Miller 1985, Hulbert 1988). Increased flower and seed production may be delayed until the second growing season following fire (summaries in Daubenmire 1968, Vogl 1974, Kucera 1981 and Risser et al. 1981). In this study, enhanced flowering and fruiting of common and rare plants was observed following burning (Connelly and Kauffman 1991).

## The plant environment in response to fire

Fires can decrease plant competition, increase light exposure of the soil surface, soil pH, and temperature fluctuations; decrease the litter layer and allelopathic chemicals, and alter nutrient composition (Daubenmire 1968, Vogl 1974, Boerner 1982, and, Kutiel and Naveh 1987). Nutrient turnover may be slowed by accumulation of nutrients in standing biomass and in litter which are unavailable to direct microbial action (Walker 1982). The chemical composition of many grassland and wetland plant species include large amounts of compounds, e.g., silica, which are highly resistant to microbial breakdown (Vogl 1974, Meentemeyer 1978, Bazilevich and Titlyanova 1980). Decomposition rates are slowed due to periodic or continuous anaerobic conditions in wetland environments (Mitsch and Gosselink 1986). As a result, fire may act as a primary decompositional agent in many North American grasslands and wetlands (Vogl 1973, Vogl 1974).

Most of the organic biomass and nutrient stocks of grasslands exist below ground; thus direct fire effects on nutrient cycling may be relatively small compared to the total nutrient pool (Boerner 1982, Walker 1982). In eutrophic grasslands, plant-fire response may be more affected by alterations in microclimate (light and temperature) than by direct nutrient changes (Boerner 1982). Increased biomass and flowering following burning in grasslands are likely due to postfire increases in solar insolation, soil surface temperature, and available nitrogen (Stone 1951, Rice and Parenti 1978, Hulbert 1988).

### Animals, insects and pathogens in response to fire

Fire may affect plant composition indirectly by impacting other organisms that subsequently affect plants. Although prescribed burns or wildfires rarely kill animals, some wildlife species have been observed to increase or decrease on burned sites compared to adjacent unburned sites (Bendell 1974). Animals may migrate to burned sites because dense vegetation is removed, succulent vegetation is available, or productivity and nutrition of vegetation and fruits is increased (Daubenmire 1968, Wright and Hinselman 1973, Bendell 1974, Smith and Kadlec 1984, Smith and Kadlec 1985). Conversely, the decline of some animals on burn sites may result from immediate reductions in food, protective shelter, and habitat availability.

Insect and pathogen populations have evolved under various fire regimes, and recent outbreak problems in some forested ecosystems are often attributed to removal of an important ecological process through fire suppression (Ahlgren and Ahlgren 1960, Wright and Hinselman 1973). Fire reduces damping-off fungi, a major case of seedling mortality (Parmeter 1977). In Oregon, fire is used to sanitize fields for commercial production of grass seed (Hardison 1957). Burning in tallgrass prairie resulted in biomass and density increases of grasshoppers (Risser et al. 1981). Conversely, fires may temporarily reduce other insect populations (Daubenmire 1968); burns have been used to reduce mosquitos in wetland areas (Duever et al. 1986). Fires may also have large effects upon microbial populations (Ahlgren 1974) thus affecting the pools and fluxes of various nutrients.

### Summary of fire and management implications

Fire has been a vital process and evolutionary force in the development and perpetuation of North American prairie/grasslands. The prairies of the Willamette Valley have also been shaped by the forces of frequent fire. It is likely that after thousands of years of annual, fall-season fires, Willamette Valley vegetation has developed adaptations to survive this particular regime of disturbance. Removal of this important process has itself been a perturbation to the prairie ecosystem. Currently, succession continues to threaten the remaining remnant prairies of the Willamette Valley. Researchers and land managers will need to determine the best methods for perpetuating prairie plant communities. These methods should include the development of burn prescriptions based upon the optimal frequency and intensity of burns that control woody and exotic plants and maximize native herbaceous species, particularly rare and endangered plants.

Burn prescriptions may be tailored to fit specific fuel quantities, fire weather, and fuel moisture conditions to attain a subsequent desired plant response (Alexander 1982). Intensity of a burn can be adjusted by varying the ignition pattern and frequency of application. Measurement of weather, fuel conditions, fire behavior, and resulting plant composition will help researchers and managers develop optimum burn prescriptions tailored to fit specific objectives (Volland and Dell 1981). Objectives for prairie burning may include: (1) reduction in height and density of shrubs and trees, (2) control and reduction of exotic plants, (3) maintenance or increase in native prairie composition and vigor, (4) maintenance or increase of aboriginal plant foods, and (5) maintenance or increase in vigor and density of rare plant species of concern.

# CHAPTER 3

# FIRE BEHAVIOR, FUEL BIOMASS, AND CLIMATIC CONDITIONS ASSOCIATED WITH PRESCRIBED FIRES AT TWO WILLAMETTE VALLEY WETLAND PRAIRIES

## Abstract

I collected above ground biomass, climate, fuel moisture, residual fuels and fire behavior data in five Willamette Valley wetland prairie plant communities prior to and following prescribed burns at two study sites during 1988 and 1989.

Total above ground biomass (TAGB) of Willamette Valley wetland prairie surpassed that of many North American grasslands. TAGB ranged from 6,958 kg $ha^{-1}$ in a *Vaccinium* community to 12,038 kg $ha^{-1}$ in a *Rosa/Anthoxanthum* community. Relative abundance of herbaceous/litter biomass was highest in the RP *Deschampsia* community (99.7%) and lowest in the *Vaccinium* community (77.7%) during 1988. Between 1988 and 1989, TAGB decreased significantly (-25.4% - $p = 0.05$) in the RP *Deschampsia* community and increased significantly (+68.1%) in the *Vaccinium* community. TAGB values were not statistically different between 1988 and 1989 for the Rose Prairie *Rosa/Anthoxanthum* community or for Fisher Butte *Deschampsia* and *Rosa/Juncus* communities.

Although fires generally reduce woody biomass in prairie ecosystems, woody biomass increased in all plant communities during the first postfire growing season. This suggests that Willamette Valley wetland prairie woody plants are highly resilient to burning quickly recover and increase following fire.

Weather and fuel conditions resulted in greater fireline and reaction intensities during 1989 (757 kW $m^{-1}$ and 788 kW $m^{-2}$, respectively) relative to 1988 (413 kW $m^{-1}$ and 261 kW $m^{-2}$, respectively) at Rose Prairie. In contrast, fireline intensity was significantly greater at Fisher Butte during 1988 (1683 kW $m^{-1}$) than in 1989 (653 kW $m^{-1}$). Fire residence times in 1988 were longer (~24 seconds) than 1989 (7-10 seconds) at both study sites.

Maximum soil surface temperatures ranged from 38° to 260°C at Rose Prairie and from 38° to 371°C at Fisher Butte. Although temperatures reached potential lethal limits for some plant tissues, fire residence time was relatively brief.

During 1988, consumption of TAGB was greatest in the RP *Deschampsia* plant community (91%) and lowest in the *Vaccinium* community (34%). Consumption of TAGB was much greater in the RP *Deschampsia* and both communities at Fisher Butte during 1988 than the 1989 burn. Consumption of woody biomass in all plant communities was higher during the 1988 than 1989 burns.

## Introduction

Natural and aboriginally set fires were extremely important in shaping and maintaining prairie in Oregon's Willamette Valley (Sprague and Hansen 1946, Habeck 1961 and 1962, Thilenius 1968, Johannessen et al. 1971, Towle 1982, Boyd 1986). Most Willamette Valley prairies have been lost to forest succession, urbanization, and intense agricultural and pastoral practices (Christy and Alverson 1994). With fire exclusion, composition of remnant prairies in the Willamette Valley has shifted toward shrub and tree dominance (Habeck 1961, Franklin and Dyrness 1973, Towle 1982, Frenkel and Heinitz 1987).

Remnant Willamette Valley prairies provide habitat for several endangered or threatened plant species that are mandated for protection on publicly owned lands (Oregon Administrative Rules 603-73-005 through 603-73-100, Rohlf 1989). Reintroduction of fire as an ecosystem process is likely necessary for the recovery of remnant prairies and their rare plant populations.

Many exotic plants have invaded Willamette Valley prairies (Frenkel and Streatfeild 1994) and are often opportunistic and sometimes increase in response to disturbances such as fire (Harper 1977). Increases in exotic species may further reduce native species. There is a regional need in the Willamette Valley for burn prescriptions best suited to maintain and restore native species composition and reduce exotic species.

Fire intensity (rate of energy release from fire) and severity (ecological effect) are influenced by weather, fuel composition, quantity, and moisture content at the time of burning (Alexander 1982). Fires of different intensities can result in different plant communities and successional trajectories. Quantifying fire behavior, fuel dynamics, and vegetation response are important in developing fire prescriptions that will ensure native prairie.

No comprehensive scientific study of burning in Willamette Valley prairies has been conducted and little is known concerning fuel biomass, fuel properties, fire behavior or fire frequency in these prairie communities. Restoration and maintenance of native prairie communities will likely require frequent use of prescribed fire.

I had one objective in this study: to quantify fuels and fire behavior in Willamette Valley wetland prairie plant communities prior to and during prescribed burning. I conducted two burn treatments: a single, fall-season prescribed burn and; two consecutive fall-season prescribed burns.

## Study Sites

### Locations

Two study sites, Rose Prairie and Fisher Butte, were selected for study. These sites are situated at the southern end of the Willamette Valley, approximately 13 km west of Eugene, Oregon at longitude 123°, latitude 44° (Figure 3.1). Both study sites are within the Fern Ridge Research Natural Area (RNA) established in 1988 to represent intact Willamette Valley wetland prairies. These prairie parcels are administered by the U.S. Army Corps of Engineers. Rose Prairie (also called the North Amazon parcel of the RNA) is located in T17S R5W S13 and is comprised of ~16 ha in area. Fisher Butte parcel of the RNA is located in T17S R5W S26,35&36, and is comprised of ~30 ha. In the

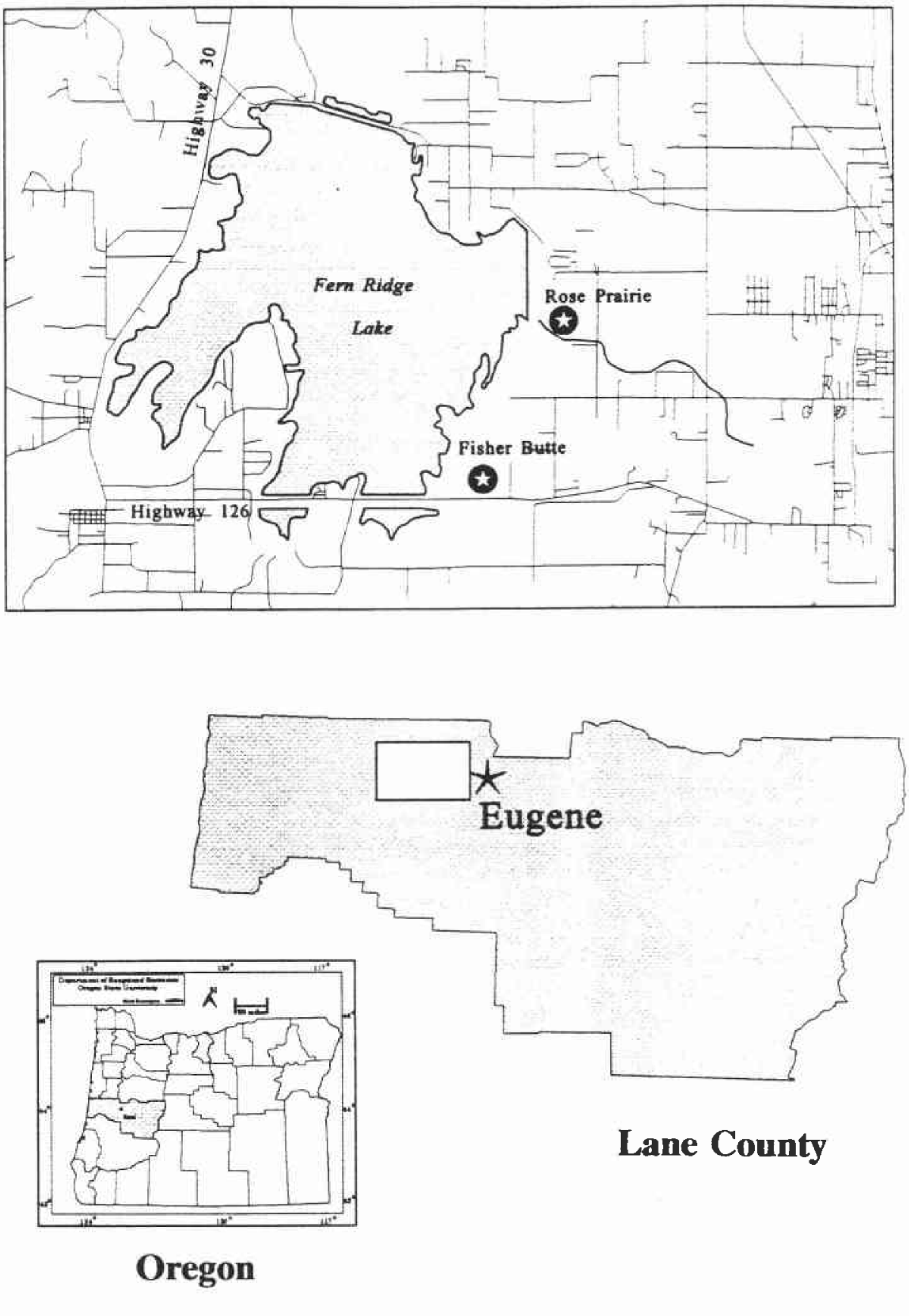

Figure 3.1. Location of study sites.

current study, intensive sampling was conducted on ~6 ha of Rose Prairie and ~20 ha of Fisher Butte.

## Climate

The southern Willamette Valley has moist, mild winters with an average annual precipitation of 114 cm and an average temperature of 12°C (USDA - Soil Conservation Service 1987). The frost-free period typically ranges between 165-210 days. Most precipitation occurs between September-May and summers are moderately warm with a long rainless period.

## General vegetation and sampled plant communities

Rose Prairie had a diverse assemblage of distinct plant communities including: (1) Oregon white oak (*Quercus garryanna*) woodland; (2) wetland prairie dominated by tufted hairgrass (*Deschampsia cespitosa)* and California oatgrass (*Danthonia californica*); (3) concentrations of Nootka rose (*Rosa nutkana*) on elevated circular mounds with a high component of exotic plant species; and (4) dwarf huckleberry (*Vaccinium cespitosa*) plant community (Table 3.1, Figure 3.2). Oak woodland delimits a portion of the eastern boundary of the Rose Prairie RNA parcels and contains California black oak (Quercus kelloggii) at the northern limit of its range, as well as the more common Oregon white oak woodland was not sampled in this study.

Table 3.1. Plant communities identified and sampled, their locations, and their codes in text, tables, and figures.

| Name of Community | Location | Code in Text, Figures and Tables |
|---|---|---|
| *Deschampsia cespitosa-Danthonia californica* | Rose Prairie | RP *Deschampsia* |
| *Rosa nutkana/Anthoxanthum odoratum* mounds | Rose Prairie | *Rosa/Anthoxanthum* |
| *Vaccinium caespitosum* | Rose Prairie | *Vaccinium* |
| *Deschampsia cespitosa-Danthonia californica* | Fisher Butte | FB *Deschampsia* |
| *Rosa nutkana/Juncus nevadensis* | Fisher Butte | *Rosa/Juncus* |

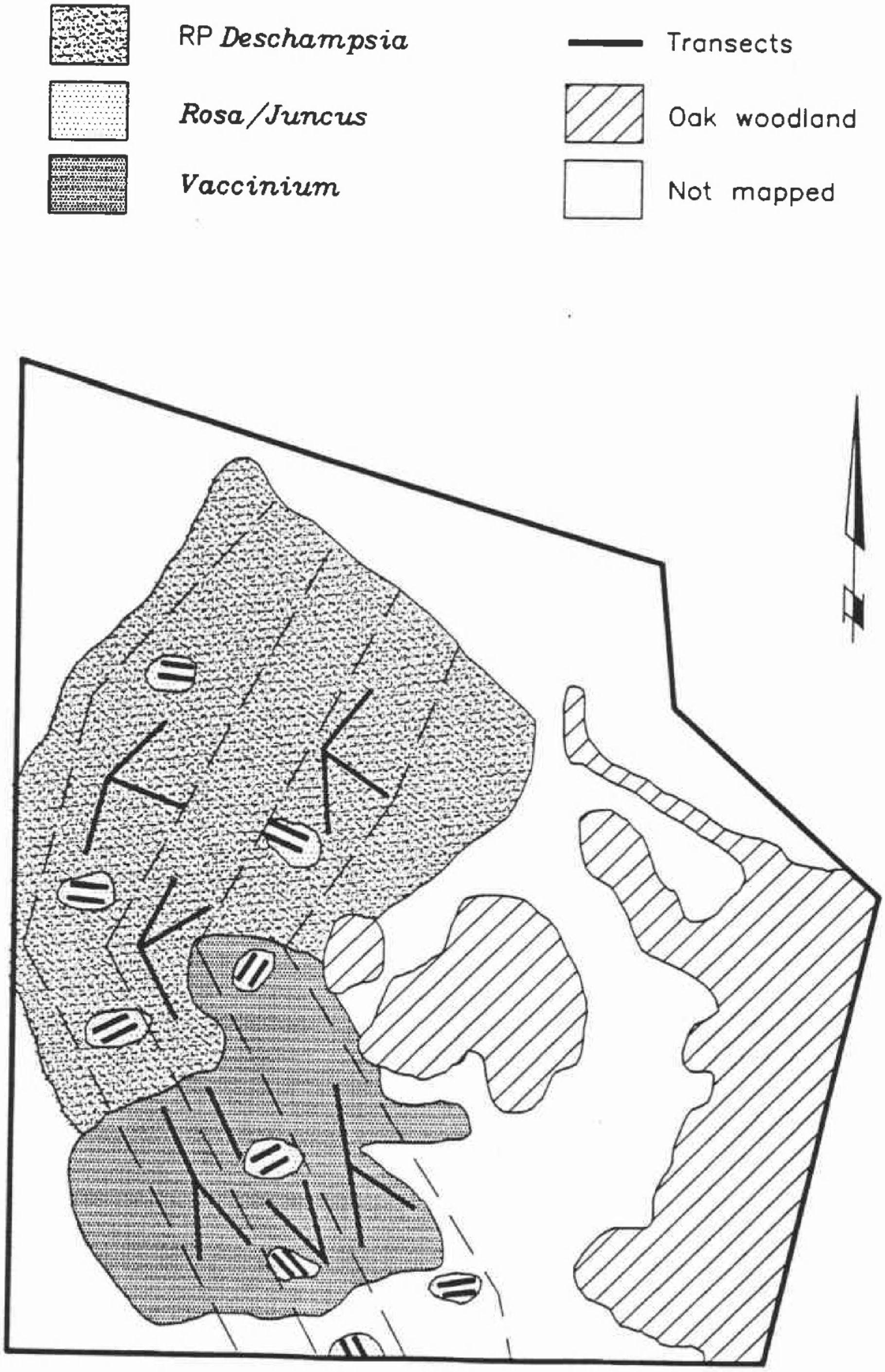

Figure 3.2. Plant communities delineated and transect lay-out at Rose Prairie. Dashed lines indicate boundaries of treatments.

The Rose Prairie *Deschampsia cespitosa-Danthonia californica* (RP Deschampsia) community occurred primarily in the northern portion of the study area which tended to be 'hummocky' or pedestalled with individual plants or groups of plants occupying pedestals.

Nootka rose and the exotic, sweet vernal grass (*Anthoxanthum ordoratum*), were dominants on circular mounds that were approximately 15-20 m diameter and elevated 50 cm above the otherwise level terrain (*Rosa/Anthoxanthum* community). The origin of these mounds is unknown although their origins may be similar to the mima mounds found in the Puget trough region of western Washington (Franklin and Dyrness 1973). This community had a thick organic horizon of moss (up to 8 cm) and a high species diversity and percent cover of exotic herbaceous plant species.

The *Vaccinium caespitosum* (*Vaccinium*) community was dominated by *Vaccinium caespitosum* and occupied the same generally level terrain as the *RP Deschampsia* community. *Vaccinium caespitosum* is a small sub-shrub commonly associated with montane meadows of the Cascade Mountains and is uncommonly in the Willamette Valley (Hitchcock et al. 1969, Frenkel pers. comm.). The *Vaccinium* community contained native herbaceous species not observed in the RP *Deschampsia* community including high densities of *Aster curtis*, a rare Willamette Valley and Puget trough prairie endemic (Clampitt 1984 and 1987, Alverson 1987 and 1991). Numerous terrestrial lichens (particularly *Cladonia* species) occurred primarily in the *Vaccinium* community but also, to a lesser extent, in the *Rosa/Anthoxanthum* community.

Abrupt ecotones between plant communities were not present at Fisher Butte. There was instead a gradual change in vegetation along a moisture/elevation gradient at the site (Finley 1994). The mesic *Rosa nutkana/Juncus nevadensis* (*Rosa/Juncus*) community graded into a drier *Deschampsia cespitosa-Danthonia californica* (FB *Deschampsia*) community (Table 3.1, Figure 3.3). *Agrostis tenuis* was dominant at the driest end of the soil moisture gradient.

Shrub and tree encroachment was further advanced at Fisher Butte than at the Rose Prairie site. Oregon ash (*Fraxinus latifolia*) was invading along the western portion of the study site roughly corresponding with the western boundary of the *Rosa/Juncus* community. *Rosa nutkana* was prevalent throughout the site.

Plant taxonomy followed that of Hitchcock et al. 1969.

### Soils and topography

Soils at the Rose Prairie and Fisher Butte sites had been mapped and classified by the USDA - Soil Conservation Service (1987) as Natroy silty clays. This soil type is alluvial, deep, poorly drained, and subject to frequent long periods of flooding from November to May. Finley (1994) measured soil textures at Rose Prairie as sandy loams and Fisher Butte as silty clays.

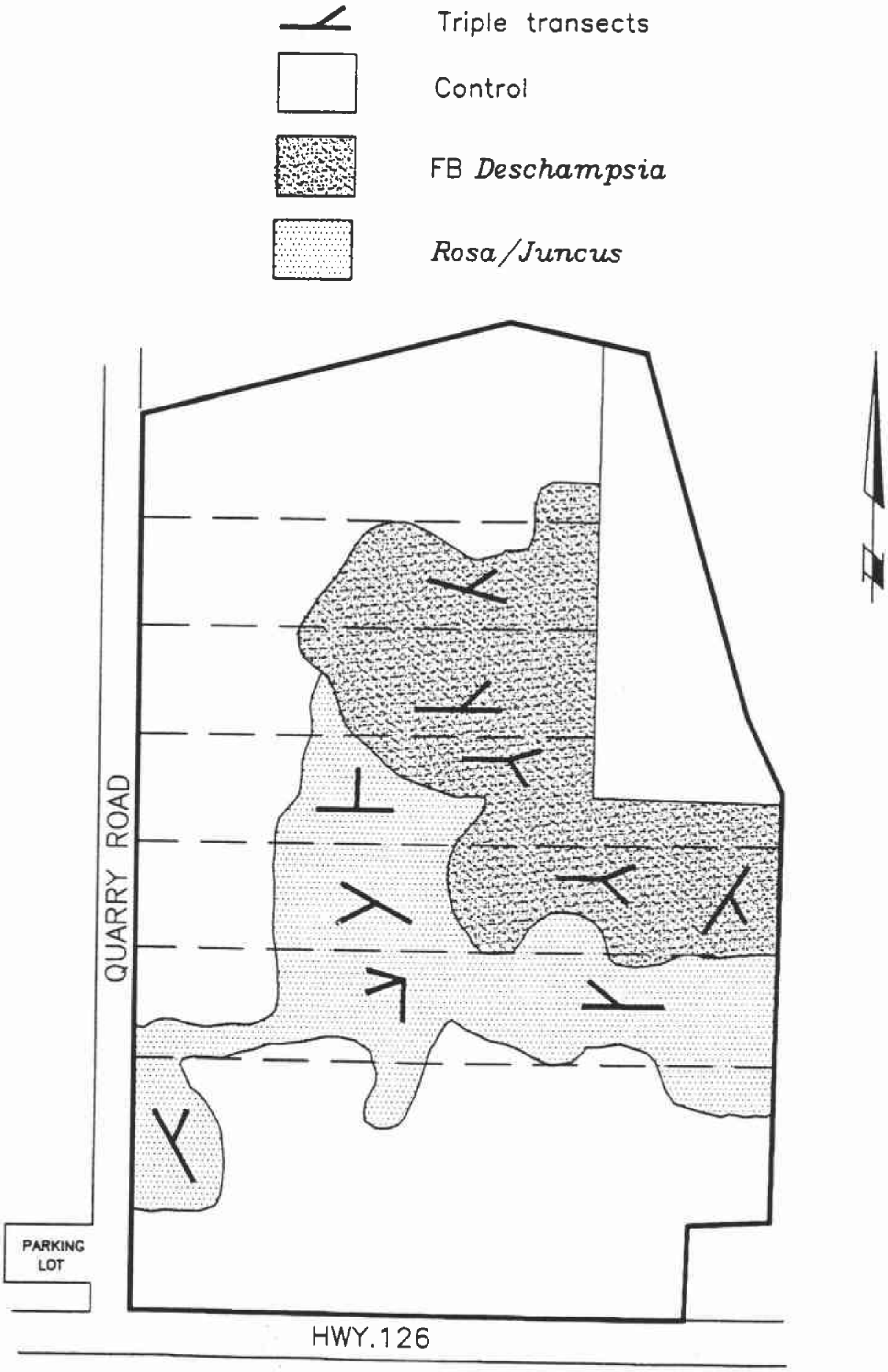

**Figure 3.3. Plant communities delineated and transect lay-out at Fisher Butte. Dashed lines indicate boundaries of treatments.**

Soil moisture at both sites is highly variable, which is characteristic of Willamette Valley wetland prairies (Finley 1994). Study sites are flooded and/or soils are reduced (anaerobic) for approximately six months. Among the plant communities in this study, RP *Deschampsia*, FB *Deschampsia*, and *Rosa/Juncus* communities were more intensely reduced than the *Vaccinium* community (Finley 1994). Duration and intensity of flooding were greatest in the RP *Deschampsia* community at Rose Prairie and in the *Rosa/Juncus* community at Fisher Butte (Finley 1994).

The period from July through September is generally warm and dry, and soils often become deeply cracked and extremely hard (USDA - Soil Conservation Service 1987). Thus, plants in these wetland prairies have adapted to survive an annual cycle of extremes in temperature and moisture availability. A majority of resident plant species are dormant by early fall, the period when natural and aboriginal fall-season burning occurred.

Topography at both sites is relatively flat, ranging between 113 to 115 meters above sea level (Finley 1994).

## Methods

### Plant communities

Prior to 1988 burns, three plant communities were delineated and sampled at Rose Prairie: *Deschampsia cespitosa-Danthonia californica* (RP *Deschampsia*);

*Rosa nutkana/Anthoxanthum ordoratum* (*Rosa/Anthoxanthum*); *and Vaccinium caespitosum* (*Vaccinium*) (Table 3.1, Figure 3.2). Two plant communities were sampled at Fisher Butte, *Deschampsia cespitosa-Danthonia californica* (FB *Deschampsia*) and *Rosa nutkana/Juncus nevadensis* (*Rosa/Juncus*) (Table 3.1, Figure 3.3).

## Biomass

Above ground biomass was sampled prior to burning in 1988 in 60, 30x60 cm plots in each Rose Prairie community and in 120 plots in each Fisher Butte community. Biomass plots were collected adjacent to established plant community transects (Figures 3.2 and 3.3).

Collected biomass was separated in the field into herbaceous/litter (inclusive of live material, standing dead, and litter) and woody (live and dead shrubs and trees) components, oven-dried for ~72 hours at 70°C, and weighed. In 1989, 30, 30x30 cm biomass plots were sampled in each Rose Prairie community, and 60, plots were collected in each Fisher Butte community.

Plots sampled in 1989 had been burned in 1988. Biomass data represent accumulated standing crop prior to fire reintroduction (1988 data) and standing crop one year following burning (1989 data).

### Moisture content

Moisture content was measured in each sampled community by randomly collecting 10 standing biomass, 10 litter, and 10 soil samples immediately prior to prescribed burns. Standing biomass included all herbaceous and woody, live and dead, materials above the litter layer. Litter samples included all dead material on the mineral soil surface. Soil samples, collected from the top 3 cm of soil, were placed in metal soil cans; seams were taped to prevent moisture loss, and transported to the laboratory where they were weighed, oven-dried for 48 hours at 70°C and reweighed. The pre- and post- oven-drying weights were used to determine biomass and soil moisture content on a dry weight basis.

Moisture content of 10-hour woody fuels were estimates with a 10-hour fuel stick at each study site. Fuel sticks were weighed just prior to fire ignition.

### Weather conditions during burning

Hand-held "belt weather kits" were used to measure air temperature, relative humidity, wind speed, and wind direction prior to ignition and at regular intervals during burning.

## Fire prescription and fire behavior

Prescribed burns were conducted at study sites on 11 October, 1988 and 19 September, 1989. Personnel of the Eugene District of the Bureau of Land Management conducted all burns utilizing strip-head burning techniques and wetlines for fire control. Fires were ignited by drip torches. Wetlines were applied and maintained utilizing pumper trucks along the burn boundaries.

Fire parameters measured included flame length, flame height, flame depth, flame angle (degrees off the horizontal), rate of spread and fire residence time for the prescribed burns (Rothermel and Deeming 1981, Alexander 1982). All fire behavior data were collected randomly, selecting 15 to 30 areas per site for observation during each burn. Flame length (FL), flame depth (D), and rate of fire spread (ROS) were used to calculate fireline intensity ($I_{fl}$), reaction intensity ($I_r$) and heat released per unit area in the active flame-front ($H_a$):

$$I_{fl} = 258FL2.17 \qquad (\mathrm{kW\ m^{-1}})$$

$$I_r = I_{fl}/D \qquad (\mathrm{kW\ m^{-2}})$$

$$H_a = I_{fl}/ROS \qquad (\mathrm{kJ\ m^{-2}})$$

(Byram 1959, Alexander 1982, Rothermel and Deeming 1981).

Fireline intensity ($I_{fl}$) is the rate of heat released per unit time per unit length of fire front (Alexander 1982). Reaction intensity is the heat release per unit area within the active combustion zone.

## Maximum fire temperatures/pyronometers

Approximate maximum temperatures attained at and below the soil surface were recorded with pyronometers assembled by painting strips of heat sensitive paints on 5x8 cm pieces of mica and stapling them to an asbestos-like backing (permafab) (Fenner and Bentley 1960). Heat sensitive paints used to assemble the 1988 pyronometers included 38°, 59°, 73°, 121°, 149°, 177°, 260°, and 371°C. In 1989, 204° and 232° paints were substituted for the 177° paint. Three or four pyronometers were positioned in each community prior to burning with ~3 cm below the soil surface and ~ 5 cm above the soil surface.

## Biomass consumption

Immediately following the prescribed fires, paired plots were clipped, separated and weighed in the same manner as described above for prefire biomass sampling. In order to shorten field time, fewer samples were collected following the prescribed burns in 1988 relative to preburn biomass samples. Thirty 30x60 cm plots were collected in each of the *RP Deschampsia*, *Rosa/Anthoxanthum,* and *Vaccinium* communities at Rose Prairie, and 60, 30x60 cm plots were collected in each of the FB *Deschampsia* and *Rosa/Juncus* communities at Fisher Butte during postfire sampling.

During 1989 the same size and number of plots were collected to determine residual biomass following burning relative to preburn biomass (30x30 cm plots). Pre and postfire biomass data were used to derive levels of fuel consumption for the 1988 and 1989 fires.

### Comparing biomass, moisture content and consumption at sites

Because weather and fire behavior conditions were measured for sites and not plant communities, plant communities were combined to help determine the influence of biomass and fuel moistures at sites upon fire behavior.

### Statistical analysis

Analysis of variance (ANOVA) and Least Significant Differences multiple range tests were utilized to determine significance in biomass and moisture contents within years among plant communities. Student's t-tests were used to determine differences in biomass and moisture contents between years within plant communities, between sites within years, and within sites between years. Student's t-tests were also used to determine differences in fire parameters between sites within years and within sites between years. Significance of all testing was determined at the $p \leq 0.05$ level.

## Results

### Above ground biomass by plant communities

Total above ground biomass (TAGB) in 1988 was not significantly different for RP *Deschampsia*, *Vaccinium*, and *Rosa/Juncus* (6,958 - 7,746 kg ha$^{-1}$) plant communities (Table 3.2). In 1988, TAGB was significantly greater in FB *Deschampsia* (8,906 kg ha$^{-1}$) and *Rosa/Anthoxanthum* (12,038 kg ha$^{-1}$) communities relative to all other communities. Mean values of the herbaceous/litter biomass component was significantly different between each plant community during 1988 and ranged from 11,209 ha$^{-1}$ in the *Rosa/Anthoxanthum* to 6,958 kg ha-1 in the *Vaccinium* community.

The relative abundance of herbaceous/litter biomass as a percent of TAGB was high in the RP *Deschampsia* (99.7%), *Rosa/Anthoxanthum* (93.1%) and FB *Deschampsia* (98.2%) communities, and it comprised only 77.7% and 83.2% of TAGB respectively in the *Vaccinium* and *Rosa/Juncus* communities.

During 1988, woody biomass was similar and relatively high in the *Vaccinium* (1551 kg ha$^{-1}$) and *Rosa/Juncus* (1320 kg ha$^{-1}$) communities, moderate in the *Rosa /Anthoxanthum* (829 kg ha$^{-1}$) community, and low in the RP *Deschampsia* (23 kg ha$^{-1}$) and FB *Deschampsia* (165 kg ha$^{-1}$) communities.

Between 1988 and 1989, TAGB decreased significantly (-25.4%) in the RP *Deschampsia* community and it increased significantly (+68.1%) in the *Vaccinium* community (Table 3.2). Concurrently, there were significant declines in the

Table 3.2. Above ground biomass (kg ha$^{-1}$) and fuel consumption (%) of plant communities at Rose Prairie and Fisher Butte for 1988 and 1989. Biomass and consumption values are partitioned into total, herbaceous, and woody components. Values in parentheses are the standard error of the mean.

| | | | ROSE PRAIRIE | | | FISHER BUTTE | |
|---|---|---|---|---|---|---|---|
| | | | RP *Deschampsia* | *Rosa/Anthoxanthum* | *Vaccinium* | FB *Deschampsia* | *Rosa/Juncus* |
| Total | 1988 | Biomass | 7705$^{1a}$ (373) | 12038$^{b}$ (507) | 6958$^{1a}$ (446) | 8906$^{c}$ (268) | 7746$^{a}$ (251) |
| | | Consumption | 91 | 48 | 34 | 79 | 68 |
| | 1989 | Biomass | 5752$^{2a}$ (315) | 12839$^{b}$ (1124) | 11699$^{2b}$ (965) | 8820$^{c}$ (423) | 8214$^{c}$ (620) |
| | | Consumption | 37 | 51 | 29 | 35 | 35 |
| Herb | 1988 | Biomass | 7682$^{1a}$ (375) | 11209$^{b}$ (487) | 5408$^{1c}$ (370) | 8741$^{d}$ (262) | 6448$^{1e}$ (193) |
| | | Consumption | 91 | 51 | 29 | 79 | 76 |
| | 1989 | Biomass | 5693$^{2a}$ (328) | 10920$^{b}$ (649) | 7957$^{2c}$ (689) | 8512$^{c}$ (421) | 5691$^{2a}$ (284) |
| | | Consumption | 37 | 62 | 22 | 34 | 48 |
| Woody | 1988 | Biomass | 23$^{a}$ (20) | 829$^{b}$ (155) | 1551$^{1c}$ (208) | 165$^{a}$ (39) | 1320$^{1c}$ (173) |
| | | Consumption | 99 | 11 | 49 | 63 | 32 |
| | 1989 | Biomass | 59$^{a}$ (59) | 1919$^{b}$ (854) | 4008$^{2c}$ (537) | 308$^{a}$ (92) | 2566$^{2b}$ (456) |
| | | Consumption | 63 | 0 | 43 | 54 | 6 |

Means with different superscripted numbers denote a significant difference ($p \leq 0.05$) between years within fuel categories; means with different superscripted letters denote a significant difference between plant communities. Data represent accumulated standing crop prior to 1988 burns and standing crop one year following fire in 1989.

herbaceous/litter component of biomass in RP *Deschampsia* (-25.9%) and *Rosa/Juncus* (-11.7%) communities, while there was a significant increase in the herbaceous/litter component in the *Vaccinium* (+47.1%) community. Woody plant biomass increased significantly in both the *Vaccinium* (+158.4%) and *Rosa/Juncus* (+94.4%) communities between 1988 and 1989.

The abundance of herbaceous/litter biomass relative to TAGB remained high in the RP *Deschampsia* (99.0%) and FB *Deschampsia* (96.5%) communities during 1989, while it dropped somewhat from preburn 1988 values and comprised 85.1%, 68.0% and 69.3% of TAGB in the *Rosa/Anthoxanthum*, *Vaccinium* and *Rosa/Juncus* communities, respectively (Table 3.2).

### Moisture content by plant communities

Moisture content of standing material, litter and soil was generally similar for the different plant communities within a site within a given year (Table 3.3). Comparing all communities at both sites, moisture content of standing material was highest in the FB *Deschampsia* community (49.0%) and lowest in the *Rosa/Anthoxanthum* community (31.2%) during 1988. During 1988, moisture content of litter was highest in the *Rosa/Anthoxanthum* community (19.8%) and lowest in the *Rosa/Juncus* community (10.9%). Moisture content of soil was highest in the FB *Deschampsia* (17.6%) and *Rosa/Juncus* (17.8%) communities and lowest in the RP *Deschampsia* (4.5%) and *Vaccinium* (3.7%) communities.

Table 3.3. Moisture content (%) of standing biomass, litter, and soil for 1988 and 1989 within plant communities at Rose Prairie and Fisher Butte. Values in parenthesis are the standard error of the mean.

| | | ROSE PRAIRIE | | | FISHER BUTTE | |
|---|---|---|---|---|---|---|
| | | RP *Deschampsia* | *Rosa/Anthoxanthum* | *Vaccinium* | FB *Deschampsia* | *Rosa/Juncus* |
| Standing | 1988 | 33.3 (3.1) | $31.2^{a}$ (5.1) | $46.4^{1}$ (7.8) | $49.0^{b}$ (7.2) | $46.8^{1}$ (6.7) |
| | 1989 | $42.6^{a}$ (3.7) | $36.3^{a}$ (3.0) | $69.2^{2b}$ (5.9) | $72.1^{b}$ (11.0) | $71.3^{2b}$ (8.7) |
| Litter | 1988 | $12.5^{1bc}$ (3.7) | $19.8^{1a}$ (1.8) | $14.9^{1b}$ (0.7) | $12.4^{1bc}$ (0.5) | $10.9^{1c}$ (0.8) |
| | 1989 | $4.3^{2ab}$ (0.5) | $5.4^{2a}$ (0.8) | $5.2^{2a}$ (0.7) | $2.2^{2c}$ (0.2) | $2.9^{2bc}$ (0.4) |
| Soil | 1988 | $4.5^{1a}$ (0.5) | $10.7^{1b}$ (0.6) | $3.7^{1a}$ (0.4) | $17.6^{1c}$ (0.6) | $17.8^{1c}$ (0.6) |
| | 1989 | $1.0^{2a}$ (0.1) | $2.6^{2b}$ (0.2) | $1.4^{2a}$ (0.1) | $2.6^{2b}$ (0.3) | $4.6^{2c}$ (0.6) |

Means with different superscripted numbers denote a significant difference ($p \leq 0.05$) between years within fuel categories; means with different superscripted letters denote a significant difference between plant communities within biomass categories.

During 1989, moisture content of standing material was high and similar for the two plant communities at Fisher Butte (*Deschampsia* 71.3% and *Rosa/Juncus* 72.1%) and the *Vaccinium* community (69.2%). Standing moisture content was lower and similar for RP *Deschampsia* (42.3%) and *Rosa/Anthoxanthum* (36.3%) (Table 3.3). Litter moisture contents were greatest in plant communities at Rose Prairie relative to Fisher Butte and ranged from 5.4% (*Rosa/Anthoxanthum*) to 2.2% (FB *Deschampsia*) during 1989. Moisture content of soil samples was highest in the *Rosa/Juncus* community (4.6%) and lowest in the RP *Deschampsia* (1.0%) and *Vaccinium* (1.4%) communities.

Overall, moisture content of standing biomass was somewhat greater in plant communities for 1989 relative to 1988 with significant differences in the *Vaccinium* and *Rosa/Juncus* communities (Table 3.3). In contrast, litter and soil moisture content was significantly lower in 1989 relative to 1988 for all plant communities.

## Weather conditions during burning

Prescribed burns at Rose Prairie and Fisher Butte were conducted during the same day in 1988 and 1989. In both years, Rose Prairie was burned first (Table 3.4). In both years, temperatures were slightly lower at Rose Prairie and humidities were slightly higher than at Fisher Butte. Ambient temperatures were higher and relative humidities were lower at each site in 1989 burns compared to 1988 burns. Wind speeds were slightly higher in 1989.

Table 3.4. Environmental conditions at Rose Prairie and Fisher Butte associated with prescribed burns conducted on 11 October, 1988 and 19 September, 1989. Values in parentheses are the standard error of the mean.

| DATE OF BURN: | October 11, 1988 | | September 19, 1989 | |
|---|---|---|---|---|
| SITE: | Rose Prairie | Fisher Butte | Rose Prairie | Fisher Butte |
| BURN TIME: | 13:00-15:00 h. | 16:15-17:45 h. | 11:25-12:05 h. | 1320-15:15 h. |
| WEATHER | | | | |
| Temperature (oC) | 16 | 18 | 18 | 21-24 |
| Relative Humidity (%) | 55-68 | 62-66 | 53 | 28-41 |
| Windspeed (kph) | ~6 | ~6 | 6-11 | 8-12 |
| Wind Direction | W by NW | W | N by NE | N by NW |
| ABOVEGROUND BIOMASS | | | | |
| Total Biomass | $8890^{1}$ (311) | 8340 (262) | $10097^{2a}$ (598) | $8517^{b}$ (375) |
| Consumption (%) | 57 | 74 | 40 | 35 |
| Herbaceous | 8084 (301) | 7568 (177) | $8193^{2}$ (401) | $7101^{b}$ (284) |
| Consumption (%) | 59 | 78 | 44 | 40 |
| Woody | $801^{1}$ (100) | $779^{1}$ (99) | $1995^{2}$ (374) | $1428^{2}$ (253) |
| Consumption (%) | 37 | 35 | 26 | 11 |
| MOISTURE CONTENT (%) | | | | |
| Standing | $36.7^{1}$ (5.8) | $47.9^{1}$ (6.8) | $40.5^{2a}$ (7.0) | $71.7^{2b}$ (9.6) |
| Litter | $15.7^{1a}$ (1.6) | $11.7^{1b}$ (0.7) | $4.8^{2a}$ (0.7) | $2.6^{2b}$ (0.3) |
| Soil | $6.4^{1a}$ (1.1) | $17.7^{1b}$ (0.6) | $1.6^{2a}$ (0.3) | $3.6^{2b}$ (0.5) |
| 10-Hour Fuel Stick | 12.0 | 11.0 | 10.0 | 9.0 |

Means with different superscripted numbers denote a significant difference ($p = 0.05$) between years within fuel categories; at a site; means with different superscripted letters denote a significant difference between study sites within a year and within a biomass category.

## Fire behavior

Flame length, flame height, flame depth, and flame angle were all greater at Fisher Butte than Rose Prairie in 1988 (Table 3.5). Fireline intensity ($I_{fl}$) and heat released per unit area ($H_a$) were about four times lower at Rose Prairie than Fisher Butte and reaction intensity was two times lower. During 1989, there were no significant differences in fire behavior between the two sites (Table 3.5). Almost all fire behavior parameters were significantly different between 1988 and 1989. Flame length and height were greater while flame depth and angle were less in 1989 than 1988 at Rose Prairie. However, at Fisher Butte, flame length, height, depth and angle were significantly less in 1989 than 1988.

Because of weather and fuel differences in the two years, greater fireline and reaction intensities occurred during 1989 than 1988 at Rose Prairie (Table 3.5). However, fireline intensity was significantly greater at Fisher Butte in 1988 than 1989. Fire residence times were considerably longer in 1988 (~24 seconds) than 1989 burns (7-10 seconds) at both sites. Generally, the 1989 burns were spotty at both study sites in contrast to fairly complete burns in 1988.

## Maximum temperatures/pyronometers

Maximum soil surface temperatures in 1988 at Rose Prairie ranged from 59° to 121°C in the RP *Deschampsia* community, 59° to 73°C in the *Rosa/Anthoxanthum* community, and 73° to 177°C in the *Vaccinium* community

Table 3.5. Fire behavior for prescribed burns conducted on 11 October, 1988 and 19 September, 1988 at Rose Prairie and Fisher Butte. Values in parentheses are the standard error of the mean.

| | **11 October, 1988** | | **19 September, 1989** | |
|---|---|---|---|---|
| | Rose Prairie | Fisher Butte | Rose Prairie | Fisher Butte |
| Flame Length (m) | $1.1^{1a}$ (0.1) | $2.2^{1b}$ (0.1) | $1.5^{2}$ (0.2) | $1.3^{2}$ (0.2) |
| Flame Height (m) | $0.8^{1a}$ (0.1) | $1.9^{1b}$ (0.2) | $1.4^{2}$ (0.2) | $1.0^{2}$ (0.2) |
| Flame Depth (m) | $1.9^{1a}$ (0.2) | $3.0^{1b}$ (0.4) | $0.9^{2}$ (0.2) | $0.9^{2}$ (0.2) |
| Flame Angle (°) | $55^{1a}$ (2) | $63^{1b}$ (4) | $46^{2}$ (1) | $47^{2}$ (2) |
| Residence Time (s) | $24^{1}$ (1.0) | $24^{1}$ (3) | $10^{2}$ (2) | $7^{2}$ (1) |
| Fireline Intensity (Kw/m) | $413^{1a}$ (56) | $1683^{1b}$ (248) | $757^{2}$ (168) | $653^{2}$ (199) |
| Rate of Spread (m/min) | $7.3^{1}$ (1.0) | 7.5 (0.9) | $13.9^{2}$ (1.6) | 9.4 (1.8) |
| Reaction Intensity (kW/m2) | $261^{1a}$ (48) | $578^{b}$ (107) | $788^{2}$ (136) | 656 (184) |
| Heat per unit area (kJ/m2) | $56^{a}$ (6) | $202^{1b}$ (48) | 64 (16) | $55^{2}$ (16) |

Means with different superscripted numers denote a significant difference between years within fuel categories; means with different superscriped letters denote a significant difference between plant communities.

(Table 3.6). Heat pulses of 59°C were attained 1 cm below the soil surface in both the RP *Deschampsia* and *Vaccinium* communities.

Maximum soil surface temperatures at Fisher Butte ranged from 59° to or greater than 371°C in *Deschampsia* and 38° to 149°C in the *Rosa/Juncus* community during the 1988 prescribed fire (Table 3.6). Temperatures up to 38°C penetrated to 2 cm below the soil surface in the FB *Deschampsia* community.

During 1989, most pyronometers were missed by fire at Rose Prairie. Maximum temperatures at the soil surface were 38 to 260°C in the *Rosa/Anthoxanthum* community, 260°C in the *Vaccinium* community while all three pyronometers placed in RP *Deschampsia* were located areas that did not burn (Table 3.7). A 93°C temperature was recorded 0.5 cm below the soil surface in the *Rosa/Anthoxanthum* community.

At Fisher Butte, maximum soil surface temperatures during 1989 ranged between 59 and 149°C in the *Deschampsia* community and 38 to 149°C in the *Rosa/Juncus* community (Table 3.7). Heat pulses of 38°C were detected 2 cm below the soil surface in the *Rosa/Juncus* community.

### Biomass consumption

During 1988, consumption of TAGB was greatest in the RP *Deschampsia* plant community (91%) and lowest in the *Vaccinium* community (34%) (Table 3.2). Consumption of TAGB was much greater in the RP *Deschampsia* and both Fisher Butte communities in 1988 than 1989. In contrast, consumption was fairly

Table 3.6. Maximum temperatures (°C), attained at depths (cm)above the soil surface in plant communities at Rose Prairie and Fisher Butte during 1988 prescribed burns. Data displayed are from pyronometers placed in communities.

| | | ROSE PRAIRIE | | | | | | | | | | | FISHER BUTTE | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RP *Deschampsia* | | | *Rosa/Anthoxanthum* | | | | | *Vaccinium* | | | FB *Deschampsia* | | | | *Rosa/Juncus* | | |
| | | 1 | 2 | 3 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| Height above soil surface (cm) | | | | | | | | | | | | | | | | | | | |
| | 4.0 | | | | | | | | | | | | | | | | | | |
| | 3.5 | | | | | 260 | | | | | | 371 | | | | | | 371 | |
| | 3.0 | | | | | | | 371 | | | | | | | | | | 260 | 371 |
| | 2.5 | | 371 | 371 | | | 371 | 260 | | | | 260 | | | | 371 | 371 | 260 | 260 |
| | 2.0 | | 260 | 177 | 371 | | 260 | 149 | | | | | | | | 260 | 260 | 177 | 260 |
| | 1.5 | 260 | 177 | 121 | 177 | 177 | 177 | | 260 | 371 | | 177 | | | | 260 | 260 | 177 | 177 |
| | 1.0 | 177 | 59 | | 121 | 149 | 121 | 121 | 149 | | 371 | 149 | | | 371 | 177 | 260 | 121 | 149 |
| | 0.5 | 149 | | 73 | 73 | 121 | | | | 260 | 260 | | | 371 | 149 | 121 | 177 | 73 | 121 |
| Soil Surface | 0.0 | 121 | | 59 | 59 | 73 | | 73 | 73 | 177 | 177 | 73 | 371 | 177 | 59 | 73 | 149 | 38 | 73 |
| | -0.5 | 73 | | | | 59 | | 59 | | 121 | 73 | 59 | 149 | 59 | | 38 | 59 | | 59 |
| | -1.0 | 59 | | | | 35 | | | 38 | 59 | 59 | | 73 | 38 | | | 38 | | |
| | -1.5 | | | | | | | 38 | | | | | 73 | | | | | | |
| | -2.0 | | | | | | | | | | | | 38 | | | | | | |

Table 3.7. Maximum temperatures (°C) attained at depths (cm) above the soil surface in plant communities at Rose Prairie and Fisher Butte during 1989 prescribed burns. Data displayed are from pyronometers placed in communities.

| | | ROSE PRAIRIE | | | FISHER BUTTE | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Rosa/Anthoxanthum* | | *Vaccinium* | FB *Deschampsia* | | | | *Rosa/Juncus* | | | |
| | | 1 | 2 | 1 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Height above soil surface (cm) | | | | | | | | | | | | |
| | 4.0 | | 260 | | | | | | | | | |
| | 3.5 | 371 | 204 | 371 | | | | | | | | |
| | 3.0 | 371 | 121 | 371 | 121 | | | 93 | | | | |
| | 2.5 | 371 | 93 | 371 | 121 | 260 | | 73 | 371 | | | |
| | 2.0 | 371 | | 371 | 121 | 260 | | 59 | 371 | | 371 | 371 |
| | 1.5 | 371 | 73 | 371 | 121 | 204 | | 59 | 371 | 204 | 260 | 371 |
| | 1.0 | 371 | 59 | 371 | 121 | 149 | 371 | 59 | 232 | 121 | 260 | 371 |
| | 0.5 | 371 | | 371 | 93 | 121 | 260 | 59 | 149 | 93 | 232 | 260 |
| Soil surface | 0.0 | 260 | 38 | 260 | 73 | 93 | 149 | 59 | 38 | 73 | 149 | 93 |
| | -0.5 | 93 | | | 59 | 38 | 38 | 38 | | 59 | 73 | 38 |
| | -1.0 | | | | 38 | | | 38 | | 38 | 38 | |
| | -1.5 | | | | | | | | | 38 | 38 | |
| | -2.0 | | | | | | | | | 38 | 38 | |

low and approximately the same between years for the *Rosa/Anthoxanthum* and *Vaccinium* communities. Percent consumption of TAGB was lowest in the *Vaccinium* community for both years (34% - 1988; 29% - 1989).

Percent consumption of herbaceous/litter biomass was very similar to TAGB for all communities within a given year (Table 3.2). Consumption of herbaceous/litter biomass was generally lower in 1989 than 1988 burns except for in the *Rosa/Anthoxanthum* community where consumption was 51% in 1988 compared with 62% in 1989.

Like consumption of herbaceous/litter biomass and overall TAGB, consumption of woody biomass was generally lower during the 1989 burns relative to the 1988 burns.

### Comparison of sites across plant communities

No significant differences in TAGB exist when herbaceous/litter or woody biomass components were combined for study site plant communities in 1988 (Table 3.4). During 1989, TAGB and herbaceous/litter biomass were significantly greater at Rose Prairie (10,097 and 8,193 kg ha$^{-1}$, respectively) than Fisher Butte (8,517 and 7,101 kg ha$^{-1}$). Woody biomass almost doubled between 1988 and 1989 at both study sites.

When moisture content data from all communities were combined in 1988, litter moisture was significantly greater and soil moisture significantly less at Rose Prairie than at Fisher Butte (Table 3.4). In 1989, there were significant differences in moisture contents of all components (standing biomass, litter and soil) between the two study sites. Moisture in standing biomass and soil were greater at Fisher Butte than at Rose Prairie; litter moisture was greater at Rose Prairie than at Fisher Butte.

Standing biomass moisture was significantly greater at the time of burning in 1988 than 1989. However, litter and soil moisture content were significantly drier at both study sites in 1989 than in 1988 (Table 3.4). Moisture content of 10-hour fuel sticks was less at both sites during 1989 relative to 1988 and also less at Fisher Butte than Rose Prairie in both years (Table 3.4).

Total fuel consumption was greater at Fisher Butte (74%) than at Rose Prairie (57%) during 1988 (Tables 3.4). Consumption of TAGB was lower at Rose Prairie (40%) and Fisher Butte (35%) during the 1989 burns relative to 1989. Overall, the 1988 burns had more herbaceous/litter, woody, and TAGB consumption than 1989.

## Discussion

### Biomass

Wetland prairie biomass has been estimated at the Willamette Floodplain RNA at W.L. Finley National Wildlife Refuge. Peak standing herbage in *Deschampsia cespitosa-Danthonia californica* and *Poa-Agrostis* communities in 1971 averaged 5,300 and 3,230 kg $ha^{-1}$, respectively (Moir and Mika 1972). In 1983, Frenkel and McEvoy (1983) reported total above ground biomass ranging from 9,293 to 14,004 kg $ha^{-1}$ (at a different location at the same site?). I found similar TAGB levels to Frenkel and McEvoy (1983); TAGB ranged from 6958 to 12,038 kg $ha^{-1}$. These reported biomass values and my estimates show that there is wide variation in biomass accumulation over very short distances in wetland prairie systems and this variability may relate to community composition.

The low biomass of the *Vaccinium* community may be related to low nutrient status (Finley 1994) and the high woody biomass to TAGB ratio.

There is much variation in composition and biomass of herbaceous plants and litter accumulation between all of the plant communities. High herbaceous/litter biomass in *Rosa/Anthoxanthum* at Rose Prairie in 1988 and 1989 was related primarily to the thick moss layer (up to 8 cm in depth), that resisted fire consumption, possibly due to high moisture content.

Lower herbaceous/litter and TAGB in *Deschampsia* at Rose Prairie during 1989 relative to 1988, may be a function of the loss of accumulated standing dead biomass and litter from the 1988 burn. Standing dead biomass and litter were observed to comprise much of the above ground biomass in the RP *Deschampsia* community prior to burning in 1988.

Greater *Vaccinium* community biomass during 1989 relative to 1988 may be due to rapid growth (particularly of V. caespitosum) in response to increased nutrients following the 1988 fire. Reports differ on plant growth following fire. Some reports suggest declines, others increases. Burning generally stimulates biotic nitrogen fixing activities in the soil (Ahlgren and Ahlgren 1960). Biomass productivity of various grasslands shows a wide range of values across North American grasslands (Table 3.8 after Kucera 1981). Biomass of Willamette Valley wetland prairie sites surpasses that of many other North American grasslands. Differences in wet and dry years can affect biomass production in grassland systems (Kucera 1981, Table 3.8).

Burning has generally been found to increase the production of most grassland vegetation (Vogl 1974). It takes approximately 3-6 years for standing crop and litter to return to preburn conditions in tallgrass prairie. Given the rapid recovery in biomass demonstrated by my data, Willamette Valley wetland prairie sites appear to be extremely resilient to fire.

Fires generally reduce woody biomass in prairie ecosystems, however, woody biomass increased following fires in this study. Woody biomass increased in 1989 relative to 1988 in all plant communities and particularly in the *Vaccinium* community. This increase suggests that Willamette Valley wetland prairie woody plants are resistant to burning and have a capacity to quickly recover and increase following fires (refer to Chapter 4). *Vaccinium* species and other woody species have been reported to increased following fire in other systems (Wright and Bailey 1982).

Table 3.8. Effects of burning on grassland biomass from North American stations, after Kucera 1981.

| Region | Control | Fire | References |
|---|---|---|---|
| | -----Plots----- | | |
| Illinois | 3,020 | 13,210[1/] | Hadley and Keikhefer 1963 |
| | 3,610 | 5,910[2/] | |
| Missouri | 5,090 | 9,330[1/] | Kucera and others 1967 |
| | 4,820 | 5,220[2/] | |
| Iowa | 3,490 | 7,500 | Ehrenreich and Aikman 1957 |
| Eastern Kansas | 1,860 | 3,400 | Hulbet 1969 |
| Western Kansas | 3,800 | 1,710 | Launbaugh 1964 |
| Wisconsin | | | |
| Lowland | - | +[3/] | Zedler and Loucks 1969 |
| Upland | + | - | |
| Western South Dakota | + | - | Larsen and Whitman 1942 |
| Eastern North Dakota | | | |
| Lowland | + | - | Hadley 1970 |
| Upland | - | + | |
| Eastern North Dakota | - | + | Dix and Smeins 1968 |
| Eastern North Dakota | + | - | Dix 1960 |
| Saskatchewan | + | - | Redmann 1978 |
| Oregon | 3,250 | | Moir and Mika 1972 |
| | 5,300 | | |
| | 9,293 | | Frenkel and McEvoy 1983 |
| | 14,004 | | |
| Rose Prairie | 8,890 | 10,097 | This study |
| Fisher Butte | 8,340 | 8,517 | |

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[1/], [2/] Represent wet years and dry years respectively; [3/] +, - = greater of less productivity on an annual basis; all values expressed in kg ha$^{-1}$ yr$^{-1}$.

## Moisture content

Standing live biomass moisture content depends on plant species phenology. In contrast, litter and soil moisture content will be most influenced by antecedent rainfall and weather events. Therefore, standing biomass, litter and soil moisture content in 1988 and 1989 are likely related to timing of burns in relation to growing season and weather events. The relatively low moisture content of standing materials prior to the 1988 prescribed burns reflected the end of the summer drought. The higher moisture content of litter and soils in 1988 reflected recent rainfall prior to burning. Likewise, the 1989 high moisture content of standing biomass and low moisture content of litter and soil reflected the end of a still-active growing season and the lack of antecedent rainfall prior to sampling. High standing moisture in the FB *Deschampsia* for both years indicates that this community photosynthetically active species that persist late in the season together with available soil moisture. In contrast, the *Rosa/Anthoxanthum* community had low moisture content in standing material in both years reflecting an earlier species phenology and/or drier microenvironment (i.e, the elevated mounds probably result in an earlier summer dormancy of species).

Some differences in moisture content between plant communities might be explained by the shading which reduces evaporation and wind desiccation, promoted by plant community stratification. For example, the high percent cover of *R. nutkana* in *Rosa/Anthoxanthum* and *Rosa/Juncus* communities might explain why there was higher litter and soil moisture content in these communities.

Additionally, the *Rosa/Anthoxanthum* community had a thick moss layer that likely decreased evaporative losses from surface soils. The *Deschampsia* community had low overall plant cover with more bare ground and may be susceptible to greater wind desiccation and evaporation, explaining its moisture content in litter and soil.

Some of the increase in moisture content of standing biomass in 1989 relative to 1988 may be explained by the consumption/removal of accumulated standing dead material during the 1988 burns. Loss in dead biomass may have resulted in a greater ratio of live to dead biomass in 1989 relative to 1988. Changes in plant composition could also account for some of the difference between years in moisture contents between plant communities. Curtis and Partch (1948) found a large increase in forb cover and bare ground with a concomitant decline in grasses following fire in tallgrass prairie. As forbs tend to have higher moisture content relative to graminoids (Sapsis 1990, deCastro in prep.), an increase in forbs from one year to the next could result in greater moisture content of standing vegetation.

## Pyronometers

Maximum temperatures attained at the soil surface and heat flux into the soil are known to be important in determining post fire vegetative survival, growth and seed germination (Ahlgren and Ahlgren 1960). Fire (heat) tolerance of plant tissues varies depending upon the tissue type and species under study as well as level of temperature and duration of heat. Seeds generally are most tolerant to heat damage, while roots are the least tolerant of plant tissues (Volland and Dell 1981). While 60°C (at 2-60 minutes) is the approximate lethal temperature for leaf tissue, grass seed can tolerate temperatures of 82-116°C for up to five minutes (Sampson 1944, Wright and Bailey 1982). In this study, soil surface temperatures often exceeded the lethal maximum temperatures for seeds (e.g. in excess of 371°C at Fisher Butte); however, fire residence time was relatively brief (7-24 seconds). Similar to results for other grassland systems (Scotter 1970), soil surface temperatures in this study varied widely in 1988 and 1989 and there was little heat flux deeper than 2 cm in the soil.

## Fire behavior

Fire behavior (and ultimately plant response) is greatly influenced by fuel and soil moisture. Thus, variation in fire behavior can be attributed, in part, to differences in fuel and soil moisture content at the time of burning. Fire behavior also influences plant mortality and postfire response. Flame length and fire-line intensity have been found to correlate to above-ground mortality of trees (Van Wagner 1973). The greatest flame lengths and fire-line intensity of the 1988 burn at Fisher Butte should have resulted in the greatest crown mortality compared to all burn treatments. Greater crown mortality occurred in 1988 relative to 1989, and particularly for *Fraxinus latifolia* seedlings, saplings and younger-aged trees (refer to Chapter 4).

If possible, it would be useful to measure fire parameters in each plant community in future studies in order to correlate mortality directly to fuel moisture and biomass.

## Biomass consumption

Biomass moisture content differences likely explain much of the variation in fuel consumption within and between plant communities at both study sites. The greater standing biomass moisture in 1989 relative to 1988 may have contributed to lower levels of fuel consumption at both study sites during 1989. Although TAGB consumption was generally lower in 1989, consumption of herbaceous/litter in the *Rosa/Anthoxanthum* community was greater during 1989 (62%) relative to 1988 (51%). Of all plant communities, this community had the lowest standing moisture content (36.3%) during 1989, which likely facilitated consumption of herbaceous/litter biomass.

The low fuel consumption in the *Vaccinium* community in both years is likely a function of the high moisture content of standing and litter components contents as well as plant species chemical composition (Rundel 1981).

There was a general trend of poor woody biomass consumption as a function of *R. nutkana* cover for both 1988 and 1989, thus R. nutkana appears to be resistant to fire consumption.

In future studies, biomass samples and fuel moisture content samples should be collected within the same categories (i.e. collect samples for biomass and moisture content by standing herbaceous, standing woody, litter, and 10-hour fuel categories) so their values and inferences about consumption levels would directly correspond.

## Conclusion

To perpetuate native Willamette Valley prairies, land managers need to know optimal fire frequency, fire intensity and fuel conditions to control woody and exotic plants. To achieve this objective, there is a need for an integrative process of evaluating effects of specific fire treatments on plant composition. Different prescriptions will have different effects in controlling woody and/or exotic plant species. The characteristics of prescribed burns should be thoroughly documented and the subsequent plant responses should be periodically evaluated to determine the effectiveness of prescribed burns in maintaining native composition and controlling woody plants. With public resistance to burning in the Willamette Valley, land managers need to demonstrate that carefully designed prescribed burns are essential for restoring and maintaining these rare native prairie ecosystems.

# CHAPTER 4
# SYNECOLOGY AND RESPONSE TO FIRE OF NATIVE WILLAMETTE VALLEY WETLAND PRAIRIES

## Abstract

Species richness is high in native wetland prairies; a total of 205 species was observed in five plant communities at two study sites. Species richness in all communities was dominated by native forbs. Vegetative cover was dominated by native perennial graminoids in all communities except *Rosa/Anthoxanthum* where exotic perennial graminoids dominated.

Response to burning varied greatly by species and community. Native species that established or significantly increased in frequency in burned areas included the perennials *Panicum occidentale, Aster chilensis* var. *hallii, Brodiaea* spp., *Camassia quamash, Microseris laciniata, Prunella vulgaris, Sisyrinchium angustifolium, Veronica scutellata,* and the annuals *Epilobium paniculatum, Gnaphalium palustre*, and *Madia glomerata*. Exotic species that established and increased significantly in frequency following fire included the perennials *Agrostis spp., Hypericum perforatum, Hypochaeris radicata,* and *Leontodon nudicaulis* and the annual *Briza minor*. Cover of *Agrostis* spp. increased significantly in one or both burn treatments in all communities as well as in some unburned treatments. Cover of two dominant species, *Danthonia californica* and *Deschampsia cespitosa,* declined significantly in the first postfire year following a single burn and then returned to preburn cover in both burn treatments.

Relative frequency of all natives increased significantly and relative frequency of all exotics declined significantly in once burned treatments in RP *Deschampsia* and *Rosa/Anthoxanthum* communities. After two burns, relative frequency of native perennial forbs increased significantly in three communities, RP *Deschampsia*, *Rosa/Anthoxanthum*, and *Rosa/Juncus*. Relative frequency of native perennial forbs also increased significantly in FB *Deschampsia* control treatments. Relative frequency of perennial exotic graminoids declined significantly in burn treatments in all but the *Vaccinium* community where they increased in the control treatment. Native annual forbs increased in burns in all except the *Vaccinium* community. Native annual forbs increased significantly only in controls within the *Vaccinium* community.

Significant increases in vegetative cover of perennial graminoids occurred in burned areas in the RP *Deschampsia, Vaccinium*, and FB *Deschampsia* communities. Total cover of exotic species significantly increased following one or two burns in all communities except the *Rosa/Anthoxanthum* community; measured increases were primarily due to increases in exotic perennial graminoid cover. Significant increases in exotic forb cover occurred in *Rosa/Anthoxanthum* and FB *Deschampsia*. In both communities at Fisher Butte native annual forb cover declined significantly the first postfire season following one burn.

Shrub cover increased the first or second post fire season after burning in some plant communities. The cover of *Rosa nutkana* increased significantly following burning in both communities at Fisher Butte while *Vaccinium* *caespitosum* cover increased the second postfire year following burning in the *Vaccinium* community.

A number of plant species that increased following burning in this study were important foods plants to the Native American people of the Pacific Northwest (e.g., *Vaccinium* spp., *Brodiaea* spp., *Camassia* spp., *Perideridia* spp.). Former inhabitants of the Willamette Valley may have burned on a cycle to enhance favored plant foods. Information on the response of woody and exotic plants and aboriginal foods will assist land managers in determining optimal fire frequency for burning  Willamette Valley wetland prairies.

## Introduction

Prior to euroamerican settlement, the Kalapuya people maintained an expansive prairie landscape in the Willamette Valley by frequent burning during late summer and early fall to facilitate hunting and food gathering (Clarke 1905, Sprague and Hansen 1946, Boyd 1986, Johannessen et. al 1971, Habeck 1961). Fire exclusion in native prairie ecosystems generally began with euroamerican settlement during the 1840's (Bowen 1978, Towle 1982). Prairies were maintained in some places by continued use of fire by settlers and by grazing (Boag 1982, Frenkel and Heinitz 1987, Streitfeild 1995). Fire exclusion has generally resulted in a succession to woodlands and forests of former prairies (Sprague and Hansen 1946, Thilenius 1968).

Remnant prairies provide habitat for several rare, endemic plant species. State and federal laws mandate public land management to perpetuate the existence of these species. Recovery and improvement of remnant prairies and their rare species may be facilitated by the reintroduction of fire as an ecosystem process.

Remnant prairies currently contain many introduced exotic plant species (Towle 1982, Streatfeild 1995). Management practices that enhance exotics might further reduce native and rare plant species in prairie landscapes. The response of exotic species to burning is uncertain. Initial and sometimes unanalyzed, tentative results from other studies in Willamette Valley prairies suggest that exotic species may increase in response to burning (TNC Stipa, Magee 1986, Frenkel and McEvoy 1983, Acker 1990, Frenkel and Steinfeild 1994, Streatfeild 1995). However, these same studies indicate that some native species have also increased in percent cover or frequency following burning. Optimal fire frequency of prairies should be based upon responses of exotics, woody, and rare species as well as species which were important staple food sources of Native Americans (e.g. *Camassia spp.*, *Madia* spp., etc.). Optimal burns should (1) control woody species, (2) control exotic plants, (3) maximize cover and frequency of native plants, (4) increase density of aboriginal food plants, and/or (5) increase density or vigor of rare plants.

Primary objectives of this study were to describe plant species composition of five Willamette Valley wetland prairie plant communities and the responses of species and life forms to two different burn treatments. Treatments included unburned controls, and once and twice burned treatments.

This research initiates a long-term assessment of fire effects on Willamette Valley vegetation to determine optimal burn prescriptions for wetland prairies.

## Study Sites

A complete description of study sites including location, climate, general vegetation, soils, and topography is included in Chapter 3.

## Methods

### Treatments

Plant composition changes were measured following three treatments: 1) no burn/control, 2) a single, fall-season, prescribed fire in 1988 (once-burned), and 3) two, consecutive fall-season, prescribed fires in 1988 and 1989 (twice-burned). Treatments were parallel to each other at Rose Prairie (Figure 4.1). Due to a small fire escape during the 1988 burn, treatment boundaries were modified to maintain an even sample size within treatment areas and plant communities. At Fisher Butte, treatment areas were large rectangular blocks, oriented perpendicular to a road that delimits the western boundary of the study site (Figure 4.2). Treatment areas were ~2 ha at Rose Prairie and ~4 ha at

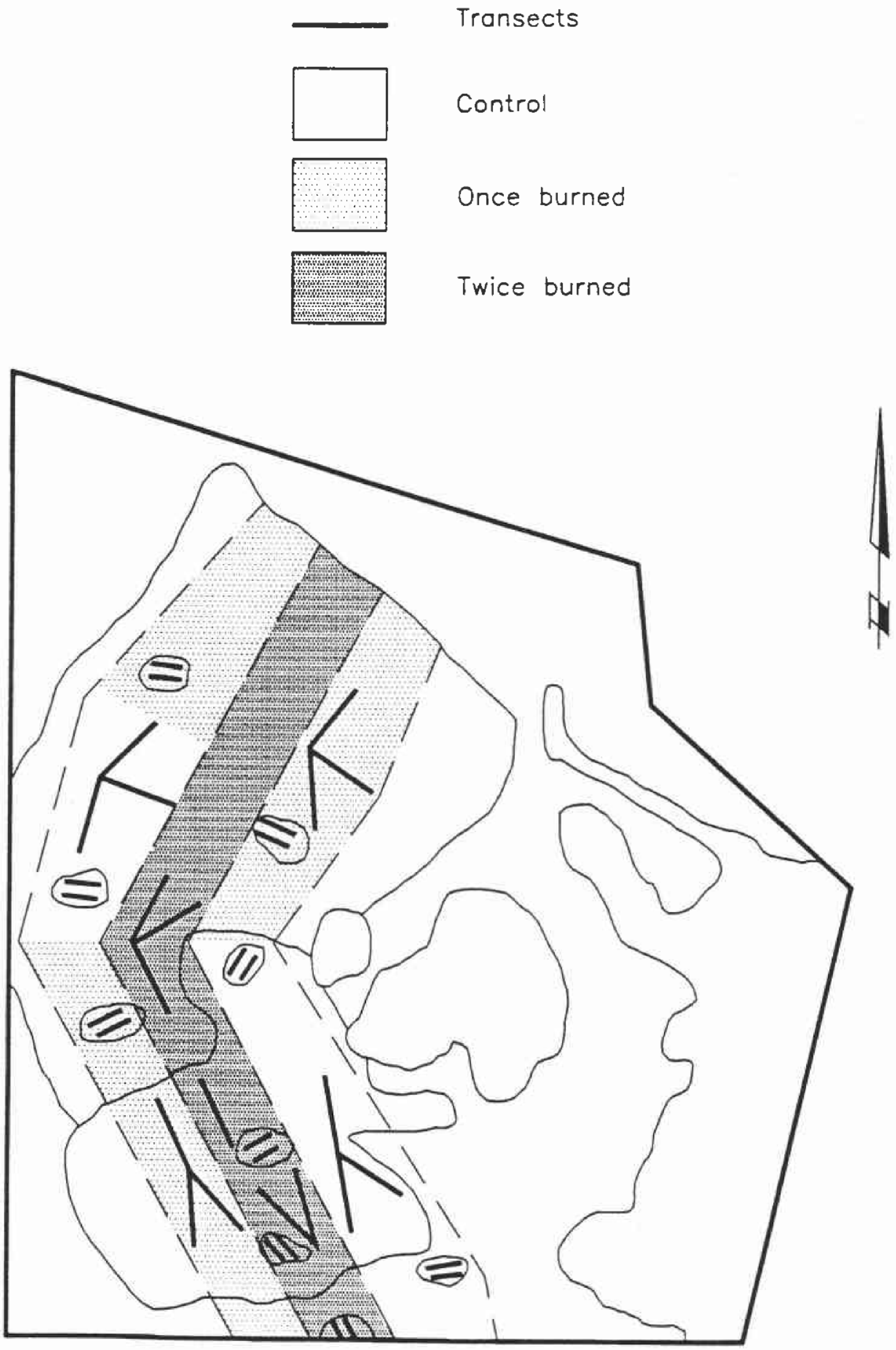

**Figure 4.1. Treatment lay-out at Rose Prairie.** **Light solid lines delineate plant communities.**

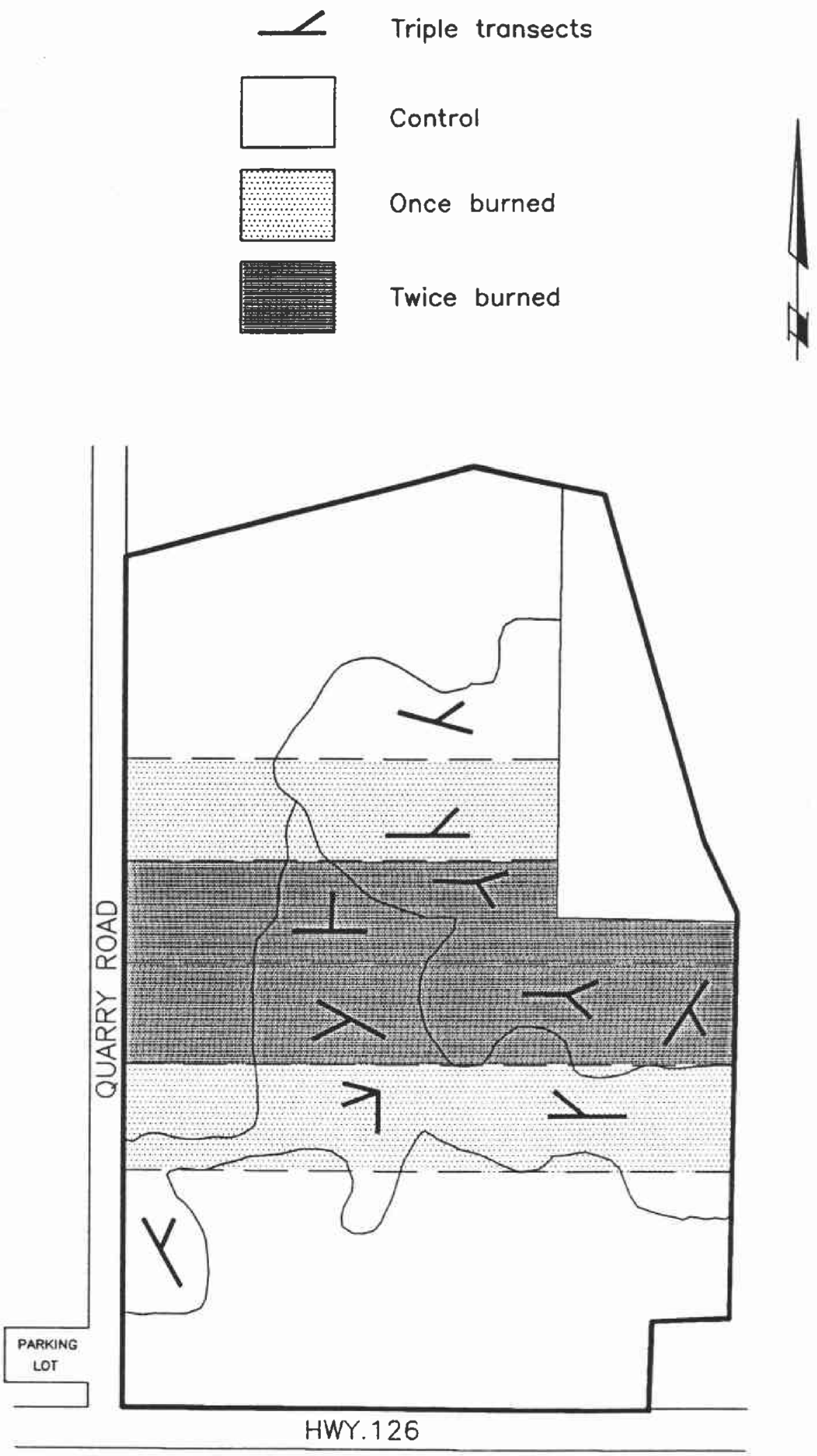

**Figure 4.2. Treatment lay-out at Fisher Butte. Light solid lines delineate plant communities.**

Fisher Butte. Each treatment was replicated once at Rose Prairie; two replicates of each burn treatment and one control treatment were established at Fisher Butte. After treatments areas were delineated, they were randomly assigned to specific treatments.

### Sample layout

At Rose Prairie, a total of 27 permanent transects were established in 1988, prior to fire treatments. Nine transects were in each of the control, once-burned, and twice-burned treatments (Figure 4.1). Three plant communities were delineated within each treatment, *Deschampsia cespitosa-Danthonia californica* (RP *Deschampsia*), *Rosa nutkana/Anthoxanthum odoratum* (*Rosa/Anthoxanthum*) and *Vaccinium caespitosum* (*Vaccinium*)(Table 4.1). Nine transects each 30 m long were laid out in the RP *Deschampsia* and nine in the *Vaccinium* communities. The *Rosa/Anthoxanthum* community was restricted to small mounds; therefore, the 30 m transects were laid out as nine parallel pairs of 1 x 15 m transects, two meters apart (Figure 4.3).

At Fisher Butte, a total of 30 permanent transects each 30 m long were established in 1988. In the control treatment (Figure 4.2), three transects were laid out in each of the two plant communities, *Deschampsia cespitosa-Danthonia californica* (FB *Deschampsia*) and *Rosa nutkana/Juncus nevadensis* (*Rosa/Juncus*)(Figure 4.4). In each of the two burn treatments (Figure 4.2), 6 transects were established in each of the two communities (Figure 4.4).

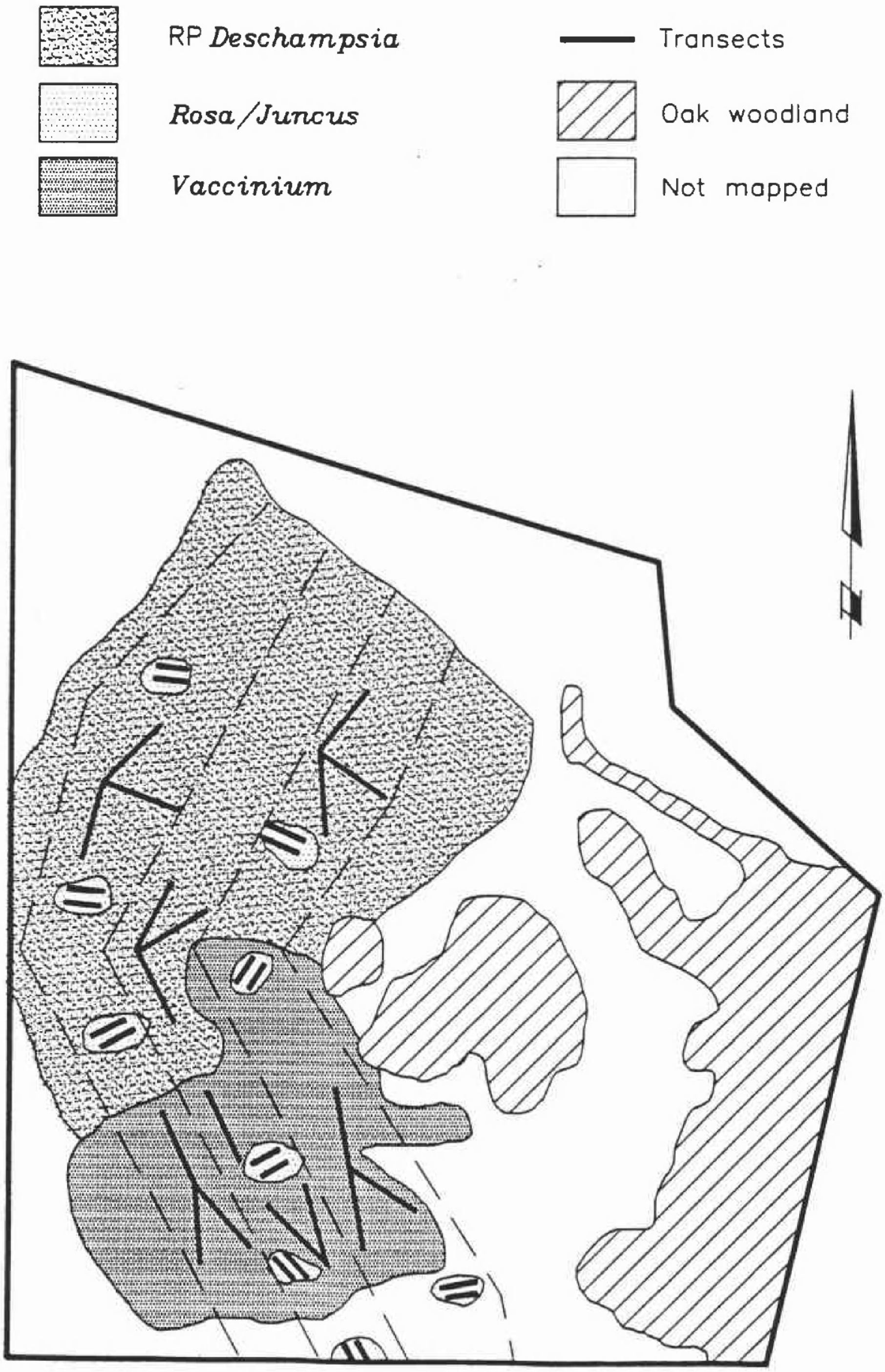

**Figure 4.3. Plant communities delineated and transect lay-out at Rose Prairie. Dashed lines indicate boundaries of treatments.**

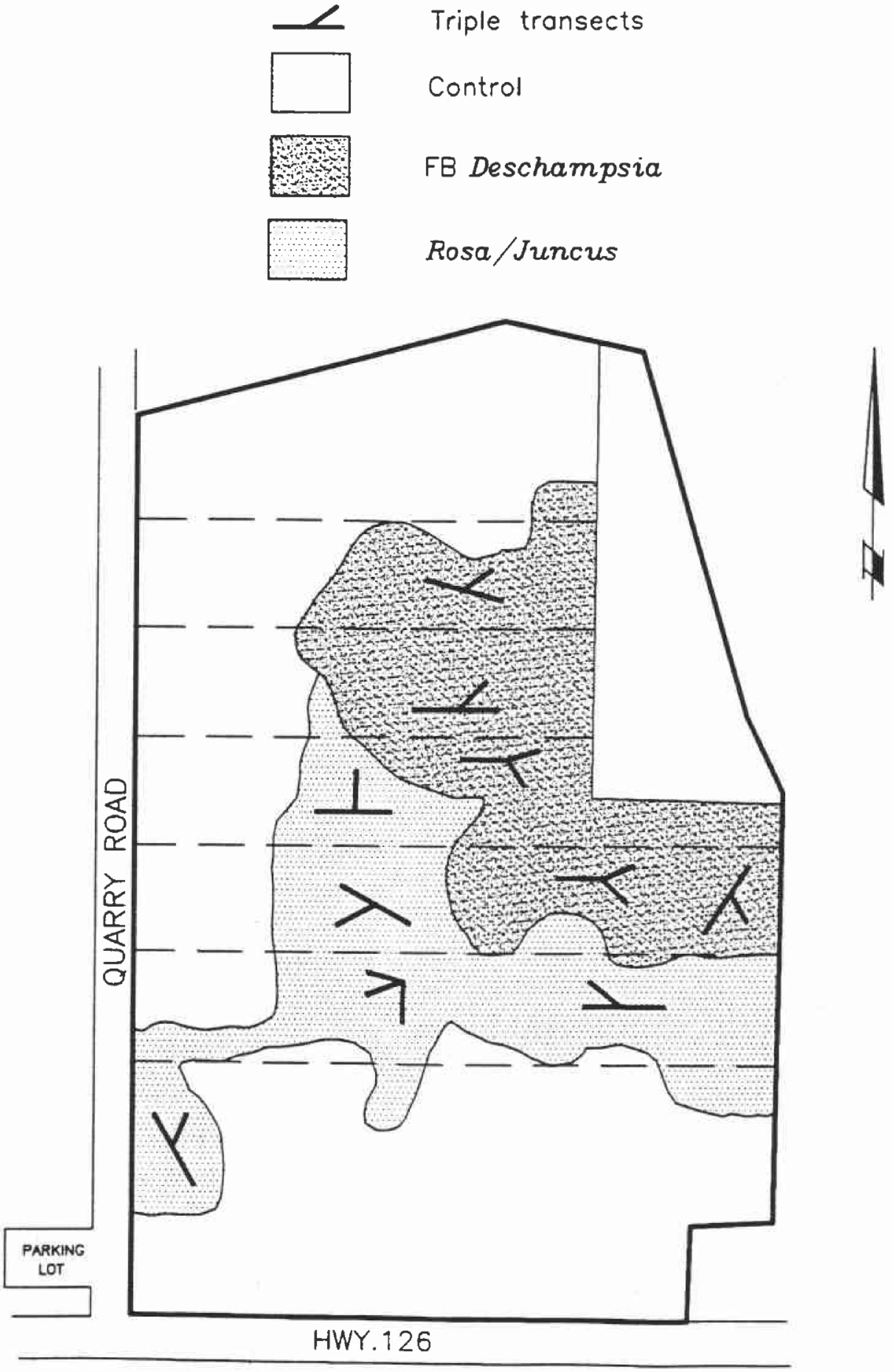

**Figure 4.4. Plant communities delineated and transect lay-out at Fisher Butte. Dashed lines indicate boundaries of treatments.**

Table 4.1. Plant communities identified and sampled, their locations, their codes in text, tables, and figures, and the number of transects installed in each.

| Name of Community | Location | Code in Text, Figures and Tables | Number of transects |
|---|---|---|---|
| *Deschampsia cespitosa-Danthonia californica* | Rose Prairie | RP *Deschampsia* | 9 (3 Control/unburned, 3 once burned, 3 twice burned) |
| *Rosa nutkana/Anthoxanthum odoratum* mounds | Rose Prairie | *Rosa/Anthoxanthum* | 9 (3 Control/unburned, 3 once burned, 3 twice burned) |
| *Vaccinium caespitosum* | Rose Prairie | *Vaccinium* | 9 (3 Control/unburned, 3 once burned, 3 twice burned) |
| *Deschampsia cespitosa-Danthonia californica* | Fisher Butte | FB *Deschampsia* | 15 (3 Control/unburned, 6 once burned, 6 twice burned) |
| *Rosa nutkana/Juncus nevadensis* | Fisher Butte | *Rosa/Juncus* | 15 (3 Control/unburned, 6 once burned, 6 twice burned) |

Species were listed and percent cover and frequency were measured along each transect (Goldsmith et al. 1986, Barbour et. al 1987). Nested plots of 50x50 cm, 25x25 cm, and 12.5x12.5 cm were used to measure frequency in 30 plots along each transect (Figure 4.5). Cover was only measured in the first 15 of the 50x50 cm plots. Cover was determined to the nearest 1% for all species and for bare ground during 1988 and 1989. In 1990, cover was only determined for selected dominate species.

### Measurement periods and prescribed burning

All measurements were made during peak vegetative expression, June-July of 1988, 1989, and 1990. BLM personnel conducted prescribed fires at both study sites on 11 October, 1988 and 19 September, 1989. Wetline and strip-head burning techniques were used to implement the prescribed fires (Chapter 2).

### Site and community descriptions

Descriptions of species composition at Rose Prairie and Fisher Butte were based on a complete list of species encountered during the three years of this study, including species observed outside sampled plots. Data were analyzed according to life forms (1) trees, (2) shrubs, (3) graminoids, and (4) forbs; lifespans (a) perennials or (b) annuals/biennials; and origin (i) native or (ii)

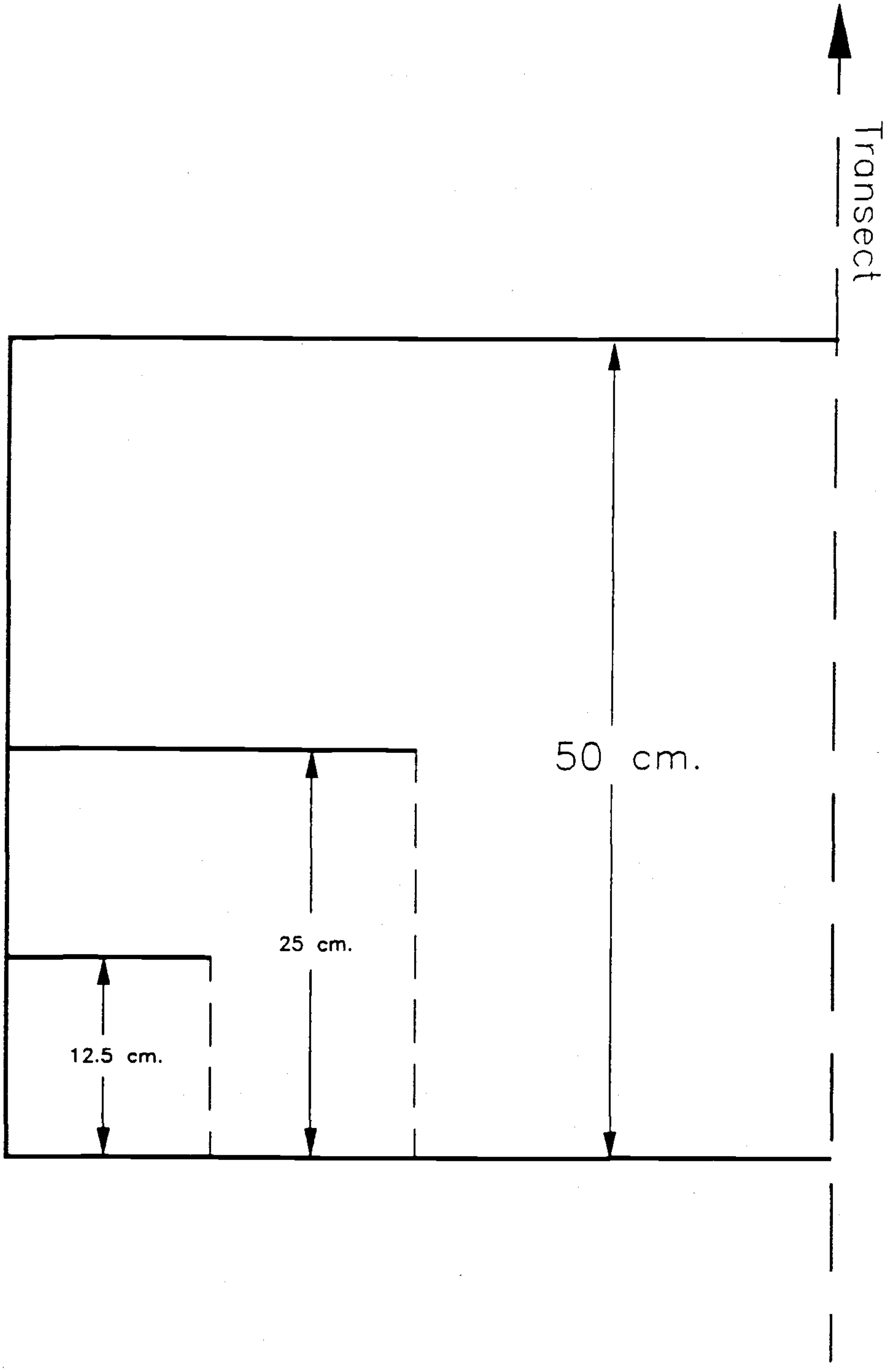

Figure 4.5. Plots used for sampling percent cover and frequency.

exotic. Floral composition of each site was also described utilizing life form, lifespan, and origin categories.

Preburn conditions of the three Rose Prairie and two Fisher Butte communities were described using 1988 data for mean percent cover and frequency of species from all transects. Only data from the 50x50 cm nested plot were used. Dominant species in a community were those with cover values of $\geq$ 2%), common species had < 2% cover but frequency $\geq$ 10%, and uncommon species were those with < 2% cover and < 10% frequency. Percent cover values for 1988 were summed by life form and origin to examine differences in these categories among plant communities. Preburn species richness was combined by life form and lifespan categories to describe floral composition. Species of *Aira, Brodiaea, Epilobium, Rubus, Carex,* and annual *Festuca* that were difficult to identify or differentiate in early developmental or non-flowering stage were combined to genus level during analysis. Plant taxonomy followed that of Hitchcock et al. (1969).

The 1989 data represent a second year of data from control treatments and the response of both the once burned and twice burned treatments to one burn. The 1990 data is the third year of data from the control treatments, the second year of data from the once burned treatment, and the first year of data from the twice burned treatment. Only those species with measured cover values of $\geq$ 1% in 1990 were included in the analysis of cover in relation to treatment effects.

Frequency was determined for all species along sampled transects. For most species, data from the 50x50 cm plot were used to report changes in frequency between years within treatments and plant communities. However, for common species with frequencies >80% in the 50x50 cm plots, data from the 25x25 cm or 12.5x12.5 cm plots were used to describe changes in relation to treatments.

Relative frequency was determined for each species in relation to total frequency along each transect, within plant communities, and treatments. Relative frequencies were then tallied within transects according to life form and origin to determine changes in these categories in relation to burn treatments and to capture trends in less dominant species.

The PC-Ord program (McCune 1991) was utilized to calculate species richness (S), species diversity (H'), and species evenness/equitability (E) from frequency data for the largest plot size (50x50 cm) along transects within communities. Species richness was the number of species present along transects in communities. Species diversity was calculated by summing the frequency of all species along transects, and dividing individual plant frequencies by the sum of the transect frequency to arrive at a proportional abundance, pi, for the ith species (ni/N):

$$H' = -\Sigma p_i \ln p_i$$

Species richness and diversity were used to calculate species equitability:

$$E = H'/\ln (S)$$

(in McCune 1991, S and H' based on Shannon and Weaver 1949, E based on Pielou 1966).

Means of S, H', and E were calculated from each of the transects within treatments and within communities at Rose Prairie and Fisher Butte.

### Statistical analysis

Differences in plant species frequency and cover were analyzed using non-parametric, Kruskal-Wallis tests to determine differences between all sampled years within treatments. If a significant change was detected for a species, Mann-Whitney tests were then used to determine which years had significant differences within treatments. Similar procedures were used to determine differences between years within treatments for percent cover and relative percent frequency for plant forms, life spans, and origins. These tests were also used to determine differences between years within treatments for S, H', and E. Significance levels of $P < 0.1$ or better are presented. Nonparametric statistical tests were use due to the small sample sizes and non-normality of the data set (Zar 1984).

# Results

## Site descriptions and comparisons

During this study, a total of 205 species were encountered at Fisher Butte and Rose Prairie (Table 4.2). One hundred seventeen species were present at both sites; 81 of the co-occurring species were native and 36 were exotics (Table 4.3). Twenty-three native species were only found at Rose Prairie, while 28 native species occurred exclusively at Fisher Butte. *Centaurea pratensis* was the only exotic species restricted to Rose Prairie. In contrast, 30 exotic species occurred only at Fisher Butte.

At Rose Prairie, exotic species were most dominant on the elevated mounds occupied by the Rosa/Anthoxanthum community. However, many exotic species, most notably *Agrostis tenuis, Anthoxanthum odoratum, Hypochaeris radicata, Leontodon nudicale*, and *Holcus lanatus,* were common and ubiquitous at Rose Prairie. At Fisher Butte, exotic graminoids and forbs including *Aira caryophyllea, Bromus mollis, Cynosurus echinatus, Festuca myuros, Poa annua, Vicia cracca, V. sativa, Dianthus armeria, Dipsacus sylvestris, Lathyrus sphaericus, Myosotis discolor*, and *Sonchus asper* occurred predominantly along the western and southern boundaries of the RNA adjacent to a gravel road and highway. Exotic herbaceous species, *Bromus mollis, Festuca myuros, F. bromoides, Myosotis discolor,* also occurred in high densities on ant mounds. *Pyrus communis, Agrostis tenuis, Anthoxanthum odoratum, Aira spp.*, and *Briza minor* occurred more commonly in

Table 4.2. Plant species occurring at Rose Prairie (RP) and Fisher Butte (FB) parcels of the Fern Ridge Research Natural Area. Scientific names, common names, plant locations, and plant families are provided. "I" indicates plant species was located in sampled plots; "O" indicates plant was observed outside of sampled plots. Species are presented by life form (trees, shrubs, graminoids, and forbs) and lifespan (perennial versus annual/biennial) categories. * Denotes exotic species, ! denotes that plant has State or Federal rare plant status.

| | **Scientific Name** | **Common Name** | **RP** | **FB** | **Family** |
|---|---|---|---|---|---|
| **TREES** | | | | | |
| | *Arbutus menziesii* | Pacific Madrone | O | | Ericaceae |
| | *Crataegus douglasii* | Black Hawthorn | I | I | Rosaceae |
| | *Crataegus monogyna** | One-seeded Hawthorn | | O | Rosaceae |
| | *Fraxinus latifolia* | Oregon Ash | O | I | Oleaceae |
| | *Populus trichocarpa* | Black Cottonwood | O | O | Salicaceae |
| | *Prunus avium** | Sweet Cherry | | O | Rosaceae |
| | *Pyrus communis** | Cultivated Pear | | I | Rosaceae |
| | *Pyrus fuscus* | Western Crabapple | I | I | Rosaceae |
| | *Pyrus malus** | Cultivated Apple | | O | Rosaceae |
| | *Quercus garryana* | Oregon White Oak | I | O | Fagaceae |
| | *Quercus kellogii* | California Black Oak | O | | Fagaceae |
| | *Rhamnus purshiana* | Cascara or Chittam | I | I | Rhamnaceae |
| | *Salix piperi* | Piper's Willow | | O | Salicaceae |
| **SHRUBS** | | | | | |
| | *Amelanchier alnifolia* | Western Serviceberry | I | I | Rosaceae |
| | *Corylus cornuta* | Filbert | | O | Betulaceae |
| | *Rhus diversiloba* | Poison Oak | O | I | Anacardiaceae |
| | *Rosa "Multiflora"** | Multiflora Rose | | O | Rosaceae |
| | *Rosa eglanteria** | Sweetbriar | O | I | Rosaceae |
| | *Rosa nutkana* | Nootka Rose | I | I | Rosaceae |
| | *Rubus discolor** | Himalayan Blackberry | I | I | Rosaceae |
| | *Rubus laciniatus** | Evergreen Blackberry | I | I | Rosaceae |
| | *Rubus ursinus* | Pacific Blackberry | O | O | Rosaceae |
| | *Spiraea douglasii* | Douglas' Spirea | O | I | Rosaceae |
| | *Vaccinium caespitosum* | Dwarf Huckelberry | I | | Ericaceae |
| **GRAMINOIDS** | | | | | |
| **Perennials** | | | | | |
| | *Agrostis exarata* | Spike Bentgrass | | I | Poaceae |
| | *Agrostis tenuis** | Colonial Bentgrass | I | I | Poaceae |
| | *Alopecurus geniculatus* | Water Foxtail | | I | Poaceae |
| | *Alopecurus pratensis** | Meadow Foxtail | | O | Poaceae |
| | *Anthoxanthum odoratum** | Sweet Vernal Grass | I | I | Poaceae |
| | *Carex densa* | Dense Sedge | | I | Cyperaceae |
| | *Carex leporina* | Hare Sedge | | I | Cyperaceae |
| | *Carex rossii* | Ross Sedge | I | I | Cyperaceae |

| Scientific Name | Common Name | RP | FB | Family |
|---|---|---|---|---|
| *Carex tumulicola* | Foothill Sedge | | O | Cyperaceae |
| *Carex unilateralis* | One-sided Sedge | | I | Cyperaceae |
| *Dactylis glomerata** | Orchard-grass | | O | Poaceae |
| *Danthonia californica* | California Oatgrass | I | O | Poaceae |
| *Deschampsia cespitosa* | Tufted Hairgrass | I | I | Poaceae |
| *Deschampsia elongata* | Slender Hairgrass | | O | Poaceae |
| *Eleocharis acicularis* | Needle Spikerush | I | I | Cyperaceae |
| *Eleocharis palustris* | Common Spikerush | | O | Cyperaceae |
| *Festuca arundinacea** | Tall Fescue | I | I | Poaceae |
| *Festuca rubra* | Red Fescue | I | I | Poaceae |
| *Glyceria occidentalis* | Western Mannagrass | O | O | Poaceae |
| *Holcus lanatus** | Common Velvet Grass | I | I | Poaceae |
| *Hordeum brachyantherum* | Meadow Barley | | I | Poaceae |
| *Juncus effusus* | Soft or Common Rush | O | O | Juncaceae |
| *Juncus ensifolius* | Dagger-leaf Rush | | O | Juncaceae |
| *Juncus nevadensis* | Sierra Rush | I | I | Juncaceae |
| *Juncus patens* | Spreading Rush | | O | Juncaceae |
| *Juncus tenuis* | Slender Rush | I | I | Juncaceae |
| *Koeleria cristata* | Prairie Junegrass | I | | Poaceae |
| *Luzula campestris* | Field Woodrush | I | I | Juncaceae |
| *Panicum occidentale* | Western Witchgrass | I | I | Poaceae |
| *Phalaris arundinacea** | Reed Canarygrass | O | O | Poaceae |
| *Poa compressa** | Canada Bluegrass | | I | Poaceae |
| *Poa pratensis** | Kentucky Bluegrass | I | I | Poaceae |
| **Annuals** | | | | |
| *Aira caryophyllea** | Silver Hairgrass | I | I | Poaceae |
| *Aira elegans** | Diffuse Hairgrass | | I | Poaceae |
| *Arista oligantha!* | Prairie Threeawn | O | | Poaceae |
| *Beckmannia syzigachne* | American Sloughgrass | | I | Poaceae |
| *Briza minor** | Little Quaking-grass | I | I | Poaceae |
| *Bromus mollis** | Soft Brome or Chess | | I | Poaceae |
| *Bromus rigidus** | Ripgut Brome | | O | Poaceae |
| *Cynosurus echinatus** | Hedgehog Dogtail | | I | Poaceae |
| *Echinochloa crusgalli** | Large Barnyard Grass | | O | Poaceae |
| *Festuca bromoides** | Barren Fescue | | O | Poaceae |
| *Festuca myuros** | Rat-tail Fescue | O | I | Poaceae |
| *Juncus emarginata** | | I | O | Juncaceae |
| *Juncus bufonius** | Toad Rush | I | I | Juncaceae |
| *Poa annua** | Annual Bluegrass | | O | Poaceae |

| Scientific Name | Common Name | RP | FB | Family |
|---|---|---|---|---|
| **FORBS** | | | | |
| **Perennials** | | | | |
| _Achillea millefolium_ | Common Yarrow | I | | Asteraceae |
| _Alisma plantago-aquatica_ | American Waterplaintain | O | I | Alismataceae |
| _Allium amplectens_ | Slim-leaf onion | I | I | Liliaceae |
| _Apocynum androsaemifolium_ | Spreading Dogbane | I | | Apocynaceae |
| _Aster chilensis v. hallii_ | Hall's Aster | I | I | Asteraceae |
| _Aster curtus!_ | White-top Aster | I | I | Asteraceae |
| _Brodiaea congesta_ | Northern Saitas | O | | Liliaceae |
| _Brodiaea coronaria_ | Harvest Brodiaea | I | I | Liliaceae |
| _Brodiaea hyacinthina_ | Hyacinth Brodiaea | I | I | Liliaceae |
| _Calochortus tolmiei_ | Tolmie's Mariposa | I | | Liliaceae |
| _Calochortus uniflorus!_ | Large-flowered Star Tulip | O | I | Liliaceae |
| _Camassia quamash_ | Common Camas | I | I | Liliaceae |
| _Cardamine penduliflora_ | Willamette Valley Bittercress | I | I | Brassicaceae |
| _Centaurea pratensis_* | Meadow Knapweed | O | | Asteraceae |
| _Chrysanthemum leucanthemum_* | Oxeye Daisy | O | O | Asteraceae |
| _Cirsium arvense_* | Canada Thistle | I | I | Asteraceae |
| _Comandra umbellata_ | Bastard Toad Flax | I | | Santalaceae |
| _Delphinium menziesii_ | Menzies' Larkspur | I | | Ranunculaceae |
| _Dodecatheon hendersonii_ | Henderson's Shooting Star | I | | Primulaceae |
| _Epilobium glandulosum_ | Common Willow-weed | I | I | Onagraceae |
| _Epilobium watsonii_ | Watson's Willow-weed | I | I | Onagraceae |
| _Erigeron decumbens v. decumbens!_ | Willamette Valley Daisy | | I | Asteraceae |
| _Eriophyllum lanatum_ | Oregon Sunshine | I | I | Asteraceae |
| _Eryngium petiolatum_ | Coyote Thistle | I | I | Apiaceae |
| _Erythronium oregonum_ | Dogtooth Violet | O | | Liliaceae |
| _Fragaria virginiana_ | Broad-petal Strawberry | I | I | Rosaceae |
| _Galium trifidum_ | Small bedstraw | I | I | Rubiaceae |
| _Grindelia integrifolia_ | Willamette Valley Gumweed | I | I | Asteraceae |
| _Haplopappus racemosus_ | Racemed Goldenweed | I | | Asteraceae |
| _Horkelia congesta!_ | Shaggy Horkelia | I | I | Rosaceae |
| _Hypericum anagalloides_ | Bog St. John's-wort | | I | Hyperaceae |
| _Hypericum perforatum_* | Klamath Weed | I | I | Hyperaceae |
| _Hypochaeris radicata_* | Hairy Cat's-ear | I | I | Asteraceae |
| _Iris tenax_ | Oregon Iris | I | | Iridaceae |
| _Isoetes nuttallii_ | Nuttall's Quillwort | I | I | Isoetaceae |

Table 4.2., Continued.

| Scientific Name | Common Name | RP | FB | Family |
|---|---|---|---|---|
| *Leontodon nudicaulis** | Hairy Hawkbit | I | I | Asteraceae |
| *Lomatium bradshawii!* | Bradshaw's Lomatium | I | I | Apiaceae |
| *Lotus corniculatus** | Birdsfoot Trefoil | | O | Fabiaceae |
| *Lotus formosissimus* | Seaside Lotus | I | I | Fabiaceae |
| *Ludwigia palustris* | Water Purslane | O | O | Onagraceae |
| *Lycopus americana* | Northern Bugleweed | | O | Lycopodiaceae |
| *Mentha pulegium** | Pennyroyal | | I | Laminaceae |
| *Microseris laciniata* | Cut-leaved Microseris | I | I | Asteraceae |
| *Mimulus guttatus* | Yellow Monkeyflower | | O | Scrophulariaceae |
| *Orobanche californica* | California Broomrape | I | I | Orobanchaceae |
| *Perideridia oregana* | Oregon Yampah | I | I | Apiaceae |
| *Plantago lanceolata** | Buckhorn Plaintain | I | I | Plantaginaceae |
| *Polystichum munitum* | Sword Fern | O | O | Polypodiaceae |
| *Potentilla gracilis* | Slender Cinquefoil | I | I | Rosaceae |
| *Prunella vulgaris* | Self Heal or Heal All | I | I | Lamiaceae |
| *Ranunculus alismaefolius* | Water-plantain Buttercup | O | I | Ranunculaceae |
| *Ranunculus aquatilis* | White Water-buttercup | | O | Ranunculaceae |
| *Ranunculus flammula* | Creeping Buttercup | | O | Ranunculaceae |
| *Ranunculus occidentalis* | Western Buttercup | I | I | Ranunculaceae |
| *Ranunculus orthorhynchus* | Straightbeak Buttercup | O | I | Ranunculaceae |
| *Ranunculus uncinatus* | Little Buttercup | O | O | Ranunculaceae |
| *Rumex acetosella** | Sheep Sorrel | I | I | Polygonaceae |
| *Rumex crispus** | Curly Dock | O | I | Polygonaceae |
| *Sanicula bipinnatifida* | Purple Sanicle | I | | Apiaceae |
| *Satureja douglasii* | Yerba Buena | O | | Laminaceae |
| *Saxifraga oregana* | Bog or Oregon Saxifrage | O | I | Saxifragaceae |
| *Sidalcea virgata* | Rose Checker Mallow | O | | Malvaceae |
| *Sisyrinchium angustifolium* | Blue-eyed grass | I | I | Iridaceae |
| *Spiranthes romanzoffiana* | Ladies Tresses | I | I | Orchidaceae |
| *Taraxacum officinale** | Dandelion | | O | Asteraceae |
| *Trifolium repens** | White or Dutch Clover | | O | Fabiaceae |
| *Typha latifolia* | Common Cat-tail | O | O | Typhaceae |
| *Veronica scutellata* | Marsh Speedwell | I | I | Scrophulariaceae |
| *Vicia cracca** | Tinegrass, Cat Peas | | O | Fabiaceae |
| *Vicia sativa** | Common Vetch | | O | Fabiaceae |
| *Viola adunca* | Early Blue Violet | I | | Violaceae |
| *Viola hallii* | Hall's Violet | O | | Violaceae |
| *Wyethia angustifolia* | Mule's-ears | I | | Asteraceae |
| *Zigadenus venosus v. venosus* | Meadow Death-camas | I | I | Liliaceae |
| **Annuals/Biennials** | | | | |
| *Anthemis cotula** | Mayweed, Chamomile | | I | Asteraceae |
| *Anthriscus scandicina* | Chervil | | O | Apiaceae |

Table 4.2., Continued.

| Scientific Name | Common Name | RP | FB | Family |
|---|---|---|---|---|
| *Barbarea orthoceras* | American Wintercress | I | O | Brassicaceae |
| *Bidens frondosa* | Leafy Beggar's Tick | | I | Asteraceae |
| *Boisduvalia densiflora* | Dense Spike-primrose | O | I | Onagraceae |
| *Callitriche heterophylla* | Different-leaved Water-starwort | | O | Callitrichaceae |
| *Cardamine oligosperma* | Little Western Bittercress | O | O | Brassicaceae |
| *Centaurium muhlenbergii* | Muhlenberg's Centaury | I | I | Gentianaceae |
| *Centaurium umbellatum** | Common Centaury | I | I | Gentianaceae |
| *Centunculus minimus* | Chaffweed | I | I | Primulaceae |
| *Cerastium viscosum** | Mouse-ear Chickweed | I | I | Caryophyllaceae |
| *Cirsium vulgare** | Bull or Common Thistle | I | I | Asteraceae |
| *Crepis capillaris** | Smooth Hawksbeard | | O | Asteraceae |
| *Daucus carota** | Queen Ann's Lace | I | I | Apiaceae |
| *Dianthus armeria** | Grass Pink | | O | Caryophyllaceae |
| *Dipsacus sylvestris** | Teasel | | O | Dipsacaceae |
| *Downingia elegans* | Showy Downingia | | O | Campanulaceae |
| *Downingia yina* | Common Downingia | I | I | Campanulaceae |
| *Epilobium paniculatum* | Autumn Willow-weed | I | I | Onagraceae |
| *Galium aparine* | Cleavers or Goose grass | I | O | Rubiaceae |
| *Galium parisiense** | Wall Bedstraw | I | I | Rubiaceae |
| *Geranium dissectum** | Cut-leaf Geranium | I | O | Geraniaceae |
| *Gnaphalium palustre* | Lowland cudweed | I | I | Asteraceae |
| *Gnaphalium purpureum* | Purple cudweed | I | I | Asteraceae |
| *Gratiola ebracteata* | Bractless Hedge-hyssop | I | I | Scrophulariaceae |
| *Heterocodon rariflorum* | Heterocodon | I | | Campanulaceae |
| *Hypochaeris glabra** | Smooth Cat's-ear | I | I | Asteraceae |
| *Lactuca serriola** | Prickly Lettuce | | O | Asteraceae |
| *Lasthenia glaberrima* | Smooth Lasthenia | | O | Asteraceae |
| *Lathyrus sphaericus** | Grass Pea | O | I | Fabiaceae |
| *Linum angustifolium** | Flax | | I | Linaceae |
| *Lotus micranthus* | Small-flowered Deervetch | I | O | Fabiaceae |
| *Lotus purshiana* | Spanish Clover | I | I | Fabiaceae |
| *Lupinus micranthus* | Small-flowered Lupine | | O | Fabiaceae |
| *Madia elegans* | Showy Tarweed | | O | Asteraceae |
| *Madia glomerata* | Cluster Tarweed | I | I | Asteraceae |
| *Madia sativa* | Chile or Coast Tarweed | I | I | Asteraceae |
| *Matricaria matricarioides* | Pineapple Weed | | O | Asteraceae |
| *Microcala quadrangularis!* | Timwort | I | I | Gentianaceae |
| *Microsteris gracilis* | Pink Microsteris | O | I | Polemoniaceae |
| *Montia fontana* | Water Chickweed | | O | Portulaceae |
| *Montia linearis* | Narrow-leaved Montia | O | I | Portulaceae |

Table 4.2., Continued.

| | Scientific Name | Common Name | RP | FB | Family |
|---|---|---|---|---|---|
| | *Myosotis discolor** | Yellow and Blue Forget-me-not | I | I | Boraginaceae |
| | *Myosotis laxa* | Small-flowered Forget-me-not | I | I | Boraginaceae |
| | *Navarretia intertexta* | Needleleaf Navarretia | | I | Polimoniaceae |
| | *Orthocarpus bracteosus* | Rosy Owl-clover | I | I | Scrophulariaceae |
| | *Orthocarpus hispidus* | Hairy Owl-clover | I | I | Scrophulariaceae |
| | *Orthocarpus pusillus* | Dwarf Owl-clover | O | I | Scrophulariaceae |
| | *Parentucellia viscosa** | Yellow Parentucellia | I | I | Scrophulariaceae |
| | *Plagiobothrys figuratus* | Fragrant Popcorn-flower | I | I | Boraginaceae |
| | *Polygonum douglasii* | Douglas Knotweed | | I | Polygonaceae |
| | *Rorippa curvisiliqua* | Western Yellowcress | | I | Brassicaceae |
| | *Senecio jacobaea** | Tansy Ragwort | I | I | Asteraceae |
| | *Senecio vulgaris** | Groundsel | I | I | Asteraceae |
| | *Sherardia arvensis** | Blue Field-madder | I | I | Rubiaceae |
| | *Sonchus asper** | Prickly Sow Thistle | I | I | Asteraceae |
| | *Trichostema lanceolatum* | Vinegar Weed | O | | Lamiaceae |
| | *Trifolium dubium** | Least Hopclover | I | O | Fabiaceae |
| | *Vicia hirsuta** | Hairy or Tiny Vetch | | I | Fabiaceae |
| | *Vicia tetrasperma** | Slender Vetch | | I | Fabiaceae |
| **LICHENS** | | | | | |
| | *Cladonia spp.* | Lichen (terrestrial) | I | | |

Table 4.3. Flora observed at sites during the course of this study. Plants are catergorized by life form (trees, shrubs, graminoids, forbs), life span (perennials versus annual/biennial) and origin (native versus exotic) information from Table 4.2.

| | | | Number of Plant Species Present at Both Sites | Number of Plant Species in Common to Both Sides | Number of Plant Species Present at Rose Prairie | Number of Plant Species Present at Fisher Bitte | Number of Plant Species Unique to Rose Prairie | Number of Plant Species Unique to Fisher Butte |
|---|---|---|---|---|---|---|---|---|
| All Species: | | | 204 | 117 | 142 | 179 | 25 | 62 |
| | | Native | 137 | 81 | 105 | 113 | 24 | 32 |
| | | Exotic | 67 | 36 | 37 | 66 | 1 | 30 |
| By Life Forms: | | | | | | | | |
| Trees | | | 13 | 6 | 8 | 11 | 2 | 5 |
| | | Native | 9 | 6 | 8 | 7 | 2 | 1 |
| | | Exotic | 4 | 0 | 0 | 4 | 0 | 4 |
| Shrubs | | | 11 | 8 | 9 | 10 | 1 | 2 |
| | | Native | 7 | 5 | 6 | 6 | 1 | 1 |
| | | Exotic | 4 | 3 | 3 | 4 | 0 | 1 |
| Graminoids | | | 46 | 22 | 24 | 44 | 2 | 22 |
| | Total Native | | 25 | 11 | 13 | 23 | 2 | 12 |
| | Total Exotic | | 21 | 11 | 11 | 21 | 0 | 10 |
| | Perennials | | 32 | 17 | 18 | 31 | 1 | 14 |
| | | Native | 23 | 11 | 12 | 22 | 1 | 11 |
| | | Exotic | 9 | 6 | 6 | 9 | 0 | 3 |
| | Annuals | | 14 | 5 | 6 | 13 | 1 | 8 |
| | | Native | 2 | 0 | 1 | 1 | 1 | 1 |
| | | Exotic | 12 | 5 | 5 | 12 | 0 | 7 |
| Forbs | | | 134 | 81 | 101 | 114 | 20 | 33 |
| | Total Native | | 96 | 59 | 78 | 77 | 19 | 18 |
| | Total Exotic | | 38 | 22 | 23 | 37 | 1 | 15 |
| | Perennials | | 74 | 45 | 62 | 57 | 17 | 12 |
| | | Native | 59 | 37 | 53 | 43 | 16 | 6 |
| | | Exotic | 15 | 8 | 9 | 14 | 1 | 6 |
| | Annuals | | 60 | 36 | 39 | 57 | 3 | 21 |
| | | Native | 37 | 22 | 25 | 34 | 3 | 12 |
| | | Exotic | 23 | 14 | 14 | 23 | 0 | 9 |

the drier eastern and more upslope regions of the site, i.e. the FB *Deschampsia* community. *Phalaris arundinacea, Echinochloa crusgalli*, and *Mentha pulegium* were exotics located in wetter locations (i.e. *Rosa/Juncus* community) at Fisher Butte while *Holcus lanatus, Hypochaeris radicata*, and *Leontodon nudicale* were widespread.

Rose Prairie had lower total species richness, including both native and exotic species than did Fisher Butte (Table 4.3). Rose Prairie had fewer species in every life form and lifespan category except native trees and forbs. Forbs were the predominant life form in floras at both study sites, 71% of the species at Rose Prairie and 64% of those at Fisher Butte were forbs. The life form/lifespan combination with the greatest proportion of native species at both sites was perennial forbs. The life form/lifespan combination with the greatest proportion of exotic species was annual/biennial forbs.

## Preburn plant community descriptions and comparisons

At the onset of the study, species richness, cover and frequency varied among plant communities (Table 4.4). Twenty-nine plant species, 19 natives and 10 exotics, occurred in all communities at both sites during 1988. The three plant communities at Rose Prairie mutually shared 20 native and 10 exotic plant species in 1988 prior to burning.

Table 4.4. Cover (%) and frequency (%) of plant species in 50x50 cm plots at Rose Prairie and Fisher Butte during 1988. n = 135 for cover and 270 for frequency in communities at Rose Prairie and n = 225 for cover and 450 for frequency in communities at Fisher Butte. * denotes exotic species.

| | Rose Praire: | | | | | | | | | | | | Fisher Butte: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Deschampsia | | | | Rosa/Anthoxanthum | | | | Vaccinium | | | | Deschampsia | | | | Rosa/Juncus | | | |
| | Cover | | Frequency | | Cover | | Frequency | | Cover | | Frequency | | Cover | | Frequency | | Cover | | Frequency | |
| | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| **BARE GROUND** | 4.6 | 0.5 | | | 0.6 | 0.2 | | | 6.6 | 1.2 | | | 5.5 | 1.0 | | | 6.6 | 1.3 | | |
| **TREES** | | | | | | | | | | | | | | | | | | | | |
| *Amelanchier alnifolia* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.5 | 0.0 | 0.0 | 1.1 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Crataegus douglasii* | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.5 | 0.0 | 0.0 | 1.1 | 0.5 | 0.1 | 0.1 | 0.4 | 0.3 |
| *Fraxinus latifolia* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.1 | 0.0 | 11.1 | 3.7 |
| *Pyrus communis** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.3 | 0.0 | 0.0 | 0.2 | 0.2 |
| *Pyrus fusca* | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.5 | 0.0 | 0.0 |
| *Quercus garryana* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Rhamnus purshiana* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.4 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| **SHRUBS** | | | | | | | | | | | | | | | | | | | | |
| *Rhus diversiloba* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 |
| *Rosa eglanteria** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Rosa nutkana* | 0.1 | 0.1 | 4.4 | 1.8 | 10.9 | 2.0 | 63.3 | 4.8 | 0.7 | 0.2 | 23.3 | 3.5 | 1.2 | 0.3 | 28.2 | 6.2 | 4.2 | 0.7 | 70.9 | 7.3 |
| *Rubus spp.** | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.7 | 0.5 | 0.0 | 0.0 | 1.1 | 0.8 | 0.0 | 0.0 | 0.4 | 0.3 | 0.0 | 0.0 | 0.2 | 0.2 |
| *Spiraea douglasii* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 |
| *Vaccinium caespitosum* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.6 | 2.2 | 67.0 | 3.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **GRAMINOIDS** | | | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | | | |
| *Agrostis exarata* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.2 | 2.0 | 0.8 | 0.3 | 29.3 | 3.8 |
| *Agrostis tenuis** | 2.0 | 0.4 | 83.3 | 5.6 | 0.1 | 0.1 | 4.8 | 2.6 | 1.6 | 0.3 | 67.0 | 3.9 | 0.6 | 0.1 | 50.0 | 7.4 | 0.2 | 0.1 | 16.0 | 4.5 |
| *Anthoxanthum odoratum** | 2.5 | 0.3 | 94.8 | 3.4 | 40.9 | 6.0 | 99.3 | 0.5 | 2.2 | 0.4 | 96.3 | 1.8 | 0.3 | 0.1 | 22.9 | 6.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Carex leporina* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.8 | 1.5 |
| *Carex rossii* | 0.0 | 0.0 | 1.5 | 1.0 | 0.0 | 0.0 | 3.7 | 1.7 | 0.2 | 0.1 | 27.8 | 6.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Carex spp.* | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 2.2 | 2.2 | 0.0 | 0.0 | 4.8 | 4.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 8.4 | 2.4 |
| *Carex unilateralis* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 1.1 | 0.7 |
| *Danthonia californica* | 3.4 | 0.3 | 96.3 | 0.9 | 0.4 | 0.3 | 23.3 | 7.4 | 1.2 | 0.4 | 74.4 | 6.1 | 11.7 | 1.2 | 100 | 0.0 | 7.6 | 1.2 | 91.1 | 3.1 |
| *Deschampsia cespitosa* | 10.0 | 1.5 | 95.2 | 1.3 | 0.0 | 0.0 | 1.1 | 0.8 | 3.6 | 0.7 | 77.4 | 5.5 | 9.1 | 0.9 | 96.4 | 1.2 | 6.4 | 1.5 | 72.7 | 3.3 |
| *Eleocharis acicularis* | 0.0 | 0.0 | 0.7 | 0.5 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 0.6 | 25.1 | 7.9 |
| *Festuca arundinacea** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 1.1 | 0.9 |
| *Festuca rubra* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 |
| *Glyceria occidentalis* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 |
| *Holcus lanatus** | 0.1 | 0.0 | 24.1 | 5.5 | 0.1 | 0.1 | 10.0 | 4.5 | 0.0 | 0.0 | 0.7 | 0.7 | 1.5 | 0.2 | 74.7 | 4.6 | 3.5 | 0.7 | 70.7 | 6.2 |
| *Juncus effusus* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Juncus nevadensis* | 0.0 | 0.0 | 18.9 | 6.6 | 0.0 | 0.0 | 0.4 | 0.4 | 0.1 | 0.0 | 18.1 | 6.1 | 0.1 | 0.0 | 15.8 | 4.4 | 7.4 | 1.4 | 72.7 | 6.3 |

## Table 4.4., Continued.

| | Rose Praire: | | | | | | | | | | | | Fisher Butte: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Deschampsia | | | | Rosa/Anthoxanthum | | | | Vaccinium | | | | Deschampsia | | | | Rosa/Juncus | | | |
| | Cover | | Frequency | | Cover | | Frequency | | Cover | | Frequency | | Cover | | Frequency | | Cover | | Frequency | |
| | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| **BARE GROUND** | 4.6 | 0.5 | | | 0.6 | 0.2 | | | 6.6 | 1.2 | | | 5.5 | 1.0 | | | 6.6 | 1.3 | | |
| *Juncus spp.* | 0.0 | 0.0 | 2.6 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 3.8 | 3.8 |
| *Juncus tenuis* | 0.0 | 0.0 | 34.8 | 4.4 | 0.0 | 0.0 | 1.5 | 1.1 | 0.0 | 0.0 | 4.4 | 1.2 | 0.0 | 0.0 | 24.0 | 3.0 | 0.1 | 0.0 | 21.1 | 4.7 |
| *Luzula campestris* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Panicum occidentale* | 0.4 | 0.1 | 27.4 | 5.1 | 0.2 | 0.1 | 5.9 | 2.5 | 5.9 | 0.5 | 74.8 | 2.7 | 0.8 | 0.5 | 10.9 | 5.4 | 0.0 | 0.0 | 0.9 | 0.7 |
| *Poa spp.** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 | 1.3 | 0.0 | 0.0 | 1.1 | 1.1 |
| **Annuals** | | | | | | | | | | | | | | | | | | | | |
| *Aira spp.** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.6 | 2.6 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 6.0 | 2.4 | 0.0 | 0.0 | 0.7 | 0.5 |
| *Beckmannia syzigachne* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.9 | 1.8 |
| *Briza minor** | 0.0 | 0.0 | 0.7 | 0.7 | 0.0 | 0.0 | 8.5 | 2.8 | 0.0 | 0.0 | 9.3 | 3.0 | 0.1 | 0.0 | 19.6 | 6.6 | 0.0 | 0.0 | 4.0 | 1.4 |
| *Bromus mollis** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.5 | 0.0 | 0.0 | 1.6 | 1.6 |
| *Cynosurus echinatus** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Festuca myuros** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 |
| *Juncus emarginata** | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.8 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Juncus bufonius** | 0.0 | 0.0 | 13.0 | 3.3 | 0.0 | 0.0 | 4.8 | 4.0 | 0.0 | 0.0 | 21.9 | 6.8 | 0.0 | 0.0 | 14.0 | 4.9 | 0.0 | 0.0 | 6.4 | 3.0 |
| **FORBS** | | | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | | | |
| *Achillea millefolium* | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 8.1 | 5.9 | 0.0 | 0.0 | 5.9 | 5.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Alisma plantago-aquatica* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 |
| *Allium amplectens* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.4 | 0.0 | 0.0 | 1.1 | 0.9 |
| *Apocynum androsaemifolium* | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 5.2 | 5.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Aster chilensis v. hallii* | 0.1 | 0.0 | 7.4 | 2.9 | 0.0 | 0.0 | 1.5 | 1.0 | 0.1 | 0.1 | 20.4 | 6.0 | 0.7 | 0.1 | 54.9 | 4.8 | 0.4 | 0.1 | 18.7 | 3.1 |
| *Aster curtus* | 0.0 | 0.0 | 1.1 | 0.8 | 0.0 | 0.0 | 0.4 | 0.4 | 1.6 | 0.5 | 69.6 | 4.9 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Brodiaea spp.* | 0.0 | 0.0 | 9.6 | 5.9 | 0.0 | 0.0 | 9.6 | 5.3 | 0.0 | 0.0 | 10.4 | 3.9 | 0.0 | 0.0 | 4.9 | 2.3 | 0.0 | 0.0 | 6.7 | 2.0 |
| *Calochortus tolmiei* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Camassia quamash* | 0.0 | 0.0 | 72.2 | 4.7 | 0.0 | 0.0 | 3.3 | 2.4 | 0.0 | 0.0 | 57.8 | 4.1 | 0.1 | 0.1 | 26.2 | 8.6 | 0.0 | 0.0 | 11.3 | 3.7 |
| *Cardamine penduliflora* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 |
| *Cirsium arvense** | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 8.9 | 5.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Comandra umbellata* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.6 | 1.7 | 0.2 | 0.1 | 15.6 | 7.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Dodecatheon hendersonii* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 1.1 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Epilobium spp.* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.9 | 1.7 | 0.0 | 0.0 | 20.7 | 7.7 |
| *Erigeron decumbens* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 4.7 | 2.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Eriophyllum lanatum* | 0.5 | 0.1 | 51.9 | 4.1 | 0.0 | 0.0 | 1.9 | 1.1 | 0.2 | 0.1 | 25.2 | 5.5 | 0.5 | 0.1 | 50.7 | 4.5 | 1.0 | 0.4 | 30.4 | 6.6 |
| *Eryngium petiolatum* | 0.0 | 0.0 | 2.2 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 6.9 | 1.8 |
| *Fragaria virginiana* | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.3 | 4.8 | 2.9 | 0.9 | 0.4 | 20.0 | 6.6 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Galium trifidum* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 15.6 | 6.6 | 0.3 | 0.1 | 68.7 | 5.0 |
| *Grindelia integrifolia* | 0.8 | 0.3 | 44.8 | 6.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.2 | 40.4 | 6.2 | 1.6 | 0.5 | 42.0 | 5.9 | 3.2 | 1.5 | 34.0 | 9.4 |
| *Haplopappus racemosus* | 0.1 | 0.1 | 2.2 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.4 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

# Table 4.4., Continued.

| | Rose Praire: | | | | | | | | | | | | Fisher Butte: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Deschampsia | | | | Rosa/Anthoxanthum | | | | Vaccinium | | | | Deschampsia | | | | Rosa/Juncus | | | |
| | Cover | | Frequency | | Cover | | Frequency | | Cover | | Frequency | | Cover | | Frequency | | Cover | | Frequency | |
| | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| **BARE GROUND** | 4.6 | 0.5 | | | 0.6 | 0.2 | | | 6.6 | 1.2 | | | 5.5 | 1.0 | | | 6.6 | 1.3 | | |
| *Horkelia congesta* | 0.0 | 0.0 | 2.6 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 22.6 | 6.1 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.4 | 0.4 |
| *Hypericum perforatum** | 0.0 | 0.0 | 7.0 | 2.9 | 3.3 | 0.6 | 96.3 | 1.5 | 0.2 | 0.1 | 53.3 | 5.3 | 0.1 | 0.0 | 36.9 | 4.1 | 0.0 | 0.0 | 10.7 | 2.6 |
| *Hypocharis radicata** | 1.6 | 0.4 | 81.9 | 5.5 | 0.2 | 0.1 | 33.3 | 5.6 | 1.0 | 0.3 | 74.4 | 4.4 | 0.2 | 0.1 | 21.3 | 3.2 | 0.1 | 0.0 | 6.0 | 1.8 |
| *Leontodon nudicaulis** | 0.8 | 0.3 | 61.9 | 5.9 | 0.1 | 0.1 | 18.5 | 6.8 | 3.7 | 1.6 | 52.6 | 14.0 | 0.9 | 0.1 | 63.8 | 3.6 | 0.1 | 0.1 | 6.2 | 2.3 |
| *Lomatium bradshawii* | 0.0 | 0.0 | 3.0 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.3 | 1.6 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Lotus formosissimus* | 0.0 | 0.0 | 6.7 | 1.8 | 0.1 | 0.1 | 11.5 | 7.2 | 0.2 | 0.1 | 57.4 | 8.5 | 0.3 | 0.1 | 21.6 | 5.5 | 0.2 | 0.1 | 7.6 | 4.2 |
| *Mentha pulegium** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 1.1 | 0.3 | 42.7 | 8.0 |
| *Microseris laciniata* | 0.1 | 0.0 | 30.0 | 6.2 | 0.0 | 0.0 | 1.5 | 1.1 | 0.0 | 0.0 | 10.4 | 2.6 | 0.1 | 0.0 | 18.2 | 3.3 | 0.2 | 0.1 | 8.9 | 4.1 |
| *Orobanche californica* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.3 |
| *Perideridia oregana* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.7 | 3.6 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 3.1 | 1.0 | 0.0 | 0.0 | 1.8 | 1.8 |
| *Plantago lanceolata** | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 0.5 | 51.5 | 8.6 | 0.1 | 0.0 | 16.3 | 4.5 | 0.2 | 0.1 | 26.7 | 5.3 | 0.0 | 0.0 | 0.2 | 0.2 |
| *Polygonum douglasii* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 0.8 | 0.0 | 0.0 | 12.2 | 3.1 |
| *Potentilla gracilis* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.4 | 1.7 | 0.2 | 0.1 | 2.7 | 1.0 |
| *Prunella vulgaris* | 0.0 | 0.0 | 10.7 | 3.9 | 0.0 | 0.0 | 4.1 | 2.2 | 0.7 | 0.2 | 67.4 | 3.3 | 0.9 | 0.2 | 63.8 | 4.9 | 0.5 | 0.2 | 17.8 | 5.0 |
| *Ranunculus occidentalis* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Ranunculus orthorhynchus* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Ranunculus spp.* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Rumex acetosella** | 0.0 | 0.0 | 0.4 | 0.4 | 0.8 | 0.4 | 29.6 | 9.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Rumex crispus** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.5 |
| *Sanicula bipinnatifida* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Sisyrinchium angustifolium* | 0.0 | 0.0 | 2.6 | 1.4 | 0.0 | 0.0 | 0.4 | 0.4 | 0.1 | 0.0 | 36.3 | 4.8 | 0.3 | 0.1 | 42.2 | 5.8 | 0.0 | 0.0 | 2.9 | 1.4 |
| *Spiranthes romanzoffiana* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.8 | 0.0 | 0.0 | 0.4 | 0.3 | 0.0 | 0.0 | 0.4 | 0.4 |
| *Veronica scutellata* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.5 | 1.1 | 0.4 | 28.2 | 6.4 |
| *Vicia sativa** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Viola adunca* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.7 | 0.6 | 0.2 | 37.0 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Wyethia angustifolia* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Zigadenus venosus* | 0.0 | 0.0 | 1.1 | 0.6 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.7 | 0.5 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.7 | 0.4 |
| **Annuals and Biennials** | | | | | | | | | | | | | | | | | | | | |
| *Anthemis cotula** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 |
| *Barbarea orthoceras* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Bidens frondosa* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 6.7 | 3.0 |
| *Boisduvalia densiflora* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 12.9 | 3.7 |
| *Centaurium muhlenbergii* | 0.0 | 0.0 | 42.2 | 4.1 | 0.0 | 0.0 | 8.5 | 6.9 | 0.0 | 0.0 | 45.6 | 11.9 | 0.0 | 0.0 | 6.9 | 2.4 | 0.0 | 0.0 | 3.6 | 1.2 |
| *Centaurium umbellatum** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.1 | 60.7 | 4.7 | 0.1 | 0.1 | 12.7 | 6.4 |
| *Centunculus minimus* | 0.0 | 0.0 | 16.7 | 7.2 | 0.0 | 0.0 | 1.5 | 1.1 | 0.1 | 0.1 | 39.3 | 11.4 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.9 | 0.5 |
| *Cirsium vulgare** | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 13.0 | 5.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 0.5 | 0.0 | 0.0 | 0.2 | 0.2 |
| *Daucus carota** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.1 | 1.5 | 0.0 | 0.0 | 0.9 | 0.9 |
| *Downingia yina* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.9 |
| *Epilobium paniculatum* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.1 | 1.4 | 0.0 | 0.0 | 8.1 | 3.1 |

Table 4.4., Continued.

| | Rose Praire: | | | | | | | | | | | | Fisher Butte: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Deschampsia | | | | Rosa/Anthoxanthum | | | | Vaccinium | | | | Deschampsia | | | | Rosa/Juncus | | | |
| | Cover | | Frequency | | Cover | | Frequency | | Cover | | Frequency | | Cover | | Frequency | | Cover | | Frequency | |
| | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| **BARE GROUND** | 4.6 | 0.5 | | | 0.6 | 0.2 | | | 6.6 | 1.2 | | | 5.5 | 1.0 | | | 6.6 | 1.3 | | |
| _Galium aparine_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| _Galium parisiense_* | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 4.4 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 0.5 |
| _Geranium dissectum_* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.6 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| _Gnaphalium palustre_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.3 | 0.0 | 0.0 | 1.1 | 0.5 |
| _Gnaphalium purpureum_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| _Gratiola ebracteata_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.3 | 2.6 |
| _Heterocodon rariflorum_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 25.9 | 9.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| _Hypocharis glabra_* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| _Lathyrus sphaericus_* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| _Lotus purshiana_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 22.6 | 8.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.5 | 0.0 | 0.0 | 0.2 | 0.2 |
| _Madia glomerata_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.2 | 58.4 | 6.2 | 1.7 | 0.5 | 66.0 | 5.3 |
| _Madia sativa_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 3.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 |
| _Microcala quadrangularis_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.3 | 2.8 | 0.0 | 0.0 | 1.6 | 0.6 |
| _Microsteris gracilis_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 16.2 | 4.1 |
| _Montia linearis_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 |
| _Myosotis discolor_* | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 35.9 | 8.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 | 0.8 | 0.0 | 0.0 | 0.4 | 0.3 |
| _Myosotis laxa_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.3 | 2.3 | 0.0 | 0.0 | 4.4 | 1.9 |
| _Navarretia intertexta_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.2 | 0.2 |
| _Orthocarpus bracteosus_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.5 | 0.0 | 0.0 | 3.1 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| _Orthocarpus hispidus_ | 0.0 | 0.0 | 0.7 | 0.7 | 0.0 | 0.0 | 2.2 | 1.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.4 | 2.3 | 0.0 | 0.0 | 1.3 | 0.9 |
| _Parentucellia viscosa_* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.4 | 5.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| _Plagiobothrys figuratus_ | 0.0 | 0.0 | 0.7 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 3.8 | 1.4 |
| _Senecio jacobaea_* | 0.0 | 0.0 | 0.4 | 0.4 | 0.5 | 0.3 | 19.6 | 12.4 | 0.0 | 0.0 | 0.4 | 0.4 | 0.1 | 0.0 | 12.7 | 4.6 | 0.0 | 0.0 | 2.7 | 1.2 |
| _Senecio vulgaris_* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| _Sherardia arvensis_* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| _Sonchus asper_* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.5 | 0.0 | 0.0 | 2.7 | 1.3 |
| _Trifolium dubium_* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| _Veronica spp._* | 0.0 | 0.0 | 1.5 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| _Vicia tetrasperma_* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 1.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| **LICHEN** | | | | | | | | | | | | | | | | | | | | |
| _Ground lichens_ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 | 1.6 | 5.9 | 3.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

## Rose Prairie

### *Deschampsia* Community

In 1988 species richness in the *Deschampsia* community was 43 (30 native, 13 exotic), the lowest species richness measured (Table 4.5). No plant species were unique to this community (Table 4.4). The *Deschampsia* community had the lowest total live plant cover (22%), but over half of the cover present was provided by native species (Table 4.6). Shrub and tree cover was <1%. Graminoids, predominantly natives, comprised ~82% of the total live plant cover. *Deschampsia cespitosa* and *Danthonia* californica were dominant native graminoids. Common native graminoids included *Juncus nevadensis*, *Juncus tenuis*, and *Panicum occidentale*. *Anthoxanthum odoratum* and *Agrostis tenuis* were dominant exotic graminoids while *Holcus lanatus* and *Juncus bufonius* were common exotic graminoids.

Forbs comprised ~18% of the total live plant cover in the *Deschampsia* plant community. Common native forbs included *Camassia quamash*, *Centunculus minimus*, *Centaurium muhlenbergii*, *Eriophyllum lanatum*, *Grindelia integrifolia*, *Microseris laciniata* and *Prunella vulgaris*. Common exotic forbs included *Hypochaeris radicata* and *Leontodon nudicaulis* (Table 4.4).

Table 4.5. Summary of species richness observed during 1988 sampling. Species are categorized by life form, lifespan, and origin categories and summarized within plant communities. n = 270 for communities at Rose Prairie and 450 for communities at Fisher Butte.

| | Rose Prairie | | | Fisher Butte | |
|---|---|---|---|---|---|
| | RP Deschampsia | Rosa/Anthoxanthum | Vaccinium | FB Deschampsia | Rosa/Juncus |
| All Species | 43 | 66 | 51 | 84 | 85 |
| Total Natives | 30 | 42 | 38 | 53 | 59 |
| Total Exotics | 13 | 24 | 13 | 31 | 26 |
| Life Forms | | | | | |
| | 2 | 2 | 4 | 5 | 3 |
| Trees | | | | | |
| Native | 2 | 1 | 4 | 4 | 2 |
| Exotic | 0 | 1 | 0 | 1 | 1 |
| Shrubs | 2 | 2 | 3 | 3 | 4 |
| Native | 1 | 1 | 2 | 1 | 3 |
| Exotic | 1 | 1 | 1 | 2 | 1 |
| Graminoids | 13 | 14 | 13 | 17 | 22 |
| Total Native | 7 | 8 | 6 | 7 | 12 |
| Total Exotic | 6 | 6 | 7 | 10 | 10 |
| Perennials | 10 | 11 | 9 | 12 | 15 |
| Native | 7 | 8 | 6 | 7 | 11 |
| Exotic | 3 | 3 | 3 | 5 | 4 |
| Annuals | 3 | 3 | 4 | 5 | 7 |
| Native | 0 | 0 | 0 | 0 | 1 |
| Exotic | 3 | 3 | 4 | 5 | 6 |
| Forbs | 26 | 48 | 30 | 59 | 56 |
| Total Native | 20 | 32 | 25 | 41 | 42 |
| Total Exotic | 6 | 16 | 5 | 18 | 14 |
| Perennials | 21 | 29 | 26 | 32 | 29 |
| Native | 16 | 23 | 22 | 25 | 23 |
| Exotic | 5 | 6 | 4 | 7 | 6 |
| Annuals | 5 | 19 | 4 | 27 | 27 |
| Native | 4 | 9 | 3 | 16 | 19 |
| Exotic | 1 | 10 | 1 | 11 | 8 |

Table 4.6. Summary of species percent cover by life form, life span, and origin data from 1988 data. Species are categorized by life form, life span, and origin categories and summarized within plant communities.

| | Rose Prairie | | Fisher Butte | | |
|---|---|---|---|---|---|
| | RP Deschampsia | Rosa/Anthoxanthum | Vaccinium | FB Deschampsia | Rosa/Juncus |
| Total Plant Cover | 22.5 | 61.6 | 41.6 | 33.0 | 43.4 |
| Total Native | 15.6 | 13.1 | 32.8 | 28.7 | 38.1 |
| Total Exotic | 7.0 | 48.5 | 8.8 | 4.4 | 5.4 |
| By Life Forms | | | | | |
| Trees | 0.0 | 0.0 | 0.0 | 0.1 | 0.7 |
| Native | 0.0 | 0.0 | 0.0 | 0.1 | 0.7 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Shrubs | 0.1 | 10.9 | 14.4 | 1.6 | 6.2 |
| Native | 0.1 | 10.9 | 14.3 | 1.2 | 4.2 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| Gramminoids | 18.4 | 41.8 | 14.8 | 24.3 | 27.8 |
| Total Native | 13.8 | 0.7 | 11.0 | 21.7 | 24.0 |
| Total Exotic | 4.6 | 41.1 | 3.9 | 2.5 | 3.8 |
| Perennials | 128.4 | 41.8 | 14.8 | 24.2 | 27.8 |
| Native | 13.8 | 0.7 | 11.0 | 21.7 | 24.0 |
| Exotic | 4.6 | 41.0 | 3.8 | 2.4 | 3.8 |
| Annuals | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| Forbs | 4.0 | 8.9 | 10.6 | 7.4 | 10.7 |
| Total Native | 1.6 | 1.5 | 5.6 | 5.6 | 9.2 |
| Total Exotic | 2.4 | 7.4 | 5.0 | 1.8 | 1.5 |
| Perennials | 4.0 | 7.5 | 10.5 | 5.9 | 8.5 |
| Native | 1.6 | 1.2 | 5.5 | 4.6 | 7.3 |
| Exotic | 2.4 | 6.3 | 5.0 | 1.4 | 1.3 |
| Annuals/Biennials | 0.0 | 1.4 | 0.1 | 1.4 | 2.1 |
| Native | 0.0 | 0.3 | 0.1 | 1.0 | 1.9 |
| Exotic | 0.0 | 1.1 | 0.0 | 0.4 | 0.2 |

### *Rosa/Anthoxanthum* community

Species richness of the *Rosa/Anthoxanthum* plant community was 68 (44 native, 24 exotic)(Table 4.4). Plant cover was greatest in the *Rosa/Anthoxanthum* community (61.6%) but, native plants were only 31% of the total plant cover. Six native species occurred exclusively in *Rosa/Anthoxanthum* community plots during 1988, *Apocynum androsaemifolium, Calochortus tolmiei, Sanicula bipinnatifida, Barbarea orthoceras, Galium aparine,* and *Heterocodon rariflorum,* while three exotics were unique, *Circium arvense, Geranium dissectum* and *Trifolium dubium.*

Shrubs comprised ~18% of the total plant cover in the *Rosa/Anthoxanthum* community; *R. nutkana* was the predominant woody plant species (Table 4.4). Graminoids comprised 68% of the total live plant cover, but only ~2% of graminoid cover was native species. *Danthonia californica* was the only common native graminoids present while *Anthoxanthum odoratum* (41% cover) was the dominant exotic graminoid and *Holcus lanatus* a common exotic graminoid. Forbs comprised ~14% of the total live plant cover in 1988; only 17% of forb cover was from native species.

### *Vaccinium* community

Species richness of the *Vaccinium* community was 52 (39 native, 13 exotic) during 1988 sampling (Table 4.4). Plant cover was 41% composed predominantly of native species. The *Vaccinium* community and RP *Deschampsia* communities shared 40 species, but the *Vaccinium* community contained 11 plant species not observed in the adjacent RP *Deschampsia* community. Numerous terrestrial lichens (Cladonia spp.) occurred within the *Vaccinium* community, but they also occurred to a lesser extent and outside of study plots in the *Rosa/Anthoxanthum* community. Native species unique to the *Vaccinium* community included *Quercus garryana*, *Vaccinium caespitosum* and *Wyethia angustifolia*; no exotics were uniquely found in this community.

*Vaccinium* had the highest total and proportional shrub cover (14.4 and 36%, respectively) and forb cover (10.6 and 27%), and the lowest total and proportional graminoid cover (14.8 and 37%) relative to other plant communities (Table 4.4). *Vaccinium caespitosum* was the dominant shrub present, and *R. nutkana* was a common shrub species in this community. Dominant native graminoids included *Deschampsia cespitosa* and *Panicum occidentale* while common native graminoids included *Carex rossii, Danthonia californica,* and *Juncus nevadensis*. The dominant exotic graminoid was *Anthoxanthum odoratum*, while common exotic graminoids were *Agrostis tenuis, Holcus lanatus,* and *Juncus bufonius*. There were 16 common native forbs included *Comandra umbellata,* a root parasite that appeared to be parasitizing *V. caespitosum*. Total cover of exotic perennial forbs was relatively high in this community (5%), approaching that of the Rosa/Anthoxanthum community. Common exotic forbs were *Hypericum perforatum, Hypochaeris radicata, Leontodon nudicaulis,* and *Plantago lanceolata*.

## Fisher Butte

Forty-three native and 22 exotic plant species were present in both plant communities at Fisher Butte (Table 4.4). Total live plant cover was lower in the *Deschampsia cespitosa-Danthonia californica* community (33.1) than the *Rosa/Juncus* community (43.4). The proportional cover of natives was high in both communities (87% and 88%, respectively), native and exotic graminoid and forb cover were similar, but Rosa/Juncus had a much greater cover of native trees and shrubs.

### FB *Deschampsia* community

Species richness of the *Deschampsia* community was 84 (53 native and 31 exotics) in 1988 plots (Table 4.4). No native species were exclusive to the *Deschampsia* community, but three exotic species, *Rosa eglanteria, Hypochaeris glabra,* and *Lathyrus sphaericus*, were found only in that community.

Percent cover of shrubs and trees was low during 1988 (1.7% cover); *R. nutkana* was the most common shrub. Graminoids constituted 73% and forbs 22% of the total plant cover. Dominant native grasses included *Deschampsia cespitosa* and *Danthonia californica.* Common native graminoids were *Juncus nevadensis, Juncus tenuis,* and *Panicum occidentalis*. Common exotic graminoids included *Agrostis tenuis, Anthoxanthum odoratum, Holcus lanatus, Briza minor* and

*Juncus bufonius*. Ten native and six exotic forbs were common in the *Deschampsia* community.

### *Rosa/Juncus* community

Species richness of the *Rosa/Juncus* community was 86 (61 native and 25 exotic)( Table 4.5). This community had the greatest number of species of all communities sampled and the highest live plant cover (43.4) at Fisher Butte. Nine native species, *Rhus diversiloba, Alisma plantao-aquatica, Cardamine penduliflora, Downingia yina, Montia linearis, Beckmania syzigachne, Carex leporina, C. unilateralis*, and *Glyceria occidentalis,* and two exotic *species, Rumex crispus* and *Anthemis cotula,* were only found in the *Rosa/Juncus* community.

Shrubs, predominantly *R. nutkana,* and trees were ~11%, graminoids 64%, and forbs 25% of the total plant cover in the *Rosa/Juncus* community. Dominant native graminoids included *Danthonia californica, Deschampsia cespitosa*, and *Juncus nevadensis*; common native graminoids were *Agrostis exerata, Eleocharis acicularis,* and *Juncus tenuis* (Table 4.4). Common exotic graminoids included *Agrostis tenuis* and *Holcus lanatus*. Twelve common native forbs and three exotic common forbs, *Hypericum perforatum, Mentha pulegium,* and *Centaurium umbellatum,* were encountered.

## Rare plant distributions

Although plant community sampling was not designed to document the distributions of rare plant species, individuals of six rare species were occasionally encountered (Table 4.2 and 4.4). *Aster curtus* was most abundant in the *Vaccinium* community at Rose Prairie and was located in three other communities. *Calochortus uniflorus* was sampled only in the FB *Deschampsia* community at Fisher Butte (at less than 10% frequency); it was also found outside of plots at Rose Prairie. *Erigeron decumbens* var. *decumbens* occurred only at the Fisher Butte site and almost exclusively within the *Deschampsia* community. *Horkelia congesta* occurred in all communities at both sites, but it occurred with most abundance at Rose Prairie within the *Vaccinium* community. *Lomatium bradshawii* occurred with most abundance at an intermediate moisture regime between the moisture extremes of the Deschampsia and Rosa/Juncus communities at Fisher Butte and was most abundant in the *Vaccinium* community at Rose Prairie. *Microcala quadrangularis* was sampled at both sites but was most abundant at Fisher Butte within the *Deschampsia* community.

The *Deschampsia* community at Fisher Butte contained more rare plant species (6) than any of the other communities at either site (Table 4.2 and 4.4). The *Vaccinium* community at Rose Prairie contained only three rare species, but their cover and frequencies were relatively high. The *Rosa/Deschampsia* community at Fisher Butte also contained three rare plant species, but their cover and frequency were the lowest measured.

## Fire effects plant species frequency

### Rose Prairie

#### RP *Deschampsia* plant community

In the unburned control treatments, the frequency of only one native, *Luzula campestris*, increased significantly between 1988 and 1990, while the frequency of two exotics, *Hypochaeris radicata* and *Leontodon nudicaulis*, increased in the *Deschampsia* community (Table 4.7). Response to fire varied widely by species. The increase in *V. caespitosum* was probably due to seedlings that established in burned areas during 1989 and then disappeared by 1990. *Agrostis* spp. frequency increased significantly in both burn treatments but not in control treatments. *Danthonia californica* frequency increased in 50x50 cm plots but significantly decreased in the 12.5x12.5 cm plots in once burn treatments between 1988 and 1989. Frequency of *Anthoxanthum ordoratum, Holcus lanatus*, and *Leontodon nudicaulis* decreased the first post fire year, 1989, and increased in 1990, regardless of whether a second burn was applied. Native graminoids, *Juncus tenuis* and *Panicum occidentale*, increased significantly between 1988 and 1990 in twice burned treatments. Between 1988 and 1989, *Aira* spp. and *Juncus bufonius* increased in burn treatments, while between 1989 and 1990, *J. bufonius* declined to preburn levels. A number of native forbs established and/or increased in one

Table 4.7. Species frequency by treatments in the RP *Deschampsia* community. Only species with at least 10% frequency are presented. Data is presented for the 50*50 cm plot except where presented for nested plots. The 50*50 cm plot is indicated with a 3, the 25*25 cm plot is indicated with a 2, and the 12.5*12.5 cm plot is indicated with a 1. Superscripted letters indicate a significant (p = 0.1) difference between years within treatments. * Denotes exotic species.

| | CONTROL/UNBURNED | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **SHRUBS** | | | | | | | | | | | | | | | | | | |
| *Rosa nutkana* | 6 | 4 | 9 | 5 | 10 | 5 | 1 | 1 | 3 | 3 | 3 | 2 | 7 | 4 | 7 | 5 | 8 | 4 |
| *Vaccinium caespitosum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 6 | 0 | 0 | 0$^{a}$ | 0 | 9$^{b}$ | 1 | 0$^{a}$ | 0 |
| **GRAMINOIDS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Agrostis tenuis*3* | 90 | 4 | 99 | 1 | 98 | 1 | 66$^{a}$ | 11 | 93 | 7 | 91$^{b}$ | 4 | 94$^{a}$ | 2 | 100$^{b}$ | 0 | 100$^{b}$ | 0 |
| *Agrostis tenuis*1* | 54 | 6 | 68 | 5 | 71 | 4 | 24 | 11 | 49 | 11 | 56 | 13 | 47$^{a}$ | 2 | 77$^{b}$ | 5 | 79$^{b}$ | 5 |
| *Anthoxanthum odoratum*3* | 86 | 9 | 94 | 1 | 100 | 0 | 99 | 1 | 92 | 4 | 99 | 1 | 100$^{a}$ | 0 | 86$^{a}$ | 3 | 96 | 4 |
| *Anthoxanthum odoratum*1* | 47 | 8 | 48 | 6 | 53 | 5 | 60 | 8 | 38$^{a}$ | 7 | 61$^{b}$ | 3 | 74$^{a}$ | 3 | 32$^{b}$ | 4 | 56$^{c}$ | 2 |
| *Carex rossii* | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Danthonia californica3* | 98 | 1 | 100 | 0 | 100 | 0 | 96$^{a}$ | 1 | 100$^{b}$ | 0 | 99 | 1 | 96 | 2 | 96 | 3 | 99 | 1 |
| *Danthonia californica1* | 42 | 4 | 47 | 4 | 38 | 3 | 54 | 9 | 39 | 7 | 41 | 2 | 51$^{a}$ | 3b | 33$^{b}$ | 4 | 38 | 7 |
| *Deschampsia cespitosa3* | 99 | 1 | 99 | 1 | 100 | 0 | 93 | 2 | 98 | 1 | 98 | 1 | 93 | 2 | 98 | 1 | 97 | 0 |
| *Deschampsia cespitosa1* | 57 | 8 | 49 | 8 | 50 | 8 | 62 | 8 | 57 | 8 | 63 | 3 | 53 | 3 | 48 | 4 | 48 | 2 |
| *Eleocharis acicularis* | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 4 | 3 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Holcus lanatus** | 16 | 12 | 17 | 13 | 12 | 9 | 39$^{a}$ | 2 | 28$^{b}$ | 3 | 41$^{a}$ | 2 | 18 | 6 | 12 | 2 | 19 | 2 |
| *Juncus nevadensis* | 6 | 4 | 13 | 10 | 16 | 9 | 24 | 12 | 32 | 11 | 29 | 11 | 27 | 15 | 48 | 13 | 48 | 11 |
| *Juncus tenuis* | 24 | 5 | 37 | 3 | 36 | 7 | 43 | 11 | 63 | 10 | 77 | 12 | 37$^{a}$ | 2 | 50 | 6 | 57$^{b}$ | 8 |
| *Luzula campestris* | 0$^{a}$ | 0 | 38$^{b}$ | 6 | 53$^{b}$ | 8 | 0$^{a}$ | 0 | 19$^{b}$ | 10 | 7$^{b}$ | 3 | 0$^{a}$ | 0 | 49$^{b}$ | 7 | 61$^{b}$ | 6 |
| *Panicum occidentale* | 23 | 8 | 31 | 15 | 30 | 13 | 16 | 3 | 17 | 2 | 22 | 4 | 43$^{a}$ | 5 | 66$^{b}$ | 6 | 80$^{b}$ | 3 |
| **Annuals** | | | | | | | | | | | | | | | | | | |
| *Aira spp.** | 0 | 0 | 2 | 1 | 0 | 0 | 0$^{a}$ | 0 | 16$^{b}$ | 4 | 29$^{b}$ | 10 | 0$^{a}$ | 0 | 3$^{b}$ | 0 | 10$^{b}$ | 4 |
| *Briza minor** | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 9 | 4 | 10 | 2 | 0 | 0 | 1 | 1 | 4 | 3 |
| *Juncus bufonius** | 8$^{a}$ | 1 | 3$^{b}$ | 0 | 0$^{c}$ | 0 | 19$^{a}$ | 8 | 50$^{b}$ | 8 | 11$^{a}$ | 6 | 12$^{a}$ | 6 | 50$^{b}$ | 7 | 19$^{a}$ | 5 |
| **FORBS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Aster chilensis v. hallii* | 14 | 7 | 21 | 14 | 23 | 10 | 1 | 1 | 0 | 0 | 7 | 7 | 7 | 2 | 9 | 3 | 10 | 4 |
| *Aster curtus* | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 2 | 3 | 2 | 12 | 4 |

Table 4.7., Continued.

| | CONTROL/UNBURNED | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| *Brodiaea spp.* | 21 | 6 | 20 | 10 | 50 | 15 | 2 | 2 | 17 | 10 | 13 | 7 | $4^a$ | 3 | $26^b$ | 4 | $51^b$ | 9 |
| *Camassia quamash3* | 82 | 6 | 97 | 3 | 98 | 1 | $66^a$ | 1 | $82^b$ | 6 | $83^b$ | 3 | 69 | 12 | $84^a$ | 2 | $97^b$ | 2 |
| *Camassia quamash2* | 54 | 6 | 69 | 8 | 64 | 3 | $38^a$ | 2 | $48^b$ | 3 | $51^b$ | 2 | $41^a$ | 14 | $54^a$ | 7 | $81^b$ | 3 |
| *Eriophyllum lanatum* | 51 | 13 | 64 | 9 | 64 | 11 | 50 | 4 | 58 | 8 | 73 | 5 | 54 | 4 | 59 | 5 | 63 | 5 |
| *Eryngiumpetiolatum* | 0 | 0 | 1 | 1 | 1 | 1 | 6 | 4 | 11 | 6 | 21 | 9 | 1 | 1 | 3 | 2 | 3 | 2 |
| *Grindelia integrifolia* | 56 | 12 | 62 | 12 | 66 | 16 | 34 | 16 | 28 | 13 | 27 | 8 | $44^a$ | 3 | $34^b$ | 2 | $53^a$ | 2 |
| *Haplopappus racemosus* | 6 | 4 | 7 | 4 | 7 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Horkelia congesta* | 7 | 2 | 7 | 4 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Hypericum perforatum** | 14 | 6 | 16 | 9 | 20 | 10 | 1 | 1 | 11 | 4 | 8 | 4 | 6 | 4 | 10 | 3 | 8 | 3 |
| *Hypocharis radicata*3* | 93 | 5 | 100 | 0 | 100 | 0 | $61^a$ | 1 | $53^a$ | 9 | $96^b$ | 3 | $91^a$ | 3 | $90^a$ | 0 | $100^b$ | 0 |
| *Hypocharis radicata*1* | $44^a$ | 1 | $77^b$ | 5 | $89^b$ | 6 | $16^a$ | 10 | $13^a$ | 7 | $69^b$ | 7 | $40^a$ | 5 | $23^b$ | 2 | $82^c$ | 1 |
| *Leontodon nudicaulis*3* | 74 | 4 | 84 | 10 | 98 | 1 | 40 | 4 | $22^a$ | 7 | $50^b$ | 6 | $71^a$ | 5 | $40^b$ | 10 | 72 | 8 |
| *Leontodon nudicaulis*2* | $54^a$ | 8 | 66 | 13 | $91^b$ | 4 | 31 | 5 | 19 | 7 | 39 | 2 | $49^a$ | 6 | $17^b$ | 6 | $47^a$ | 3 |
| *Lomatium bradshawii* | 6 | 4 | 7 | 5 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 3 | 2 | 6 | 1 | 9 | 3 |
| *Lotus formosissinus* | 3 | 3 | 4 | 3 | 16 | 8 | 9 | 2 | 11 | 3 | 20 | 7 | 8 | 4 | 10 | 6 | 16 | 6 |
| *Microseris laciniata* | 49 | 12 | 74 | 11 | 61 | 9 | $16^a$ | 1 | $87^b$ | 2 | $74^b$ | 8 | $26^a$ | 6 | $73^b$ | 4 | $82^b$ | 3 |
| *Prunella vulgaris* | 8 | 5 | 14 | 9 | 21 | 15 | 12 | 12 | 11 | 11 | 13 | 12 | 12 | 2 | 14 | 5 | 13 | 5 |
| *Sisyrinchium angustifolium* | 2 | 1 | 1 | 1 | 3 | 0 | 1 | 1 | 3 | 3 | 3 | 3 | 4 | 4 | 13 | 2 | 13 | 2 |
| *Veronica scutellata* | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 6 | 3 |
| *Zigadenus venosus* | 3 | 0 | 9 | 5 | 9 | 4 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 4 | 2 | 3 | 2 |
| **Annuals** | | | | | | | | | | | | | | | | | | |
| *Centaurium muhlenbergii* | 50 | 7 | 58 | 16 | 42 | 14 | $36^a$ | 2 | $69^b$ | 4 | $50^b$ | 6 | 41 | 10 | 58 | 12 | 68 | 6 |
| *Centunculus minimus* | 29 | 21 | 30 | 25 | 33 | 22 | $18^a$ | 3 | $42^b$ | 4 | $49^b$ | 8 | 3 | 3 | 6 | 4 | 12 | 1 |
| *Epilobium paniculatum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Gnaphalium palustre* | 0 | 0 | 1 | 1 | 1 | 1 | $0^a$ | 0 | 4 | 2 | $8^b$ | 2 | 0 | 0 | 6 | 3 | 1 | 1 |
| *Gratiola ebracteata* | 0 | 0 | 0 | 0 | 0 | 0 | $0^a$ | 0 | 4 | 3 | $13^b$ | 6 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Orthocarpus hispidus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 7 | 7 | 2 | 2 | 2 | 2 | 9 | 7 |
| *Plagiobothrys figuratus* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 9 | 9 | 11 | 11 | 0 | 0 | 0 | 0 | 0 | 0 |

or both burn treatments between years including the perennials *Camassia quamash, Brodiaea spp., Microseris laciniata, Veronica scutellata* and *Zigadenus venosus*, and the annuals *Centaurium muhlenbergii, Centunculus minimus, Gnaphalium palustre*, and *Gratiola ebrateata*.

### ***Rosa/Anthoxanthum* plant community**

No statistically significant changes in species frequency occurred between years within the control treatment in the *Rosa/ Anthoxanthum* community (Table 4.8). *Vaccinium caespitosum* seedlings established in all treatments during 1989. Frequency of an exotic annual, *Aira caryophyllea*, increased in all treatments; changes were only significant in burn treatments. Percent frequency of another exotic annual, *Briza minor*, increased with increasing frequency of burning. *Juncus bufonius* declined in the control treatment; it increased following one burn in 1989 and decreased in both burn treatments in 1990. A similar pattern was also noted in the RP *Deschampsia* community.

As noted for the RP *Deschampsia* community, *Hypochaeris radicata* frequency also increased with burning in the *Rosa/Anthoxanthum* community (Table 4.8). *Perideridia oregana* was the only native perennial with a significant increase of frequency in fire treatments within the *Rosa/Anthoxanthum* community; its frequency increased over nine-fold between 1988 and 1990. A number of native perennials, annuals and biennials established (*Aster hallii, Calochortus tolmiei, Camassia quamash, Comandra umbellata, Microseris laciniata,*

Table 4.8. Species frequency by treatment in the *Rosa/Anthoxanthum* community. Only species with at least 10% frequency are presented. Data are presented for the 50*50 cm plot except where presented for nested plots. The 50*50 cm plot is indicated with a 3, the 25*25 cm is indicated with a 2, the 12.5*12.5 cm plot is indicated with a 1. Superscripted letters indicate a significant (p = 0.1) difference between years within treatments. * Denotes exotic species.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **SHRUBS** | | | | | | | | | | | | | | | | | | |
| *Rosa nutkana* | 60 | 5 | 64 | 7 | 69 | 6 | 70 | 11 | 76 | 7 | 79 | 7 | 60 | 10 | 73 | 10 | 76 | 10 |
| *Rubus spp.** | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 1 | 1 | 12 | 8 | 11 | 3 |
| *Vaccinium caespitosum* | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 9 | 6 | 2 | 2 | $0^a$ | 0 | $11^b$ | 4 | 1 | 1 |
| **GRAIMOIDS** | | | | | | | | | | | | | | | | | | |
| Perennials | | | | | | | | | | | | | | | | | | |
| *Agrostis tenuis** | 4 | 4 | 9 | 9 | 7 | 7 | 10 | 6 | 21 | 7 | 27 | 10 | $0^a$ | 0 | $6^b$ | 1 | $7^b$ | 2 |
| *Anthoxanthum odoratum*3* | 99 | 1 | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 99 | 1 | 100 | 0 | 100 | 0 |
| *Anthoxanthum odoratum*1* | 98 | 1 | 100 | 0 | 100 | 0 | 99 | 1 | 100 | 0 | 99 | 1 | 98 | 1 | 100 | 0 | 100 | 0 |
| *Carex rossii* | 1 | 1 | 0 | 0 | 0 | 0 | 7 | 7 | 9 | 6 | 8 | 5 | 9 | 3 | 19 | 5 | 20 | 7 |
| *Danthonia californica* | 23 | 19 | 30 | 28 | 42 | 23 | 21 | 15 | 22 | 12 | 29 | 13 | 26 | 10 | 22 | 11 | 32 | 5 |
| *Deschampsia cespitosa* | 1 | 1 | 12 | 9 | 2 | 2 | 2 | 2 | 3 | 3 | 4 | 3 | 0 | 0 | 19 | 19 | 1 | 1 |
| *Festuca arundinacea** | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Festuca rubra* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 4 | 4 | 3 | 3 | 0 | 0 | 0 | 0 | 2 | 2 |
| *Holcus lanatus** | 4 | 4 | 8 | 4 | 10 | 10 | 12 | 12 | 28 | 13 | 37 | 15 | 13 | 7 | 31 | 10 | 33 | 9 |
| *Juncus tenuis* | 1 | 1 | 1 | 1 | 0 | 0 | 3 | 3 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Luzula campestris* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 4 | 2 | 2 | 0 | 0 | 3 | 3 | 1 | 1 |
| *Panicum occidentale* | 4 | 4 | 4 | 4 | 11 | 11 | 11 | 6 | 8 | 4 | 18 | 8 | 2 | 2 | 3 | 3 | 4 | 3 |
| *Poa spp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 6 | 4 | 1 |
| Annuals | | | | | | | | | | | | | | | | | | |
| *Aira spp.** | 0 | 0 | 4 | 4 | 6 | 6 | 8 | 8 | 22 | 9 | 34 | 23 | $0^a$ | 0 | $8^b$ | 3 | $16^b$ | 4 |
| *Briza minor** | 10 | 7 | 4 | 4 | 9 | 9 | $10^a$ | 6 | $38^b$ | 7 | 26 | 10 | $6^a$ | 2 | $37^b$ | 11 | $62^b$ | 16 |
| *Juncus bufonius** | 13 | 12 | 0 | 0 | 0 | 0 | $1^a$ | 1 | $11^b$ | 3 | $0^a$ | 0 | $0^a$ | 0 | $10^b$ | 7 | 2 | 1 |
| **FORBS** | | | | | | | | | | | | | | | | | | |
| Perennials | | | | | | | | | | | | | | | | | | |
| *Achillea millefolium* | 0 | 0 | 0 | 0 | 0 | 0 | 22 | 16 | 24 | 18 | 36 | 21 | 2 | 2 | 2 | 2 | 6 | 4 |
| *Apocynum androsaemifolium* | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 16 | 23 | 23 | 27 | 27 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Aster chilensis v. hallii* | 2 | 2 | 7 | 7 | 6 | 6 | 2 | 2 | 8 | 5 | 13 | 7 | 0 | 0 | 2 | 1 | 2 | 1 |
| *Brodiaea spp.* | 17 | 17 | 19 | 17 | 23 | 22 | 9 | 3 | 38 | 13 | 36 | 11 | 3 | 3 | 17 | 13 | 50 | 14 |
| *Calochortus tolmiei* | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 10 | 6 |
| *Camassia quamash* | 7 | 7 | 9 | 9 | 7 | 7 | 3 | 3 | 3 | 3 | 9 | 9 | 0 | 0 | 0 | 0 | 2 | 2 |
| *Cirsium arvense** | 20 | 14 | 17 | 17 | 7 | 7 | 0 | 0 | 1 | 1 | 0 | 0 | 7 | 7 | 4 | 3 | 1 | 1 |
| *Comandra umbellata* | 0 | 0 | 2 | 1 | 2 | 1 | 8 | 4 | 8 | 4 | 3 | 2 | 0 | 0 | 1 | 1 | 1 | 1 |
| *Eriophyllum lanatum* | 3 | 3 | 6 | 6 | 3 | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 0 | 0 |

Table 4.8., Continued.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| _Fragaria virginiana_ | 9 | 9 | 12 | 11 | 12 | 11 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 3 | 2 | 3 | 2 |
| _Hypericum perforatum_*3 | 97 | 2 | 98 | 1 | 100 | 0 | 93 | 4 | 100 | 0 | 100 | 0 | 99 | 1 | 100 | 0 | 100 | 0 |
| _Hypericum perforatum_*1 | 56 | 8 | 52 | 4 | 31 | 2 | 59 | 6 | 91 | 9 | 82 | 14 | $66^{a}$ | 1 | $98^{b}$ | 1 | $98^{b}$ | 1 |
| _Hypocharis radicata_* | 40 | 13 | 43 | 22 | 60 | 18 | $36^{a}$ | 9 | 61 | 12 | $88^{b}$ | 7 | 24 | 7 | 43 | 13 | 64 | 15 |
| _Leontodon nudicaulis_* | 22 | 17 | 32 | 29 | 31 | 28 | 23 | 14 | 27 | 18 | 30 | 15 | 10 | 2 | 13 | 7 | 22 | 9 |
| _Lotus formosissimus_ | 17 | 17 | 24 | 23 | 22 | 22 | 13 | 10 | 16 | 10 | 14 | 14 | 1 | 1 | 1 | 1 | 0 | 0 |
| _Microseris laciniata_ | 4 | 3 | 4 | 4 | 2 | 2 | 0 | 0 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| _Perideridia oregana_ | 13 | 10 | 12 | 8 | 2 | 2 | 2 | 2 | 10 | 7 | 7 | 3 | $4^{a}$ | 3 | $27^{b}$ | 2 | $38^{b}$ | 5 |
| _Plantago lanceolata_*3 | 37 | 3 | 50 | 5 | 47 | 8 | 52 | 22 | 63 | 16 | 64 | 15 | 66 | 14 | 64 | 16 | 67 | 15 |
| _Plantago lanceolata_*2 | 18 | 1 | 21 | 6 | 38 | 9 | 40 | 16 | 48 | 18 | 50 | 18 | 50 | 17 | 47 | 21 | 53 | 20 |
| _Potentilla gracilis_ | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| _Prunella vulgaris_ | 6 | 6 | 4 | 4 | 11 | 11 | 7 | 4 | 7 | 3 | 22 | 9 | 0 | 0 | 2 | 2 | 1 | 1 |
| _Rumex acetosella_* | 24 | 12 | 36 | 23 | 37 | 19 | 46 | 21 | 54 | 24 | 56 | 22 | 19 | 14 | 32 | 19 | 37 | 18 |
| _Sisyrinchium angustifolium_ | 0 | 0 | 2 | 2 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| _Veronica spp._* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 3 |
| _Viola adunca_ | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 6 | 4 | 8 | 4 |
| Annuals/Biennials | | | | | | | | | | | | | | | | | | |
| _Centaurium muhlenbergii_ | 21 | 21 | 13 | 13 | 14 | 9 | $2^{a}$ | 1 | $28^{b}$ | 18 | 13 | 10 | 2 | 1 | 9 | 7 | 12 | 6 |
| _Centaurium umbellatum_* | 0 | 0 | 2 | 2 | 8 | 8 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| _Centunculus minimus_ | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| _Cirsium vulgare_* | 7 | 3 | 14 | 3 | 14 | 3 | 10 | 10 | 19 | 14 | 9 | 7 | 22 | 13 | 34 | 18 | 33 | 18 |
| _Daucus carota_* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| _Epilobium paniculatum_ | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 6 | 3 | 9 | 5 | $0^{a}$ | 0 | 2 | 2 | $28^{b}$ | 12 |
| _Galium parisiense_* | 0 | 0 | 1 | 1 | 2 | 1 | 10 | 6 | 27 | 15 | 53 | 23 | 3 | 3 | 11 | 11 | 41 | 22 |
| _Geranium dissectum_* | 1 | 1 | 1 | 1 | 2 | 2 | 7 | 7 | 8 | 8 | 14 | 13 | 0 | 0 | 0 | 0 | 0 | 0 |
| _Gnaphalium purpureum_ | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 13 | 8 | 17 | 9 | 0 | 0 | 1 | 1 | 1 | 1 |
| _Heterocodon rariflorum_ | 19 | 17 | 12 | 12 | 17 | 15 | 56 | 10 | 62 | 5 | 76 | 9 | 3 | 3 | 16 | 10 | 19 | 12 |
| _Hypocharis glabra_* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 4 | 0 | 0 | 0 | 0 | 2 | 2 |
| _Lotus micranthus_ | 0 | 0 | 1 | 1 | 3 | 2 | 0 | 0 | 0 | 0 | 11 | 7 | $0^{a}$ | 0 | $0^{a}$ | 0 | $7^{b}$ | 3 |
| _Lotus purshiana_ | 37 | 18 | 49 | 28 | 46 | 26 | 27 | 17 | 40 | 19 | 54 | 24 | $4^{a}$ | 3 | $10^{a}$ | 3 | $21^{b}$ | 1 |
| _Madia sativa_ | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 9 | 13 | 13 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 0 |
| _Myosotis discolor_ | 32 | 15 | 28 | 15 | 40 | 18 | 50 | 16 | 78 | 4 | 68 | 12 | $26^{a}$ | 11 | $74^{b}$ | 6 | $92^{b}$ | 5 |
| _Orthocarpus hispidus_ | 6 | 6 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| _Parentucellia viscosa_* | 18 | 16 | 20 | 20 | 19 | 17 | 10 | 8 | 39 | 11 | 52 | 20 | $3^{a}$ | 2 | $30^{b}$ | 7 | $44^{b}$ | 2 |
| _Senecio jacobaea_* | 1 | 1 | 2 | 2 | 12 | 12 | 26 | 26 | 18 | 16 | 27 | 25 | 32 | 31 | 28 | 28 | 18 | 18 |
| _Sherardia arvensis_* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 4 | 3 | 4 | 2 | 6 | 3 |

*Gnaphalium purpureum*) and/or increased significantly between years in one or both burn treatments (*Centaurium muhlenbergii, Epilobium paniculatum, Lotus micranthus*, and *L. purshiana*), while exotic perennials and annuals also established (*Cirsium arvense, Daucus carota*) and/or increased (*Myosotis discolor* and *Parentucellia viscosa*) in burned areas.

### ***Vaccinium* plant community**

The frequency of *Eriophyllum lanatum, Hypericum perforatum, Leontondon nudicaulis, Centaurium muhlenbergii* and *Centunculus minimus* significantly increased in control treatments in the *Vaccinium* community while their frequencies remained statistically unchanged in burn treatments (Table 4.9). Frequency of seedling *Rubus* spp. significantly increased in the twice burned treatment between 1988 and 1990 with a similar trend in control and once burned treatments. The frequency of *Agrostis tenuis* increased in 1989 following burning and then declined in 1990 in both burn treatments. Between 1989 and 1990, there was a significant decline in *Juncus nevadensis* frequency in once burned treatments, while *J. tenuis* declined in twice burned treatments. *Panicum occidentale* frequency significantly increased in all treatments. *Juncus bufonius* significantly declined following burning. The frequency of *Brodiaea* spp. significantly increased in all treatments, although changes were greatest within burn treatments. *Hypochaeris radicata* increased in 25x25 cm plots in once burned treatments. Frequency of *Sisyrinchium angustifolium* tended to increase in all

Table 4.9. Species frequency separated by treatment in the *Vaccinium* community. Only species with at least 10% frequency are presented. Data are presented for the 50*50 plot except where presented for nested plots. The 50*50 cm plot is indicated with a 3, the 25*25 cm is indicated with a 2, and the 12.5*12.5 cm plot is indicated with a 1. Superscripted letters indicate a significant (p = 0.1) difference between years within treatments. * Denotes exotic species.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **TREES** | | | | | | | | | | | | | | | | | | |
| *Crataegus douglasii* | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 4 | 3 | 2 | 2 |
| **SHRUBS** | | | | | | | | | | | | | | | | | | |
| *Rosa nutkana* | 11 | 3 | 12 | 2 | 10 | 4 | 33 | 2 | 36 | 1 | 36 | 4 | 26 | 3 | 27 | 2 | 30 | 4 |
| *Rubusspp.** | 0 | 0 | 1 | 1 | 2 | 1 | 3 | 2 | 2 | 1 | 7 | 4 | $0^a$ | 0 | 3 | 2 | $6^b$ | 2 |
| *Vaccinium caespitosum* | 73 | 5 | 78 | 5 | 78 | 6 | 64 | 7 | 64 | 6 | 67 | 7 | 63 | 7 | 63 | 8 | 63 | 7 |
| **GRAMINOIDS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Agrostis tenuis**3 | 71 | 3 | 79 | 4 | 77 | 3 | $58^a$ | 6 | $77^b$ | 5 | 74 | 8 | 72 | 9 | 88 | 4 | 90 | 5 |
| *Agrostis tenuis**2 | 43 | 3 | 54 | 12 | 59 | 3 | 37 | 7 | 50 | 2 | 50 | 2 | $52^a$ | 4 | $80^b$ | 8 | $77^b$ | 9 |
| *Anthoxanthum odoratum**3 | 91 | 4 | 98 | 2 | 89 | 11 | 99 | 1 | 98 | 1 | 94 | 4 | 99 | 1 | 96 | 3 | 98 | 1 |
| *Anthoxanthum odoratum**2 | 47 | 4 | 71 | 4 | 58 | 14 | 58 | 6 | 58 | 5 | 67 | 2 | 63 | 5 | 48 | 4 | 62 | 8 |
| *Carex rossii* | 29 | 8 | 46 | 13 | 44 | 11 | 32 | 14 | 47 | 5 | 30 | 12 | 38 | 9 | 43 | 5 | 50 | 12 |
| *Danthoniacalifornica3* | 76 | 10 | 83 | 7 | 91 | 6 | 62 | 3 | 60 | 4 | 59 | 10 | 86 | 14 | 77 | 14 | 67 | 19 |
| *Danthonia californica2* | 48 | 15 | 54 | 10 | 62 | 9 | 37 | 4 | 39 | 9 | 31 | 8 | 56 | 16 | 43 | 11 | 42 | 16 |
| *Deschampsia cespitosa3* | 71 | 8 | 77 | 8 | 82 | 9 | 70 | 12 | 71 | 13 | 67 | 10 | 91 | 5 | 89 | 3 | 88 | 9 |
| *Deschampsia cespitosa2* | 41 | 5 | 40 | 6 | 41 | 8 | 52 | 15 | 43 | 7 | 43 | 10 | 67 | 6 | 68 | 6 | 69 | 9 |
| *Holcus lanatus** | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 6 | 3 | 3 | 3 | 2 | 2 | 6 | 3 | 6 | 3 |
| *Juncus nevadensis* | 3 | 3 | 0 | 0 | 2 | 1 | 41 | 3 | $47^a$ | 2 | $33^b$ | 4 | 10 | 5 | 18 | 7 | 14 | 6 |
| *Juncus tenuis* | 0 | 0 | 0 | 0 | 7 | 7 | 7 | 0 | 9 | 3 | 6 | 2 | 7 | 2 | $13^a$ | 3 | $3^b$ | 2 |
| *Luzula campestris* | $0^a$ | 0 | 2 | 2 | $34^b$ | 16 | $0^a$ | 0 | $38^b$ | 6 | 16 | 10 | $0^a$ | 0 | $49^b$ | 6 | $50^b$ | 13 |
| *Panicum occidentale3* | $74^a$ | 4 | $86^b$ | 2 | $88^b$ | 2 | $81^a$ | 3 | $98^b$ | 1 | $100^b$ | 0 | $69^a$ | 5 | $93^b$ | 5 | $90^b$ | 2 |
| *Panicum occidentale1* | 38 | 8 | 47 | 2 | 56 | 5 | $40^a$ | 8 | $82^b$ | 2 | $72^b$ | 6 | $29^a$ | 3 | $70^b$ | 7 | $71^b$ | 5 |
| **Annuals** | | | | | | | | | | | | | | | | | | |
| *Aira spp.** | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 9 | 4 | 7 | 7 | 0 | 0 | 6 | 3 | 4 | 1 |
| *Briza minor** | 7 | 2 | 10 | 2 | 7 | 3 | 14 | 8 | 19 | 10 | 22 | 6 | 7 | 5 | 16 | 4 | 24 | 9 |
| *Juncus (annual)** | 0 | 0 | 4 | 3 | 1 | 1 | 10 | 2 | 23 | 10 | 7 | 4 | 4 | 4 | 8 | 8 | 2 | 2 |
| *Juncus bufonius** | 3 | 0 | 3 | 0 | 1 | 1 | $43^a$ | 11 | $47^a$ | 10 | $10^b$ | 5 | 19 | 6 | $48^a$ | 19 | $8^b$ | 5 |

Table 4.9., Continued.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **FORBS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Achillea millefolium* | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Aster chilensis v. hallii* | 7 | 5 | 7 | 2 | 8 | 1 | 13 | 4 | 23 | 10 | 11 | 3 | 41 | 7 | 43 | 11 | 39 | 8 |
| *Aster curtus* | 68 | 6 | 78 | 9 | 78 | 12 | 64 | 11 | 66 | 12 | 71 | 9 | 77 | 10 | 74 | 11 | 77 | 5 |
| *Brodiaea spp.* | 0$^a$ | 0 | 12$^b$ | 2 | 7 | 2 | 18$^a$ | 5 | 8$^a$ | 5 | 40$^b$ | 5 | 11$^a$ | 4 | 17 | 2 | 38$^b$ | 9 |
| *Camassia quamash* | 56 | 10 | 76 | 4 | 70 | 17 | 59 | 10 | 72 | 1 | 61 | 5 | 59 | 3 | 70 | 10 | 77 | 5 |
| *Comandra umbellata* | 21 | 18 | 24 | 18 | 27 | 19 | 24 | 14 | 26 | 14 | 28 | 13 | 1 | 1 | 2 | 1 | 2 | 1 |
| *Eriophyllum lanatum* | 16$^a$ | 4 | 26$^b$ | 1 | 23 | 2 | 18 | 7 | 17 | 7 | 12 | 3 | 42 | 9 | 38 | 14 | 37 | 10 |
| *Fragaria virginiana* | 32 | 16 | 34 | 18 | 32 | 16 | 19 | 10 | 24 | 13 | 20 | 10 | 9 | 5 | 8 | 4 | 9 | 4 |
| *Grindelia integrifolia* | 34 | 4 | 31 | 7 | 33 | 5 | 27 | 7 | 22 | 4 | 16 | 4 | 60 | 10 | 47 | 7 | 43 | 5 |
| *Haplopappus racemosus* | 6 | 6 | 6 | 6 | 8 | 8 | 3 | 3 | 4 | 4 | 4 | 2 | 4 | 2 | 8 | 4 | 8 | 4 |
| *Horkelia congesta* | 20 | 13 | 30 | 15 | 31 | 17 | 16 | 8 | 19 | 5 | 13 | 5 | 32 | 11 | 26 | 7 | 33 | 11 |
| *Hypericum perforatum** | 38$^a$ | 8 | 60 | 6 | 71$^b$ | 7 | 59 | 4 | 61 | 14 | 60 | 0 | 63 | 9 | 76 | 11 | 69 | 11 |
| *Hypocharis radicata*3* | 58 | 3 | 86 | 6 | 78 | 13 | 83 | 2 | 89 | 4 | 87 | 5 | 82 | 4 | 87 | 5 | 93 | 2 |
| *Hypocharis radicata*2* | 41 | 8 | 58 | 11 | 70 | 15 | 62$^a$ | 3 | 63 | 5 | 78$^b$ | 6 | 64 | 13 | 59 | 7 | 83 | 7 |
| *Leontodon nudicaulis** | 1$^a$ | 1 | 28$^b$ | 11 | 34$^b$ | 2 | 92 | 2 | 81 | 6 | 77 | 5 | 64 | 13 | 57 | 15 | 66 | 12 |
| *Lomatium bradshawii* | 7 | 2 | 6 | 1 | 9 | 4 | 6 | 1 | 8 | 1 | 10 | 2 | 7 | 5 | 6 | 4 | 9 | 7 |
| *Lotus formosissimus* | 41 | 16 | 67 | 15 | 60 | 13 | 77 | 6 | 86 | 3 | 88 | 4 | 54 | 16 | 61 | 16 | 84 | 7 |
| *Microseris laciniata* | 4 | 2 | 12 | 4 | 10 | 3 | 17 | 5 | 16 | 1 | 9 | 3 | 10 | 4 | 30 | 3 | 32 | 12 |
| *Plantago lanceolata** | 18 | 13 | 31 | 23 | 27 | 22 | 20 | 7 | 22 | 9 | 14 | 6 | 11 | 3 | 10 | 2 | 8 | 2 |
| *Prunella vulgaris* | 59 | 8 | 69 | 7 | 66 | 13 | 68 | 1 | 67 | 10 | 47 | 6 | 76 | 1 | 71 | 6 | 69 | 12 |
| *Sisyrinchium angustifolium* | 24$^a$ | 4 | 44$^b$ | 8 | 31 | 9 | 50 | 10 | 61 | 13 | 50 | 8 | 34$^a$ | 2 | 52$^b$ | 6 | 46 | 6 |
| *Viola adunca* | 27 | 5 | 31 | 12 | 33 | 8 | 49 | 8 | 48 | 9 | 41 | 5 | 36 | 10 | 23 | 3 | 24 | 2 |
| *Wyethia angustifolia* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Annuals/Biennials | | | | | | | | | | | | | | | | | | |
| *Centaurium muhlenbergii* | 0$^a$ | 0 | 23$^b$ | 3 | 18$^b$ | 2 | 73 | 6 | 81 | 7 | 62 | 6 | 63 | 9 | 82 | 6 | 70 | 4 |
| *Centunculus minimus* | 0$^a$ | 0 | 24$^b$ | 14 | 21$^b$ | 8 | 73 | 5 | 63 | 7 | 81 | 2 | 44 | 13 | 40 | 18 | 60 | 3 |
| *Cirsium vulgare** | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| *Gnaphalium palustre* | 0 | 0 | 0 | 0 | 0 | 0 | 0$^a$ | 0 | 12$^b$ | 4 | 2 | 2 | 0$^a$ | 0 | 6b | 2 | 0$^a$ | 0 |
| *Gnaphalium purpureum* | 0 | 0 | 1 | 1 | 3 | 2 | 0 | 0 | 1 | 1 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| **LICHENS** | | | | | | | | | | | | | | | | | | |
| *Cladonia spp.* | 14 | 8 | 11 | 8 | 12 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 |

treatments from 1988 to 1989 and to decline from 1989 to 1990, although only the increases between 1988 and 1989 for control and once burned treatments were significant.

## Fisher Butte

### FB *Deschampsia* plant community

The frequency of only three exotic species, *Leontodon nudicaulus, Centaurium umbellatum,* and *Daucus carota*, significantly increased between 1988 and 1990 in the control treatment in this community; (Table 4.10). *Agrostis* spp. frequency remained unchanged through time in control plots and increased in burn treatments, although changes were only significant between 1988 and 1989 in once burned treatments. The frequency of *D. cespitosa* remained unchanged following one burn but significantly increased in 1990 with both burn treatments. Similar to results in the RP *Deschampsia* community, frequency of *D. californica* decreased the first postfire year following one burn. Frequency of *D. californica* remained lower into 1990 in both burn treatments in the FB *Deschampsia* community. The frequency of *Holcus lanatus* increased significantly between 1988 and 1990 in burn treatments. In burn treatments, there was a general trend of decrease between 1988 and 1989 followed by a significant increase between 1989 and 1990 for two exotics, *Hypochaeris radicata* and *Leontodon nudicaulis*, and one native, *Madia glomerata*.

Table 4.10. Treatment effects on species frequency in the FB *Deschampsia* community. Only species with at least 10% frequency are presented. Data are presented for the 50*50 plot except where presented for nested plots. The 50*50 cm plot is indicated with a 3, the 25*25 cm is indicated with a 2, and the 12.5*12.5 cm plot is indicated with a 1. Superscripted letters indicate a significant (p = 0.1) difference between years within treatments. * Denotes exotic species.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **TREES** | | | | | | | | | | | | | | | | | | |
| *Crataegus douglasii* | 1 | 1 | 3 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 2 | 2 | 2 | 2 | 4 | 2 |
| *Fraxinus latifolia* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **SHRUBS** | | | | | | | | | | | | | | | | | | |
| *Rosa nutkana* | 6 | 1 | 10 | 2 | 8 | 1 | 7 | 2 | 11 | 1 | 12 | 2 | 22 | 1 | 29 | 1 | 30 | 1 |
| *Rubus discolor** | 1 | 1 | 2 | 1 | 3 | 3 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| **GRAMINOIDS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Agrostis exarata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Agrostis spp.* | 62 | 15 | 58 | 9 | 63 | 10 | $52^a$ | 5 | $78^b$ | 6 | $90^b$ | 4 | 44 | 9 | 63 | 8 | 74 | 9 |
| *Anthoxanthum odoratum** | 16 | 3 | 18 | 4 | 30 | 8 | 41 | 15 | 37 | 13 | 46 | 15 | 26 | 16 | 20 | 12 | 33 | 17 |
| *Danthonia californica3* | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 99 | 1 | 97 | 1 | 100 | 0 | 99 | 1 | 99 | 1 |
| *Danthonia californica1* | 91 | 1 | 91 | 4 | 94 | 2 | $88^a$ | 2 | $52^b$ | 5 | $53^b$ | 7 | $77^a$ | 6 | $42^b$ | 6 | $47^b$ | 8 |
| *Deschampsia cespitosa3* | 94 | 4 | 99 | 1 | 100 | 0 | 94 | 2 | 97 | 1 | 98 | 2 | 98 | 2 | 100 | 0 | 97 | 0 |
| *Deschampsia cespitosa1* | 51 | 17 | 53 | 12 | 54 | 8 | $40^a$ | 3 | $40^a$ | 3 | $55^b$ | 6 | $62^a$ | 4 | $54^a$ | 2 | $74^b$ | 3 |
| *Holcus lanatus** | 64 | 17 | 64 | 18 | 81 | 9 | 67 | 11 | $70^a$ | 6 | $90^b$ | 4 | $78^a$ | 4 | $58^a$ | 1 | $92^b$ | 3 |
| *Juncus nevadensis* | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 1 | 18 | 2 | 19 | 3 |
| *Juncus tenuis* | 12 | 5 | 9 | 6 | 8 | 74 | $13^a$ | 4 | $34^b$ | 5 | $13^a$ | 1 | $27^a$ | 1 | $46^b$ | 3 | $38^b$ | 4 |
| *Luzula campestris* | 0 | 0 | 1 | 1 | 0 | 0 | $0^a$ | 0 | $27^b$ | 6 | $20^b$ | 5 | 4 | 2 | 1 | 1 | 1 | 1 |
| *Panicum occidentale* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Poa compressa** | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 9 | 4 | 11 | 5 |
| *Poa spp.** | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 4 | 0 | 0 | 0 | 0 |
| **Annuals** | | | | | | | | | | | | | | | | | | |
| *Aira caryophyllea** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Briza minor** | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 8 | 3 | 1 | 1 | 3 | 2 | 10 | 1 |
| *Bromus mollis** | 1 | 1 | 3 | 3 | 1 | 1 | 2 | 2 | 1 | 1 | 0 | 0 | 2 | 1 | 1 | 1 | 3 | 2 |
| *Juncus bufonius** | 21 | 21 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 0 | 2 | 2 | 0 | 0 | 1 | 1 | 2 | 2 |

Table 4.10., Continued.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **FORBS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Allium amplectens* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 1 |
| *Aster chilensis v. hallii* | 38 | 9 | 37 | 10 | 47 | 10 | 41 | 9 | 40 | 10 | 67 | 10 | 63$^{a}$ | 5 | 67$^{a}$ | 5 | 83$^{b}$ | 2 |
| *Brodiaea spp.* | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 3 | 9 | 4 | 14 | 7 | 6 | 3 | 4 | 2 | 18 | 9 |
| *Camassia quamash* | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 3 | 4 | 2 | 4 | 2 | 1 | 1 | 0 | 0 | 4 | 2 |
| *Epilobium glandulosum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Epilobium watsonii* | 3 | 2 | 0 | 0 | 0 | 0 | 3$^{a}$ | 2 | 3$^{a}$ | 1 | 0$^{b}$ | 0 | 0 | 0 | 3 | 1 | 0 | 0 |
| *Erigeron decumbens* | 0 | 0 | 2 | 2 | 1 | 1 | 4 | 1 | 3 | 0 | 7 | 2 | 9 | 4 | 14 | 4 | 20 | 5 |
| *Eriophyllum lanatum* | 31 | 9 | 34 | 8 | 42 | 8 | 48 | 8 | 44 | 6 | 53 | 8 | 61 | 2 | 53 | 2 | 68 | 2 |
| *Galium trifidum* | 54 | 22 | 51 | 23 | 48 | 25 | 11 | 4 | 12 | 2 | 18 | 2 | 10 | 2 | 3 | 1 | 7 | 1 |
| *Grindelia integrifolia* | 63 | 16 | 68 | 10 | 77 | 10 | 39 | 14 | 32 | 12 | 37 | 13 | 39 | 9 | 30 | 2 | 41 | 5 |
| *Hypericum perforatum** | 43 | 6 | 40 | 2 | 47 | 2 | 47 | 8 | 72 | 6 | 64 | 8 | 31$^{a}$ | 4 | 71$^{b}$ | 3 | 84$^{b}$ | 5 |
| *Hypocharis radicata** | 11 | 4 | 23 | 10 | 47 | 15 | 23$^{a}$ | 5 | 11$^{a}$ | 2 | 80$^{b}$ | 4 | 21$^{a}$ | 3 | 11$^{a}$ | 3 | 61$^{b}$ | 8 |
| *Leontodon nudicaulis** | 77$^{a}$ | 5 | 83 | 8 | 98$^{b}$ | 2 | 63$^{a}$ | 3 | 24$^{b}$ | 7 | 63$^{a}$ | 6 | 68$^{a}$ | 4 | 36$^{b}$ | 4 | 60$^{a}$ | 0 |
| *Lotus formsissimus* | 16 | 14 | 17 | 12 | 17 | 11 | 43 | 6 | 46 | 6 | 43 | 7 | 27 | 11 | 33 | 8 | 44 | 10 |
| *Mentha pulegium** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 4 | 2 | 0 | 0 | 1 | 1 | 1 | 1 |
| *Microseris laciniata* | 8 | 1 | 12 | 5 | 6 | 2 | 21$^{a}$ | 3 | 39$^{b}$ | 9 | 38$^{b}$ | 8 | 30$^{a}$ | 6 | 60$^{b}$ | 6 | 73$^{b}$ | 4 |
| *Perideridia oregana* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 2 | 2 | 4 | 2 |
| *Plantago lanceolata** | 41 | 8 | 44 | 3 | 51 | 5 | 24 | 7 | 13 | 6 | 18 | 5 | 9 | 3 | 2 | 1 | 6 | 2 |
| *Potentilla gracilis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Prunella vulgaris* | 71 | 6 | 71 | 6 | 64 | 9 | 49 | 8 | 51 | 9 | 80 | 7 | 46$^{a}$ | 6 | 46$^{a}$ | 4 | 76$^{b}$ | 2 |
| *Ranunculus occidentalis* | 0 | 0 | 9 | 5 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 |
| *Ranunculus orthorhynchus* | 6 | 6 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Ranunculus spp.* | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Rumex acetosella** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 4 | 9 | 3 |
| *Sisyrinchium angustifolium* | 68 | 12 | 68 | 6 | 71 | 7 | 38 | 13 | 51 | 14 | 40 | 12 | 39$^{a}$ | 2 | 20$^{a}$ | 14 | 56$^{b}$ | 2 |
| *Veronica scutellata* | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 6 | 2 |
| *Zigadenus venosus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 4.10., Continued.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **Annuals/Biennials** | | | | | | | | | | | | | | | | | | |
| *Bidens frondosa* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 9 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Centaurium muhlenbergii* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 1 |
| *Centaurium umbellatum** | $38^a$ | 9 | 42 | 7 | $71^b$ | 10 | $70^a$ | 3 | 77 | 5 | $88^b$ | 2 | $52^a$ | 2 | $40^a$ | 15 | $79^b$ | 0 |
| *Cirsium vulgare** | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Daucus carota** | $12^a$ | 3 | $18^a$ | 8 | $53^b$ | 7 | 3 | 2 | 6 | 4 | 8 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Epilobium paniculatun* | 8 | 5 | 13 | 4 | 7 | 2 | $7^a$ | 2 | 10 | 1 | $18^b$ | 1 | $1^a$ | 1 | $2^a$ | 1 | $20^b$ | 4 |
| *Galium parisiense** | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Gnaphalium palustre* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 3 | 3 | 2 | $1^a$ | 1 | $19^b$ | 2 | $7^a$ | 3 |
| *Gnaphalium purpureum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Lathyrus sphaericus* | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 2 | 2 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Lotus purshiana* | 2 | 2 | 1 | 1 | 0 | 0 | 2 | 1 | 4 | 2 | 9 | 3 | 1 | 1 | 0 | 0 | 7 | 1 |
| *Madia glomerata* | 72 | 15 | 76 | 11 | 88 | 9 | $56^a$ | 7 | $21^b$ | 1 | $60^a$ | 8 | $69^a$ | 6 | $18^b$ | 3 | $32^a$ | 6 |
| *Microcala quadrangularis* | 2 | 2 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 1 | 10 | 3 | 1 | 1 | 1 | 1 | 2 | 2 |
| *Myosotis discolor* | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 6 | 3 | 1 | 1 | 1 | 1 | 3 | 1 | 3 | 0 |
| *Myosotis laxa* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Orthocarpus bracteosus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| *Orthocarpus hispidus* | 4 | 3 | 6 | 3 | 2 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 6 | 3 | 9 | 5 |
| *Parentucellia viscosa* | 1 | 1 | 1 | 1 | 1 | 1 | $1^a$ | 1 | $0^b$ | 0 | $36^c$ | 7 | $1^a$ | 1 | $1^a$ | 1 | $8^b$ | 2 |
| *Plagiobothrys figuratus* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 2 | 2 | 2 | 0 | 0 | 2 | 1 | 2 | 2 |
| *Polygonum douglasii* | 0 | 0 | 1 | 1 | 0 | 0 | 6 | 2 | 4 | 1 | 4 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| *Senecio jacobaea** | 11 | 5 | 11 | 1 | 17 | 2 | 6 | 2 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Vicia tetrasperma** | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

A number of species established in burned areas between 1988 and 1990 including *Panicum occidentale, Allium amplectans, Mentha pulegium, Perideridia oregana, Potentilla gracilis, Rumex acetosella, Orthocarpus hispidus*, and *Plagiobothrys figuratus*. The frequency of a number of native perennial (*Aster chilensis, Microseris laciniata, Prunella vulgaris, Sisyrinchium angustifolium*), native annual (*Gnaphalium palustre*), exotic perennial (*Hypericum perforatum*), and exotic annual/biennial (*Centaurium umbellatum* and *Parentucellia viscosa*) species increased significantly in one or both burn treatments between years (Table 4.10).

### *Rosa/Juncus* plant community

In the control transects of the *Rosa/Juncus* community, frequency of *Madia glomerata* and *Polygonum douglasii* significantly increased between 1988 and 1990. Also in the control, *Agrostis* spp. and *Microseris laciniata* frequencies decreased between 1988 and 1989 and then increased in 1990 (Table 4.11).

*Fraxinus latifolia* seedlings and saplings were eliminated from burn treatments. *Agrostis exerata* increased in burn treatments, although results were only significant in twice burned treatments. Frequency of *Danthonia californica* decreased following one burn and remained depressed in both burn treatments in 1990. Species that established in burned areas between 1988 and 1990 included exotics, *Leontodon nudicaulis* and *Sonchus asper*, and natives, *Perideridia oregana* and *Myosotis laxa*. The frequency of a number of native perennial (*Aster chilensis, Brodiaea* spp., *Camassia quamash, Cardamine penduliflora, Microseris laciniata,*

Table 4.11. Species frequency separated by treatments in the *Rosa/Juncus* community. Only species with at least 10% frequency are presented. Data are presented for the 50*50 cm plot excepted where presented for nested plots. The 50*50 cm plot is indicated with a 3, the 25*25 cm plot is indicated with a 2, and the 12.5*12.5 cm plots is indicated with a 1. Superscripted letters ndicate a significant (p = 0.1) difference between years within treatments. * Denotes exotic species.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **TREES** | | | | | | | | | | | | | | | | | | |
| *Fraxinus latifolia* | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 4 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 |
| *Pyrus communis** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **SHRUBS** | | | | | | | | | | | | | | | | | | |
| *Rosa nutkana* | 24 | 10 | 24 | 9 | 27 | 7 | 87 | 4 | 88 | 5 | 92 | 2 | 77 | 11 | 81 | 10 | 81 | 12 |
| *Rubus discolor** | 0 | 0 | 1 | 1 | 2 | 1 | $0^a$ | 0 | $3^b$ | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GRAMINOIDS** | | | | | | | | | | | | | | | | | | |
| Perennials | | | | | | | | | | | | | | | | | | |
| *Agrostis exarata* | 22 | 9 | 39 | 10 | 12 | 6 | 38 | 3 | 54 | 6 | 61 | 9 | $32^a$ | 3 | $61^b$ | 10 | $66^b$ | 11 |
| *Agrostis spp.* | $21^a$ | 3 | $4^b$ | 2 | $30^a$ | 12 | 19 | 5 | 27 | 6 | 43 | 12 | 10 | 5 | 9 | 3 | 23 | 7 |
| *Carex spp.* | 4 | 2 | 4 | 2 | 3 | 3 | 12 | 4 | 12 | 4 | 14 | 5 | 21 | 6 | 19 | 5 | 13 | 5 |
| *Danthonia californica3* | 96 | 3 | 99 | 1 | 99 | 1 | $87^a$ | 7 | $40^b$ | 2 | $54^b$ | 3 | $83^a$ | 6 | $52^b$ | 1 | $51^b$ | 4 |
| *Danthonia californica1* | 84 | 5 | 88 | 3 | 89 | 4 | $74^a$ | 4 | $25^b$ | 5 | $31^b$ | 4 | $67^a$ | 7 | $38^b$ | 5 | $31^b$ | 3 |
| *Deschampsia cespitosa3* | 82 | 5 | 91 | 6 | 92 | 3 | 67 | 3 | 64 | 4 | 72 | 4 | 83 | 5 | 79 | 3 | 79 | 3 |
| *Deschampsia cespitosa2* | 56 | 9 | 63 | 10 | 70 | 11 | 44 | 4 | 38 | 3 | 41 | 3 | 44 | 6 | 47 | 4 | 49 | 5 |
| *Eleocharis acicularis* | 64 | 15 | 68 | 15 | 67 | 17 | 8 | 4 | 6 | 3 | 14 | 7 | 0 | 0 | 1 | 1 | 0 | 0 |
| *Festuca arundinacea* | 6 | 4 | 6 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| *Festuca rubra* | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 3 | 2 | 3 | 2 |
| *Holcus lanatus** | 96 | 3 | 92 | 4 | 97 | 3 | 72 | 6 | 69 | 8 | 80 | 7 | 38 | 10 | 34 | 12 | 42 | 14 |
| *Juncus nevadensis* | 69 | 11 | 73 | 15 | 69 | 16 | 90 | 2 | 96 | 3 | 93 | 5 | 67 | 14 | 69 | 13 | 69 | 13 |
| *Juncus tenuis* | 4 | 2 | 2 | 2 | 6 | 1 | 13 | 3 | 7 | 1 | 6 | 2 | 21 | 8 | 13 | 4 | 18 | 5 |
| *Panicum occidentale* | 0 | 0 | 0 | 0 | 0 | 0 | $0^a$ | 0 | 6 | 3 | $13^b$ | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Poa compressa** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 4 | 3 |
| *Poa spp.** | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 6 | 4 | $7^a$ | 2 | $0^b$ | 0 |
| Annuals | | | | | | | | | | | | | | | | | | |
| *Beckmannia syzigachne** | 3 | 2 | 1 | 1 | 0 | 0 | 10 | 6 | 13 | 5 | 6 | 4 | 0 | 0 | 20 | 7 | 12 | 5 |
| *Briza minor** | 2 | 1 | 2 | 2 | 3 | 2 | 7 | 4 | 7 | 3 | 9 | 3 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Bromus mollis** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 5 | 9 | 6 | 17 | 12 |
| *Festuca myuros** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| *Juncus bufonius** | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **FORBS** | | | | | | | | | | | | | | | | | | |
| Perennials | | | | | | | | | | | | | | | | | | |
| *Allium amplectens* | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 3 | 9 | 4 | 7 | 4 | 1 | 1 | 0 | 0 | 2 | 2 |
| *Aster chilensis v. hallii* | 10 | 10 | 10 | 8 | 13 | 8 | $18^a$ | 4 | $13^a$ | 4 | $40^b$ | 5 | 28 | 6 | 29 | 5 | 46 | 7 |

Table 4.11., Continued.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| *Brodiaea spp.* | 6 | 3 | 2 | 2 | 2 | 1 | $6^a$ | 2 | $15^b$ | 4 | $44^c$ | 6 | $7^a$ | 3 | $9^a$ | 2 | $32^b$ | 8 |
| *Camassia quamash* | 7 | 4 | 2 | 2 | 12 | 3 | $1^a$ | 1 | 1 | 1 | $13^b$ | 1 | $6^a$ | 2 | $9^a$ | 3 | $53^b$ | 12 |
| *Cardamine penduliflora* | 1 | 1 | 4 | 1 | 8 | 5 | $0^a$ | 0 | $16^b$ | 3 | $21^b$ | 7 | $0^a$ | 0 | $50^b$ | 11 | $33^b$ | 14 |
| *Epilobium glandulosum* | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Epilobium watsonii* | 8 | 2 | 6 | 2 | 2 | 2 | $6^a$ | 3 | $6^a$ | 3 | $1^b$ | 1 | $2^a$ | 1 | $6^a$ | 2 | $0^b$ | 0 |
| *Eriophyllum lanatum* | 71 | 3 | 70 | 7 | 76 | 11 | $21^a$ | 2 | $11^b$ | 2 | 14 | 2 | 2 | 1 | 1 | 1 | 6 | 4 |
| *Eryngium petiolatum* | 4 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 4 | 3 | 12 | 2 | 12 | 2 | 13 | 4 |
| *Galium trifidum* | 69 | 9 | 69 | 4 | 69 | 4 | 73 | 1 | 56 | 3 | 66 | 4 | 72 | 11 | 54 | 6 | 61 | 4 |
| *Grindelia integrifolia* | 0 | 0 | 1 | 1 | 1 | 1 | 48 | 10 | 34 | 8 | 56 | 11 | 89 | 8 | 78 | 8 | 84 | 5 |
| *Hypericum perforatum** | 2 | 1 | 2 | 1 | 7 | 2 | 9 | 1 | 20 | 2 | 29 | 5 | 11 | 5 | 28 | 8 | 37 | 14 |
| *Hypocharis radicata** | 17 | 3 | 36 | 11 | 30 | 7 | $0^a$ | 0 | $1^a$ | 1 | $20^b$ | 1 | $1^a$ | 1 | 1 | 1 | $13^b$ | 7 |
| *Leontodon nudicaulis** | 10 | 4 | 6 | 4 | 17 | 7 | 2 | 1 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 3 | 2 |
| *Lotus formosissimus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Mentha pulegium** | 63 | 12 | 74 | 4 | 96 | 2 | $71^a$ | 4 | $64^a$ | 3 | $82^b$ | 5 | 10 | 0 | 16 | 3 | 38 | 8 |
| *Microseris laciniata* | 30 | 17 | 8 | 8 | 36 | 24 | $4^a$ | 2 | 8 | 3 | $11^b$ | 2 | 1 | 1 | 1 | 1 | 2 | 1 |
| *Perideridia oregana* | 9 | 9 | 4 | 4 | 7 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 1 |
| *Potentilla gracilis* | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 4 | 3 |
| *Prunella vulgaris* | 1 | 1 | 3 | 3 | 3 | 3 | 17 | 6 | 11 | 3 | 28 | 9 | 11 | 4 | 18 | 7 | 33 | 12 |
| *Rumex crispus** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 6 | 3 | 6 | 2 |
| *Sisyrinchium angustifolium* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 1 | 1 | 1 | 2 | 1 |
| *Spiranthes romanzoffiana* | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Veronica scutellata* | 31 | 19 | 29 | 17 | 28 | 15 | $16^a$ | 9 | $2^a$ | 2 | $29^b$ | 4 | 59 | 3 | 20 | 4 | 30 | 7 |
| Annuals/Biennials | | | | | | | | | | | | | | | | | | |
| *Bidens frondosa* | 2 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 6 | 2 | 28 | 12 | 11 | 7 | 16 | 3 | 30 | 2 |
| *Boisduvalia densiflora* | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 7 | 16 | 9 | 32 | 10 | 6 | 4 | 10 | 7 | 16 | 11 |
| *Centaurium muhlenbergii* | 3 | 2 | 0 | 0 | 2 | 1 | $2^a$ | 2 | $0^b$ | 0 | $3^a$ | 2 | 0 | 0 | 0 | 0 | 2 | 2 |
| *Centaurium umbellatum** | 3 | 3 | 6 | 4 | 8 | 6 | 2 | 2 | 0 | 0 | 3 | 1 | 2 | 2 | 3 | 1 | 3 | 1 |
| *Centunculus minimus* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Daucus carota** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Epilobium paniculatum* | 24 | 7 | 47 | 10 | 53 | 15 | $0^a$ | 0 | $1^a$ | 1 | $26^b$ | 9 | $1^a$ | 1 | $0^a$ | 0 | $13^b$ | 5 |
| *Galium parisiense** | 1 | 1 | 2 | 2 | 8 | 6 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Gnaphalium palustre* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 4 | 2 | 2 | 1 | 1 | 1 | 4 | 3 | 2 | 1 |
| *Gratiola ebracteata* | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Madia glomerata* | $61^a$ | 9 | 86 | 7 | $100^b$ | 0 | $69^a$ | 5 | $41^b$ | 6 | $83^a$ | 2 | 89 | 4 | 74 | 6 | 59 | 10 |
| *Microsteris gracilis* | 14 | 10 | 8 | 6 | 14 | 8 | $23^a$ | 8 | $22^a$ | 9 | $34^b$ | 10 | 22 | 5 | 30 | 4 | 33 | 3 |
| *Myosotis laxa* | 18 | 2 | 16 | 1 | 19 | 7 | 2 | 2 | 3 | 1 | 17 | 4 | 0 | 0 | 1 | 1 | 2 | 1 |
| *Orthocarpus hispidus* | 1 | 1 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Parentucellia viscosa** | 0 | 0 | 0 | 0 | 0 | 0 | $0^a$ | $0^a$ | 0 | $0^a$ | $2^b$ | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Plagiobothrys figuratus* | 0 | 0 | 1 | 1 | 0 | 0 | $1^a$ | 1 | 4 | 2 | $12^b$ | 5 | 9 | 3 | 26 | 7 | 33 | 7 |
| *Polygonum douglasii* | $10^a$ | 6 | 32 | 6 | $36^b$ | 6 | $13^a$ | 5 | $2^b$ | 1 | $9^b$ | 1 | 17 | 9 | 8 | 5 | 4 | 3 |
| *Senecio jacobaea** | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| *Sonchus asper** | 2 | 1 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

*Veronica scutellata*), native annual (*Epilobium paniculatum, Microsteris gracilis*, and *Plagiobothrys figuratus*), and exotic perennial (*Hypochaeris radicata* and *Mentha pulegium*) forbs increased significantly between years in one or both burn treatments. Frequency of *Microseris laciniata* increased in both control and once burn treatments. *Madia glomerata* and *Polygonum douglasii* frequency increased in the control treatment over time while its frequency declined following one burn event (Table 4.11).

## Fire effects on cover of plant species

### Rose Prairie

#### RP *Deschampsia* plant community

Significant changes in the cover of bare ground and species occurred between years within all treatments in the *Deschampsia* community at Rose Prairie (Table 4.12). In both burn treatments, bare ground increased from 3-6% to ~50% of the sampled area between 1988 and 1989. Bare ground decreased to 26% of once burned and 38% of twice burned areas between 1989 and 1990. Bare ground also significantly increased in control treatments between 1988 and 1990, but the magnitude of the change was only from 5 to 11% bare ground. The cover of *Agrostis tenuis* increased significantly across all treatments between 1988

Table 4.12. Treatment effects on species cover within the RP *Deschampsia* plant community. Only species with at least 1% cover along any sampled transect and where cover values were determined for every year are presented. Superscripted letters indicate a significant ($p = 0.1$) difference between years within treatments. *Denotes exotic species.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **BARE GROUND** | $5.2^a$ | 1.0 | $4.6^a$ | 1.0 | $10.7^b$ | 2.1 | $3.1^a$ | 0.7 | $47.6^b$ | 1.9 | $26.4^c$ | 1.7 | 5.5 | 0.3 | 50.6 | 2.5 | 38.2 | 0.5 |
| **SHRUBS** | | | | | | | | | | | | | | | | | | |
| *Rosa nutkana* | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| **GRAMINOIDS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Agrostis tenuis** | $2.0^a$ | 0.7 | 5.4 | 1.1 | $9.0^b$ | 1.7 | $1.7^a$ | 0.9 | $5.9^b$ | 0.7 | $8.5^b$ | 0.9 | $2.3^a$ | 0.5 | $5.4^b$ | 0.4 | $10.3^c$ | 0.7 |
| *Anthoxanthum odoratum** | 1.5 | 0.6 | 1.5 | 0.1 | 2.2 | 0.3 | 3.0 | 0.6 | 1.7 | 0.4 | 2.6 | 0.8 | $2.9^a$ | 0.2 | $0.4^b$ | 0.1 | $1.0^c$ | 0.2 |
| *Danthonia californica* | $2.7^a$ | 0.4 | $2.4^a$ | 0.3 | $1.6^b$ | 0.1 | 4.0 | 0.7 | 3.9 | 0.6 | 4.1 | 1.0 | $3.6^a$ | 0.3 | $2.1^b$ | 0.2 | 2.9 | 0.3 |
| *Deschampsia cespitosa* | 7.0 | 0.8 | 4.4 | 0.6 | 5.9 | 0.8 | $14.2^a$ | 3.3 | $6.7^b$ | 0.0 | $13.8^a$ | 1.6 | $8.8^a$ | 0.9 | $4.5^b$ | 0.2 | $10.6^a$ | 1.1 |
| *Juncus tenuis* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | $0.1^a$ | 0.0 | $0.8^b$ | 0.3 | $0.6^b$ | 0.2 | $0.0^a$ | 0.0 | 0.3 | 0.1 | $0.3^b$ | 0.0 |
| *Panicum occidentale* | 0.6 | 0.3 | 1.0 | 0.6 | 1.3 | 0.7 | 0.1 | 0.1 | 0.2 | 0.2 | 0.0 | 0.0 | 0.4 | 0.2 | 0.4 | 0.3 | 0.6 | 0.4 |

and 1990. In twice burned treatments, *Anthoxanthum odoratum* cover significantly decreased the first year following the 1988 burn then significantly increased between 1989 and 1990 following a second burn, although by 1990 cover remained significantly below 1988 levels. In burn treatments, *Deschampsia cespitosa* cover declined significantly (~50%) the first year following the 1988 burn event, but returned to preburn levels in 1990 for both burn treatments. *Juncus tenuis* cover increased significantly in both burn treatments between 1988 and 1990, although cover values were extremely low.

### ***Rosa/Anthoxanthum* plant community**

Few significant changes in species cover were measured between years for treatments in the *Rosa/Anthoxanthum* plant community (Table 4.13). In both burn treatments, bare ground increased from less than 1% to 4-6% between 1988 and 1989, then remained unchanged between 1989 and 1990. Cover of *Agrostis tenuis* and *Hypericum perforatum* increased significantly between 1989 and 1990 in twice burned treatments.

### ***Vaccinium* plant community**

Bare ground increased significantly from 9 to 19% and from 7 to 28% in the *Vaccinium* community burn treatments between 1988 and 1989, then declined significantly to 11% in the once burned treatment and remained unchanged in the

Table 4.13. Treatment effects on species cover within the *Rosa/Anthoxanthum* plant community. Only species with at least 1% cover along any sampled transect and where cover values were determined for every year are presented. Superscripted letters indicate a significant ($p = 0.1$) difference between years within treatments. * denotes exotic species.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **BARE GROUND** | 0.4 | 0.3 | 0.4 | 0.2 | 1.8 | 1.1 | $0.5^a$ | 0.3 | $3.9^b$ | 0.3 | $2.7^b$ | 0.6 | $0.9^a$ | 0.3 | $5.7^b$ | 1.1 | $8.3^b$ | 1.5 |
| **TREES** | | | | | | | | | | | | | | | | | | |
| *Crataegus douglasii* | 0.0 | 0.0 | 0.4 | 0.4 | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **SHRUBS** | | | | | | | | | | | | | | | | | | |
| *Rosa eglanteria** | 0.0 | 0.0 | 0.1 | 0.1 | 0.3 | 0.2 | 0.0 | 0.0 | 0.3 | 0.3 | 0.2 | 0.2 | 0.0 | 0.0 | 1.3 | 1.3 | 0.4 | 0.4 |
| *Rosa nutkana* | 14.2 | 4.8 | 7.6 | 3.2 | 10.6 | 3.5 | 11.0 | 2.2 | 8.9 | 1.4 | 9.2 | 0.4 | 7.5 | 3.0 | 5.8 | 0.3 | 5.7 | 0.3 |
| **GRAMINOIDS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Agrostis tenuis** | 0.2 | 0.2 | 0.5 | 0.5 | 1.6 | 1.6 | 0.1 | 0.1 | 0.9 | 0.6 | 0.9 | 0.4 | $0.0^a$ | 0.0 | $0.3^b$ | 0.2 | $0.8^b$ | 0.4 |
| *Anthoxanthum odoratum** | 43.7 | 17.1 | 39.3 | 3.0 | 33.3 | 0.9 | 33.0 | 8.1 | 22.3 | 1.2 | 37.9 | 4.6 | 45.8 | 5.2 | 36.5 | 3.8 | 31.3 | 6.7 |
| *Danthonia californica* | 0.7 | 0.7 | 1.4 | 1.4 | 2.1 | 2.0 | 0.5 | 0.5 | 0.4 | 0.4 | 0.3 | 0.2 | 0.1 | 0.1 | 0.2 | 0.1 | 0.4 | 0.2 |
| *Festuca rubra* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.6 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Holcus lanatus** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.3 | 0.6 | 0.5 | 0.1 | 0.1 | 0.0 | 0.0 | 0.4 | 0.3 | 0.2 | 0.1 |
| *Panicum occidentale* | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.4 | 0.1 | 0.1 | 0.0 | 0.0 | 0.2 | 0.2 |
| **FORBS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Apocynum androsaemifolium* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 1.2 | 2.2 | 2.2 | 2.7 | 2.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Hypericum perforatum** | 4.3 | 1.4 | 1.5 | 0.3 | 1.9 | 0.1 | $3.2^a$ | 1.1 | $4.0^b$ | 1.2 | 2.8 | 1.5 | $2.5^a$ | 0.4 | $8.3^b$ | 1.6 | $15.2^b$ | 3.4 |
| *Rumex acetosella** | 0.3 | 0.1 | 0.5 | 0.3 | 0.3 | 0.1 | 1.8 | 0.9 | 2.1 | 1.0 | 1.4 | 0.8 | 0.2 | 0.2 | 1.3 | 0.9 | 0.5 | 0.4 |
| **Annuals** | | | | | | | | | | | | | | | | | | |
| *Galium parisiense** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.8 | 0.4 | 3.4 | 2.7 | 0.1 | 0.1 | 1.0 | 1.0 | 3.5 | 3.5 |
| *Madia sativa* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 1.2 | 1.2 | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

twice burned treatment between 1989 and 1990 (Table 4.14). In once burned treatments, *V. caespitosum* cover increased significantly from 13 to 24% from 1989 and 1990. *Agrostis tenuis* cover increased significantly between 1988 and 1990 in both burn treatments.

## Fisher Butte

### FB *Deschampsia* plant community

Bare ground increased significantly from 6 to 31% and from 6 to 25% between 1988 and 1989 in the burn treatments and then decreased significantly in once burned treatments and remained unchanged in twice burned treatments (Table 4.15). The cover of *R. nutkana* in twice burned treatments increased significantly from <2% to >3% between 1988 and 1989 and decreased to preburn levels between 1989 and 1990. Cover of *Agrostis* spp. increased significantly from <1% in both burns to >8% in the once burned and >4% in the twice burned between 1988 and 1990. *Danthonia californica* cover declined significantly in both burn treatments between 1988 and 1990. Similar to results in the RP *Deschampsia* community, *D. cespitosa* significantly decreased in 1989 but returned to preburn levels in 1990 in both burn treatments.

Table 4.14. Treatment effects on species cover within the *Vaccinium* plant community. Only species with at 1% cover along any sampled transect and where cover values were determined for every year are presented. Superscripted letters indicate a significant (p = 0.1) difference between years within treatments. *denotes exotic species.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **BARE GROUND** | 3.4 | 1.6 | 4.0 | 1.6 | 2.4 | 0.5 | $9.4^a$ | 2.1 | $19.3^b$ | 2.2 | $11.4^a$ | 1.0 | $7.1^a$ | 1.0 | $28.2^b$ | 7.7 | $17.0^b$ | 1.3 |
| **SHRUBS** | | | | | | | | | | | | | | | | | | |
| *Rosa nutkana* | 0.2 | 0.1 | 0.4 | 0.2 | 0.2 | 0.1 | 1.0 | 0.3 | 1.2 | 0.4 | 1.4 | 0.6 | 0.9 | 0.1 | 0.7 | 0.6 | 1.3 | 0.9 |
| *Vaccinium caespitosum* | 14.1 | 1.8 | 14.5 | 4.2 | 20.2 | 6.2 | 18.0 | 3.8 | $13.2^a$ | 1.7 | $23.5^b$ | 1.7 | 8.8 | 4.2 | 7.6 | 3.1 | 12.8 | 5.3 |
| **GRAMINOIDS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Agrostis tenuis** | 2.4 | 0.6 | 3.0 | 0.9 | 6.2 | 2.1 | $1.2^a$ | 0.3 | $3.0^b$ | 0.9 | $5.3^b$ | 1.0 | $1.3^a$ | 0.3 | $3.7^b$ | 1.2 | $6.2^b$ | 1.3 |
| *Anthoxanthum odoratum** | 1.6 | 0.4 | 1.6 | 0.5 | 1.7 | 0.7 | 2.9 | 1.0 | 2.8 | 1.2 | 4.3 | 1.5 | 2.0 | 0.1 | 1.5 | 0.2 | 1.9 | 0.4 |
| *Carex rossii* | 0.0 | 0.0 | 0.4 | 0.3 | 0.0 | 0.0 | $0.0^a$ | 0.0 | $0.1^b$ | 0.1 | $0.0^a$ | 0.0 | 0.1 | 0.1 | $0.2^a$ | 0.1 | $0.0^b$ | 0.0 |
| *Danthonia californica* | 1.8 | 1.0 | 1.3 | 0.4 | 1.3 | 0.5 | 0.5 | 0.0 | 0.4 | 0.1 | 0.6 | 0.1 | 1.2 | 0.5 | 1.2 | 0.6 | 1.7 | 0.9 |
| *Deschampsia cespitosa* | 4.0 | 2.0 | 2.0 | 0.3 | 2.9 | 0.5 | 3.0 | 1.5 | 1.1 | 0.3 | 2.4 | 0.6 | 3.6 | 0.4 | 2.4 | 0.3 | 3.5 | 0.4 |
| *Panicum occidentale* | 5.0 | 1.0 | 7.4 | 0.8 | 7.7 | 1.1 | 5.8 | 0.4 | 6.2 | 1.0 | 9.9 | 2.2 | 6.9 | 1.2 | 3.5 | 0.4 | 4.8 | 0.8 |
| **LICHENS** | | | | | | | | | | | | | | | | | | |
| *Cladonia spp.* | 4.9 | 4.7 | 5.1 | 5.1 | 4.7 | 4.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 |

Table 4.15. Treatment effects on species cover within the FB *Deschampsia* plant community. Only species with at least 1% cover along any sampled transect and where cover values were determined for every year are presented Superscripted letters indicate a significant ($p = 0.1$) difference between years within treatments. *denotes exotic species.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **BARE GROUND** | 2.5 | 0.6 | 1.5 | 0.5 | 1.2 | 0.3 | $6.3^{a}$ | 2.2 | $31.3^{b}$ | 3.2 | $16.9^{c}$ | 2.7 | $6.2^{a}$ | 0.7 | $24.9^{b}$ | 4.7 | $25.6^{b}$ | 4.1 |
| **SHRUBS** | | | | | | | | | | | | | | | | | | |
| *Rosa nutkana* | 0.7 | 0.2 | 1.0 | 0.3 | 0.3 | 0.1 | 1.0 | 0.5 | 1.7 | 0.9 | 1.4 | 0.8 | $1.8^{a}$ | 0.3 | $3.3^{b}$ | 0.4 | $1.7^{a}$ | 0.4 |
| **GRAMINOIDS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Agrostis spp.** | 0.7 | 0.2 | 1.0 | 0.1 | 0.8 | 0.3 | $0.9^{a}$ | 0.3 | $4.6^{b}$ | 1.3 | $8.7^{b}$ | 2.9 | $0.3^{a}$ | 0.1 | 2.3 | 1.2 | $4.5^{b}$ | 2.3 |
| *Anthoxanthum odoratum** | 0.2 | 0.1 | 0.4 | 0.2 | 1.1 | 0.4 | 0.6 | 0.2 | 0.4 | 0.1 | 0.6 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.2 | 0.2 |
| *Danthonia californica* | 14.0 | 3.9 | 13.4 | 2.6 | 11.7 | 2.7 | $11.1^{a}$ | 2.2 | $3.3^{b}$ | 0.4 | $6.1^{c}$ | 0.6 | $11.2^{a}$ | 1.0 | $3.1^{b}$ | 0.5 | $4.8^{b}$ | 0.7 |
| *Deschampsia cespitosa* | 7.8 | 2.3 | 7.0 | 1.8 | 8.9 | 1.9 | $6.7^{a}$ | 1.2 | $3.2^{b}$ | 0.7 | $7.8^{a}$ | 1.9 | $12.0^{a}$ | 0.8 | $7.0^{b}$ | 1.0 | $12.8^{a}$ | 1.1 |
| *Festuca rubra* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.3 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| *Holcus lanatus** | 0.8 | 0.4 | 1.0 | 0.4 | 1.2 | 0.3 | 1.8 | 0.3 | 1.5 | 0.4 | 3.6 | 1.0 | 1.5 | 0.3 | 1.6 | 0.9 | 2.9 | 0.8 |
| *Juncus nevadensis* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 0.4 | 0.2 | 0.2 | 0.1 | 0.1 | 0.0 | 0.5 | 0.2 | 0.3 | 0.2 |
| *Panicum occidentale* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 1.1 | 0.8 | 0.5 | 2.2 | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| **Annuals** | | | | | | | | | | | | | | | | | | |
| *Briza minor** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.9 | 0.5 | 1.7 | 0.8 | 0.0 | 0.0 | 0.6 | 0.5 | 2.1 | 1.4 |
| **FORBS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Aster chilensis v. hallii* | 0.7 | 0.2 | 1.1 | 0.3 | 0.8 | 0.2 | 0.7 | 0.2 | 1.6 | 0.4 | 1.0 | 0.2 | 0.6 | 0.2 | 2.5 | 0.9 | 1.1 | 0.3 |
| *Grindelia integrifolia* | 3.1 | 1.7 | 1.4 | 0.5 | 1.4 | 0.6 | 0.9 | 0.6 | 0.2 | 0.1 | 0.6 | 0.2 | 1.5 | 0.4 | 1.0 | 0.4 | 1.3 | 0.4 |
| *Hypericum perforatum** | $0.1^{a}$ | 0.0 | $0.1^{a}$ | 0.0 | $0.2^{b}$ | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | $0.1^{a}$ | 0.0 | $0.1^{a}$ | 0.0 | $0.6^{b}$ | 0.2 |
| *Microseris laciniata* | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | $0.1^{a}$ | 0.1 | $0.5^{b}$ | 0.0 | $0.1^{a}$ | 0.0 | $0.1^{a}$ | 0.1 | $1.5^{b}$ | 0.4 | $0.4^{c}$ | 0.1 |
| *Sisyrinchium angustifolium* | 0.6 | 0.3 | 0.7 | 0.2 | 0.6 | 0.2 | 0.3 | 0.2 | 0.5 | 0.3 | 0.6 | 0.4 | $0.1^{a}$ | 0.0 | 0.2 | 0.1 | $0.2^{b}$ | 0.0 |
| **Annuals** | | | | | | | | | | | | | | | | | | |
| *Centaurium umbellatum** | 0.1 | 0.0 | 0.1 | 0.1 | 0.3 | 0.1 | $0.5^{a}$ | 0.1 | $0.0^{b}$ | 0.0 | $1.6^{c}$ | 0.3 | $0.2^{a}$ | 0.1 | $0.0^{b}$ | 0.0 | $0.7^{c}$ | 0.3 |
| *Madia glomerata* | 1.5 | 0.1 | 1.7 | 0.7 | 1.4 | 0.2 | 0.7 | 0.3 | 0.2 | 0.1 | 0.8 | 0.4 | $1.0^{a}$ | 0.3 | $0.0^{b}$ | 0.0 | $0.4^{a}$ | 0.2 |

### ***Rosa/Juncus* plant community**

Bare ground increased significantly in all treatments between 1988 and 1989 in the *Rosa/Juncus* plant community (Table 4.16). The increase in controls was only from 3% to 5%, but in once burned and twice burned treatments bare ground increased from 6 to 27% and from 9 to 26%, respectively. Between 1989 and 1990, bare ground return to preburn levels in control and once burned treatments while it remained elevated in twice burned treatments. Cover of *R. nutkana* increased significantly between 1988 and 1989 and remained elevated in 1990 in both burn treatments. *Agrostis exerata* cover increased from <1% to >9% between 1988 and 1990 in twice burned treatments. Cover of *D. californica* declined from 11% to 1% and from 5% to <1% in once burned and twice burned treatments between 1988 and 1989 and remained low in 1990 in both burn treatments. Significant increases in *Madia glomerata* cover, from <1% to 11%, were measured between 1988 and 1990 in controls; cover was unchanged in the once burned and deceased significantly in the twice burned treatments.

Table 4.16. Treatment effects on species cover within the *Rosa/Juncus* plant community. Only species with at least 1% cover along any sampled transect and where cover values were determined for every year are presented. Superscripted letters indicate a significant (p = 0.1) difference between years within treatments. *denotes exotic species.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **BARE GROUND** | $2.7^{a}$ | 0.1 | $4.9^{b}$ | 0.3 | $2.4^{a}$ | 0.2 | $6.3^{a}$ | 1.1 | $27.1^{b}$ | 5.2 | $9.5^{a}$ | 1.9 | $8.9^{a}$ | 2.8 | $25.8^{b}$ | 2.5 | $25.8^{b}$ | 2.4 |
| **TREES** | | | | | | | | | | | | | | | | | | |
| *Crataegus douglasii* | 0.6 | 0.6 | 0.4 | 0.4 | 0.6 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Pyrus fusca* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **SHRUBS** | | | | | | | | | | | | | | | | | | |
| *Rosa nutkana* | 1.7 | 0.2 | 1.6 | 0.3 | 1.4 | 0.3 | $3.4^{a}$ | 0.6 | $10.0^{b}$ | 1.7 | $9.7^{b}$ | 1.6 | $6.2^{a}$ | 1.1 | $15.6^{b}$ | 2.3 | $11.3^{b}$ | 2.0 |
| **GRAMINOIDS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Agrostis exarata* | 0.3 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.9 | 0.6 | 1.7 | 0.9 | 1.4 | 0.7 | $0.9^{a}$ | 0.3 | 1.6 | 0.7 | $9.3^{b}$ | 2.2 |
| *Agrostis spp.** | 0.1 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.4 | 0.3 | 1.6 | 0.9 | 7.0 | 3.8 | 0.1 | 0.1 | 0.4 | 0.3 | 3.8 | 1.6 |
| *Carex spp.* | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.3 | 0.5 | 0.3 | 0.4 | 0.3 |
| *Danthonia californica* | 7.1 | 2.1 | 6.4 | 2.1 | 5.8 | 1.6 | $10.5^{a}$ | 2.2 | $1.0^{b}$ | 0.2 | $2.4^{b}$ | 0.8 | $4.9^{a}$ | 0.8 | $0.8^{b}$ | 0.4 | $0.7^{b}$ | 0.2 |
| *Deschampsia cespitosa* | 14.5 | 4.8 | 11.0 | 2.2 | 11.1 | 3.1 | 2.4 | 0.6 | 1.1 | 0.4 | 3.4 | 0.7 | 6.3 | 1.2 | 4.0 | 1.0 | 5.6 | 0.7 |
| *Juncus nevadensis* | $1.7^{a}$ | 0.3 | $3.6^{b}$ | 0.2 | $1.3^{a}$ | 0.2 | $10.4^{a}$ | 1.0 | $15.2^{a}$ | 2.2 | $5.9^{b}$ | 0.9 | 7.2 | 2.6 | 11.8 | 5.2 | 5.6 | 2.9 |
| *Panicum occidentale* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | $0.0^{a}$ | 0.0 | 0.0 | 0.0 | $0.6^{b}$ | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Annuals** | | | | | | | | | | | | | | | | | | |
| *Aira spp.** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **FORBS** | | | | | | | | | | | | | | | | | | |
| **Perennials** | | | | | | | | | | | | | | | | | | |
| *Aster chilensis v. hallii* | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.9 | 0.4 | 0.8 | 0.3 | $0.6^{a}$ | 0.2 | 1.7 | 0.7 | $2.3^{b}$ | 0.6 |
| *Grindelia integrifolia* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.6 | 0.4 | 0.3 | 1.2 | 0.6 | 7.1 | 3.2 | 3.0 | 1.3 | 4.4 | 1.9 |
| *Mentha pulegium** | 2.3 | 0.8 | 4.1 | 1.3 | 6.3 | 2.0 | 0.9 | 0.4 | 0.3 | 0.1 | 2.5 | 1.1 | 0.7 | 0.5 | 0.9 | 0.5 | 3.1 | 2.6 |
| **Annuals** | | | | | | | | | | | | | | | | | | |
| *Gratiola ebracteata* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.4 | 0.4 | 0.0 | 0.0 |
| *Madia glomerata* | $0.8^{a}$ | 0.4 | $3.5^{b}$ | 0.4 | $10.5^{c}$ | 2.1 | $1.9^{a}$ | 1.2 | $0.2^{b}$ | 0.1 | $0.9^{a}$ | 0.3 | $1.9^{a}$ | 0.6 | $3.9^{a}$ | 1.7 | $0.3^{b}$ | 0.1 |

# Fire effects on frequency of plant forms, lifespans and origins

## Rose Prairie

### RP *Deschampsia* plant community

Relative frequency of total natives and exotics was unchanged in control and once burned treatments, but the component parts that made up these totals did change through the sampling period (Table 4.17). Exotic annual graminoids dropped out of the control treatments by 1990. In once burned treatments, relative frequency of exotic perennial graminoids decreased significantly from 24 to 18%. Annual native forbs increased significantly from 6 to 11% in the once burned treatment.

In twice burned treatments, relative frequencies increased significantly for all natives, from 60 to 70%, between 1988 and 1990. The relative frequency of graminoids declined significantly, from 54 to 48%, while the relative frequency of forbs increased significantly, from 45 to 51%, between 1989 and 1990. This graminoid decline is attributed to a decrease in exotic perennials while the forb increase is due to an increase in native perennials and a decline in exotic perennials.

Table 4.17. Summary of species relative percent frequency by life form, lifespan, and origin for the *Deschampsia* plant community at Rose Prairie. Superscripted letters indicate a significant difference (p = 0.1) between years within treatments.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **Total Native** | 62.8 | 3.3 | 65.5 | 3.0 | 66.1 | 2.6 | 61.6 | 2.5 | 67.2 | 1.4 | 65.4 | 1.3 | 59.7$^{a}$ | 2.4 | 67.8$^{b}$ | 0.8 | 70.0$^{c}$ | 1.0 |
| **Total Exotic** | 37.2 | 3.3 | 34.5 | 3.0 | 33.9 | 2.6 | 38.4 | 2.5 | 32.8 | 1.4 | 34.6 | 1.3 | 40.3$^{a}$ | 2.4 | 32.2$^{b}$ | 0.8 | 30.0$^{c}$ | 1.0 |
| **By Life Forms:** | | | | | | | | | | | | | | | | | | |
| **Trees** | 0.2 | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| Native | 0.2 | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Shrubs** | 0.7 | 0.3 | 0.7 | 0.4 | 0.8 | 0.4 | 0.1 | 0.1 | 1.3 | 0.6 | 0.4 | 0.1 | 0.7 | 0.4 | 1.2 | 0.4 | 0.8 | 0.2 |
| Native | 0.5 | 0.4 | 0.7 | 0.3 | 0.7 | 0.4 | 0.1 | 0.1 | 1.2 | 0.6 | 0.2 | 0.1 | 0.7 | 0.4 | 1.2 | 0.4 | 0.5 | 0.3 |
| Exotic | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 |
| **Graminoids** | 44.3 | 2.6 | 44.0 | 3.4 | 42.8 | 3.6 | 58.1 | 3.8 | 52.9 | 2.7 | 49.0 | 2.3 | 53.4$^{a}$ | 2.3 | 53.6$^{a}$ | 1.8 | 48.0$^{b}$ | 0.5 |
| Total Native | 24.8 | 1.0 | 26.0 | 0.9 | 26.2 | 1.5 | 32.1 | 2.2 | 28.4 | 1.6 | 26.9 | 2.5 | 30.3$^{a}$ | 0.4 | 33.0$^{b}$ | 0.6 | 30.8 | 1.1 |
| Total Exotic | 19.5 | 2.5 | 18.0 | 2.7 | 16.7 | 2.2 | 25.9 | 2.4 | 24.5 | 1.1 | 22.1 | 0.3 | 23.1$^{a}$ | 2.2 | 20.6 | 1.2 | 17.2$^{b}$ | 1.0 |
| Perennials | 43.5 | 2.6 | 43.5 | 3.4 | 42.8 | 3.6 | 55.7 | 3.0 | 46.5 | 2.3 | 45.1 | 3.2 | 52.0$^{a}$ | 1.7 | 49.1$^{a}$ | 1.3 | 45.7$^{b}$ | 0.7 |
| Native | 24.8 | 1.0 | 26.0 | 0.9 | 26.2 | 1.5 | 32.1 | 2.2 | 28.4 | 1.6 | 26.9 | 2.5 | 30.3$^{a}$ | 0.4 | 33.0$^{b}$ | 0.6 | 30.8 | 1.1 |
| Exotic | 18.7 | 2.5 | 17.5 | 2.6 | 16.7 | 2.2 | 23.5$^{a}$ | 1.3 | 18.2$^{b}$ | 0.8 | 18.3$^{b}$ | 0.8 | 21.7$^{a}$ | 1.5 | 16.1$^{b}$ | 0.7 | 14.9$^{b}$ | 0.4 |
| Annuals | 0.8$^{a}$ | 0.1 | 0.5$^{a}$ | 0.1 | 0.0$^{b}$ | 0.0 | 2.4$^{a}$ | 1.1 | 6.3$^{b}$ | 0.6 | 3.8$^{a}$ | 1.0 | 1.4$^{a}$ | 0.8 | 4.5$^{b}$ | 0.6 | 2.3$^{a}$ | 0.6 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.8$^{a}$ | 0.1 | 0.5$^{a}$ | 0.1 | 0.0$^{b}$ | 0.0 | 2.4$^{a}$ | 1.1 | 6.3$^{b}$ | 0.6 | 3.8$^{a}$ | 1.0 | 1.4$^{a}$ | 0.8 | 4.5$^{b}$ | 0.6 | 2.3$^{a}$ | 0.6 |
| **Forbs** | 54.9 | 2.6 | 55.1 | 3.1 | 56.4 | 3.3 | 41.8 | 3.8 | 45.9 | 3.3 | 50.6 | 2.4 | 46.0$^{a}$ | 2.5 | 45.2$^{a}$ | 1.4 | 51.2$^{b}$ | 0.3 |
| Total Native | 37.2 | 3.3 | 38.6 | 3.4 | 39.2 | 3.8 | 29.3 | 3.7 | 37.7 | 3.2 | 38.3 | 2.8 | 28.8$^{a}$ | 2.8 | 33.6$^{a}$ | 1.0 | 38.5$^{b}$ | 0.9 |
| Total Exotic | 17.7 | 0.7 | 16.5 | 0.4 | 17.2 | 0.6 | 12.5$^{a}$ | 0.4 | 8.2$^{b}$ | 1.1 | 12.3$^{a}$ | 0.9 | 17.2$^{a}$ | 0.5 | 11.6$^{b}$ | 0.7 | 12.6$^{b}$ | 0.5 |
| Perennials | 47.4 | 0.4 | 48.2 | 1.1 | 50.6 | 1.6 | 35.2 | 3.8 | 33.9 | 3.7 | 39.6 | 2.9 | 41.3 | 1.8 | 39.4 | 0.8 | 44.8 | 0.2 |
| Native | 29.8 | 1.1 | 31.9 | 1.6 | 33.6 | 2.0 | 22.9 | 3.6 | 26.3 | 3.2 | 27.4 | 3.0 | 24.1$^{a}$ | 2.2 | 27.8$^{a}$ | 0.7 | 32.1$^{b}$ | 0.8 |
| Exotic | 17.7 | 0.7 | 16.3 | 0.5 | 17.1 | 0.6 | 12.3$^{a}$ | 0.3 | 7.5$^{b}$ | 1.1 | 12.2$^{a}$ | 1.0 | 17.2$^{a}$ | 0.5 | 11.6$^{b}$ | 0.7 | 12.6$^{b}$ | 0.5 |
| Annuals | 7.4 | 2.3 | 6.9 | 2.7 | 5.7 | 2.3 | 6.6$^{a}$ | 0.3 | 12.0$^{b}$ | 1.2 | 11.0$^{b}$ | 1.1 | 4.7 | 1.2 | 5.7 | 0.7 | 6.4 | 0.1 |
| Native | 7.4 | 2.3 | 6.7 | 2.5 | 5.6 | 2.2 | 6.4$^{a}$ | 0.4 | 11.3$^{b}$ | 1.2 | 10.9$^{b}$ | 1.0 | 4.7 | 1.2 | 5.7 | 0.7 | 6.4 | 0.1 |
| Exotic | 0.0 | 0.0 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1$^{a}$ | 0.1 | 0.7$^{b}$ | 0.1 | 0.2$^{a}$ | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

### *Rosa/Anthoxanthum* plant community

No significant changes were noted between years for relative frequencies of life forms, life spans, or origin in control treatments (Table 4.18). In both burn treatments, there were significant declines in exotic perennial graminoids while there were significant increases in native forbs (primarily perennials) between 1988 and 1990. In twice burned treatments, natives increased significantly between 1989 and 1990, from 29 to 32% with a concurrent significant decline in exotics, from 71 to 68%. Relative frequency of native perennial forbs increased significantly while exotic perennial forbs declined significantly in twice burned treatments between 1988 and 1990. Perennial graminoids declined in twice burned treatments over time while relative frequency of annual graminoids increased, due to exotics in both cases. Native annual forbs also increased significantly in twice burned treatments during the course of this study, from 2 to 8%.

### *Vaccinium* plant community

Most changes in relative frequency between years in this community occurred in the control treatment; shrubs and graminoids decreased and forbs increased (Table 4.19). The only significant change in relative frequency between years that occurred in once burned treatments was an increase in all annuals between 1989 and 1990, from 9 to 10%. In the twice burned treatment,

Table 4.18. Summary of species relative percent frequency by life form, lifespan, and origin for the *Rosa/Anthoxanthum* plant community at Rose Prairie. Superscripted letters indicate a significant difference (p = 0.1) between years within treatments.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **Total Native** | 32.4 | 9.0 | 33.1 | 9.1 | 32.6 | 8.2 | 37.6 | 3.2 | 38.6 | 3.0 | 39.1 | 4.4 | 23.2$^{a}$ | 0.5 | 28.9$^{b}$ | 1.8 | 32.2$^{b}$ | 0.9 |
| **Total Exotic** | 67.6 | 9.0 | 66.9 | 9.1 | 67.1 | 8.2 | 62.1 | 3.2 | 61.5 | 3.0 | 59.8 | 4.4 | 76.8$^{a}$ | 0.5 | 71.1$^{b}$ | 1.8 | 67.5$^{b}$ | 1.0 |
| **By Life Forms:** | | | | | | | | | | | | | | | | | | |
| **Trees** | 0.0 | 0.0 | 0.4 | 0.4 | 0.4 | 0.4 | 0.0 | 0.0 | 0.2 | 0.2 | 0.1 | 0.1 | 0.4 | 0.2 | 0.1 | 0.1 | 0.6 | 0.2 |
| Native | 0.0 | 0.0 | 0.4 | 0.4 | 0.4 | 0.4 | 0.0 | 0.0 | 0.2 | 0.2 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.6 | 0.2 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Shrubs** | 10.6 | 3.0 | 10.9 | 3.1 | 11.0 | 3.3 | 9.4 | 2.4 | 7.6 | 0.3 | 6.4 | 1.0 | 10.7 | 1.9 | 10.8 | 1.0 | 7.8 | 1.1 |
| Native | 10.3 | 3.0 | 10.5 | 3.3 | 10.4 | 3.3 | 9.4 | 2.4 | 7.3 | 0.5 | 6.3 | 1.1 | 10.6 | 1.8 | 9.2 | 1.0 | 6.7 | 0.9 |
| Exotic | 0.2 | 0.2 | 0.4 | 0.2 | 0.6 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.1 | 0.1 | 0.2$^{a}$ | 0.2 | 1.6$^{b}$ | 0.7 | 1.2$^{b}$ | 0.2 |
| **Graminoids** | 23.5 | 0.6 | 23.2 | 1.7 | 21.8 | 1.2 | 22.5 | 3.0 | 23.1 | 1.8 | 20.8 | 3.1 | 27.2 | 1.8 | 29.0 | 2.4 | 24.9 | 2.2 |
| Total Native | 3.6 | 1.8 | 4.9 | 2.3 | 5.4 | 2.3 | 5.3 | 2.5 | 4.6 | 1.8 | 4.7 | 1.8 | 6.4 | 0.9 | 7.3 | 1.1 | 5.6 | 0.7 |
| Total Exotic | 19.9 | 1.9 | 18.3 | 2.6 | 16.4 | 1.1 | 17.2 | 0.7 | 18.5 | 0.6 | 16.1 | 1.6 | 20.8 | 1.9 | 21.7 | 2.9 | 19.3 | 1.7 |
| Perennials | 21.1 | 1.4 | 22.5 | 2.2 | 20.7 | 0.2 | 20.5 | 1.9 | 17.3 | 1.1 | 16.9 | 1.9 | 26.2$^{a}$ | 1.4 | 23.3$^{a}$ | 1.1 | 18.0$^{b}$ | 1.1 |
| Native | 3.6 | 1.8 | 4.9 | 2.3 | 5.4 | 2.3 | 5.3 | 2.5 | 4.6 | 1.8 | 4.7 | 1.8 | 6.4 | 0.9 | 7.3 | 1.1 | 5.6 | 0.7 |
| Exotic | 17.5 | 3.2 | 17.6 | 3.3 | 15.3 | 2.1 | 15.2$^{a}$ | 0.6 | 12.7$^{b}$ | 0.9 | 12.1$^{b}$ | 0.3 | 19.8$^{a}$ | 1.5 | 15.9$^{a}$ | 1.0 | 12.5$^{b}$ | 0.4 |
| Annuals | 2.4 | 1.5 | 0.7 | 0.7 | 1.1 | 1.1 | 2.0 | 1.2 | 5.8 | 0.7 | 3.9 | 1.7 | 1.0$^{a}$ | 0.4 | 5.7$^{b}$ | 1.9 | 6.8$^{b}$ | 1.4 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 2.4 | 1.5 | 0.7 | 0.7 | 1.1 | 1.1 | 2.0 | 1.2 | 5.8 | 0.7 | 3.9 | 1.7 | 1.0$^{a}$ | 0.4 | 5.7$^{b}$ | 1.9 | 6.8$^{b}$ | 1.4 |
| **Forbs** | 66.0 | 2.9 | 65.4 | 4.2 | 66.5 | 2.2 | 67.8 | 2.9 | 69.2 | 1.7 | 71.6 | 3.4 | 61.7$^{a}$ | 0.1 | 60.1$^{a}$ | 2.0 | 66.4$^{b}$ | 1.8 |
| Total Native | 18.5 | 10.2 | 17.3 | 10.2 | 16.4 | 9.3 | 22.9$^{a}$ | 0.4 | 26.5$^{b}$ | 2.0 | 28.0$^{b}$ | 2.4 | 6.1$^{a}$ | 1.1 | 12.3$^{b}$ | 2.5 | 19.4$^{c}$ | 0.5 |
| Total Exotic | 47.4 | 7.4 | 48.2 | 7.0 | 50.1 | 7.2 | 45.0 | 3.3 | 42.7 | 2.7 | 43.6 | 5.4 | 55.7 | 1.2 | 47.8 | 3.8 | 47.0 | 2.1 |
| Perennials | 47.8 | 4.3 | 49.6 | 5.8 | 45.8 | 8.2 | 42.0 | 4.3 | 38.1 | 3.1 | 38.8 | 3.6 | 43.8 | 3.3 | 35.9 | 2.8 | 37.2 | 1.6 |
| Native | 8.5 | 5.6 | 9.2 | 6.4 | 8.3 | 6.3 | 11.1 | 1.3 | 12.4 | 0.8 | 13.4 | 2.1 | 4.3$^{a}$ | 1.8 | 8.3$^{a}$ | 1.5 | 11.8$^{b}$ | 0.1 |
| Exotic | 39.3 | 9.2 | 40.3 | 9.5 | 37.5 | 9.2 | 30.9 | 3.0 | 25.7 | 2.5 | 25.4 | 1.8 | 39.5$^{a}$ | 1.8 | 27.6$^{b}$ | 1.3 | 25.4$^{b}$ | 1.7 |
| Annuals | 18.1 | 6.5 | 15.9 | 6.9 | 20.7 | 9.4 | 25.9 | 7.2 | 31.1 | 4.1 | 32.8 | 6.0 | 17.9$^{a}$ | 3.4 | 24.1$^{b}$ | 3.7 | 29.2$^{b}$ | 3.1 |
| Native | 10.0 | 4.6 | 8.0 | 4.3 | 8.1 | 4.1 | 11.8 | 1.0 | 14.1 | 1.7 | 14.6 | 0.2 | 1.8$^{a}$ | 0.7 | 4.0$^{a}$ | 1.3 | 7.6$^{b}$ | 0.6 |
| Exotic | 8.1 | 2.3 | 7.9 | 2.6 | 12.6 | 6.5 | 14.1 | 6.3 | 17.0 | 5.0 | 18.2 | 6.2 | 16.2 | 2.9 | 20.2 | 5.0 | 21.6 | 3.7 |

Table 4.19. Summary of species relative percent frequency by life form, life span, and origin for the *Vaccinium* plant community at Rose Prairie. Superscripted letters indicate a significant difference (p = 0.1) between years within treatments.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **Total Native** | 73.1 | 0.1 | 71.2 | 1.5 | 72.5 | 1.0 | 69.3 | 0.1 | 69.2 | 0.9 | 70.1 | 0.5 | 71.5 | 0.7 | 70.5 | 1.2 | 72.0 | 1.5 |
| **Total Exotic** | 26.9 | 0.1 | 28.7 | 1.5 | 27.5 | 1.0 | 30.7 | 0.1 | 30.8 | 0.9 | 29.9 | 0.5 | 28.5 | 0.7 | 29.5 | 1.2 | 28.0 | 1.5 |
| **By Life Forms:** | | | | | | | | | | | | | | | | | | |
| **Trees** | 0.4 | 0.1 | 0.4 | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | $0.1^{a}$ | 0.1 | $0.5^{b}$ | 0.1 | $0.3^{a}$ | 0.0 |
| Native | 0.4 | 0.1 | 0.4 | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | $0.1^{a}$ | 0.1 | $0.5^{b}$ | 0.1 | $0.3^{a}$ | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Shrubs** | $7.9^{a}$ | 0.4 | $6.4^{b}$ | 0.3 | $6.5^{b}$ | 0.3 | 6.5 | 0.8 | 6.0 | 0.6 | 7.0 | 0.7 | 6.0 | 0.4 | 5.6 | 0.6 | 5.9 | 0.6 |
| Native | $7.9^{a}$ | 0.4 | $6.3^{b}$ | 0.3 | $6.3^{b}$ | 0.5 | 6.3 | 0.6 | 5.8 | 0.5 | 6.6 | 0.6 | 6.0 | 0.4 | 5.4 | 0.6 | 5.5 | 0.6 |
| Exotic | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.4 | 0.2 | 0.0 | 0.0 | 0.2 | 0.1 | 0.3 | 0.1 |
| **Graminoids** | $39.9^{a}$ | 1.3 | $35.2^{b}$ | 1.0 | 37.4 | 1.2 | 32.9 | 0.9 | 37.2 | 1.4 | 33.7 | 1.3 | $34.1^{a}$ | 0.8 | $38.4^{b}$ | 0.8 | $34.8^{a}$ | 0.8 |
| Total Native | $23.7^{a}$ | 0.4 | $21.3^{b}$ | 0.1 | $24.8^{a}$ | 0.8 | 18.7 | 1.0 | 21.3 | 1.2 | 19.8 | 0.5 | 20.4 | 1.2 | 22.7 | 1.7 | 21.1 | 1.8 |
| Total Exotic | $16.2^{a}$ | 0.9 | 14.0 | 0.9 | $12.5^{b}$ | 0.6 | 14.2 | 0.8 | 15.9 | 1.1 | 13.9 | 0.8 | 13.7 | 0.8 | 15.6 | 1.1 | 13.8 | 1.2 |
| Perennials | $39.0^{a}$ | 1.4 | $33.9^{b}$ | 0.8 | 36.8 | 1.4 | 28.7 | 1.6 | 31.7 | 2.0 | 30.8 | 1.1 | 32.1 | 1.6 | 34.0 | 2.4 | 32.4 | 1.7 |
| Native | $23.7^{a}$ | 0.4 | $21.3^{b}$ | 0.1 | $24.8^{a}$ | 0.8 | 18.7 | 1.0 | 21.3 | 1.2 | 19.8 | 0.5 | 20.4 | 1.2 | 22.7 | 1.7 | 21.1 | 1.8 |
| Exotic | 15.3 | 1.0 | 12.6 | 0.7 | 11.9 | 0.8 | 10.0 | 0.6 | 10.4 | 0.9 | 11.0 | 1.0 | 11.6 | 0.6 | 11.2 | 0.8 | 11.4 | 0.4 |
| Annuals | 0.9 | 0.2 | 1.3 | 0.2 | 0.6 | 0.2 | 4.2 | 1.1 | 5.5 | 1.7 | 2.9 | 0.8 | 2.0 | 1.0 | 4.4 | 1.7 | 2.4 | 1.0 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.9 | 0.2 | 1.3 | 0.2 | 0.6 | 0.2 | 4.2 | 1.1 | 5.5 | 1.7 | 2.9 | 0.8 | 2.0 | 1.0 | 4.4 | 1.7 | 2.4 | 1.0 |
| **Forbs** | $50.3^{a}$ | 1.7 | $57.1^{b}$ | 1.4 | 54.9 | 2.2 | 60.4 | 1.5 | 56.7 | 1.6 | 59.2 | 1.6 | $59.6^{a}$ | 1.2 | $55.6^{b}$ | 1.4 | $59.0^{a}$ | 0.9 |
| Total Native | 39.7 | 1.0 | 42.4 | 1.4 | 40.1 | 1.2 | 44.2 | 1.5 | 42.0 | 1.1 | 43.6 | 0.9 | $44.7^{a}$ | 0.7 | $42.0^{b}$ | 1.0 | $45.1^{a}$ | 0.7 |
| Total Exotic | $10.7^{a}$ | 0.8 | $14.7^{b}$ | 1.6 | $14.8^{b}$ | 1.2 | 16.2 | 0.7 | 14.7 | 0.5 | 15.6 | 0.8 | 14.9 | 0.5 | 13.7 | 0.4 | 13.9 | 0.4 |
| Perennials | 50.3 | 1.7 | 53.4 | 2.6 | 51.6 | 2.9 | 51.1 | 1.8 | 47.5 | 2.4 | 49.0 | 1.6 | 52.2 | 0.4 | 47.7 | 1.4 | 50.9 | 1.1 |
| Native | 39.7 | 1.0 | 38.9 | 2.2 | 36.9 | 2.0 | 34.9 | 1.7 | 32.9 | 1.8 | 33.8 | 1.1 | 37.3 | 0.4 | 34.1 | 1.2 | 37.1 | 1.1 |
| Exotic | 10.7 | 0.8 | 14.5 | 1.8 | 14.7 | 1.2 | 16.2 | 0.6 | 14.6 | 0.6 | 15.2 | 0.6 | 14.9 | 0.5 | 13.6 | 0.3 | 13.8 | 0.4 |
| Annuals | $0.0^{a}$ | 0.0 | $3.7^{b}$ | 1.2 | $3.2^{a}$ | 0.9 | $9.4^{a}$ | 0.4 | $9.2^{a}$ | 0.9 | $10.2^{b}$ | 0.0 | 7.4 | 1.2 | 7.9 | 1.2 | 8.1 | 0.4 |
| Native | $0.0^{a}$ | 0.0 | $3.5^{b}$ | 1.2 | $3.1^{b}$ | 0.8 | 9.3 | 0.4 | 9.1 | 0.8 | 9.8 | 0.2 | 7.4 | 1.2 | 7.8 | 1.3 | 8.1 | 0.5 |
| Exotic | 0.0 | 0.0 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.4 | 0.2 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 |

graminoids increased significantly between 1988 and 1989, from 34 to 38%, and then returned to preburn levels in 1990. Native forbs decreased from 44 to 42% and then returned to preburn levels in 1990.

## Fisher Butte

### FB *Deschampsia* plant community

Relative frequency did not change significantly between years for total natives or exotics in any treatments in the *Deschampsia* community, but there were a similar suite of changes with in categories in all three treatments (Table 4.20). Graminoids significantly declined and forbs significantly increased between years in all treatments. Relative frequency of native annuals decreased significantly from 11 to 6-7% in 1989 in burned plots. Between 1989 and 1990, native annuals increased significantly but only returned to preburn levels in the once burned treatment.

### *Rosa/Juncus* plant community

As in the FB Deschampsia community, relative frequency of total natives and exotics in the *Rosa/Juncus* community were not significantly different in any treatments during the study, but individual life forms, lifespans or origins differed (Table 4.21). In both burn treatments, native graminoids decreased significantly

Table 4.20. Summary of species relative percent frequency by life form, life span, and origin for the *Deschampsia* plant community at Fisher Butte. Superscripted letters indicate a significant difference (p = 0.1) between years within treatments.

| | CONTROL/NOBURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **Total Native** | 68.2 | 1.0 | 68.6 | 1.0 | 64.6 | 1.9 | 64.8 | 1.1 | 66.7 | 0.5 | 65.8 | 0.7 | 72.3 | 1.3 | 70.6 | 1.8 | 71.5 | 0.8 |
| **Total Exotic** | 31.8 | 1.0 | 31.4 | 1.0 | 35.4 | 1.9 | 35.2 | 1.2 | 33.3 | 0.5 | 34.2 | 0.7 | 27.7 | 1.3 | 29.4 | 1.8 | 28.5 | 0.8 |
| **By Life Forms:** | | | | | | | | | | | | | | | | | | |
| **Trees** | 0.2 | 0.2 | 0.4 | 0.1 | 0.3 | 0.2 | 0.4 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.5 | 0.1 | 0.3 | 0.1 | 0.4 | 0.1 |
| Native | 0.2 | 0.2 | 0.4 | 0.1 | 0.3 | 0.2 | 0.3 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.5 | 0.1 | 0.3 | 0.1 | 0.4 | 0.1 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Shrubs** | 0.6 | 0.2 | 1.1 | 0.2 | 1.0 | 0.5 | 0.7 | 0.3 | 1.0 | 0.0 | 1.1 | 0.1 | 2.2 | 0.0 | 2.9 | 0.2 | 2.3 | 0.1 |
| Native | 0.5 | 0.1 | 0.9 | 0.2 | 0.6 | 0.1 | 0.6 | 0.2 | 1.0 | 0.0 | 1.0 | 0.1 | 2.1 | 0.1 | 2.9 | 0.2 | 2.3 | 0.1 |
| Exotic | 0.1 | 0.1 | 0.2 | 0.1 | 0.4 | 0.4 | 0.1 | 0.1 | 0.0 | 0.0 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Graminoids** | $34.9^a$ | 2.6 | $32.2^a$ | 0.4 | $26.9^b$ | 0.8 | $36.6^a$ | 1.1 | $42.0^b$ | 0.6 | $29.5^a$ | 1.2 | $40.0^a$ | 1.2 | $42.5^b$ | 1.0 | $30.6^c$ | 0.5 |
| Total Native | 25.4 | 1.9 | 24.8 | 1.8 | 24.2 | 1.4 | $26.9^a$ | 2.4 | $30.5^b$ | 1.3 | $25.1^a$ | 0.3 | $30.3^a$ | 0.2 | $31.7^a$ | 1.5 | $26.2^b$ | 0.7 |
| Total Exotic | $9.5^a$ | 0.7 | $7.3^a$ | 1.5 | $2.8^b$ | 0.7 | $9.7^a$ | 1.6 | $11.5^b$ | 1.0 | $4.4^a$ | 1.5 | 9.7 | 1.3 | 10.8 | 0.5 | 4.4 | 1.0 |
| Perennials | $34.6^a$ | 2.7 | $31.8^a$ | 0.6 | $26.8^b$ | 0.9 | $36.3^a$ | 0.9 | $41.8^b$ | 0.7 | $28.9^c$ | 1.0 | $39.6^a$ | 1.3 | $42.0^b$ | 0.9 | $29.6^c$ | 0.6 |
| Native | 25.4 | 1.9 | 24.8 | 1.8 | 24.2 | 1.4 | $26.9^a$ | 2.4 | $30.5^b$ | 1.3 | $25.1^a$ | 0.3 | $30.3^a$ | 0.2 | $31.7^a$ | 1.5 | $26.2^b$ | 0.7 |
| Exotic | $9.2^a$ | 0.8 | $6.9^a$ | 1.2 | $2.7^b$ | 0.7 | $9.4^a$ | 1.7 | $11.3^a$ | 0.9 | $3.8^b$ | 1.3 | $9.3^a$ | 1.5 | $10.4^a$ | 0.7 | $30.4^b$ | 1.0 |
| Annuals | 0.3 | 0.2 | 0.4 | 0.3 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 | 0.6 | 0.2 | 0.4 | 0.2 | 0.5 | 0.2 | 1.0 | 0.1 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.3 | 0.2 | 0.4 | 0.3 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 | 0.6 | 0.2 | 0.4 | 0.2 | 0.5 | 0.2 | 1.0 | 0.1 |
| **Forbs** | $64.3^a$ | 2.5 | $66.4^a$ | 0.2 | $71.8^b$ | 0.7 | $62.3^a$ | 0.8 | $56.8^b$ | 0.5 | $69.3^a$ | 1.2 | $57.2^a$ | 1.1 | $54.4^b$ | 1.1 | $66.6^a$ | 0.6 |
| Total Native | 42.1 | 0.9 | 42.5 | 0.6 | 39.5 | 1.1 | 36.9 | 1.8 | 35.1 | 1.7 | 39.8 | 0.8 | $39.4^a$ | 1.1 | $35.8^b$ | 0.2 | $42.6^a$ | 0.3 |
| Total Exotic | $22.2^a$ | 1.7 | $23.9^a$ | 0.5 | $32.3^b$ | 0.9 | $25.3^a$ | 1.8 | $21.7^a$ | 1.3 | $29.6^b$ | 1.5 | $17.8^a$ | 0.1 | $18.5^a$ | 1.3 | $24.0^b$ | 0.3 |
| Perennials | 43.0 | 1.2 | 42.8 | 0.5 | 41.3 | 0.3 | 39.1 | 0.3 | 38.2 | 1.1 | 39.9 | 0.6 | 38.3 | 1.6 | 41.6 | 0.7 | 46.0 | 1.5 |
| Native | $28.0^a$ | 0.7 | $27.7^a$ | 0.7 | $25.0^b$ | 0.6 | 25.9 | 1.9 | 27.8 | 1.2 | 28.0 | 0.8 | 28.0 | 1.0 | 30.0 | 0.7 | 34.0 | 1.1 |
| Exotic | 14.9 | 0.7 | 15.1 | 0.1 | 16.3 | 0.5 | 13.3 | 1.6 | 10.3 | 0.3 | 11.9 | 0.1 | 10.3 | 0.6 | 11.5 | 0.4 | 12.1 | 0.6 |
| Annuals | $21.3^a$ | 1.3 | $23.6^a$ | 0.4 | $30.4^b$ | 0.6 | $23.1^a$ | 0.8 | $18.7^b$ | 0.7 | $29.5^a$ | 1.3 | $18.8^a$ | 0.8 | $12.8^b$ | 1.8 | $20.6^a$ | 1.8 |
| Native | 14.1 | 0.2 | 14.8 | 0.1 | 14.5 | 0.8 | $11.1^a$ | 0.5 | $7.3^b$ | 0.5 | 11.8 | 0.1 | $11.3^a$ | 0.4 | $5.8^b$ | 0.6 | $8.6^c$ | 1.3 |
| Exotic | $7.2^a$ | 1.1 | $8.7^a$ | 0.4 | $16.0^b$ | 0.5 | $12.1^a$ | 0.3 | $11.4^b$ | 1.2 | $17.7^c$ | 1.4 | $7.5^a$ | 0.6 | $7.0^a$ | 1.4 | $12.0^b$ | 0.6 |

Table 4.21. Summary of species relative percent frequency by life form, lifespan, and origin for the *Rosa/Juncus* plant community at Fisher Butte. Superscripted letters indicate a significant difference ($p = 0.1$) between years within treatments.

| | CONTROL/NOBURN | | | | | | ONCEBURNED | | | | | | TWICEBURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| **Total Native** | 86.5 | 0.8 | 86.2 | 0.5 | 84.6 | 1.1 | 87.8 | 1.4 | 84.6 | 0.8 | 87.1 | 0.6 | 94.5 | 1.7 | 91.0 | 1.7 | 89.2 | 1.3 |
| **Total Exotic** | 13.5 | 0.8 | 13.8 | 0.5 | 15.4 | 1.0 | 12.2 | 1.4 | 15.4 | 0.8 | 12.9 | 0.6 | 5.5 | 1.7 | 9.0 | 1.7 | 10.8 | 1.3 |
| **By Life Forms:** | | | | | | | | | | | | | | | | | | |
| **Trees** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.1 | 0.4 | 0.1 | 0.1 | 0.1 | 0.1 | $0.4^{a}$ | 0.0 | $0.1^{b}$ | 0.1 | $0.1^{b}$ | 0.1 |
| Native | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | $1.1^{a}$ | 0.4 | $0.1^{b}$ | 0.1 | $0.0^{b}$ | 0.0 | $0.4^{a}$ | 0.0 | $0.1^{b}$ | 0.1 | $0.1^{b}$ | 0.1 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Shrubs** | 2.6 | 1.1 | 2.5 | 0.9 | 2.5 | 0.7 | 9.4 | 0.2 | 11.0 | 0.8 | 7.9 | 0.2 | 8.5 | 1.5 | 8.5 | 1.4 | 7.2 | 1.2 |
| Native | 2.6 | 1.1 | 2.4 | 0.9 | 2.3 | 0.6 | 9.2 | 0.1 | 10.4 | 0.6 | 7.6 | 0.2 | 8.5 | 1.5 | 8.5 | 1.4 | 7.2 | 1.2 |
| Exotic | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.1 | $0.1^{a}$ | 0.1 | 0.7 | 0.4 | $0.4^{b}$ | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Graminoids** | 48.0 | 1.7 | 46.8 | 2.2 | 39.8 | 3.7 | $44.3^{a}$ | 0.9 | $47.0^{a}$ | 2.1 | $33.7^{b}$ | 0.7 | $40.3^{a}$ | 2.3 | $39.5^{a}$ | 1.3 | $32.4^{b}$ | 1.8 |
| Total Native | 45.0 | 1.7 | 45.4 | 1.9 | 39.4 | 3.9 | $41.2^{a}$ | 0.5 | $42.6^{a}$ | 1.3 | $33.0^{b}$ | 0.5 | $37.7^{a}$ | 1.5 | $36.4^{a}$ | 1.6 | $30.3^{b}$ | 1.1 |
| Total Exotic | $3.0^{a}$ | 0.1 | $1.4^{b}$ | 0.3 | $0.4^{c}$ | 0.2 | 3.1 | 0.8 | 4.3 | 0.9 | 0.7 | 0.3 | 2.7 | 1.6 | 3.1 | 1.1 | 2.1 | 1.4 |
| Perennials | 47.5 | 1.8 | 46.5 | 2.0 | 39.5 | 3.8 | $42.6^{a}$ | 1.1 | $44.7^{a}$ | 1.9 | $32.5^{b}$ | 0.2 | $39.5^{a}$ | 1.9 | $36.8^{a}$ | 1.2 | $29.7^{b}$ | 0.8 |
| Native | 44.7 | 1.9 | 45.3 | 1.8 | 39.4 | 3.9 | $40.2^{a}$ | 1.0 | $41.2^{a}$ | 1.2 | $32.5^{b}$ | 0.2 | $37.7^{a}$ | 1.5 | $34.5^{a}$ | 1.7 | $29.2^{b}$ | 0.6 |
| Exotic | $2.8^{a}$ | 0.1 | $1.2^{b}$ | 0.1 | $0.1^{c}$ | 0.1 | $2.4^{a}$ | 0.5 | $3.5^{a}$ | 0.7 | $0.0^{b}$ | 0.0 | 1.8 | 1.0 | 2.3 | 0.6 | 0.6 | 0.4 |
| Annuals | 0.6 | 0.1 | 0.3 | 0.2 | 0.3 | 0.1 | 1.7 | 0.9 | 2.3 | 0.8 | 1.2 | 0.5 | 0.8 | 0.6 | 2.7 | 1.0 | 2.6 | 1.1 |
| Native | 0.3 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 1.0 | 0.6 | 1.5 | 0.6 | 0.5 | 0.3 | 0.0 | 0.0 | 1.9 | 0.6 | 1.1 | 0.5 |
| Exotic | 0.2 | 0.1 | 0.2 | 0.2 | 0.3 | 0.1 | 0.7 | 0.4 | 0.8 | 0.3 | 0.7 | 0.3 | 0.8 | 0.6 | 0.8 | 0.5 | 1.5 | 1.0 |
| **Forbs** | 49.3 | 2.7 | 50.7 | 2.5 | 57.6 | 3.7 | $45.3^{a}$ | 1.1 | $41.9^{a}$ | 2.9 | $58.3^{b}$ | 0.8 | $50.8^{a}$ | 2.0 | $51.9^{a}$ | 1.7 | $60.3^{b}$ | 1.3 |
| Total Native | 38.9 | 2.9 | 38.3 | 2.1 | 42.8 | 3.1 | $36.3^{a}$ | 1.6 | $31.5^{a}$ | 2.6 | $46.6^{b}$ | 1.3 | $48.0^{a}$ | 1.5 | $46.0^{a}$ | 1.0 | $51.6^{b}$ | 0.4 |
| Total Exotic | $10.4^{a}$ | 0.9 | $12.3^{a}$ | 0.7 | $14.9^{b}$ | 0.8 | 9.0 | 0.7 | 10.4 | 0.3 | 11.7 | 0.5 | $2.8^{a}$ | 0.6 | 5.9 | 0.7 | $8.8^{b}$ | 1.1 |
| Perennials | 32.6 | 1.7 | 27.8 | 2.5 | 33.1 | 1.9 | 26.2 | 0.6 | 26.7 | 0.1 | 31.5 | 0.9 | $24.0^{a}$ | 2.1 | $26.9^{a}$ | 0.1 | $34.6^{b}$ | 2.1 |
| Native | 24.9 | 2.6 | 19.9 | 2.5 | 22.6 | 2.2 | 17.7 | 0.2 | 17.0 | 0.3 | 22.4 | 1.4 | $21.7^{a}$ | 1.6 | $21.8^{a}$ | 0.5 | $27.4^{b}$ | 2.0 |
| Exotic | 7.7 | 1.5 | $7.9^{a}$ | 0.1 | $10.5^{b}$ | 0.4 | 8.5 | 0.4 | 9.6 | 0.3 | 9.1 | 0.5 | $2.3^{a}$ | 0.4 | $5.1^{b}$ | 0.5 | $7.2^{c}$ | 0.4 |
| Annuals | $16.6^{a}$ | 0.9 | $22.9^{b}$ | 0.4 | $24.6^{b}$ | 1.9 | $19.1^{a}$ | 1.6 | $15.2^{a}$ | 3.0 | $26.8^{b}$ | 1.4 | 26.8 | 0.0 | 25.0 | 1.8 | 25.7 | 2.5 |
| Native | $14.0^{a}$ | 0.9 | $18.4^{b}$ | 0.4 | $20.2^{b}$ | 1.1 | 18.7 | 1.9 | $14.4^{a}$ | 2.9 | $24.2^{b}$ | 1.7 | 26.2 | 0.2 | 24.2 | 1.5 | 24.1 | 2.4 |
| Exotic | 2.7 | 0.6 | 4.4 | 0.6 | 4.4 | 1.1 | 0.4 | 0.3 | 0.8 | 0.1 | 2.6 | 0.3 | 0.5 | 0.2 | 0.8 | 0.4 | 1.6 | 0.7 |

while native forbs increased significantly between 1989 and 1990. Between 1989 and 1990, exotic perennial forbs increased significantly from 8 to 11% in unburned controls and from 5 to 7% in twice burned treatments.

## Fire effects on cover of plant forms, lifespans and origins

### Rose Prairie

#### RP *Deschampsia* plant community

From 1988 to 1990, total plant cover increased in all three treatments but was only significantly higher in the two burn treatments (Table 4.22). Significant cover increases were more common in exotic species than native species. Following the first burn in twice burned treatments, cover of native perennial graminoids significantly decreased from 18 to 13% in 1989. Native perennial graminoid cover then returned to preburn cover levels in 1990. A similar trend of decline and then increase in successive years was also noted for once burned treatments, although changes were not significant. Cover of exotic perennial graminoids tripled in the control and both fire treatments, from ~5 to 11%.

Table 4.22. Summary of species percent cover by life form, life span, and origin for the *Deschampsia* plant community at Rose Prairie. Superscripted letters indicate a significant difference ($p = 0.1$) between years within treatments.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| Total Plant Cover | 14.2 | 2.1 | 15.1 | 0.7 | 20.4 | 1.8 | $23.1^{a}$ | 2.6 | $20.6^{a}$ | 1.6 | $30.7^{b}$ | 2.0 | $18.2^{a}$ | 0.5 | $13.3^{b}$ | 0.3 | $25.9^{c}$ | 0.8 |
| Native | 10.6 | 1.0 | 8.2 | 0.5 | 9.2 | 0.2 | 18.4 | 3.2 | 13.0 | 1.6 | 19.5 | 2.1 | $13.0^{a}$ | 1.1 | $7.4^{b}$ | 0.3 | $14.5^{a}$ | 0.8 |
| Exotic | $3.6^{a}$ | 1.2 | 6.9 | 1.1 | $11.2^{b}$ | 1.8 | $4.7^{a}$ | 1.4 | $7.6^{a}$ | 0.4 | $11.2^{b}$ | 0.2 | $5.2^{a}$ | 0.6 | $5.9^{a}$ | 0.3 | $11.4^{b}$ | 0.7 |
| By Life Forms: | | | | | | | | | | | | | | | | | | |
| Trees | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Shrubs | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| Native | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Graminoids | 13.9 | 1.8 | 14.8 | 0.8 | 20.0 | 1.7 | 23.0 | 2.6 | $20.5^{a}$ | 1.6 | $29.7^{b}$ | 1.6 | $18.1^{a}$ | 0.6 | $13.2^{b}$ | 0.4 | $25.6^{c}$ | 0.8 |
| Total Native | 10.3 | 0.8 | 7.9 | 0.7 | 8.8 | 0.3 | 18.3 | 3.3 | 12.9 | 1.6 | 18.5 | 1.7 | $12.9^{a}$ | 1.1 | $7.3^{b}$ | 0.4 | $14.3^{a}$ | 0.7 |
| Total Exotic | $3.6^{a}$ | 1.2 | 6.9 | 1.1 | $11.2^{b}$ | 1.8 | $4.7^{a}$ | 1.4 | $7.6^{a}$ | 0.4 | $11.2^{b}$ | 0.2 | $5.2^{a}$ | 0.6 | $5.8^{a}$ | 0.3 | $11.3^{b}$ | 0.7 |
| Perennials | 13.9 | 1.8 | 14.8 | 0.8 | 20.0 | 1.7 | 23.0 | 2.6 | $20.5^{a}$ | 1.6 | $29.7^{b}$ | $1.6^{a}$ | $18.0^{a}$ | 0.7 | $13.1^{b}$ | 0.4 | $25.6^{c}$ | 0.8 |
| Native | 10.3 | 0.8 | 7.9 | 0.7 | 8.8 | 0.3 | 18.3 | 3.3 | 12.9 | 1.6 | 18.5 | 1.7 | $12.9^{a}$ | 1.1 | $7.3^{b}$ | 0.4 | $14.3^{a}$ | 0.7 |
| Exotic | $3.6^{a}$ | 1.2 | 6.9 | 1.1 | $11.2^{b}$ | 1.8 | $4.7^{a}$ | 1.4 | $7.5^{a}$ | 0.4 | $11.2^{b}$ | 0.2 | $5.2^{a}$ | 0.6 | $5.8^{a}$ | 0.3 | $11.3^{b}$ | 0.7 |
| Annuals | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Forbs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| Total Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| Perennials | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| Annuals | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

### *Rosa/Anthoxanthum* plant community

Cover of native species in the *Rosa/Anthoxanthum* community did not change significantly between years with any of the three treatments (Table 4.23). However, exotic perennial forb cover increased significantly from 5 to 20% in twice burned treatments between 1988 and 1990.

### *Vaccinium* plant community

In the *Vaccinium* community, cover of native species increased significant from 22 to 38% in once burned treatments between 1989 and 1990; cover of exotics increased from 4 to 8% in both control and twice burned treatments (Table 4.24). Cover of native shrubs, primarily *V. caespitosum*, increased significantly from 14 to 25% the second postfire growth year following the 1988 burn. In once burned treatments, cover of graminoids increased from 14 to 23% between 1988 and 1990. This increase was due primarily to native perennial graminoids, although exotic perennial graminoids also increased. Cover of exotic perennial graminoids also increased significantly between 1988 and 1990 in control and twice burned treatments.

Table 4.23. Summary of species percent cover by life form, life span, and origin for the *Rosa/Anthoxanthum* plant community at Rose Prairie. Superscripted letters indicate a significant difference (p = 0.1) between years within treatments.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| Total Plant Cover | 64.1 | 19.6 | 53.1 | 4.4 | 51.4 | 0.7 | 54.3 | 12.9 | 50.8 | 3.0 | 65.2 | 1.5 | 58.9 | 8.2 | 59.3 | 5.1 | 62.5 | 6.7 |
| Native | 15.2 | 3.9 | 9.8 | 2.0 | 13.5 | 1.4 | 13.6 | 3.2 | 13.4 | 3.7 | 13.6 | 2.3 | 7.8 | 3.0 | 6.5 | 0.1 | 6.7 | 0.2 |
| Exotic | 48.9 | 17.2 | 43.3 | 2.4 | 37.9 | 1.1 | 40.6 | 9.7 | 37.4 | 3.9 | 51.6 | 0.9 | 51.1 | 5.7 | 52.9 | 5.0 | 55.8 | 6.6 |
| By Life Forms: | | | | | | | | | | | | | | | | | | |
| Trees | 0.0 | 0.0 | 0.4 | 0.4 | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | $0.0^a$ | 0.0 | $0.0^a$ | 0.0 | $0.0^b$ | 0.0 |
| Native | 0.0 | 0.0 | 0.4 | 0.4 | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | $0.0^a$ | 0.0 | $0.0^a$ | 0.0 | $0.0^b$ | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Shrubs | 14.2 | 4.8 | 7.7 | 3.1 | 11.0 | 3.5 | 11.0 | 2.2 | 9.2 | 1.1 | 9.4 | 0.7 | 7.5 | 3.0 | 7.1 | 1.4 | 6.2 | 0.7 |
| Native | 14.2 | 4.8 | 7.6 | 3.2 | 10.7 | 3.6 | 11.0 | 2.2 | 8.9 | 1.4 | 9.2 | 0.4 | 7.5 | 3.0 | 5.8 | 0.3 | 5.7 | 0.3 |
| Exotic | 0.0 | 0.0 | 0.1 | 0.1 | 0.3 | 0.2 | 0.0 | 0.0 | 0.3 | 0.3 | 0.2 | 0.2 | 0.0 | 0.0 | 1.3 | 1.3 | 0.4 | 0.4 |
| Graminoids | 44.9 | 17.2 | 41.6 | 2.2 | 37.4 | 3.1 | 34.3 | 8.3 | 24.8 | 0.6 | 40.3 | 4.3 | 46.1 | 5.2 | 38.1 | 3.5 | 33.2 | 6.4 |
| Total Native | 1.0 | 0.9 | 1.8 | 1.7 | 2.4 | 2.4 | 0.9 | 0.6 | 1.0 | 0.6 | 1.4 | 0.6 | 0.3 | 0.1 | 0.7 | 0.2 | 1.0 | 0.4 |
| Total Exotic | 43.9 | 17.1 | 39.9 | 2.7 | 35.0 | 0.8 | 33.4 | 8.2 | 23.8 | 0.7 | 38.9 | 4.2 | 45.8 | 5.2 | 37.4 | 3.5 | 32.2 | 6.4 |
| Perennials | 44.9 | 17.2 | 41.6 | 2.2 | 37.4 | 3.1 | 34.3 | 8.3 | 24.8 | 0.6 | 40.3 | 4.3 | 46.1 | 5.2 | 38.1 | 3.5 | 33.2 | 6.4 |
| Native | 1.0 | 0.9 | 1.8 | 1.7 | 2.4 | 2.4 | 0.9 | 0.6 | 1.0 | 0.6 | 1.4 | 0.6 | 0.3 | 0.1 | 0.7 | 0.2 | 1.0 | 0.4 |
| Exotic | 43.9 | 17.1 | 39.9 | 2.7 | 35.0 | 0.8 | 33.4 | 8.2 | 23.8 | 0.7 | 38.9 | 4.2 | 45.8 | 5.2 | 37.4 | 3.5 | 32.2 | 6.4 |
| Annuals | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Forbs | 5.0 | 1.5 | 3.3 | 1.0 | 2.7 | 0.4 | 8.9 | 2.5 | 16.8 | 4.2 | 15.5 | 5.8 | $5.3^a$ | 1.0 | $14.1^b$ | 3.2 | $23.1^b$ | 2.3 |
| Total Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 1.7 | 3.5 | 3.5 | 3.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Exotic | 5.0 | 1.5 | 3.3 | 1.0 | 2.7 | 0.4 | 7.2 | 2.2 | 13.3 | 4.2 | 12.5 | 3.6 | $5.3^a$ | 1.0 | $14.1^b$ | 3.2 | $23.1^b$ | 2.3 |
| Perennials | 5.0 | 1.5 | 3.3 | 1.0 | 2.7 | 0.4 | 8.4 | 2.3 | 14.8 | 3.6 | 11.9 | 3.3 | $5.2^a$ | 0.9 | $13.2^b$ | 2.2 | $19.6^b$ | 1.9 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 1.2 | 2.2 | 2.2 | 2.7 | 2.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 5.0 | 1.5 | 3.3 | 1.0 | 2.7 | 0.4 | 7.1 | 2.2 | 12.5 | 4.0 | 9.2 | 2.7 | $5.2^a$ | 0.9 | $13.2^b$ | 2.2 | $19.6^b$ | 1.9 |
| Annuals | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.5 | 2.0 | 1.5 | 3.6 | 2.9 | 0.1 | 0.1 | 1.0 | 1.0 | 3.5 | 3.5 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 1.2 | 1.2 | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.8 | 0.4 | 3.4 | 2.7 | 0.1 | 0.1 | 1.0 | 1.0 | 3.5 | 3.5 |

Table 4.24. Summary of species percent cover by life form, life span, and origin for the *Vaccinium* plant community at Rose Prairie. Superscripted letters indicate a significant difference (p = 0.1) between years within treatments.

| | CONTROL/NO BURN | | | | | | ONCE BURNED | | | | | | TWICE BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| Total Plant Cover | 34.3 | 3.4 | 35.7 | 6.3 | 45.3 | 9.0 | 32.9 | 4.4 | $28.1^a$ | 0.4 | $47.6^b$ | 4.7 | 25.7 | 2.6 | 21.3 | 2.4 | 32.8 | 4.2 |
| Native | 30.3 | 3.3 | 31.1 | 5.9 | 37.4 | 8.0 | 28.7 | 4.5 | $22.2^a$ | 1.1 | $38.0^b$ | 2.7 | 22.4 | 2.6 | 16.1 | 2.2 | 24.8 | 3.8 |
| Exotic | $3.9^a$ | 0.2 | 4.6 | 0.4 | $7.8^b$ | 1.7 | 4.3 | 0.8 | 5.9 | 1.3 | 9.6 | 2.0 | $3.4^a$ | 0.4 | 5.3 | 1.2 | $8.1^b$ | 0.9 |
| By Life Forms: | | | | | | | | | | | | | | | | | | |
| Trees | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.1 | 0.1 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.1 | 0.1 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Shrubs | 14.3 | 1.7 | 14.9 | 3.9 | 20.4 | 6.2 | 19.0 | 3.8 | $14.4^a$ | 1.6 | $25.0^b$ | 2.2 | 9.7 | 4.2 | 8.3 | 3.5 | 14.1 | 5.8 |
| Native | 14.3 | 1.7 | 14.9 | 3.9 | 20.4 | 6.2 | 19.0 | 3.8 | $14.4^a$ | 1.6 | $25.0^b$ | 2.2 | 9.7 | 4.2 | 8.3 | 3.5 | 14.1 | 5.8 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Graminoids | 15.0 | 2.3 | 15.7 | 1.5 | 20.1 | 3.4 | $14.0^a$ | 1.7 | $13.7^a$ | 1.6 | $22.6^b$ | 3.6 | 15.5 | 1.8 | 12.8 | 2.0 | 18.6 | 2.2 |
| Total Native | 11.1 | 2.5 | 11.1 | 1.0 | 12.3 | 1.8 | 9.7 | 1.2 | $7.8^a$ | 0.8 | $13.0^b$ | 1.9 | 12.1 | 1.6 | 7.6 | 1.3 | 10.5 | 2.1 |
| Total Exotic | $3.9^a$ | 0.2 | 4.6 | 0.4 | $7.8^b$ | 1.7 | 4.3 | 0.8 | 5.9 | 1.3 | 9.6 | 2.0 | $3.4^a$ | 0.4 | 5.3 | 1.2 | $8.1^b$ | 0.9 |
| Perennials | 15.0 | 2.3 | 15.7 | 1.5 | 20.1 | 3.4 | $13.8^a$ | 1.8 | $13.6^a$ | 1.5 | $22.6^b$ | 3.6 | 15.5 | 1.8 | 12.8 | 2.0 | 18.6 | 2.2 |
| Native | 11.1 | 2.5 | 11.1 | 1.0 | 12.3 | 1.8 | 9.7 | 1.2 | $7.8^a$ | 0.8 | $13.0^b$ | 1.9 | 12.1 | 1.6 | 7.6 | 1.3 | 10.5 | 2.1 |
| Exotic | $3.9^a$ | 0.2 | 4.6 | 0.4 | $7.8^b$ | 1.7 | 4.1 | 0.9 | 5.8 | 1.3 | 9.6 | 2.0 | $3.4^a$ | 0.4 | 5.3 | 1.2 | $8.0^b$ | 0.9 |
| Annuals | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Forbs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Perennials | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Annuals | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

## Fisher Butte

### FB *Deschampsia* plant community

In the *Deschampsia* community, total plant cover was similar from 1988 to 1990 in control treatments, while total cover in burn treatments declined significantly between 1988 and 1989 and increase significantly from 1989 and 1990 (Table 4.25). Most of these changes were due to decreases or increases in native perennial graminoid cover. Cover of native perennial forbs significantly increased the first post fire growth year after a single burn, but their cover declined following a second burn.

Total exotic plant cover significantly increased from 5 to 21% in once burned and from 3 to 10% in twice burned treatments between 1988 and 1990. Changes in exotic cover were attributed to increases in both perennial graminoids and forbs.

### *Rosa/Juncus* plant community

In the *Rosa/Juncus* community, total and native plant cover did not change significantly in any treatments from 1988 to 1990. However, cover of total exotic plants increased significantly from 3 to 15% in once burned and from <1 to 8% in twice burned treatments (Table 4.26). Cover of shrubs increased significantly in burn treatments between 1988 and 1989. In contrast to results for other plant

Table 4.25. Summary of species percent cover by life form, life span, and origin for the *Deschampsia* community at Fisher Butte. Superscripted letters indicate a significant difference (p = 0.1) between years within treatments

| | CONTROL/NO BURN | | | | | | ONCE-BURNED | | | | | | TWICE-BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| Total Plant Cover | 30.6 | 0.5 | 29.2 | 1.8 | 28.9 | 1.5 | 28.7$^{a}$ | 1.9 | 20.6$^{b}$ | 0.3 | 43.9$^{c}$ | 2.4 | 32.4 | 1.9 | 28.8$^{a}$ | 2.8 | 36.7$^{b}$ | 1.5 |
| Native | 28.5 | 0.2 | 26.6 | 1.2 | 25.3 | 1.5 | 23.7$^{a}$ | 2.2 | 11.1$^{b}$ | 1.1 | 22.5$^{a}$ | 0.4 | 29.9$^{a}$ | 1.7 | 23.8$^{b}$ | 2.5 | 26.5$^{b}$ | 1.9 |
| Exotic | 2.1 | 0.3 | 2.6 | 0.6 | 3.6 | 0.1 | 5.0$^{a}$ | 0.4 | 9.5$^{b}$ | 1.1 | 21.4$^{c}$ | 2.1 | 2.5$^{a}$ | 0.2 | 4.9$^{a}$ | 1.1 | 10.2$^{b}$ | 2.6 |
| By Life Forms: | | | | | | | | | | | | | | | | | | |
| Trees | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Shrubs | 0.7 | 0.2 | 1.0 | 0.3 | 0.4 | 0.1 | 0.3 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3$^{a}$ | 0.3 | 3.7$^{b}$ | 0.5 | 2.6$^{a}$ | 0.2 |
| Native | 0.7 | 0.2 | 1.0 | 0.3 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3$^{a}$ | 0.3 | 3.7$^{b}$ | 0.5 | 2.6$^{a}$ | 0.2 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Graminoids | 23.6 | 2.2 | 22.8 | 1.4 | 23.7 | 1.9 | 24.6$^{a}$ | 2.4 | 16.9$^{b}$ | 0.9 | 38.6$^{c}$ | 2.4 | 27.0$^{a}$ | 1.5 | 17.5$^{b}$ | 1.8 | 29.6$^{a}$ | 1.9 |
| Total Native | 21.8 | 2.0 | 20.4 | 1.0 | 20.6 | 1.8 | 20.5$^{a}$ | 2.8 | 7.5$^{b}$ | 0.5 | 18.4$^{a}$ | 1.2 | 24.6$^{a}$ | 1.3 | 12.5$^{b}$ | 1.2 | 19.8$^{c}$ | 1.6 |
| Total Exotic | 1.8 | 0.3 | 2.4 | 0.5 | 3.1 | 0.1 | 4.1$^{a}$ | 0.4 | 9.4$^{b}$ | 1.1 | 20.2$^{c}$ | 2.2 | 2.4$^{a}$ | 0.2 | 4.9$^{a}$ | 1.1 | 9.8$^{b}$ | 2.6 |
| Perennials | 23.6 | 2.2 | 22.8 | 1.4 | 23.7 | 1.9 | 24.6$^{a}$ | 2.4 | 16.7$^{b}$ | 0.9 | 38.6$^{a}$ | 2.4 | 27.0$^{a}$ | 1.5 | 17.5$^{b}$ | 1.8 | 29.6$^{a}$ | 1.9 |
| Native | 21.8 | 2.0 | 20.4 | 1.0 | 20.6 | 1.8 | 20.5$^{a}$ | 2.8 | 7.5$^{b}$ | 0.5 | 18.4$^{a}$ | 1.2 | 24.6$^{a}$ | 1.3 | 12.5$^{b}$ | 1.2 | 19.8$^{c}$ | 1.6 |
| Exotic | 1.8 | 0.3 | 2.4 | 0.5 | 3.1 | 0.1 | 4.1$^{a}$ | 0.4 | 9.2 | 1.1 | 20.2$^{b}$ | 2.2 | 2.4$^{a}$ | 0.2 | 4.9 | 1.1 | 9.8$^{b}$ | 2.6 |
| Annuals | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Forbs | 6.3 | 1.7 | 5.4 | 0.7 | 4.8 | 0.5 | 3.5 | 0.3 | 3.8 | 1.0 | 5.2 | 0.7 | 4.1 | 0.4 | 7.6 | 1.1 | 4.5 | 0.4 |
| Total Native | 6.0 | 1.7 | 5.1 | 0.5 | 4.3 | 0.5 | 2.8 | 0.4 | 3.6 | 1.0 | 4.1 | 1.0 | 4.1 | 0.4 | 7.6 | 1.2 | 4.1 | 0.4 |
| Total Exotic | 0.3 | 0.0 | 0.3 | 0.2 | 0.5 | 0.1 | 0.6$^{a}$ | 0.1 | 0.1$^{b}$ | 0.1 | 1.1$^{c}$ | 0.3 | 0.1$^{a}$ | 0.0 | 0.0 | 0.0 | 0.4$^{b}$ | 0.1 |
| Perennials | 4.6 | 1.6 | 3.5 | 0.1 | 3.1 | 0.3 | 1.6 | 0.5 | 3.4 | 0.9 | 2.7 | 0.8 | 3.1$^{a}$ | 0.2 | 7.6$^{b}$ | 1.1 | 4.0$^{b}$ | 0.5 |
| Native | 4.5 | 1.6 | 3.4 | 0.1 | 2.9 | 0.3 | 1.4 | 0.5 | 3.2 | 0.9 | 2.5 | 0.8 | 3.1$^{a}$ | 0.2 | 7.6$^{b}$ | 1.2 | 3.9 | 0.5 |
| Exotic | 0.1$^{a}$ | 0.0 | 0.1$^{a}$ | 0.0 | 0.2$^{b}$ | 0.0 | 0.2 | 0.0 | 0.1 | 0.1 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1$^{b}$ | 0.1 |
| Annuals | 1.7 | 0.1 | 1.9 | 0.8 | 1.7 | 0.3 | 1.8$^{a}$ | 0.2 | 0.4$^{b}$ | 0.1 | 2.5$^{c}$ | 0.2 | 1.0$^{a}$ | 0.2 | 0.0 | 0.0 | 0.5$^{a}$ | 0.1 |
| Native | 1.5 | 0.1 | 1.7 | 0.7 | 1.4 | 0.2 | 1.4 | 0.1 | 0.4 | 0.1 | 1.6 | 0.2 | 1.0$^{a}$ | 0.2 | 0.0 | 0.0 | 0.2$^{b}$ | 0.1 |
| Exotic | 0.2 | 0.0 | 0.2 | 0.2 | 0.3 | 0.1 | 0.5$^{a}$ | 0.1 | 0.0 | 0.0 | 1.0$^{c}$ | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3$^{c}$ | 0.1 |

Table 4.26. Summary of species percent cover by life form, life span, and origin for the *Rosa/Juncus* plant community at Fisher Butte. Superscripted letters indicate a significant difference (p = 0.1) between years within treatments.

| | CONTROL/NO BURN | | | | | | ONCE-BURNED | | | | | | TWICE-BURNED | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | | 1988 | | 1989 | | 1990 | |
| | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE | MEAN | SE |
| Total Plant Cover | 29.5 | 2.3 | 31.1 | 0.9 | 37.7 | 3.8 | 32.9 | 1.4 | 33.0 | 2.3 | 44.4 | 2.2 | 44.4 | 1.9 | 40.4 | 1.8 | 47.9 | 1.1 |
| Native | 26.9 | 1.8 | 26.9 | 0.6 | 31.1 | 2.1 | 30.3 | 1.0 | 29.6 | 1.3 | 29.4 | 2.2 | 44.1 | 2.0 | 39.3 | 1.8 | 40.3 | 1.4 |
| Exotic | 2.6 | 0.6 | 4.3 | 1.3 | 6.6 | 1.7 | $2.6^{a}$ | 0.7 | $3.5^{a}$ | 1.0 | $15.1^{b}$ | 3.8 | $0.4^{a}$ | 0.2 | $1.1^{b}$ | 0.4 | $7.6^{c}$ | 0.4 |
| By Life Forms: | | | | | | | | | | | | | | | | | | |
| Trees | 0.6 | 0.6 | 0.4 | 0.4 | 0.6 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Native | 0.6 | 0.6 | 0.4 | 0.4 | 0.6 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Shrubs | 1.7 | 0.2 | 1.6 | 0.3 | 1.4 | 0.3 | $2.6^{a}$ | 0.3 | $11.3^{b}$ | 1.6 | $11.5^{b}$ | 0.6 | $4.2^{a}$ | 0.4 | $12.2^{b}$ | 2.2 | $8.6^{b}$ | 1.0 |
| Native | 1.7 | 0.2 | 1.6 | 0.3 | 1.4 | 0.3 | $2.6^{a}$ | 0.3 | $11.3^{b}$ | 1.6 | $11.5^{b}$ | 0.6 | $4.2^{a}$ | 0.4 | $12.2^{b}$ | 2.2 | $8.6^{b}$ | 1.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Graminoids | 24.1 | 2.2 | 21.4 | 0.3 | 18.7 | 1.7 | 25.6 | 0.7 | 19.2 | 1.1 | 27.3 | 2.4 | 22.2 | 3.3 | 18.3 | 3.4 | 27.5 | 2.1 |
| Total Native | 23.8 | 2.3 | 21.2 | 0.4 | 18.4 | 1.9 | $24.7^{a}$ | 1.0 | $16.1^{b}$ | 0.9 | $14.5^{c}$ | 1.8 | 22.1 | 3.4 | 17.3 | 3.8 | 20.1 | 1.8 |
| Total Exotic | 0.3 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | $0.9^{a}$ | 0.4 | $3.1^{a}$ | 1.0 | $12.8^{b}$ | 4.2 | $0.2^{a}$ | 0.1 | 1.0 | 0.3 | $7.4^{b}$ | 0.6 |
| Perennials | 24.1 | 2.2 | 21.4 | 0.3 | 18.7 | 1.7 | 25.6 | 0.7 | 19.2 | 1.1 | 27.3 | 2.4 | 22.2 | 3.3 | 18.0 | 3.4 | 27.3 | 2.1 |
| Native | 23.8 | 2.3 | 21.2 | 0.4 | 18.4 | 1.9 | $24.7^{a}$ | 1.0 | $16.1^{b}$ | 0.9 | $14.5^{c}$ | 1.8 | 22.1 | 3.4 | 17.0 | 3.8 | 20.1 | 1.8 |
| Exotic | 0.3 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.9 | 0.4 | 3.1 | 1.0 | 12.8 | 4.2 | 0.2 | 0.1 | 1.0 | 0.3 | 7.3 | 0.5 |
| Annuals | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.2 | 0.1 | 0.1 |
| Native | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.2 | 0.0 | 0.0 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| Forbs | $3.2^{a}$ | 1.1 | $7.8^{b}$ | 1.5 | $17.0^{b}$ | 3.9 | 4.7 | 0.8 | 2.6 | 0.8 | 5.6 | 1.2 | 18.0 | 1.8 | 9.9 | 1.7 | 11.9 | 1.5 |
| Total Native | $0.9^{a}$ | 0.3 | $3.6^{b}$ | 0.4 | $10.6^{c}$ | 2.0 | 3.0 | 0.5 | 2.2 | 0.7 | 3.4 | 0.8 | 17.8 | 1.8 | 9.7 | 1.6 | 11.6 | 1.5 |
| Total Exotic | 2.3 | 0.8 | 4.1 | 1.3 | 6.3 | 2.0 | 1.7 | 0.3 | 0.4 | 0.2 | 2.3 | 0.4 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.2 |
| Perennials | 2.4 | 0.7 | 4.3 | 1.2 | 6.5 | 1.9 | 3.9 | 0.9 | 2.4 | 0.8 | 5.1 | 1.0 | 15.2 | 1.3 | 8.1 | 1.3 | 11.6 | 1.5 |
| Native | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 2.2 | 0.6 | 2.0 | 0.7 | 2.9 | 0.7 | 15.0 | 1.3 | 7.9 | 1.3 | 11.4 | 1.5 |
| Exotic | 2.3 | 0.8 | 4.1 | 1.3 | 6.3 | 2.0 | 1.7 | 0.3 | 0.4 | 0.2 | 2.3 | 0.4 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.2 |
| Annuals | $0.8^{a}$ | 0.4 | $3.5^{b}$ | 0.4 | $10.5^{c}$ | 2.1 | $0.8^{a}$ | 0.1 | $0.2^{b}$ | 0.1 | $0.5^{c}$ | 0.2 | $2.8^{a}$ | 0.6 | $1.8^{a}$ | 0.6 | $0.3^{b}$ | 0.1 |
| Native | $0.8^{a}$ | 0.4 | $3.5^{b}$ | 0.4 | $10.5^{c}$ | 2.1 | $0.8^{a}$ | 0.1 | $0.2^{b}$ | 0.1 | $0.5^{c}$ | 0.2 | $2.8^{a}$ | 0.6 | $1.8^{a}$ | 0.6 | $0.3^{b}$ | 0.1 |
| Exotic | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

communities, native perennial graminoid cover declined in both the first and second post fire years after a single burn. Cover of exotic perennial graminoids increased significantly from <1 to 7% between 1988 and 1990 in twice burned treatments. Cover of native annuals increased significantly from <1 to 11% in controls and decreased significantly from 3 to <1% in twice burned treatments.

## Fire effects on species richness, diversity, and equitability

Species richness and diversity significantly increased over time within the control treatment in the *Vaccinium* community and within one or both burn treatments in all communities (Table 4.27). The only significant change in species equitability occurred in once burned treatments in the *Rosa/Juncus* community at Fisher Butte where equitability increased between 1989 and 1990.

In the RP *Deschampsia* community, species richness and diversity increased significantly in burn treatments between 1988 and 1989 (Table 4.28). During 1990, species richness and diversity values remained comparable to 1989 values in once burned treatments but increased significantly in twice burned treatments. In the *Rosa/Anthoxanthum* community, species richness and diversity increased significantly in the twice burned treatment between 1988 and 1989. Similarly, species richness and diversity increased significantly between 1988 and 1989 in both control and twice burned treatments within the *Vaccinium* community.

At Fisher Butte, significant increases in species richness and diversity occurred between 1988 and 1990 in twice burned treatments in the *Deschampsia*

Table 4.27. Plant species diversity information by plant communities, treatments, and years. Superscripted letters indicate a significant difference (p = 0.1) between years within treatments. Grand means are presented for all years and all treatments for plant communities.

| | | Species Richness | | Species Equitability | | Species Diversity | |
|---|---|---|---|---|---|---|---|
| Rose Prairie Study Site | | | | | | | |
| *Deschampsia* plant community | | Mean | SE | Mean | SE | Mean | SE |
| Control | 1988 | 27.7 | 0.9 | 0.860 | 0.016 | 2.854 | 0.064 |
| | 1989 | 29.0 | 2.6 | 0.871 | 0.010 | 2.925 | 0.105 |
| | 1990 | 30.0 | 2.6 | 0.875 | 0.005 | 2.970 | 0.091 |
| Once Burned | 1988 | $24.0^a$ | 0.6 | 0.883 | 0.005 | $2.804^a$ | 0.007 |
| | 1989 | $33.0^b$ | 1.5 | 0.877 | 0.011 | $3.064^b$ | 0.008 |
| | 1990 | $32.3^b$ | 3.2 | 0.889 | 0.000 | $3.080^b$ | 0.094 |
| Twice Burned | 1988 | $24.7^a$ | 0.7 | 0.877 | 0.010 | $2.811^a$ | 0.018 |
| | 1989 | $32.0^b$ | 1.0 | 0.884 | 0.009 | $3.063^b$ | 0.009 |
| | 1990 | $38.3^c$ | 1.2 | 0.870 | 0.004 | $3.170^c$ | 0.019 |
| Grand Mean | | 30.0 | | 0.877 | | 2.972 | |
| *Rosa/Anthoxanthum* plant community | | | | | | | |
| Control | 1988 | 24.3 | 7.4 | 0.831 | 0.028 | 2.598 | 0.331 |
| | 1989 | 25.7 | 8.4 | 0.820 | 0.029 | 2.593 | 0.358 |
| | 1990 | 25.0 | 5.6 | 0.842 | 0.033 | 2.685 | 0.282 |
| Once Burned | 1988 | 27.0 | 3.6 | 0.860 | 0.018 | 2.818 | 0.162 |
| | 1989 | 39.0 | 4.6 | 0.876 | 0.004 | 3.198 | 0.121 |
| | 1990 | 38.7 | 3.8 | 0.880 | 0.012 | 3.210 | 0.136 |
| Twice Burned | 1988 | $23.0^a$ | 0.6 | 0.797 | 0.029 | $2.499^a$ | 0.083 |
| | 1989 | $35.7^b$ | 2.4 | 0.850 | 0.009 | $3.037^b$ | 0.088 |
| | 1990 | $43.3^b$ | 3.2 | 0.856 | 0.005 | $3.221^b$ | 0.052 |
| Grand Mean | | 31.3 | | 0.847 | | 2.879 | |
| *Vaccinium* plant community | | | | | | | |
| Control | 1988 | $29.7^a$ | 0.3 | 0.898 | 0.003 | $3.043^a$ | 0.011 |
| | 1989 | $37.3^b$ | 0.3 | 0.894 | 0.001 | $3.235^b$ | 0.012 |
| | 1990 | $36.3^b$ | 0.9 | 0.897 | 0.014 | $3.221^b$ | 0.035 |

Table 4.27., Continued

| | | Species Richness | | Species Equitability | | Species Diversity | |
|---|---|---|---|---|---|---|---|
| Once Burned | 1988 | 38.7 | 0.9 | 0.916 | 0.009 | 3.350 | 0.051 |
| | 1989 | 41.7 | 1.9 | 0.918 | 0.013 | 3.420 | 0.044 |
| | 1990 | 40.3 | 2.2 | 0.911 | 0.010 | 3.365 | 0.018 |
| Twice Burned | 1988 | 35.7 | 0.3 | 0.914 | 0.006 | 3.268 | 0.016 |
| | 1989 | 41.7[a] | 0.7 | 0.910 | 0.004 | 3.392[a] | 0.029 |
| | 1990 | 40.3[b] | 0.9 | 0.911 | 0.006 | 3.368[b] | 0.014 |
| Grand Mean | | 37.9[b] | | 0.908 | | 3.298[b] | |
| Fisher Butte Study Site | | | | | | | |
| *Deschampsia* plant community | | | | | | | |
| Control | 1988 | 31.7 | 2.6 | 0.872 | 0.009 | 3.004 | 0.052 |
| | 1989 | 31.3 | 0.3 | 0.879 | 0.007 | 3.028 | 0.028 |
| | 1990 | 29.3 | 2.3 | 0.891 | 0.014 | 3.003 | 0.028 |
| Once Burned | 1988 | 37.3 | 2.5 | 0.890 | 0.011 | 3.214 | 0.091 |
| | 1989 | 42.3 | 2.1 | 0.878 | 0.010 | 3.286 | 0.077 |
| | 1990 | 43.2 | 1.8 | 0.881 | 0.008 | 3.312 | 0.057 |
| Twice Burned | 1988 | 34.0[a] | 1.3 | 0.885 | 0.008 | 3.117[a] | 0.046 |
| | 1989 | 37.3 | 2.4 | 0.880 | 0.004 | 3.179 | 0.061 |
| | 1990 | 42.0[b] | 0.7 | 0.890 | 0.010 | 3.325[b] | 0.044 |
| Grand Mean | | 37.6 | | 0.883 | | 3.193 | |
| *Rosa/Juncus* plant community | | | | | | | |
| Control | 1988 | 33.3 | 4.5 | 0.855 | 0.015 | 2.981 | 0.094 |
| | 1989 | 31.0 | 2.1 | 0.851 | 0.009 | 2.921 | 0.088 |
| | 1990 | 35.7[a] | 2.7 | 0.846 | 0.010 | 3.020 | 0.095 |
| Once Burned | 1988 | 37.8[a] | 3.4 | 0.868 | 0.003 | 3.135[a] | 0.082 |
| | 1989 | 41.0[b] | 3.1 | 0.870 | 0.006 | 3.222[b] | 0.089 |
| | 1990 | 48.8[b] | 2.8 | 0.895 | 0.006 | 3.472[b] | 0.069 |
| Twice Burned | 1988 | 35.7 | 2.3 | 0.857 | 0.014 | 3.055 | 0.088 |
| | 1989 | 36.8 | 2.0 | 0.870 | 0.010 | 3.135 | 0.077 |
| | 1990 | 40.0 | 1.0 | 0.877 | 0.009 | 3.235 | 0.050 |
| Grand Mean | | 38.7 | | 0.868 | | 3.162 | |

community while significant increases in species richness, diversity, and equitability occurred between 1989 and 1990 in once burned treatments in the *Rosa/Juncus* community.

### Floristic changes in communities through time

Species richness in sampled plots increased from 1988 to 1990 in all plant communities except in the *Rosa/Juncus* community at Fisher Butte (Table 4.28). Native species richness increased in all plant communities between 1988 and 1990. Exotic species richness increased in all communities at Rose Prairie, remained unchanged in FB *Deschampsia* and declined in the *Rosa/Juncus* community. Most of the observed change in exotic species was due to exotic forb species, both perennial and annual/biennial. Native graminoid species increased from 7 to 12 in the FB *Deschampsia* community over the period of this research.

## Summary of results - across plant communities

### Preburn

Although plant communities were species rich, a relatively few species dominated the cover of plant communities in these native Willamette Valley wetland prairies. Species composition of the *Rosa/Anthoxanthum* community was very different from that of all of other plant communities.

Table 4.28. Summary of species numbers in life form (trees, shrubs, graminoids, forbs), lifespan (perennials versus annual/biennial) and origin (native versus exotic) categories summarized for all years by plant communities.

| | RP *Deschampsia* | | | *Rosa/Anthoxanthum* | | | *Vaccinium* | | | FB *Deschampsia* | | | *Rosa/Juncus* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | 1989 | 1990 | 1988 | 1989 | 1990 | 1988 | 1989 | 1990 | 1988 | 1989 | 1990 | 1988 | 1989 | 1990 |
| All Species: | 43 | 54 | 51 | 66 | 77 | 78 | 51 | 60 | 64 | 84 | 89 | 88 | 85 | 84 | 93 |
| Total Natives | 30 | 36 | 37 | 42 | 50 | 49 | 38 | 43 | 44 | 53 | 56 | 56 | 59 | 55 | 63 |
| Total Exotics | 13 | 18 | 14 | 24 | 27 | 29 | 13 | 17 | 20 | 31 | 33 | 32 | 26 | 29 | 30 |
| Life Forms: | | | | | | | | | | | | | | | |
| Trees | 2 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 4 | 5 | 4 | 6 | 3 | 4 | 3 |
| Native | 2 | 1 | 1 | 1 | 3 | 3 | 4 | 4 | 4 | 4 | 3 | 5 | 2 | 3 | 2 |
| Exotic | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Shrubs | 2 | 3 | 2 | 2 | 5 | 6 | 3 | 4 | 4 | 3 | 3 | 5 | 4 | 4 | 4 |
| Native | 1 | 2 | 1 | 1 | 3 | 4 | 2 | 3 | 2 | 1 | 2 | 2 | 3 | 2 | 2 |
| Exotic | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 3 | 1 | 2 | 2 |
| Graminoids | 13 | 14 | 14 | 14 | 15 | 16 | 13 | 15 | 16 | 17 | 23 | 20 | 22 | 24 | 22 |
| Total Native | 7 | 7 | 8 | 8 | 7 | 9 | 6 | 7 | 7 | 7 | 11 | 10 | 12 | 13 | 13 |
| Total Exotic | 6 | 7 | 6 | 6 | 8 | 7 | 7 | 8 | 9 | 10 | 12 | 10 | 10 | 11 | 9 |
| Perennials | 10 | 10 | 11 | 11 | 12 | 13 | 9 | 11 | 12 | 12 | 17 | 15 | 15 | 18 | 16 |
| Native | 7 | 7 | 8 | 8 | 7 | 9 | 6 | 7 | 7 | 7 | 11 | 10 | 11 | 12 | 12 |
| Exotic | 3 | 3 | 3 | 3 | 5 | 4 | 3 | 4 | 5 | 5 | 6 | 5 | 4 | 6 | 4 |
| Annuals | 3 | 4 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 5 | 6 | 5 | 7 | 6 | 6 |
| Native | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| Exotic | 3 | 4 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 5 | 6 | 5 | 6 | 5 | 5 |
| Forbs | 26 | 36 | 34 | 48 | 54 | 53 | 30 | 36 | 39 | 59 | 59 | 57 | 56 | 52 | 64 |
| TotalNative | 20 | 26 | 27 | 32 | 37 | 33 | 25 | 28 | 30 | 41 | 40 | 39 | 42 | 37 | 46 |
| TotalExotic | 6 | 10 | 7 | 16 | 17 | 20 | 5 | 8 | 9 | 18 | 19 | 18 | 14 | 15 | 18 |
| Perennials | 21 | 25 | 24 | 29 | 33 | 31 | 26 | 27 | 26 | 32 | 36 | 32 | 29 | 28 | 34 |
| Native | 16 | 19 | 19 | 23 | 27 | 24 | 22 | 22 | 22 | 25 | 28 | 25 | 23 | 21 | 26 |
| Exotic | 5 | 6 | 5 | 6 | 6 | 7 | 4 | 5 | 4 | 7 | 8 | 7 | 6 | 7 | 8 |
| Annuals | 5 | 11 | 10 | 19 | 21 | 22 | 4 | 9 | 13 | 27 | 23 | 25 | 27 | 24 | 30 |
| Native | 4 | 7 | 8 | 9 | 10 | 9 | 3 | 6 | 8 | 16 | 12 | 14 | 19 | 16 | 20 |
| Exotic | 1 | 4 | 2 | 10 | 11 | 13 | 1 | 3 | 5 | 11 | 11 | 11 | 8 | 8 | 10 |

The only dominant species found in all communities, other than the atypical *Rosa/Anthoxanthum* community, was *Deschampsia cespitosa*. *Danthonia californica* was dominant in all communities except the *Rosa/Anthoxanthum* and *Vaccinium* communities. Common species found in all communities except the *Rosa/Anthoxanthum* community included *Agrostis* spp., *Camassia quamash, Eriophyllum lanatum, Grindelia integrifolia,* and *Prunella vulgaris*.

Total live plant cover was usually less than ~65% at the two research sites due to the presence of litter, standing dead material, and bare ground. Native composition was generally high in all communities except in the *Rosa/Anthoxanthum* community where exotics dominated plant cover. Plant communities differed in life form, lifespan, and origin compositions. Most species encountered were forbs. Aerial coverage of vegetation was typically dominated by perennial graminoids. About one third of the total vegetative cover in the *Vaccinium* community consisted of shrub cover, predominantly *V. caespitosum*. The *Rosa/Anthoxanthum* and FB *Deschampsia* plant communities also had relatively high shrub cover at 11% and 6% respectively; *R. nutkana* was the predominant shrub component.

## Fire Effects on Species Frequency

After burning, a number of species established or their frequencies increased significantly in two or more plant communities. Native species that established or significantly increased in burned areas included the perennials *Luzula campestris, Panicum occidentale, Aster chilensis* var. *hallii, Brodiaea* spp., *Camassia quamash, Microseris laciniata, Prunella vulgaris, Sisyrinchium angustifolium, Veronica scutellata,* and the annuals *Epilobium paniculatum, Gnaphalium palustre*, and *Madia glomerata*. Exotic species that established and increased significantly with fire included the perennials *Agrostis spp., Hypericum perforatum, Hypochaeris radicata,* and *Leontodon nudicaulis* and the annual *Briza minor.*

Frequency of *Danthonia californica* declined significantly in the first post fire season after one burn in RP *Deschampsia* and in both communities at Fisher Butte. *Madia glomerata* declined significantly in both communities at Fisher Butte the first postfire season after one burn then returned to preburn levels during the second postfire year.

### Fire Effects on Species Cover

The most significant changes between years in species composition within a plant community occurred in the burn treatments. Not surprisingly, bare ground significantly increased in all communities following burning as litter was consumed in the fires. Cover of *Agrostis* spp. increased significantly in one or both burn treatments in all communities, although it also increased in the control treatment in one community. In the *Vaccinium* community and both communities at Fisher Butte, *D. californica* cover decreased significantly the first year following burning and only returned to preburn levels in burned treatments in the FB *Deschampsia* community. In *Deschampsia* communities at both sites, *D. cespitosa* cover declined significantly in the first postfire year following one burn and then returned to preburn cover in 1990 in both burn treatments. Cover of *Hypericum perforatum* increased significantly in two communities in burned areas; however, it also increased in controls in one community. No other significant changes between years for species were noted in caparisons of plant communities.

### Fire effects on frequency of plant forms, lifespans, and origins

Relative frequency of all natives increased significantly in once burned treatments in RP *Deschampsia* and *Rosa/Anthoxanthum* communities. After two burns, native perennial forbs increased significantly in three communities, RP *Deschampsia*, *Rosa/Anthoxanthum*, and *Rosa/Juncus*. However, native perennial forbs also increased significantly in FB *Deschampsia* control treatments. Relative frequency of perennial exotic graminoids declined significantly in burn treatments in all but the *Vaccinium* community where they increased in the control treatment. Native annual forbs increased in burns in all except the *Vaccinium* community, where it increased significantly in controls.

## Fire effects on cover of plant forms, lifespans and origins

Significant increases in vegetative cover occurred in burned areas in the RP *Deschampsia, Vaccinium*, and FB *Deschampsia* communities. Because vegetative cover of all of these plant communities was dominated by perennial graminoids, changes in the perennial grass component greatly influenced changes in total cover. In *Deschampsia* communities at Rose Prairie and Fisher Butte, total native vegetative cover decreased significantly the first postfire season following one burn (1989) and increased significantly above preburn levels by 1990. Changes in native cover were due primarily to changes in the cover of *D. cespitosa.*

Total cover of exotic species increased following one or two burns in all communities except the *Rosa/Anthoxanthum* community; measured increases were primarily due to increases in exotic perennial graminoid cover. Cover of exotics also increased significantly in controls in RP *Deschampsia* and *Vaccinium*; also due to exotic perennial graminoid cover. Significant increases in exotic forb cover occurred in Rosa/Anthoxanthum and FB Deschampsia. In both communities at Fisher Butte native annual forbs declined significantly the first postfire following one burn.

# DISCUSSION

## Plant species compositions

Floristic composition of my study sites were very similar to floristic compositions of other Willamette Valley wetland prairies (Moir and Mika 1972, Frenkel and McEvoy 1986, Acker 1986, Frenkel and Streatfeild 1994, Streatfeild 1995). Predominant native species documented for wetland prairie sites include *Deschampsia cespitosa, Holcus lanatus, Danthonia californica, Madia glomerata, Agrostis exerata, Briza minor, Centaurium umbellatum*, and *Hypericum perforatum*. However, percent cover and frequency of species differ among various wetland prairie sites.

A total of 205 species were observed at both study sites during the course of this research. One hundred and six species of the total occurred at Rose Prairie while 123 species occurred at Fisher Butte. The high number of species unique to one or the other site indicates the extreme variability of species distribution in Willamette Valley wetland prairies. Streatfeild (1995) documented 108 species and estimated that approximately 170 species occurred at the Willamette Valley Floodplain Research Natural Area wetland prairie (hereafter referred to as the Finley prairie). This prairie is located on the W.L. Finley National Wildlife Refuge, south of Corvallis, approximately 30 miles from my research area.

Elevated mounds at Finley prairie contained a high cover of exotic plant species (Streatfeild 1995) as did the elevated mounds in the *Rosa/Anthoxanthum* community at Rose Prairie. A number of species closely correlated to mounds at Finley prairie were also associated with mounds of the *Rosa/Anthoxanthum* community at Rose Prairie, e.g., *Hypericum perforatum, Achillea millefolium*, and *Madia sativa*. However, the overall species composition of Finley mounds was very different from the *Rosa/Anthoxanthum* mound communities in this study.

Total percent cover for species at Finley were higher than those presented here (Streatfeild 1995). Estimation, sampling, and analysis techniques differed in the two studies. Only percent cover of live plant biomass of the most dominant species were included in my cover analysis.

Species composition of wetland prairies in my study were very similar to those of a "Grassland-Composite Stage" plant community studied by Lippert and Jameson (1964). They studied plant succession in temporary ponds of the Willamette Valley and determined the Grassland-Composite Stage to be a late-successional sere in pond succession. In their study, three grasses, *Deschampsia cespitosa, Agrostis alba*, and *Holcus lanatus*, were most abundant.

Finley (1994) measured environmental factors at Rose Prairie and Fisher Butte and used a portion of the vegetation data collected in this study to ordinate species composition against environmental factors. Many of the observed differences in plant species presence in communities were related to differences in water table level, elevation, and soil texture of plant communities (Finley 1994).

A moisture gradient related to topography was also the most important environmental variable affecting species distributions at the Finley prairie (Frenkel and Streatfeild 1994, Streatfeild 1995).

Past land-use history is another important factor influencing contemporary plant composition. Most of the Willamette Valley has been cultivated in one manner or another in the past (Towle 1982). If a parcel of land escaped the plow, it was probably grazed and seeded to pasture grasses. Past cultivation and/or supplemental seeding may explain the large component of exotic species in these relict wetland prairies. The co-occurrence of many exotic species at Rose Prairie suggests a history of seeding with pasture seed mixtures and heavy grazing. Numerous exotic species were also documented at Fisher Butte, although their cover was lower than at Rose Prairie. The cover of many exotics increased at the eastern, more upslope region of Fisher Butte, which may indicate seeding of pasture mixes or the presence of drier areas more susceptible to exotic invasion. Historical land use patterns are reflected in differences in species composition to the north and south of a fenceline bisecting the Fisher Butte study site and may indicate past property boundaries. Fisher Butte also has small ditchlines across the site, indicating some former attempt to drain the area. Analysis of old aerial photographs of these sites and interviews with past landowners and adjacent landowners might help in interpreting the present vegetative composition (Streatfeild 1995).

## Fire effects on species composition

### Comparisons with Finley prairie

Streatfeild (1995) found that areas experiencing more recent burning had different species composition compared to adjacent areas that had not recently burned. In the Finley prairie, a number of species correlated positively with recent burning including *Galium aparine, Perideridia gairdneri, Madia sativa, Parentucellia viscosa*, and *Hypericum perforatum*. Species that correlated negatively with recent burning included *Deschampsia cespitosa, Hordeum branchyantherum, Carex unilateralis, Juncus tenuis, Juncus oxymeris, Veronica scutellata, Galium trifidum*, and *Epilobium watsonii* (Streatfeild (1995). In this study, *P. viscosa* and *H. perforatum* significantly increased in two communities following burning, while *J. tenuis* declined significantly during the second postfire season after one fire in the FB *Deschampsia* community.

Cover of the exotic shrub, *Rosa eglanteria*, decreased following burning at the Finley prairie (Streatfeild 1995). In contrast, cover of the native shrub, *R. nutkana,* significantly increased following burning in both communities at Fisher Butte.

In an earlier study at Finley prairie, results of burning were not statistically analyzed but indicated an increase in only two of the ten most dominant species present, *Rosa* spp. and *D. cespitosa*. The remaining dominants, *Holcus lanatus,* *Myosotis laxa, Epilobium spp. Agrostis alba, P. viscosa, H. perforatum, Veronica scutellata*, and *Agrostis exarata,* all declined (Frenkel and McEvoy 1983).

## Comparisons with other prairies

Initial results (1986-1988) for burning at The Nature Conservancy Willow Creek Preserve indicated an increase in *Agrostis* spp. following burning (Acker 1990). *Agrostis* spp. and *Aira* spp. increased in cover and/or frequency in an upland Willamette Valley prairie near Wren (Magee 1986, Macdonald - undated).

In a research study conducted in a dry, upland *Stipa lemmonii-Rhacometrium canescens* grassland on Rattlesnake Butte at the edge of the Willamette Valley, the frequency of the exotic annual, *Aira caryophyllea*, increased significantly following burning (MacDonald, undated).

Declines in the frequency of annual species observed in my study were unexpected. I anticipated that spaces would open for these species to establish and flourish in the postfire environment. In contrast to my study, annuals increased in the postfire environment at Finley prairie (Frenkel and Streatfeild 1994, Streatfeild 1995).

The stem density of annual forbs increased dramatically in tallgrass prairie plots that were burned during spring or fall for six years annually in Wisconsin (Curtis and Partch 1948). They speculated that these plants came from buried seeds in the soil, since the greatest densities were attained in the first year of the burn, with gradual reductions in succeeding years.

At the Konza tallgrass prairie in Kansas, where fire was prescribed every four years, relative cover of many life forms was related to the prescribed burning cycle (Gibson 1988). Percent cover of perennial forbs and $C_3$ perennial grasses increased through the burning cycle with increasing time since burning, but total $C_3$ annual forbs, total grass and perennial short grass all declined. Despite trends in the response of life forms to burning, population dynamics of only six species were related to the burn cycle. A number of annual species generally declined immediately following burning, then increased, followed by another decline with increasing time since burning. An initial decline in abundance of some annual species following burning and a subsequent increase was noted in my study. These results lead to intriguing questions about the seed bank dynamics of prairie species in response to burning.

Most prairie species at the Konza prairie fluctuated more in relation to yearly climatic variation, soil type, and differences between watershed units than in response to burning (Gibson 1988). Yearly effects, where species abundance changed regardless of treatment, were apparent in my study.

Although overall biomass declined, forb biomass increased following burning in California annual grasslands (Hervey 1949). In contrast, total biomass was observed to increase in a number of communities following burning (Chapter 2) while forb frequency and cover were also noted to increase in my study.

A number of plant species that increased following burning in this study were important foods plants to the Native American people of the Pacific

Northwest, e.g., *Vaccinium* spp., *Brodiaea* spp., *Camassia* spp., *Perideridia* spp. (French 1965, Boyd 1986). Former inhabitants may have burned on a cycle to enhance favored plant foods and we may look to changes in abundance of these species to help determine optimal fire frequency for some Willamette Valley wetland prairies.

### Species richness, diversity and equitability

Diversity (H') was greater in burned than in unburned areas early in the growing season in a tallgrass prairie in Iowa (Hill and Platt 1975). Fires also caused a shift in dominance in this tallgrass prairie, with an increase in *Andropogon gerardii* and forbs and a decrease in *Poa pratensis* biomass (Hill and Platt 1975). Fire resulted in an significant increases in species diversity in plant communities and an increase in equitability in one plant community my study.

### Inherent difficulties with sampling techniques

Because of their open, scattered growth form, some species were particularly difficult to assess for cover (e.g. *Agrostis* spp.). When cover of only live plant material is estimated, cover values can change dramatically if yearly sampling occurs at different plant phenological stages. Such problems could mask changes in cover between years or difference in cover estimates across all treatments within one year. Cover of *Agrostis* spp. did change in a similar direction across treatments between years, although magnitudes of change were greater in burn treatments.

Dramatic increases in cover or frequency of some species between 1988 and 1989 may have been due to poor determination of early-phenology species presence during 1988. These species may have been largely missed if they were only present as standing dead or litter from previous years of growth. Species with early phenologies that were difficult to find or identify during sampling included *Cardamine penduliflora, Luzula campestris, Erythronium oreganum, Montia linearis,* and *Ranunculus* spp. Sampling should be carried out earlier in the season to adequately detect and evaluate presence, percent cover, and fire effects on such species. However, if sampling occurred earlier, late-season species would be inadequately sampled. Ideally, multiple sampling should be done at intervals during the growing season to assure adequate capture of all species, although this would be an extremely time-consuming endeavor.

Percent cover is generally sensitive to changes of dominant species abundance while frequency is more sensitive to changes in less common species (Barbour et al. 1987). Although cover estimates can be fairly subjective and may vary among technicians, frequency estimates of abundance depend largely upon quadrat size. Optimum plot size for percent frequency sampling is one where the percent frequency falls in the range of 20 to 80% (Mueller-Dombois and Ellenberg 1974). Determining an optimal plot size for all species is difficult and provides the rationale behind using a series of nested plots. The largest plot size used in this study, 50 x 50 cm, was too small to sample a majority of the uncommon plant species that occurred at sites because their percent frequency often fell below 20%. In addition, the smallest plot size, 12.5 x 12.5 cm, was also too large to adequately sample some of the most common species at the study sites, which had frequencies >80%.

## Conclusion

Prescribed burning experiments at Rose Prairie and Fisher Butte show mixed effects on vegetation composition. Fire sometimes increased frequency and cover of native species, but in other circumstances, fire increased exotic species and woody plant abundance. Additional monitoring of plant response to varying fire frequencies and intensities is necessary. Trends in vegetative changes in response to fire may not be evident immediately following burning; many years of prescribed burning may be required before patterns emerge. Fire is not a single type of treatment. Fires vary in intensity and thus their impact upon plant species and environment varies. Monitoring over extended time periods and use of varying fire frequencies will assist in determining optimum fire frequencies and intensities to maintain populations of native plants while controlling woody and exotic species in native Willamette Valley wetland prairies.

# CHAPTER 5
# SHRUB AND TREE COMPOSITION AND RESPONSE TO PRESCRIBED FIRES IN WILLAMETTE VALLEY WETLAND PRAIRIES

## Abstract

Natural and aboriginal fires were historically important in maintaining prairie habitat in the Willamette Valley. One important function of fire was the inhibition of succession to woodland of prairie communities. In this study, prescribed fires were implemented to determine response of the structure and composition of the shrub and tree component in five plant communities (RP *Deschampsia*, *Rosa/Anthoxanthum*, *Vaccinium*, FB *Deschampsia*, *Rosa/Juncus*) at two selected wetland prairie sites near Eugene, Oregon (Rose Prairie and Fisher Butte). Three treatments were assessed; unburned controls, and once and twice burned treatments.

*Rosa nutkana* was the most prevalent woody species within all plant communities. Initial preburn densities ranged from 30,519 plants ha$^{-1}$ in the mesic RP *Deschampsia* community to 50,963 plants ha$^{-1}$ in the relatively dry *Rosa/Anthoxanthum* community at Rose Prairie . Conversely, initial *R. nutkana* densities were lowest the drier FB *Deschampsia* community (17,156 ha$^{-1}$) relative to the wet *Rosa/Juncus* community (53,067 ha$^{-1}$) at Fisher Butte.

More woody plant encroachment was occurring at Rose Prairie than at Fisher Butte. Most sampled trees at both sites were in seedling and sapling size classes, ranging between 3 to 70 cm in height. Total tree density initially ranged

from 568 trees ha$^{-1}$ in the *Vaccinium* community to an absence of trees in the *Rosa/Anthoxanthum* community at Rose Prairie. Tree density was nearly four times greater in the *Rosa/Juncus* community (1644 ha$^{-1}$) than in the FB *Deschampsia* community (430 ha$^{-1}$) at Fisher Butte; due primarily to *the presence of Fraxinus latifolia* (1,071 ha$^{-1}$) invading the wet *Rosa/Juncus* community.

*Rosa nutkana* density significantly increased between years in twice burned treatments in both the dry *Rosa/Anthoxanthum* community at Rose Prairie and in the wet *Rosa/Juncus* community at Fisher Butte. No significant density changes of this species were noted in response to treatments in the other plant communities.

Mean height of *R. nutkana* significant declined in one or both burned treatments in four plant communities. Taller height classes were also eliminated; individuals shifted to shorter height classes in burn treatments relative to controls.

In twice burned treatments of the *Rosa/Juncus* community, total tree density decreased significantly (-64%) between years, due primarily to a significant decrease (-96%) in *F. latifolia*. By contrast, a single fire only reduced total tree density by 13% in this community. These data indicate that higher tree seedling and sapling mortality, particularly of *F. latifolia*, will result with repeated burning relative to a single fire in the *Rosa/Juncus* plant community. Fire effects on tree density varied greatly in all other plant communities.

Fire effects on mean tree height varied significantly between plant communities. Tree heights increased in the *Rosa/Juncus* community and decreased in *Vaccinium* and FB *Deschampsia* communities. Burning shifted trees from taller to shorter height classes.

## Introduction

Willamette Valley prairies are some of the rarest and most endangered of all natural ecosystems in the state of Oregon (1983). Natural lightning fires and those set by Native Americans have been extremely important in shaping and maintaining these prairies (Sprague and Hansen 1946, Habeck 1961, Thilenius 1968, Johannessen et al. 1971, Boyd 1986). European settlers excluded fire from these native ecosystems starting in the 1840's and continuing to the present. Most Willamette Valley prairies have been destroyed by urbanization, and agricultural conversion (Towle 1982, Christy and Alverson 1994). Remnant prairies are being invaded by shrubs and trees. The reintroduction of fire in remnant prairies may provide native species better conditions for growth, reproduction and competitive advantage.

Willamette prairies are generally separated into dry (upland) plant communities and wet, low (wetland) communities (Habeck 1961). This study focussed on wetland prairies. With fire exclusion, wetland prairies may soon be replaced by woodland communities of willow (*Salix* spp.), black cottonwood

(*Populus trichocarpa*), hawthorn (*Crataegus* spp.) or ash (*Fraxinus latifolia*). (Franklin and Dyrness 1973, Johannessen et. al 1971, Sprague and Hansen 1946, Thilenius 1968, Cole 1977, Frenkel and Heinitz 1987). Fires have been used or observed to result in retrogression of woody plant succession in numerous ecosystems (e.g. North American grasslands - Daubenmire 1968, Vogl 1974, Kucera 1981; tallgrass prairie - Collins and Wallace 1990; sagebrush steppe- Humphrey 1984; Florida wetlands - Duever et. al. 1984, Vogl 1973; and forest systems - Agee 1981, Kauffman 1990, Volland and Dell 1981).

Euroamericans have intentionally and unintentionally introduced a number of exotic shrubs and trees to Willamette Valley prairies (Towle 1982). The effects of prescribed fires on these species are unknown. The reintroduction of fire in remnant Willamette Valley prairies may control invasion and dominance of both native and exotic woody species. Prescribed fire has been used to control Oregon ash (*F. latifolia*) and cultivated pear (*Pyrus communis*) at the Willow Creek wetland prairie (The Nature Conservancy) preserve in the southern Willamette Valley (Acker 1986). Prescribed fires at Willow Creek killed most tree crowns, although trees sprouted. However, canopy cover was opened, thereby favoring prairie vegetation. Burning at Finley Research Natural Area (RNA) wetland prairie reduced the frequency of Rosa eglanteria, a dominant, exotic shrub found at that site (Streatfeild 1995).

I hypothesized that fire would reduce density and mean height of woody plants and that multiple fires may more effectively decrease woody plant dominance than a single fire. This experiment was designed to quantify the response of shrubs and trees to a single fire and to two consecutive annual fires.

The specific objectives were to (1) document the initial density, composition and structure of shrubs and trees in five wetland prairie plant communities at two study sites and (2) determine changes in the density, composition and structure of shrubs and trees in response to the single and repeated burn treatments.

## Study Sites

Chapter 2 provides a complete description of study sites including location, climate, general vegetation, soils and topography.

## Methods

### Treatments

Shrub and tree composition was measured during 1988 and 1990, prior to and following three treatments: 1) control (no burn), 2) a single, fall-season, prescribed fire in 1988 (once burned), and 3) two, consecutive fall-season, prescribed fires in 1988 and 1989 (twice burned). Treatments were established parallel to each other at Rose Prairie (Figure 5.1). At Fisher Butte, treatment areas were established in large rectangular blocks, oriented perpendicular to a

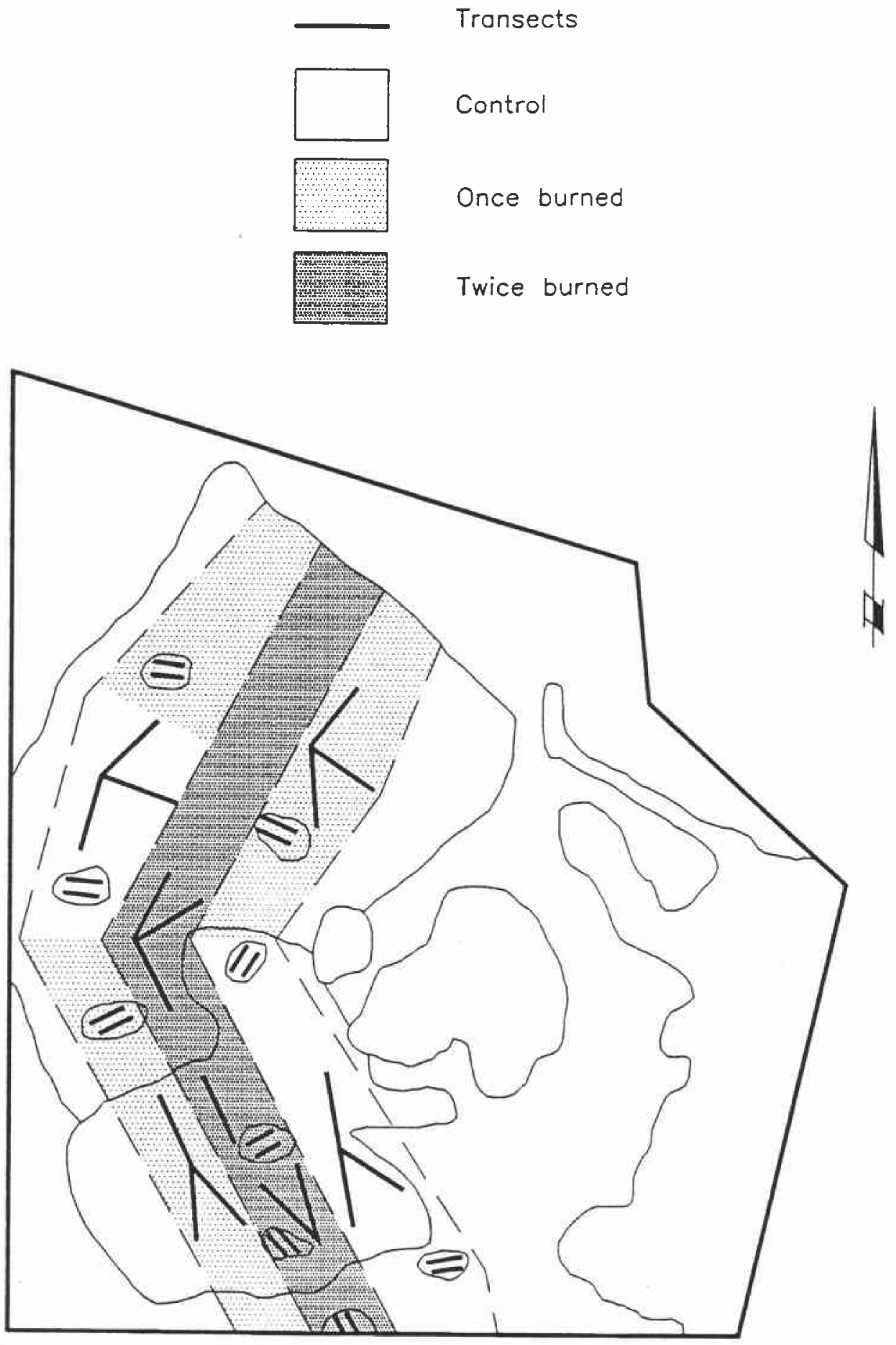

Figure 5.1. Treatment lay-out at Rose Prairie. Light solid lines delineate plant communities.

road delimiting the western boundary of the study site (Figure 5.2). Each treatment area included all of the plant communities found on each site. At Rose Prairie, each treatment area was ~2 ha; at Fisher Butte, each treatment area was ~4 ha. After areas were delineated, they were randomly assigned to specific treatments.

## Sampling design and techniques

### Rose Prairie

Three permanent belt transects were established prior to 1988 burning, in each of the RP *Deschampsia*, *Rosa/Anthoxanthum* and *Vaccinium* plant communities within each treatment (i.e. 3 transects x 3 plant communities x 3 treatments = 27 transects) (Table 5.1, Figure 5.3).

Nested belt transects were used to sample woody plants. Densities and heights of trees and shrubs (except for *Rosa nutkana*) were measured within 3 X 30 m transects within RP *Deschampsia* and *Vaccinium* plant communities. *Rosa nutkana* was generally present in high densities; it was therefore measured in 1 x 15 m transects in all plant communities. These smaller *R. nutkana* transects were nested within the 3 x 30 m transects within RP *Deschampsia* and *Vaccinium* plant communities (Figure 5.4). Due to the small size of the *Rosa/Anthoxanthum* community mounds, only 1 x 15 m transects were established to sample densities and heights of woody species within that plant community (Figure 5.3).

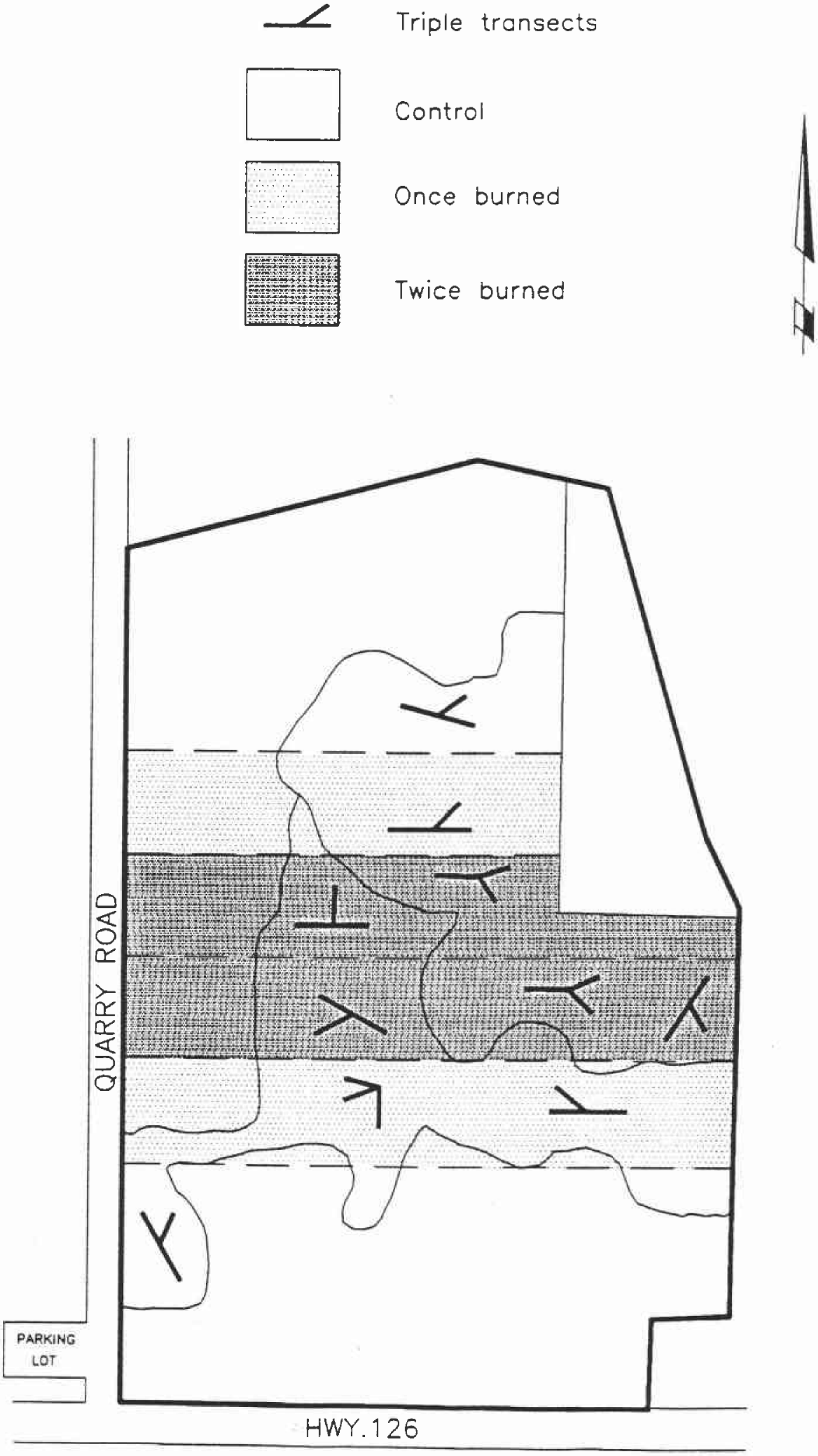

Figure 5.2. Treatment lay-out at Fisher Butte. Light solid lines delineate plant communities.

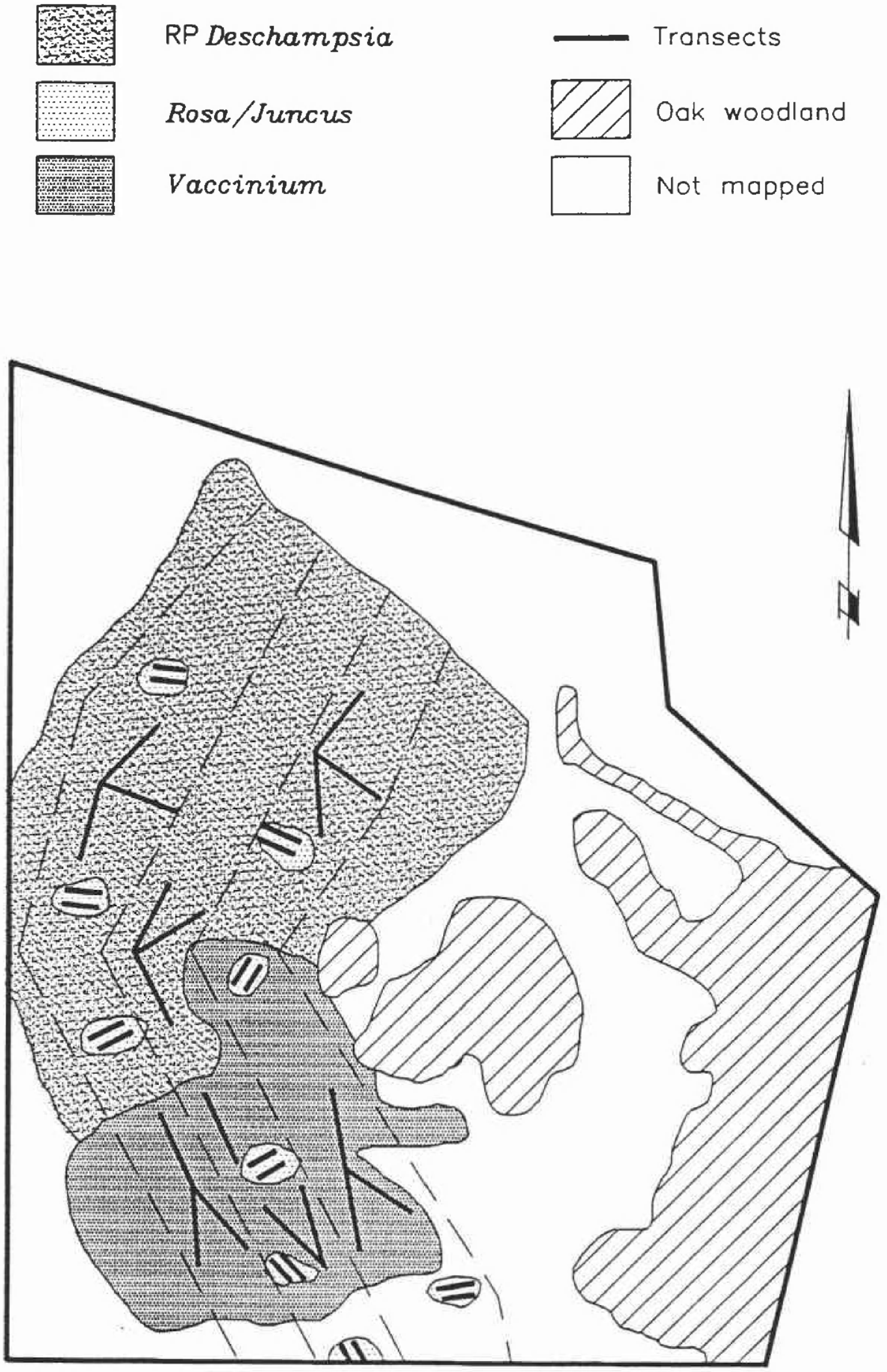

**Figure 5.3. Plant communities delineated and transect lay-out at Rose Prairie. Dashed lines indicate boundaries of treatments.**

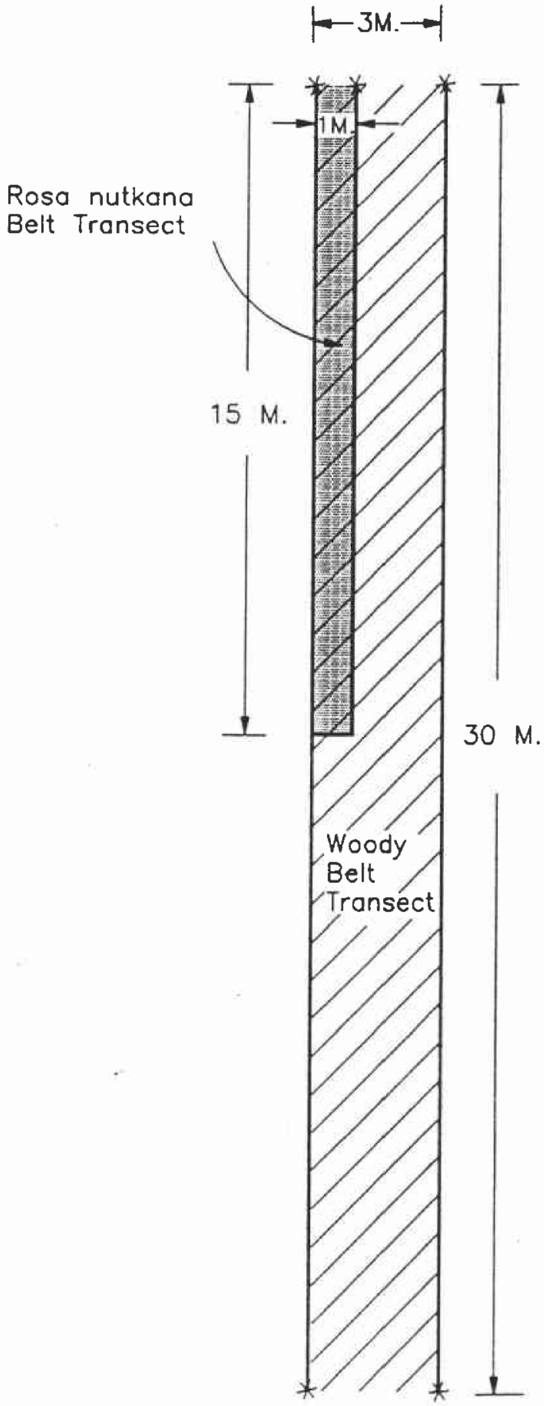

Figure 5.4. Belt transects used for sampling woody plant density and height.

Table 5.1. Plant communities identified and sampled, their locations, their codes in text, tables, and figures, and the number of transects installed in each.

| Name of Community | Location | Code in Text, Figures and Tables | Number of transects |
|---|---|---|---|
| *Deschampsia cespitosa-Danthonia californica* | Rose Prairie | RP *Deschampsia* | 9 (3 Control/unburned, 3 once burned, 3 twice burned) |
| *Rosa nutkana/Anthoxanthum odoratum* mounds | Rose Prairie | *Rosa/Anthoxanthum* | 9 (3 Control/unburned, 3 once burned, 3 twice burned) |
| *Vaccinium caespitosum* | Rose Prairie | *Vaccinium* | 9 (3 Control/unburned, 3 once burned, 3 twice burned) |
| *Deschampsia cespitosa-Danthonia californica* | Fisher Butte | FB *Deschampsia* | 15 (3 Control/unburned, 6 once burned, 6 twice burned) |
| *Rosa nutkana/Juncus nevadensis* | Fisher Butte | *Rosa/Juncus* | 15 (3 Control/unburned, 6 once burned, 6 twice burned) |

An individual *R. nutkana* plant was determined by pulling a single stem. If other aerial stems in the close proximity to the target plant moved, they were considered to be additional stems of the one individual. Mean height was calculated from the first ten *R. nutkana*. *Vaccinium caespitosum* plants were small-statured, non-invasive, and had high stem densities, therefore their changes in response to fire were evaluated by percent cover and frequency methods presented in Chapter 3. *Spiraea douglasii* was also evaluated by percent cover and frequency methods only (Chapter 3).

### Fisher Butte

Transects were established prior to 1988 burning in the control and burn treatments of the FB *Deschampsia* and *Rosa/Juncus* plant communities at Fisher Butte. Three transects were located in the control and six in each of the burn treatments [ie. (3 control + 6 once burned + 6 twice burned transects) x 2 plant communities = 30 belt transects] (Table 5.1, Figure 5.5).

Nested 1x15 m belt transects were used to sample *R. nutkana*, while the 3x30 m belt transects were used to sample all other woody species (Figure 5.4).

## Measurement periods and burn treatments

At both sites, all sampled individuals of woody species were counted and their heights measured during August and September of 1988 prior prescribed

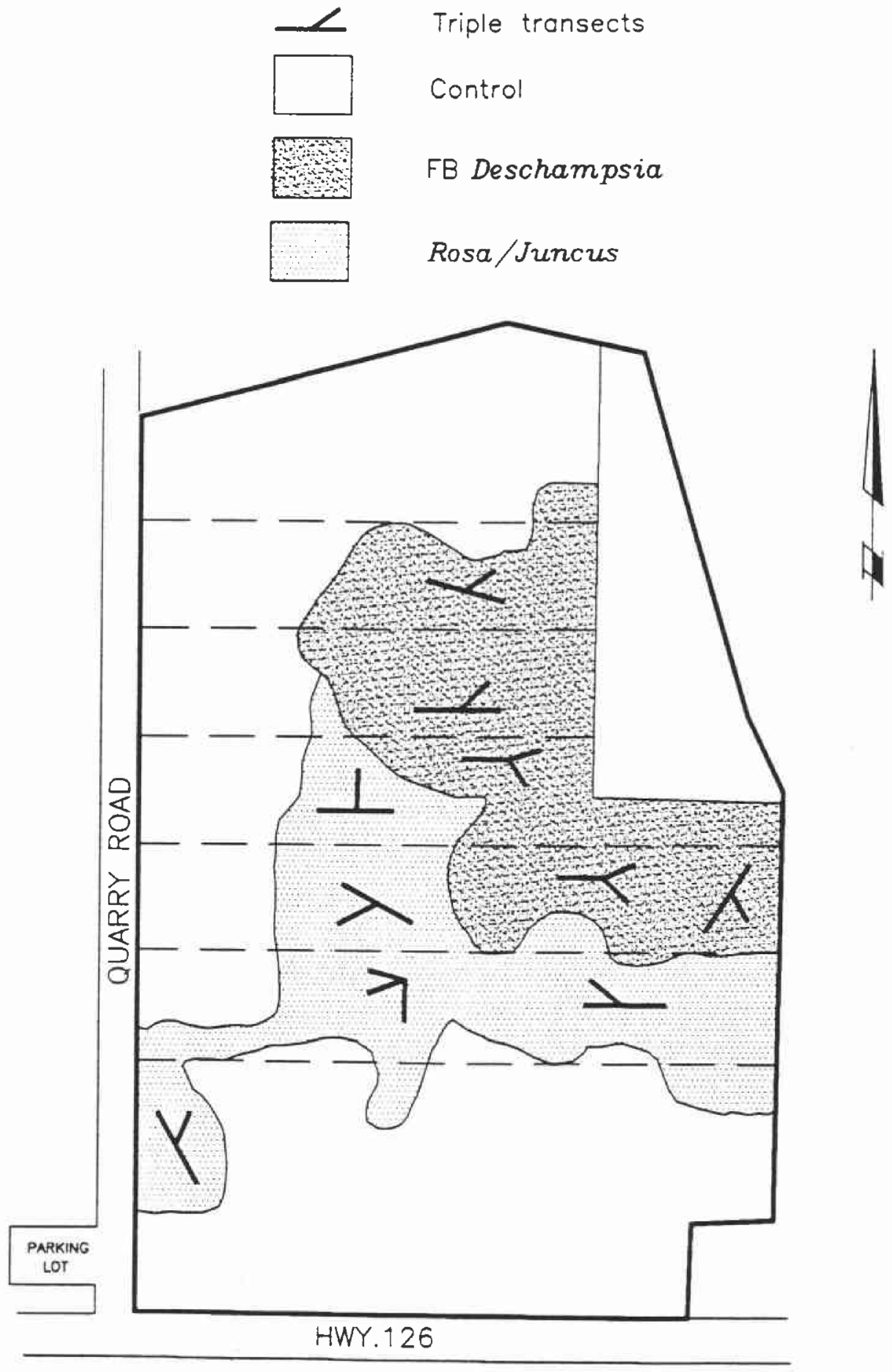

**Figure 5.5. Plant communities delineated and transect lay-out at Fisher Butte. Dashed lines indicate boundaries of treatments.**

fires on 11 October, 1988. The second set of prescribed burns was conducted on September 18, 1989. Eugene District - Bureau of Land Management personnel conducted the prescribed fires at both study sites using wetline and strip-head burning techniques (refer to Chapter 2 for more information on fire treatments). Final sampling of woody plants occurred in August and September, 1990.

### Data analysis

Descriptions of the original shrub and tree components of plant communities were based on 1988 (data prior to the prescribed fires). Mean densities and heights of woody species were derived from data pooled from all treatment areas to assess differences among plant communities. *Quercus garryana* and *Q. kellogii* seedlings and *Rubus discolor* and *R. laciniata* seedlings were initially difficult to distinguish, therefore, these species were combined and presented as *Quercus* spp. and *Rubus* spp., respectively. Data for all trees were also combined because there were so few. Trees 300 cm or taller were not included in data analysis of tree densities or heights because they were fairly sparse (<1 tree per 3x30 belt transect). They were more prevalent at Fisher Butte than Rose Prairie, and at Fisher Butte, were concentrated in wet areas (predominantly *F. latifolia*).

Mean densities and heights were calculated for all shrubs and trees for control, once burned and twice burned treatments, in the three plant communities at Rose Prairie and the two at Fisher Butte. Data are presented for the preburn conditions (1988) and post-treatment conditions (1990). 1990 data represent A) growth following no experimental treatments (control treatments), B) a second year of growth after 1988 burns (once burned treatments) C) and the first year's growth following two consecutive burns conducted in 1988 and 1989 (twice burned treatments). A more generalized view of fire effects on *R. nutkana* and trees was obtained by grouping height data into ten height size classes with the intent of examining fire effects on species demography and susceptibility of height classes to fire treatments. Plant taxonomy followed that of Hitchcock et al. 1969.

### Statistical analysis

Differences between means were tested using Mann-Whitney tests; a non-parametric analysis based on ranks (Zar 1984). This test is appropriate for data with unequal sample sizes and when assumptions associated with parametric tests can not be met. Statistical tests were applied to individual species and to "all trees combined" between years and among treatments. Since initial densities and heights of shrubs and trees were so variable among treatment areas within plant communities, the percent change between 1988 and 1990 among treatments were also tested.

# Results

## Initial woody flora

There were totals of 16 and 20 woody species at Rose Prairie and Fisher Butte, respectively (Table 5.2). Three (19%) of the 16 woody species at Rose Prairie were exotics; *Rosa eglanteria*, *Rubus discolor*, *R. laciniata*. Seven of the 20 (35%) woody species at Fisher Butte were exotics; these included the three exotics at Rose Prairie and an additional four species: *Crataegus monogyna*, *Prunus malus*, *Prunus avium* and *Pyrus communis*.

## Initial species composition and density in plant communities

### Rose Prairie

Prior to prescribed burns, RP *Deschampsia* and *Rosa/Anthoxanthum* communities contained similar shrub and tree species within sampling areas; both communities contained fewer woody species (S=4) than the *Vaccinium* community (S=10) (Table 5.3). Density of *R. eglanteria* was significantly greater in the *Vaccinium* community (148 ha$^{-1}$) compared to the RP *Deschampsia* community (37 ha$^{-1}$). Density of *R. nutkana* varied greatly in all communities (Table 5.3). The density of *R. nutkana* was significantly greater in the dry *Rosa/Anthoxanthum* community (50,963 plants ha$^{-1}$) relative to the wettest community, RP

Table 5.2. Shrub and trees species present in (X) and outside (X!) of measured transects at Rose Prairie and Fisher Butte.

| | | ROSE PRAIRIE | FISHER BUTTE |
|---|---|---|---|
| **SHRUBS** | | | |
| | *Rosa eglanteria** | X | X |
| | *Rosa* "Multiflora" | | X! |
| | *Rosa nutkana* | X | X |
| | *Rhus diversiloba* | X | X |
| | *Rubus discolor** | X | X |
| | *Rubus laciniata** | X | X |
| | *Rubus ursinus* | X! | X! |
| | *Spiraea douglasii* | X | X |
| | *Vaccinium caespitosum* | X | |
| | *Amelanchier alnifolia* | X | X |
| **TREES** | | | |
| | *Arbutus menziesii* | X! | |
| | *Crataegus douglasii* | X | X |
| | *Fraxinus latifolia* | X | X |
| | *Pinus ponderosa* | | X! |
| | *Populus trichocarpa* | X! | X! |
| | *Prunus avium** | | X! |
| | *Pyrus fuscus* | X | X |
| | *Pyrus communis** | | X! |
| | *Pyrus malus** | | X! |
| | *Quercus* spp. | X | |
| | *Rhamnus purshiana* | X | X |
| | *Salix* spp. | X! | X! |
| Total Species | | 16 | 20 |

* - exotic species

Table 5.3. Density (ha$^{-1}$) of woody plants by species, across treatments, within plant communities at Rose Prairie during 1988. Means based on 9 transects. Numbers in parentheses are the standard error of the mean.

| | | RP *Deschampsia* | *Rosa/Anthoxanthum* | *Vaccinium* |
|---|---|---|---|---|
| **SHRUBS** | | | | |
| | *Rosa eglanteria* | 37$^{a}$ (26) | 74 (41) | 148$^{b}$ (52) |
| | *Rosa nutkana* | 30519$^{a}$ (14833) | 50963$^{b}$ (6276) | 47620 (7400) |
| | *Rubus* spp. | 0 (0.0) | 62 (49) | 62 (38) |
| | *Amelanchier alnifolia* | 12 (12) | 12$^{a}$ (12) | 333$^{b}$ (72) |
| **TREES** | | | | |
| | *Crataegus douglasii* | 37$^{a}$ (37) | 0 (0) | 222$^{b}$ (69) |
| | *Pyrus fuscus* | 0 (0) | 0 (0) | 160 (85) |
| | *Quercus* spp. | 0 (0) | 0 (0) | 74 (26) |
| | *Rhamnus purshiana* | 0 (0) | 0 (0) | 99 (39) |
| | All trees combined: | 37$^{a}$ (0) | 0 (0) | 568$^{b}$ (105) |

Means with different superscripted letters denote a significant difference between plant communities ($p<0.10$).

*Deschampsia* (30,519 plants ha$^{-1}$), while the community with intermediate moisture, *Vaccinium*, had 47,620 plants ha$^{-1}$. *Amelanchier alnifolia* was present in significantly greater density in the *Vaccinium* community (333 plants ha$^{-1}$) than in the *Rosa/Anthoxanthum* (12 ha$^{-1}$) community.

Trees were absent in the *Rosa/Anthoxanthum* community and very sparse in the RP *Deschampsia* community (37 trees ha$^{-1}$) (Table 5.3). Trees were most prevalent in the *Vaccinium* community at Rose Prairie; *Crataegus douglasii* was the most abundant tree species (222 ha$^{-1}$) and the density of "all trees combined" was 568 ha$^{-1}$. There were four tree species that were present only in the *Vaccinium* community: *P. fuscus*, *Q. garryana*, *Q. kellogii* and *R. purshiana*. This community had the greatest woody species richness as well as the greatest densities of communities sampled at Rose Prairie.

### Fisher Butte

While the FB *Deschampsia* and *Rosa/Juncus* communities contained the same woody species richness (S=9), composition varied. Overall woody plant density was greater in the *Rosa/Juncus* community (Table 5.4). *Rosa eglanteria* and *C. monogyna* were only encountered in the drier FB *Deschampsia* community while *S. douglasii* was only in the wetter *Rosa/Juncus* community. *Rosa nutkana* and *F. latifolia* were present in significantly greater densities in the more mesic *Rosa/Juncus* community (53,067 and 1,071 plants ha$^{-1}$, respectively) compared to the drier *FB Deschampsia* community (17,156 and 0 plants ha$^{-1}$). *Rubus* spp. and

Table 5.4. Density (ha$^{-1}$) of shrubs and trees by species, across treatments, within plant communities at Fisher Butte during 1988. Means based on 15 transects. Numbers in parentheses are the standard error of the mean.

| | | FB *Deschampsia* | *Rosa/Juncus* |
|---|---|---|---|
| **SHRUBS** | | | |
| | *Rosa eglanteria* | 67 (34) | 0 (0) |
| | *Rosa nutkana* | 17156$^a$ (4425) | 53067$^b$ (9425) |
| | *Rubus* spp. | 44$^a$ (18) | 7$^b$ (7) |
| | *Amelanchier alnifolia* | 104$^a$ (32) | 30$^b$ (20) |
| **TREES** | | | |
| | *Crataegus douglasii* | 319 (87) | 496 (294) |
| | *Crataegus monogyna* | 7 (7) | 0 (0) |
| | *Fraxinus latifolia* | 0 (0) | 1071 (451) |
| | *Pyrus fuscus* | 37 (21) | 22 (16) |
| | *Pyrus communis* | 44 (30) | 74 (53) |
| | *Rhamnus purshiana* | 30 (13) | 44 (18) |
| | All trees combined: | 430$^a$ (88) | 1644$^b$ (512) |

Means with different superscripted letters denote a significant difference between plant communities ($p<0.10$)

*A. alnifolia* were present in significantly greater densities in the drier *FB Deschampsia* community (44 and 104 plants ha$^{-1}$, respectively) compared to the wetter *Rosa/Juncus* community (7 and 30 plants ha$^{-1}$). Crataegus douglasii was a primary tree invader in both *FB Deschampsia* (319 trees ha$^{-1}$) and *Rosa/Juncus* (496 trees ha$^{-1}$) plant communities. The density of "all trees combined" was significantly greater in the more mesic *Rosa/Juncus* community than in the drier *FB Deschampsia* community (1,644 and 430 plants ha$^{-1}$, respectively).

## Initial Species Heights in Plant Communities

### Rose Prairie

Prior to prescribed fires, *R. eglanteria* and *R. nutkana* were tallest in the dry *Rosa/Anthoxanthum* community (105 and 49 cm, respectively), shortest in the *Vaccinium* community (37 and 29 cm) and intermediate in height in the wet RP *Deschampsia* community (40 and 38 cm) (Table 5.5). Most trees occurred as seedlings or saplings with mean heights < 1m. The tallest trees were in the *Vaccinium* community; *P. fuscus* (61 cm), *C. douglasii* (57 cm), *R. purshiana* (19 cm), and *Quercus* spp. (12 cm). Only one tree was present in the RP *Deschampsia* community, a *C. douglasii* seedling 3 cm tall. No trees were present in *Rosa/Anthoxanthum* community transects.

Table 5.5. Heights (cm) of shrubs and trees by species, across treatments, within plant communities at Rose Prairie during 1988. Means based on variable numbers of transects with plants (n). Numbers in parentheses are the standard error of the mean.

| | | RP *Deschampsia* | n | *Rosa/Anthoxanthum* | n | *Vaccinium* | n |
|---|---|---|---|---|---|---|---|
| **SHRUBS** | | | | | | | |
| | *Rosa eglanteria* | 40 (7) | 2 | $105^a$ (13) | 3 | $37^b$ (9) | 6 |
| | *Rosa nutkana* | 38 (5) | 8 | $49^a$ (4) | 9 | $29^b$ (2) | 9 |
| | *Rubus* spp. | 0 (0) | 0 | 27 (3) | 2 | 20 (5) | 3 |
| | *Amelanchier alnifolia* | 31 (0) | 1 | 1 (0) | 2 | 69 (10) | 8 |
| **TREES** | | | | | | | |
| | *Crataegus douglasii* | 3 (0) | 1 | 0 (0) | 0 | 57 (16) | 7 |
| | *Pyrus fuscus* | 0 (0) | 0 | 0 (0) | 0 | 61 (16) | 5 |
| | *Quercus* spp. | 0 (0) | 0 | 0 (0) | 0 | 12 (2) | 5 |
| | *Rhamnus purshiana* | 0 (0) | 0 | 0 (0) | 0 | 19 (2) | 5 |
| | All trees combined: | 3 (0) | 1 | 0 (0) | 0 | 46 (12) | 9 |

Means with different superscripted letters denote a significant difference between plant communities ($p<0.10$).

### Fisher Butte

At Fisher Butte, *R. nutkana* was significantly shorter in the drier *FB Deschampsia* community (34 cm) than in the wetter *Rosa/Juncus* (40 cm) community (Table 5.6). Similar to Rose Prairie, most tree invasion consisted of seedlings and saplings. *Crataegus douglasii* was significantly taller in the *FB Deschampsia* community (80 cm) compared to the *Rosa/Juncus* community (61 cm). Overall, trees were significantly taller in the *FB Deschampsia* community (70 cm) than in the *Rosa/Juncus* community (46 cm).

## Fire effects on woody plant density

### Rose Prairie

Among plant communities, there was either no change or a decline (32%) in *R. nutkana* density between 1988 and 1990 in control treatments (Table 5.7). Density varied from a slight decline (9%) to a slight increase (15%) in once burned treatments and density varied from no changes to a significant increase (53%) in twice burn treatments across the different plant communities at Rose Prairie.

Within the RP *Deschampsia* community, there was a significant difference in the magnitude of change between 1988 and 1990 of *R. nutkana* density between control and twice burned treatments (Table 5.7). The density of *R. nutkana*

Table 5.6. Heights (cm) of shrubs and trees by species, across treatments, within plant communities at Fisher Butte during 1988. Means based on variable numbers of transects with plants (n). Numbers in parentheses are the standard error of the mean.

| | FB *Deschampsia* | | *Rosa/Juncus* | |
|---|---|---|---|---|
| | | n | | n |
| **SHRUBS** | | | | |
| *Rosa eglanteria* | 59 (6) | 4 | 0 (0) | 0 |
| *Rosa nutkana* | 34$^{a}$ (2) | 14 | 40$^{b}$ (2) | 14 |
| *Rubus* spp. | 50 (9) | 5 | 62 (0) | 1 |
| *Amelanchier alnifolia* | 55 (12) | 9 | 44 (30) | 2 |
| **TREES** | | | | |
| *Crataegus douglasii* | 79.4$^{a}$ (9) | 12 | 61$^{b}$ (22) | 12 |
| *Crataegus monogyna* | 86.0 (0) | 1 | 0 (0) | 0 |
| *Fraxinus latifolia* | 0.0 (0) | 0 | 19 (3) | 12 |
| *Pyrus fuscus* | 70.8 (12) | 3 | 91 (27) | 2 |
| *Pyrus communis* | 37.7 (13) | 4 | 100 (53) | 3 |
| *Rhamnus purshiana* | 33.0 (12) | 4 | 39 (14) | 5 |
| All trees combined: | 69.5$^{a}$ (7) | 12 | 46$^{b}$ (12) | 14 |

Means with different superscripted letters denote a significant difference between plant communities ($p<0.10$).

Table 5.7. Density (ha$^{-1}$) of shrubs and trees by species, within plant communities, by treatments and by years at Rose Prairie. Means based on 3 transects. Numbers in parentheses are the standard error of the mean.

| | CONTROL/NO BURN | | ONCE BURNED | | TWICE BURNED | |
|---|---|---|---|---|---|---|
| | 1988 | 1990 | 1988 | 1990 | 1988 | 1990 |
| RP *Deschampsia cespitosa* plant community | | | | | | |
| **SHRUBS** | | | | | | |
| *Rosa nutkana* | 4489 (3803) | 3044[a] (2588) | 3044 (3011) | 3511 (3445) | 1622 (905) | 1622[b] (1016) |
| *Rosa eglanteria* | 4 (4) | 4 (4) | 7 (7) | 7 (4) | 0 (0) | 4 (4) |
| *Amelanchier alnifolia* | 4 (4) | 4 (4) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| **TREES** | | | | | | |
| *Crataegus douglasii* | 0 (0) | 0 (0) | 11 (11) | 0 (0) | 0 (0) | 0 (0) |
| *Fraxinus latifolia* | 0 (0) | 4 (4) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| *Pyrus fuscus* | 0 (0) | 0 (0) | 0 (0) | 15 (15) | 0 (0) | 0 (0) |
| *Rhamnus purshiana* | 0 (0) | 4 (4) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| All trees combined: | 0 (0) | 7 (4) | 11 (11) | 15 (15) | 0 (0) | 0 (0) |
| *Rosa/Anthoxanthum* plant community | | | | | | |
| **SHRUBS** | | | | | | |
| *Rosa nutkana* | 4556 (1025) | 4489 (1075) | 6822 (968) | 6178[a] (1025) | 3911[1] (633) | 6000[2b] (115) |
| *Rosa eglanteria* | 0 (0) | 0 (0) | 111 (59) | 67 (38) | 22 (22) | 44 (44) |
| *Rhus diversiloba* | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 22 (22) |
| *Rubus* spp. | 22 (22) | 22 (22) | 0 (0) | 0 (0) | 89 (89) | 67 (67) |
| *Amelanchier alnifolia* | 0 (0) | 0 | 0 (0) | 0 (0) | 22 (22) | 22 (22) |

Table 5.7, Continued.

| | CONTROL/NO BURN | | ONCE BURNED | | TWICE BURNED | |
|---|---|---|---|---|---|---|
| | 1988 | 1990 | 1988 | 1990 | 1988 | 1990 |
| **TREES** | | | | | | |
| *Crataegus douglasii* | 0 (0) | 0 (0) | 0 (0) | 22 (22) | 0 (0) | 0 (0) |
| *Quercus* spp. | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 44 (44) |
| All trees combined: | 0 (0) | 0 (0) | 0 (0) | 22 (22) | 0 (0) | 44 (44) |
| *Vaccinium* plant community | | | | | | |
| **SHRUBS** | | | | | | |
| *Rosa nutkana* | 2867 (910) | 2756 (823) | 6667 (1411) | 7622 (1520) | 4756 (370) | 6444 (1302) |
| *Rosa eglanteria* | 22 (6) | 19 (10) | 4 (4) | 7 (4) | 19 (13) | 44 (17) |
| *Rhus diversiloba* | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 7 (7) |
| *Rubus* spp. | 4 (4) | 0 (0) | 0 (0) | 30 (30) | 15 (10) | 37 (21) |
| *Amelanchier alnifolia* | 52 (13) | 59 (4) | 19 (10) | 7 (7) | 30 (7) | 33 (11) |
| **TREES** | | | | | | |
| *Crataegus douglasii* | 11 (6) | 26 (26) | 22 (6) | 26 (4) | 33 (19) | 37 (20) |
| *Pyrus fuscus* | 26 (26) | 26 (15) | 7 (4) | 15 (10) | 15 (10) | 19 (13) |
| *Quercus* spp. | 7 (4) | 11 (11) | 4 (4) | 0 (0) | 11 (6) | 11 (6) |
| *Rhamnus purshiana* | 15 (10) | 19 (13) | 4 (4) | 4 (4) | 11 (6) | 0 (0) |
| All trees combined: | 63 (23) | 81 (32) | 37 (4) | 44 (11) | 70 (23) | 67 (6) |

Means with different superscripted numbers denote a difference between years within treatments; means with different superscripted letters denote a significant difference in the percent change between 1988 and 1990 between treatments (p<0.10).

dropped ~32% in control areas while density remained unchanged in twice burned areas. Likewise, there was a significant difference in the magnitude of change in *R. nutkana* density between once and twice burned treatments within the *Rosa/Anthoxanthum* community. The density of *R. nutkana* declined slightly between 1988 and 1990 in once burned areas while it increased by ~53% in twice burned areas.

## Fisher Butte

There were significant increases of *R. nutkana* density in twice burned treatments and of *Rubus* spp. density in once burned treatments between 1988 and 1990 within the *Rosa/Juncus* community at Fisher Butte (Table 5.8). Two consecutive burns resulted in significant declines (-76%) in the density of A. alnifolia in the FB *Deschampsia* community (Table 5.8). Concurrently, *A. alnifolia* density increased in control areas.

There were significant declines between years in the density of *F. latifolia* in once (-92%) and twice (-96%) burned treatments and of "all trees combined" within twice (-64%) burned treatments within the *Rosa/Juncus* community. In contrast, a single fire reduced total tree density only by 13% in this community. This same pattern of tree density decline with burning did not occur within the FB *Deschampsia* community. Tree density increased 27% in control, 91% in once burned and 116% in twice burned treatments, although results were not significant.

Table 5.8. Density (ha$^{-1}$) of shrubs and trees by species, within plant communities, by treatments and by years at Fisher Butte. Means based on 3 transects for control treatments and 6 transects for burn treatments. Numbers in parentheses are the standard error of the mean.

| | CONTROL/NO BURN | | ONCE BURNED | | TWICE BURNED | |
|---|---|---|---|---|---|---|
| | 1988 | 1990 | 1988 | 1990 | 1988 | 1990 |
| FB *Deschampsia* plant community | | | | | | |
| **SHRUBS** | | | | | | |
| *Rosa nutkana* | 311 (174) | 267 (133) | 2678 (813) | 2033 (502) | 1456 (555) | 1722 (542) |
| *Rosa eglanteria* | 0 (0) | 0 (0) | 15 (7) | 0 (0) | 2 (2) | 2 (2) |
| *Rubus* spp. | 7 (7) | 7 (4) | 6 (2) | 33 (15) | 2 (2) | 9 (6) |
| *Amelanchier alnifolia* | 11 (0) | 22[a] (6) | 4 (2) | 6 (4) | 17 (7) | 4[b] (2) |
| **TREES** | | | | | | |
| *Crataegus douglasii* | 44 (17) | 63 (21) | 26 (16) | 54 (25) | 31 (14) | 67 (31) |
| *Crataegus monogyna* | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 2 (2) | 2 (2) |
| *Fraxinus latifolia* | 0 (0) | 0 (0) | 2 (2) | 0 (0) | 0 (0) | 0 (0) |
| *Pyrus fuscus* | 4 (4) | 7 (7) | 4 (4) | 7 (5) | 4 (4) | 6 (4) |
| *Pyrus communis* | 15 (15) | 7 (4) | 4 (2) | 6 (2) | 2 (2) | 6 (4) |
| *Rhamnus purshiana* | 7 (4) | 11 (6) | 2 (2) | 0 (0) | 2 (2) | 0 (0) |
| All trees combined: | 70 (10) | 89 (22) | 35 (16) | 67 (28) | 37 (13) | 80 (27) |

Table 5.8, Continued.

| | CONTROL/NO BURN | | ONCE BURNED | | TWICE BURNED | |
|---|---|---|---|---|---|---|
| | 1988 | 1990 | 1988 | 1990 | 1988 | 1990 |
| *Rosa/Juncus* plant community | | | | | | |
| **SHRUBS** | | | | | | |
| *Rosa nutkana* | 2044 (1193) | 2422 (1368) | 7456 (1574) | 9900 (1966) | $4789^1$ (1190) | $8422^2$ (1852) |
| *Rhus diversiloba* | 0 (0) | 0 (0) | 0 (0) | 7 (7) | 0 (0) | 0 (0) |
| *Rubus* spp. | 0 (0) | 0 (0) | $2^1$ (2) | $11^2$ (4) | 0 (0) | 4 (2) |
| *Amelanchier alnifolia* | 0 (0) | 7 (7) | 4 (4) | 2 (2) | 4 (4) | 2 (2) |
| **TREE** | | | | | | |
| *Crataegus douglasii* | 22 (17) | 41 (35) | 22 (8) | 33 (11) | 91 (73) | 104 (74) |
| *Fraxinus latifolia* | 0 (0) | 0 (0) | $52^1$ (25) | $4^2$ (2) | $200^1$ (97) | $9^2$ (5) |
| *Pyrus fuscus* | 0 (0) | 0 (0) | 6 (4) | 13 (7) | 0 (0) | 0 (0) |
| *Pyrus communis* | 0 (0) | 0 (0) | 19 (12) | 39 (32) | 0 (0) | 0 (0) |
| *Rhamnus purshiana* | 7 (4) | 7 (7) | 0 (0) | 2 (2) | 7 (4) | 0 (0) |
| All trees combined: | 30 (20) | 48 (43) | 98 (31) | $85^a$ (53) | $298^1$ (105) | $113^{2b}$ (73) |

Means with different superscripted numbers denote a significant difference between years within treatments; means with different superscripted letters denote a significant difference in the percent change between 1988 and 1990 between treatments ($p<0.10$)

## Fire effects on mean plant height

### Rose Prairie

Heights of *R. nutkana* were significantly reduced (-43%) between 1988 and 1990 in once burned treatments within the *Vaccinium* community (Table 5.9). Likewise, R. nutkana heights significantly declined (-60%) in twice burned treatments within the *Rosa/Anthoxanthum* community. Within the *Vaccinium* plant community, the magnitude of change in heights of *A. alnifolia* differed significantly between once and twice burned treatments; heights increased 40% in once burned areas while heights decreased 31% in twice burned areas.

### Fisher Butte

Heights of *R. nutkana* were significantly reduced by both burn treatments in both plant communities (Table 5.10). Heights were reduced by 67% (FB *Deschampsia*) and 31% (*Rosa/Anthoxanthum*) in once burned areas and by 34% (*FB Deschampsia*) and 53% (*Rosa/Anthoxanthum*) in twice burned areas. Likewise, the heights of *Rubus* spp. were significantly reduced in once burned treatments within the *FB Deschampsia* community (-67%).

The mean height of *C. douglasii*, was significantly reduced in twice burned treatments within the *FB Deschampsia* community (-51%) (Table 5.10). Within the *FB Deschampsia* community at Fisher Butte, fires resulted in significant

Table 5.9. Height (cm) of shrubs and trees by species, within plant communities, by treatments and by years at Rose Prairie. Means based on variable numbers of transects with plants present (n). Numbers in parentheses are the standard error of the mean.

| | 1988 | n | 1990 | n | 1988 | n | 1990 | n | 1988 | n | 1990 | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RP *Deschampsia* plant community | | | | | | | | | | | | |
| **SHRUBS** | | | | | | | | | | | | |
| *Rosa nutkana* | 35 (2) | 3 | 35 (2) | 3 | 35 (19) | 2 | 19 (15) | 2 | 43 (11) | 3 | 34 (13) | 3 |
| *Rosa eglanteria* | 47 (0) | 1 | 49 (0) | 1 | 33 (0) | 1 | 19 (9) | 2 | 0 (0) | 0 | 14 (0) | 1 |
| *Amelanchier alnifolia* | 31 (0) | 1 | 23 (0) | 1 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 |
| **TREES** | | | | | | | | | | | | |
| *Crataegus douglasii* | 0 (0) | 0 | 0 (0) | 0 | 60 (0) | 1 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 |
| *Fraxinus latifolia* | 0 (0) | 0 | 10 (0) | 1 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 |
| *Pyrus fuscus* | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 28 (0) | 1 | 0 (0) | 0 | 0 (0) | 0 |
| *Rhamnus purshiana* | 0 (0) | 0 | 11 (0) | 1 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 |
| All trees Combined: | 0 (0) | 0 | 11 (0) | 2 | 60 (0) | 1 | 28 (0) | 1 | 0 (0) | 0 | 0 (0) | 0 |
| *Rosa/Anthoxanthum* plant community | | | | | | | | | | | | |
| **SHRUBS** | | | | | | | | | | | | |
| *Rosa nutkana* | 60 (7) | 3 | 47 (8) | 3 | 44 (7) | 3 | 25 (6) | 3 | 43[1] (1) | 3 | 17[2] (2) | 3 |
| *Rosa eglanteria* | 0 (0) | 0 | 0 (0) | 0 | 95 (157) | 2 | 83 (19) | 2 | 124 (0) | 1 | 35 (0) | 1 |
| *Rhus diversiloba* | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 8 (0) | 1 |
| *Rubus* spp. | 30 (0) | 1 | 45 (0) | 1 | 0 (0) | 0 | 0 (0) | 0 | 24 (0) | 1 | 20 (0) | 1 |
| *Amelanchier alnifolia* | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 38 (0) | 1 | 44 (0) | 1 |

Table 5.9, Continued.

| | 1988 | n | 1990 | n | 1988 | n | 1990 | n | 1988 | n | 1990 | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TREES** | | | | | | | | | | | | |
| *Crataegus douglasii* | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 34 (0) | 1 | 0 (0) | 0 | 0 (0) | 0 |
| *Quercus* spp. | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 9 (0) | 1 |
| All trees Combined: | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 34 (0) | 1 | 0 (0) | 0 | 9 (0) | 1 |
| *Vaccinium* plant community | | | | | | | | | | | | |
| **SHRUBS** | | | | | | | | | | | | |
| *Rosa nutkana* | 29 (2) | 3 | 39 (22) | 3 | $28^1$ (5) | 3 | $16^2$ (2) | 3 | 30 (1) | 3 | 20 (5) | 3 |
| *Rosa eglanteria* | 29 (5) | 3 | 22 (4) | 2 | 25 (0) | 1 | 24 (7) | 2 | 55 (23) | 2 | 18 (7) | 3 |
| *Rhus diversiloba* | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 4 (0) | 1 |
| *Rubus* spp. | 29 (0) | 1 | 0 (0) | 0 | 0 (0) | 0 | 2 (0) | 1 | 16 (3) | 2 | 11 (5) | 3 |
| *Amelanchier alnifolia* | 65 (6) | 3 | 60 (13) | 3 | 89 (34) | 2 | $125^a$ (0) | 1 | 59 (15) | 3 | $41^b$ (20) | 3 |
| **TREES** | | | | | | | | | | | | |
| *Crataegus douglasii* | 87 (56) | 2 | 75 (0) | 1 | 46 (10) | 3 | 35 (7) | 3 | 42 (24) | 2 | 16 (11) | 2 |
| *Crataegus monogyna* | 0 (0) | 0 | 0 (0) | | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 |
| Pyrus fuscus | 84 (0) | 1 | 59 (33) | 3 | 55 (24) | 2 | 28 (15) | 2 | 56 (39) | 2 | 33 (7) | 2 |
| *Quercus* spp. | 14 (3) | 2 | 9 (0) | 1 | 12 (0) | 1 | 0 (0) | 0 | 9 (2) | 2 | 9 (0) | 2 |
| *Rhamnus purshiana* | 17 (4) | 2 | 22 (4) | 2 | 25 (0) | 1 | 25 (0) | 1 | 19 (2) | 2 | 0 (0) | 0 |
| All trees Combined: | 44 (27) | 3 | 45 (26) | 3 | 41 (13) | 3 | 31 (3) | 3 | 50 (23) | 3 | 20 (6) | 3 |

Means with different superscripted numbers denote a significant difference between years within treatments; means with different superscripted letters denote a significant difference in the percent change between 1988 and 1990 between treatments ($p<0.10$).

Table 5.10. Height (cm) of shrubs and trees by species, within plant communities, by treatments and by years at Fisher Butte. Means based on variable numbers of transects with plants present (n). Numbers in parentheses are the standard error of the mean.

| | CONTROL/NO BURN | | | | ONCE BURNED | | | | TWICE BURNED | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1990 | | 1988 | | 1990 | | 1988 | | 1990 | |
| | | n | | n | | n | | n | | n | | n |
| FB *Deschampsia* plant community | | | | | | | | | | | | |
| **SHRUBS** | | | | | | | | | | | | |
| *Rosa nutkana* | 36 (5) | 2 | 40 (1) | 2 | $35^1$ (3) | 6 | $23^2$ (2) | 6 | $32^1$ (4) | 6 | $21^2$ (2) | 6 |
| *Rosa eglanteria* | 0 (0) | 0 | 0 (0) | 0 | 53 (2) | 3 | 0 (0) | 0 | 76 (0) | 1 | 56 (0) | 1 |
| *Rubus* spp. | 21 (0) | 1 | 31 (19) | 2 | 55 (8) | 3 | 18 (4) | 4 | 64 (0) | 1 | 15 (7) | 2 |
| *Amelanchier alnifolia* | 60 (38) | 3 | 51 (16) | 3 | 51 (18) | 2 | 42 (5) | 2 | 55 (10) | 4 | 39 (1) | 2 |
| **TREES** | | | | | | | | | | | | |
| *Crataegus douglasii* | 57 (11) | 3 | 37 (11) | 3 | 101 (18) | 4 | 34 (7) | 5 | $76^1$ (12) | 5 | $37^2$ (5) | 5 |
| *Crataegus monogyna* | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 87 (0) | 1 | 83 (0) | 1 |
| *Fraxinus latifolia* | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 |
| *Pyrus fuscus* | 94 (0) | 1 | 60 (0) | 1 | 55 (0) | 1 | 27 (8) | 2 | 64 (0) | 1 | 25 (17) | 2 |
| *Pyrus communis* | 8 (0) | 1 | 18 (3) | 2 | 51 (20) | 2 | 23 (5) | 3 | 41 (0) | 1 | 9 (2) | 2 |
| *Rhamnus purshiana* | 38 (28) | 2 | 22 (2) | 2 | 36 (0) | 1 | 0 (0) | 0 | 21 (0) | 1 | 0 (0) | 0 |
| All trees Combined: | 41 (11) | 3 | $35^a$ (7) | 3 | $68^1$ (9) | 5 | $30^{2b}$ (5) | 6 | $70^1$ (9) | 6 | $34^{2b}$ (4) | 6 |

Table 5.10., Continued.

| | CONTROL/NO BURN | | | | ONCE BURNED | | | | TWICE BURNED | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1990 | | 1988 | | 1990 | | 1988 | | 1990 | |
| | | n | | n | | n | | n | | n | | n |
| *Rosa/Juncus* plant community | | | | | | | | | | | | |
| **SHRUBS** | | | | | | | | | | | | |
| *Rosa nutkana* | 39 (5) | 2 | 31 (2) | 2 | $42^1$ (3) | 6 | $29^2$ (2) | 6 | $38^1$ (2) | 6 | $18^2$ (3) | 6 |
| *Rhamnus purshiana* | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 7 (0) | 1 | 0 (0) | 0 | 0 (0) | 0 |
| *Rubus* spp. | 0 (0) | 0 | 0 (0) | 0 | 62 (0) | 1 | 13 (5) | 4 | 0 (0) | 0 | 12 (0) | 2 |
| *Amelanchier alnifolia* | 0 (0) | 0 | 7 (0) | 1 | 74 (0) | 1 | 65 (0) | 1 | 15 (0) | 1 | 6 (0) | 1 |
| **TREES** | | | | | | | | | | | | |
| *Crataegus douglasii* | 182 (96) | 2 | 161 (105) | 2 | 44 (19) | 5 | 23 (3) | 6 | 29 (8) | 5 | 38 (11) | 6 |
| *Fraxinus latifolia* | 0 (0) | 0 | 0 (0) | 0 | 16 (6) | 5 | 10 (3) | 2 | 23 (1) | 6 | 34 (9) | 3 |
| *Pyrus fuscus* | 0 (0) | 0 | 0 (0) | 0 | 91 (27) | 2 | 63 (17) | 3 | 0 (0) | 0 | 0 (0) | 0 |
| *Pyrus communis* | 0 (0) | 0 | 0 (0) | 0 | 100 (53) | 3 | 75 (19) | 4 | 0 (0) | 0 | 0 (0) | 0 |
| *Rhamnus purshiana* | 55 (31) | 2 | 20 (0) | 1 | 0 (0) | 0 | 7 (0) | 1 | 20 (7) | 3 | 0 (0) | 0 |
| All trees Combined: | 129 (53) | 2 | 158 (108) | 2 | 30 (8) | 6 | $38^a$ (6) | 6 | 24 (2) | 6 | $37^b$ (9) | 6 |

Means with different superscripted numbers denote a significant difference between years within treatments; means with different superscripted letters denote a significant difference in the percent change between 1988 and 1990 between treatments ($p<0.10$).

declines in the overall heights of trees. While they declined 15% in control areas, decreases of 56% in once and 51% in twice burned treatments occurred.

The magnitude of change in heights of "all trees combined" was significant between once and twice burned treatments within the *Rosa/Juncus* community, however, mean tree heights increased. In this community, the heights of trees increased 22% in control treatments, while heights increased 31% and 54% in once and twice burned treatments, respectively.

## Fire effects on *Rosa nutkana* height structure

### Rose Prairie

Between 1988 and 1990, the number of *R. nutkana* in control treatments within the 91-100 cm and 101-110 cm height classes had increased six fold indicating a growing dominance of these plants in unburned areas (Figure 5.6). In contrast, changes in the distribution of individuals in height size classes between 1988 and 1990 in the burned treatments was quite different. In the once burned treatment, the number of individuals in the 1-10 cm class had increased by 900% and all individuals taller than 60 cm had been eliminated. In the twice burned treatment, populations of *R. nutkana* shifted dramatically into the shortest (1-20 cm) height classes (from 10% in 1988 to 64% in 1990). Individuals in the taller

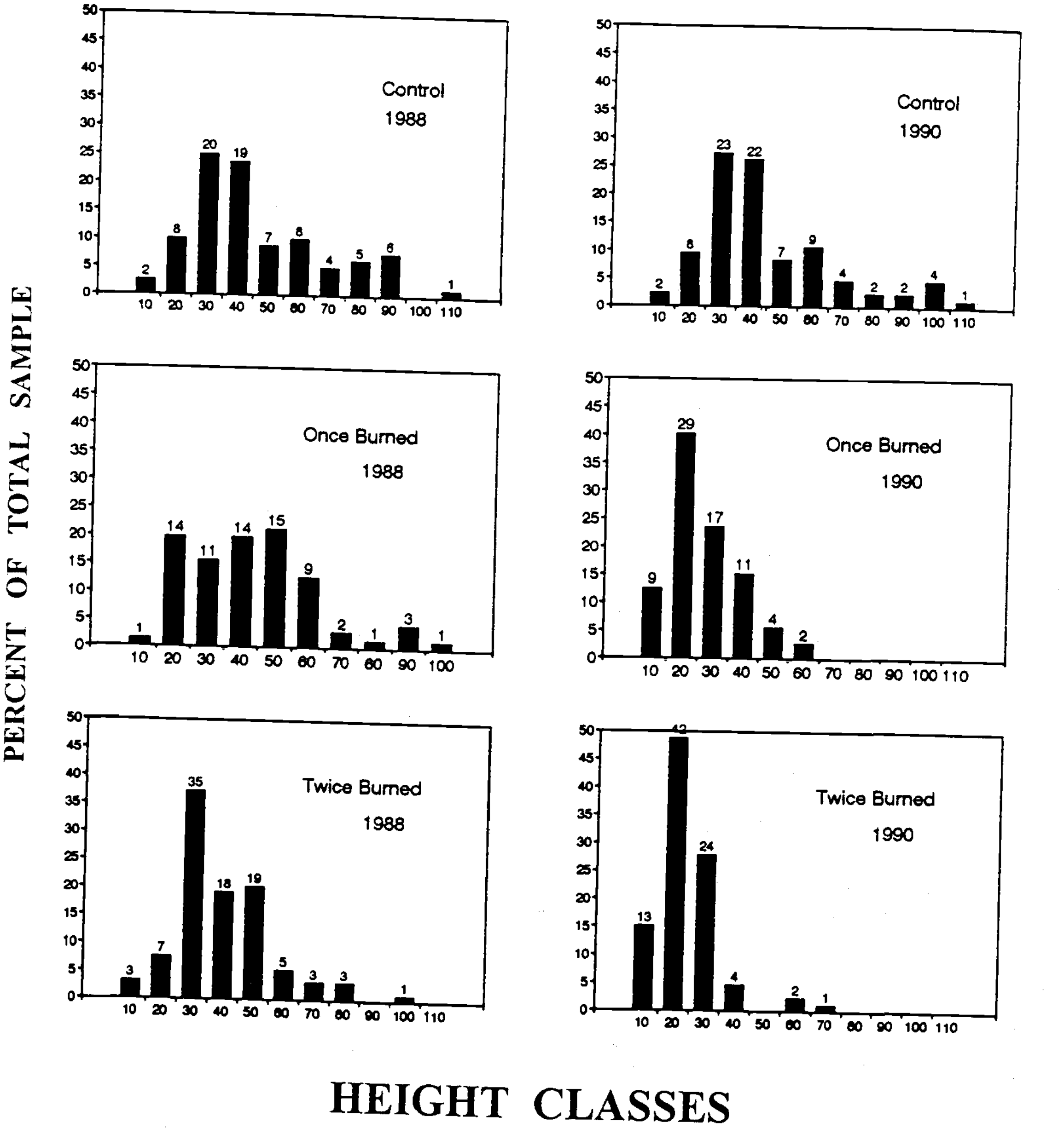

**Figure 5.6. Height class distribution for *Rosa nutkana* at Rose Prairie. Small numbers above bars indicate number of plants.**

classes (41-110 cm) represented 32% of the total population in 1988 and only 3% after two fires.

### Fisher Butte

Distributions shifted into larger and smaller height classes between 1988 and 1990 in the control treatment (Figure 5.7). In contrast, fires produced notable shifts toward shorter height classes. All individuals greater than 60 cm tall were eliminated from once and twice burned treatments. Individuals in the 1-10 cm and 11-20 cm height classes increased from 9% in 1988 to 62% in 1990 in once burned treatments and from 13% to 32% in twice burned treatments.

## Fire effects on tree height structure

### Rose Prairie

Between 1988 to 1990, there were increases in shorter height classes in the control treatment, indicating a continued invasion of trees (Figure 5.8). Trees taller than 75 cm were eliminated in burn treatments, while the proportion of trees in the shortest height classes (1-50 cm) increased from 62% to 82% in once burned treatments and increased from 84% to 95% in twice burned treatments.

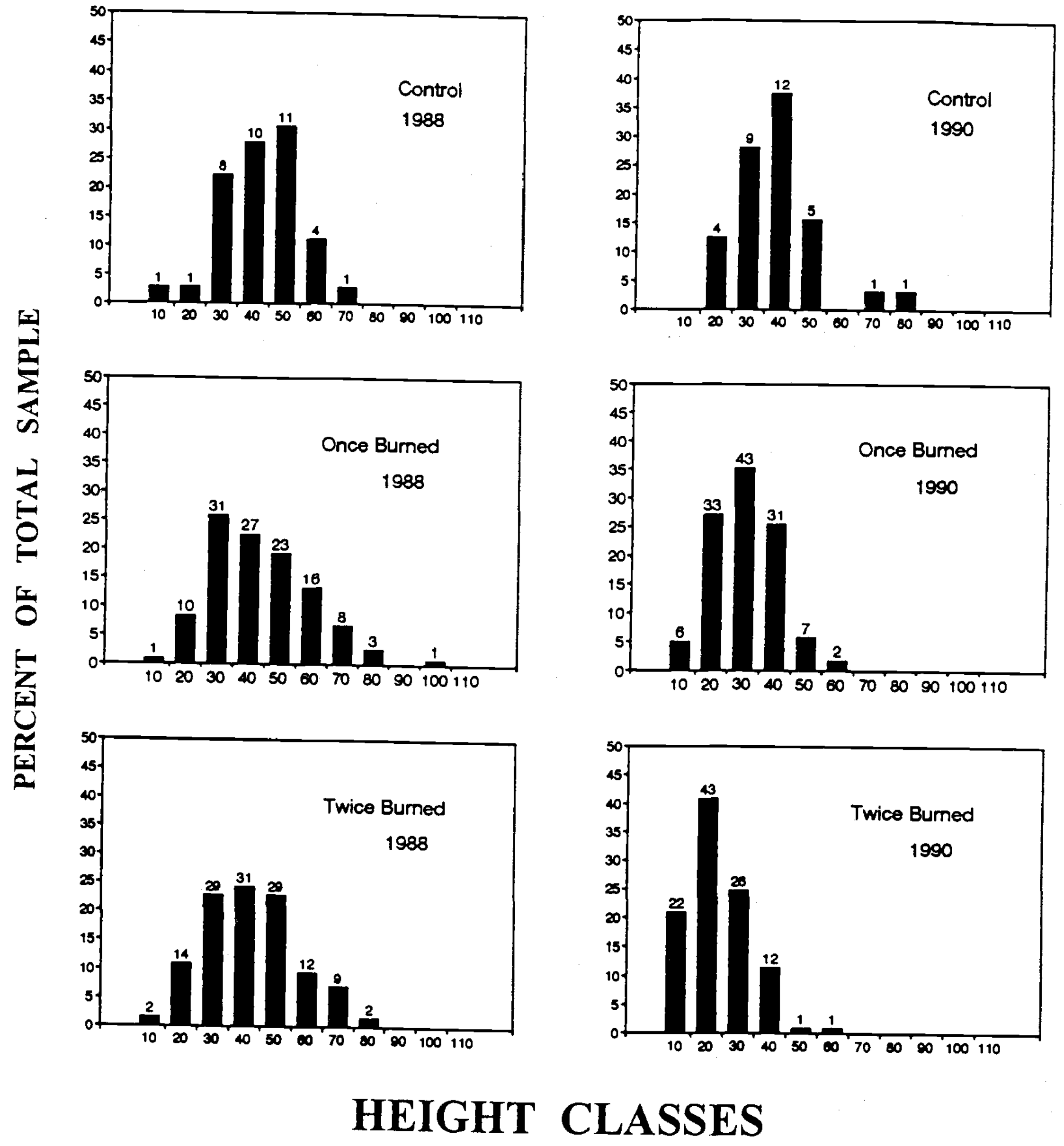

Figure 5.7. Height class distribution for *Rosa nutkana* at Fisher Butte. Small numbers above bars indicate number of plants.

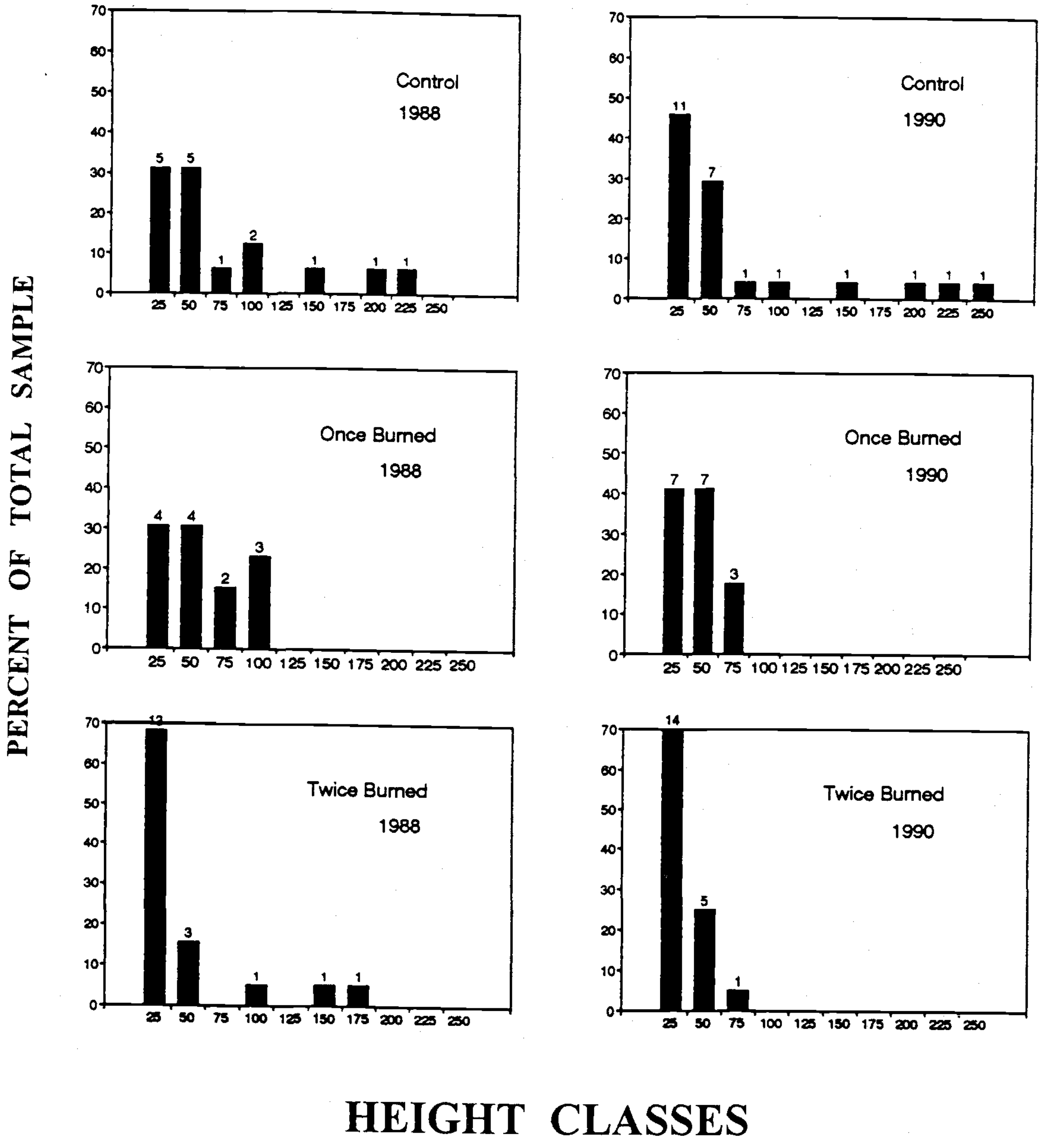

Figure 5.8. Height class distribution for trees at Rose Prairie. Small numbers above bars indicate number of plants.

### Fisher Butte

The distribution of size classes in control treatments changed little over the course of this study (Figure 5.9). In contrast to controls, most trees taller than 125 cm had been eliminated by burn treatments at Fisher Butte. The proportion of trees in the shortest height class (1-25 cm) decreased by 10% in once burned treatments and decreased by 16% in twice burned transects.

## Discussion

### Initial species composition in plant communities

The shrub and tree species common to both study sites are typical invaders of wet prairie remnants of the southern Willamette Valley (Acker 1986, Moir and Mika 1972, Frenkel and McEvoy 1983, Frenkel and Streatfeild 1994, Streatfeild 1995). Generally, shrub and tree distribution was very patchy and woody plant densities and heights were variable across plant communities at the study sites.

Edaphic, hydrologic and other chance factors have influenced the pre-burn species composition at these two study sites. No environmental factors measured by Finley (1994) clearly explained the greater species richness in the *Vaccinium* ($S=10$) community relative to either the RP *Deschampsia* ($S=4$) or *Rosa/Anthoxanthum* ($S=4$) communities at Rose Prairie or the *FB Deschampsia* ($S=9$) and *Rosa/Juncus* ($S=9$) communities at Fisher Butte. Both RP

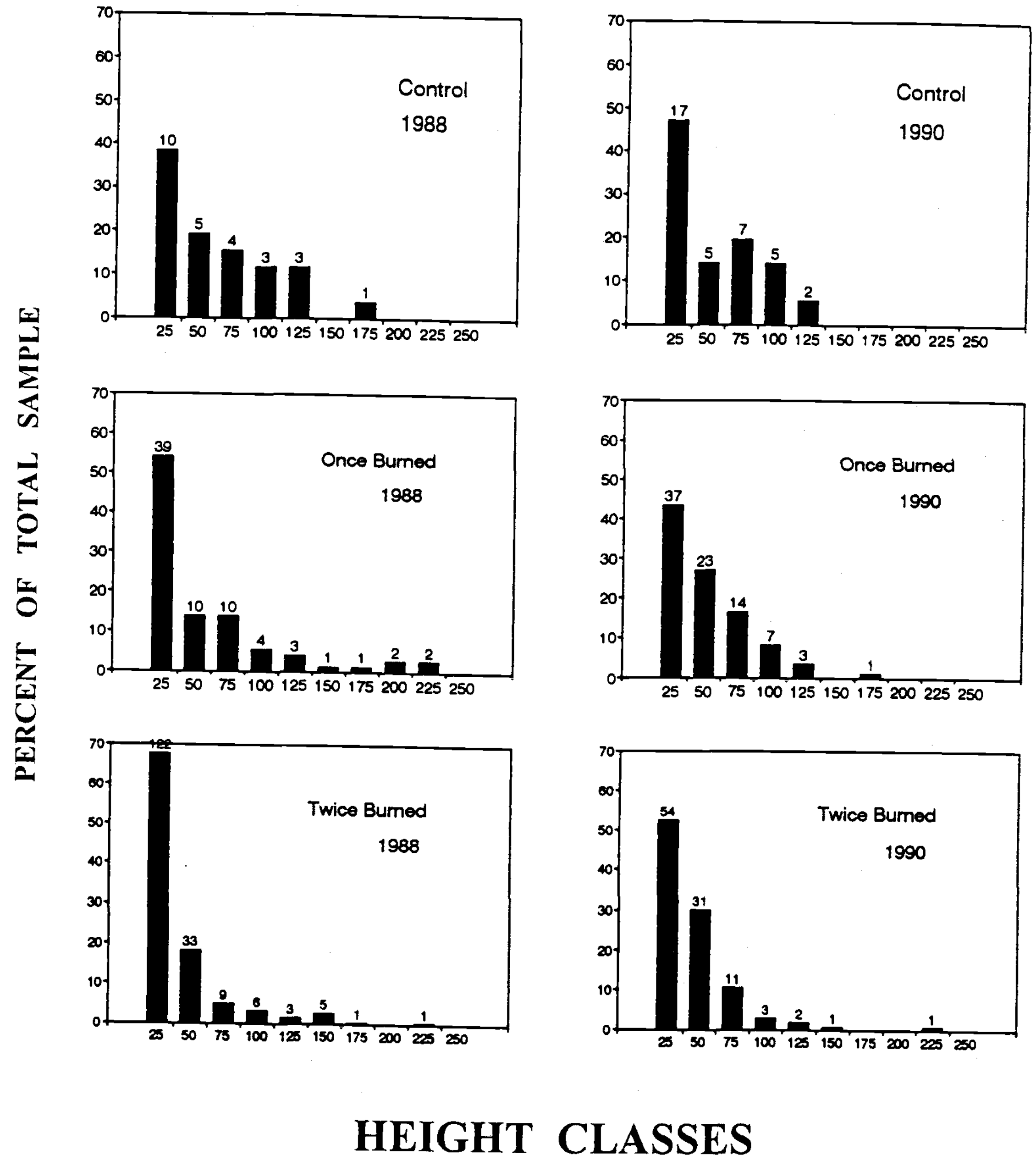

**Figure 5.9. Height class distribution for trees at Fisher Butte. Small numbers above bars indicate number of plants.**

*Deschampsia* and *Vaccinium* communities had low iron, sulphate and organic matter content in soils relative to Fisher Butte communities, but the differences between plant communities within sites were not significant (Finley 1994). Soil pH was 5.3 at both study sites with no significant differences among plant communities at either site.

There were some species affinities to plant communities that appeared to relate to environmental differences. Varied dominance within different communities may indicate that *C. douglasii*, *F. latifolia*, *P. communis*, and *R. purshiana* establish more readily in wetter locations while *A. alnifolia* and *P. fuscus* are better adapted to slightly drier locations.

There was no relationship of *R. nutkana* density to environmental moisture gradients. The mean density of *R. nutkana* was greatest in the wet *Rosa/Juncus* community at Fisher Butte, but greatest in the dry *Rosa/Anthoxanthum* plant community at Rose Prairie.

Overall density and height measurements indicate that Fisher Butte is experiencing far more exotic as well as total woody invasion than Rose Prairie. Initially, the density of "all trees combined" was nearly four times greater in the more mesic *Rosa/Juncus* community than in the *FB Deschampsia* community. This was due primarily to the large numbers of *F. latifolia* invading the wet *Rosa/Juncus* community.

At Fisher Butte, lower densities and the greater mean heights of *Crataegus douglasii* and "all trees combined" within the *FB Deschampsia* community indicated that the *Rosa/Juncus* community is experiencing much more seedling establishment relative to the *FB Deschampsia* community (thus depressing the overall mean).

Prairie sites with established trees may be more prone to woody invasion because established trees act as direct sources of seed and vegetative colonization. Shrubs and trees established at these study sites have characteristic wind dispersal (i.e. *Populus trichocarpa*, *Salix* spp, and *Fraxinus latifolia*), gravity, and/or animal and bird seed dispersal mechanisms. Established trees also function as attractive perching sites for birds and more frequent bird visits may increase the number of propagules brought to the site from elsewhere. Many woody species at the study sites produce seeds within an edible berry or fruit and thus are known or likely to be dispersed by birds and/or mammals. Although mammals may help disperse woody plant seeds, seed survival and seedling establishment within these communities may be negatively impacted by seed predation, trampling and grazing effects from mammal populations (Frenkel and Heinitz 1987, Howard 1992).

### Fire effects on individual species and total trees

Increases in *R. eglanteria* and *R. nutkana* density were most likely a response of vigorous sprouting from below-ground tissues when the aerial portions of plants were killed by fire. *Rosa* spp. are known to sprout from crowns and extensive rhizomes following burning (Young 1983, Bradley et al. 1992, Reed 1993). In contrast to the results of this study, Frenkel and Streatfeild (1994) found decreases in the frequency of *Rosa eglanteria* following burning at another wetland prairie site. Individual *R. nutkana* plants were difficult to distinguish; in future studies it would be best to relate plant density using total aboveground stem density.

Mean height of *R. eglanteria* and *R. nutkana* consistently declined in the burn treatments. The distribution of *R.nutkana* height classes at both sites also shifted from the taller to the shorter height classes within burn treatments compared to control treatments. Because *R. nutkana* is such a dominant structural feature on these sites, height reduction with burning causes a change in the physiognomy of the study sites to a more prairie-like structure.

Prescribed burns seemed to dramatically reduce stem densities and stem heights of *Spiraea douglasii* and *Rosa* "Multiflora", although these species either occurred outside sampled transects or parameters were they inadequately measured to report quantitative results.

Thermal effects of burns can stimulate germination or post fire conditions may become conducive to the germination and establishment of some woody species from refractory seeds buried in the soil (Keeley 1988, Kauffman and Martin 1992). Establishment of shrub and tree seedlings were observed in all treatments. An observed increase of shrub and tree seedlings in burn plots may be due to the removal of thatch/litter and the opening of bare soil for the establishment of new seedlings. The period of this research may also have coincided with good seed production years followed by good tree seedling establishment conditions. Increased seed production and establishment might explain the increased number of tree seedlings also observed in control plots.

*Rubus* spp. established in a number of plant communities following burning. Although mean height of *Rubus* spp. were reduced in once burned treatments within the *Rosa/Juncus* community, *Rubus* spp. established in *Vaccinium* and *Rosa/Juncus* communities and increased in a number of communities following burning. Many Rubus spp. are known to readily regenerate vegetatively from underground structures such as roots, rhizomes, or rootstocks when aboveground foliage is removed by fire or other means; seeds are also known to germinate readily from soil seed stocks (Tirmenstein 1989).

The reduction of *A. alnifolia* density in twice burned treatments relative to controls may indicate that burning will reduce densities of this plant. Also the significant reduction of height in twice burned treatments relative to once burned treatments indicates the effectiveness of multiple burns in controlling this species. Though the aerial portions of this species are known to be killed by fire, it readily sprouted from underground rhizomes (Young 1983, Bradley et al. 1992, Hickerson 1986). Anderson and Bailey (1980) reported a decline in cover but an increase in frequency and density of A. alnifolia after an early spring burn. It is possible that a single burn may enhance populations of this plant while frequent, multiple burns may result in its decline. The Stl'at'imx tribe of British Columbia historically burned to encourage stands of this species (Pojar and MacKinnon 1994). The berries produced by this plant were a prized food of the Kalapuya people of the

Willamette Valley (Horn 1972) and berry production may have been enhanced by specific burning regimes.

*Crataegus douglasii* disappeared from once burned treatments in Rose Prairie RP *Deschampsia*, established in once burned treatments in *Rosa/Anthoxanthum*, and increased within all other treatments and plant communities at the two study sites. This species is known to sprout following fire and its berries are eaten and dispersed by a wide variety of birds and animals (Hitchcock et al. 1969, Habeck 1991). There was a significant decrease in mean height of C. douglasii within twice burned treatments in *FB Deschampsia*. The height decline was likely due to a downward trend in the mean from more individuals in seedling and sprouting height sizes.

*Fraxinus latifolia* established in control treatments within the Rose Prairie RP *Deschampsia* community while there were significant declines in density in once and twice burned treatments within the *Rosa/Juncus* community. The mean height of *F. latifolia* decreased in once burned treatments while it increased in twice burned treatments in the *Rosa/Juncus* community. These data indicate that for *F. latifolia* density was reduced overall in both burn treatments within the *Rosa/Juncus* community, but more individuals died in twice burned areas than in once burned areas (resulting in greater mean height). These data indicate that *F. latifolia* more mortality (particularly seedling and sapling height classes) occurs with repeated burning in wet prairie locations.

Seedlings and saplings of *Rhamnus purshiana* appeared to be more fire sensitive than other tree species invading Willamette Valley wet prairies. *R. purshiana* densities increased or were unchanged in controls while they disappeared from a number of plant communities with burning (i.e. twice burned *Vaccinium*, once and twice burned FB *Deschampsia*, and twice burned *Rosa/Juncus*). *Rhamnus purshiana* is usually top-killed by fire but will readily sprout from surviving root crowns following low-intensity fires (Habeck 1992). Its berries are also known to be readily dispersed by birds.

There were inconsistent trends for density and mean heights of "all trees combined" for the different treatments and plant communities; likely related to the different responses that individual tree species display toward burning. Ahlgren and Ahlgren (1960) found that the effects of fire will vary depending upon different structural and physiological adaptations of individual tree species as well as the age of specific trees. Tree density increased between 1988 and 1990 in *Vaccinium* at Rose Prairie and in FB *Deschampsia* at Fisher Butte while there was a significant decrease in tree density in *Rosa/Juncus* in twice burned treatments at Fisher Butte. The greater decline in density in twice burned treatments relative to once burned treatments in *Rosa/Juncus* indicates a greater effectiveness of multiple burns at reducing tree (particularly *F. latifolia*) density in that plant community.

Unlike the reduction in the mean height of *R. nutkana* observed with burning, height reduction of trees was not consistently related to burning. Some trees in the taller height classes were eliminated in burn treatments and others became more proportionally concentrated into the shorter height classes.

All of the tree species sampled in this study were observed to sprout from epicormic or below ground tissues, resulting in a greater density of stems per plant. Additionally, woody plants can readily reoccupy these sites from seeds stored in the soil or via animal or wind dispersal.

Trees over 3 m in height appeared to be little affected by the low intensity fires prescribed and characteristic to Willamette Valley wet prairies. Fire has resulted in little mortality of taller trees at other wetland prairie sites (Acker 1986).

Overall results from this study indicate that an eventual reduction in shrub and tree dominance would be expected with repeated burning at the Rose Prairie and Fisher Butte study sites. Repeated burning will not result in the immediate elimination of woody species from these sites but would maintain a low woody height stature and control further shrub and tree seedling establishment and woody plant expansion at these sites.

## Conclusion

Shrubs and trees of Willamette Valley wet prairies are generally resilient to the effects of burning and are adapted for regrowth and reoccupation of sites following fire. *Rosa nutkana* has a particularly high rate of survival and regrowth as well as the capacity to increase shoot density following fire. In this study, the distribution of *R. nutkana* and tree height classes became much more concentrated into the shorter height classes following burn treatments. This trend indicates the possibility of reducing the dominance of shrubs and trees if fire is reintroduced into native Willamette Valley prairie and areas are repeatedly burned. Young (1983) suggests that burning with moist soils may result in better control of a number of shrubs and trees; e.g. *Rosa* spp. and *A. alnifolia*. Specific burn prescriptions may need to be developed to maximized woody plant mortality. Trees greater than 3 m in height may need to be removed manually to reduce some of the on-site seed source maintained by these trees. After the desired community structure is achieved, fire may be utilized to restrict renewed shrub and tree establishment.

# CHAPTER 6
# CONCLUSION AND RECOMMENDATIONS

Fire has been a vital process and evolutionary force in the development and perpetuation of Willamette Valley prairies. Currently, succession continues to threaten the remaining remnant prairies of the Willamette Valley. There is an urgent need to determine optimal methods for perpetuating prairie plant communities including the reintroduction of fire as an ecological process. This research endeavor initiates a long-term study to determine optimal burn prescriptions for maintaining and restoring native Willamette Valley wetland prairies. Measurement of weather, fuel conditions, fire behavior, and resulting plant composition will help researchers and managers develop optimum burn prescriptions tailored to fit specific objectives. Objectives for prairie burning may include: (1) reduction in height and density of shrubs and trees, (2) control and reduction of exotic plants, (3) maintenance or increase in native prairie composition and vigor, (4) maintenance or increase of aboriginal plant foods, and (5) maintenance or increase in vigor and density of rare plant species of concern.

In this study, the density of *Rosa nutkana* increased significantly in a number of plant communities with burning; however, plants generally were restricted to shorter height classes following burning. Tree seedlings and saplings were eliminated or their densities were significantly reduced in some communities. Fire had little effect on trees greater than 3 m in height. Taller trees may need to be manually removed to reduce some of the on-site seed source. After the desired community structure is achieved, fire should be utilized to restrict renewed shrub and tree establishment.

Prescribed burning produced in mixed effects on herbaceous plants. Fire sometimes increased frequency and cover of native species, but in other circumstances, fire increased exotic species abundance. Increases and decreases were noted for a number of traditional aboriginal food plants in response to burning. No conclusive changes in rare plant abundance were observed during this study. Additional monitoring of plant response to varying fire frequencies and intensities is necessary. Trends in vegetative changes in response to fire may not be evident immediately following burning; many years of prescribed burning may be required before patterns emerge.

I recommend monitoring plant composition in conjunction with burning prairie parcels at specific fire intervals (e.g. every year, alternate years, every three years, or every five years). Vegetation monitoring should minimally include preburn measures of composition to be used as baselines in comparing burn treatments over time. Monitoring over extended time periods and use of varying fire frequencies will assist in determining optimum fire frequencies and intensities to maintain populations of native plants while controlling woody and exotic species in native Willamette Valley wetland prairies.

## REFERENCES

Acker, S. A. 1986. Analysis of experimental tree burning at the Willow Creek Preserve, Lane County, Oregon. Unpublished report on file at the Oregon Field Office of The Nature Conservancy. Portland, Oregon.

Acker, S. A. 1990. Monitoring Deschampsia grassland at the Willow Creek Preserv; An exploratory analysis of nested frequency data. Unpublished report on file at the Oregon Field Office of The Nature Conservancy. Portland, Oregon.

Agee, J. K. 1981. Fire effects on Pacific Northwest forests: Flora, fuels and fauna. Conf. Proc. Northwest Fire Council. 1981. Portland, OR. p. 54-66

Ahlgren, I.F. 1974. The effect of fire on soil organisms. In: Kozlowski, T.T. and C.E. Ahlgren (eds.). Fire and Ecosystems. pp. 47-72.

Ahlgren, I.F., and C.E. Ahlgren. 1960. Ecological effects of forest fires. Bot. Review 26:483-533.

Aikens, C.M. 1993. Archaeology of Oregon. U.S.D.I. Bureau of Land Management. Portland, Oregon. 302 p.

Albini, F.A. 1976. Estimating wildfire behavior and effects. USDA For. Serv. Gen. Tech. Rep. INT-30, 92 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Alexander, M.E. 1982. Calculation and interpretation forest fire intensities. Can. J. Bot. 60:349-357.

Alverson, E. R. 1987. Report on the status of *Aster curtus* Cronquist. Unpublished report on file at the Oregon Natural Heritage Program.

Alverson, E. R. 1991. New localities for *Aster curtus* in western Oregon. Madrono 38:202-203.

Alt, D.D. and D.W. Hyndman. 1978. Roadside geology of Oregon. Mountain Press, Missoula. 272 p.

Anderson, H.G. and A.W. Bailey. 1980. Effects of annual burning on grassland in the aspen parkland of east-central Alberta. Can. J. of Bot. 58:985-996.

Anderson, R.C. 1973. The use of fire as a management tool on the Curtis Prairie. Tall Timbers Fire Ecology Conf. pp 23-35.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial plant ecology. Benjamin/Cummings Publi. Co., Inc. 634 pp.

Bazilevich, N.I. and A.A. Titlyanova. 1980. Comparative studies of ecosystem function. In: Breymeyer, A.I. and G.M. VanDyne. Grasslands, systems analysis and man. IBP #19. Cambridge Univ. Press. pp.713-759.

Bendell, J.F. 1974. Effects of fire on birds and mammals. In: Kozlowski, T.T. and C.E. Ahlgren (eds.). Fire and Ecosystems. pp. 73-138.

Blaisdel, J.P. 1953. Ecological effects of planned burning of sagebrush-grass range on the Upper Snake River plains. U.S. Dept. Agr. Tech. Bull. 1075.

Boag, P.G. 1992. Environment and experience: settlement culture in the nineteenth-century Oregon. University of California Press. 209 pages.

Boerner, R.E.S. 1982. Fire and nutrient cycling in temperate ecosystems. Bioscience 32:187-192.

Bowen, W.A. 1978. The Willamette Valley, migration and settlement on the Oregon frontier. University of Washington Press. 120 pages.

Boyd, R. 1986. Strategies of Indian burning in the Willamette Valley. Can. J. of Anthropology 5:65-85.

Bradley, A.F., N.V. Noste, and W.C. Fischer. 1992. Fire ecology of forest and woodlands in Utah. Gen. Tech. Rep. INT-287. USDA For. Serv., Intermountain Research Station. 128 p.

Bragg, T.B. and L.C. Hulbert. 1976. Woody plant invasion of unburned Kansas bluestem prairie. J. Range Manage. 29:19-24.

Byram, G.M. 1959. Combustion of forest fuels. In: K.P. Davis (ed.), Forest fire control and use. pp. 61-89. McGraw-Hill Co., New York.

Christensen, N.L. and C.H. Muller. 1975. Effects of fire on factors controlling plant growth in Adenostoma chaparral. Ecol. Monogr. 45:29-55.

Christy, J.A. and E.R. Alverson. 1994. Saving the Valley's wet prairie. The Nature Conservancy - Oregon Chapter Newsletter. Portland, Oregon.

Clampitt, C.A. 1984. The ecological life history of Aster curtus, a grassland endemic in a forested region. M.S. Thesis. Univ. of Wash. 95p.

Clampitt, C. A. 1987. Reproductive biology of *Aster curtus* (Asteraceae), a Pacific Northwest endemic. Amer. J. Bot. 74:941-946.

Clarke, S.A. 1905. Pioneer Days of Oregon History. Vol. I. J.K. Gill, Portland, Oregon.

Cole, D. 1977. Ecosystem dynamics in the coniferous forest of the Willamette Valley, Oregon, U.S.A. J. of Biogeography 4:181-192.

Collins, S.L. and L.L. Wallace (eds.). 1990. Fire in North American tallgrass prairies. University of Oklahoma Press. 175 pp.

Connelly, K. P., and J. B. Kauffman. 1991. Ecological effects of fire in Willamette Valley wetland prairies with species emphasis on Lomatium *bradshawii* and *Erigeron decumbens*, two rare endemic plants. Unpublished report prepared for The Nature Conservancy, Portland, Oregon. 45 pages.

Conrad, C.E. and C.E. Poulton. 1966. Effect of a wildfire on Idaho fescue and bluebunch wheatgrass. J. Range Manage. 19:138-141.

Curtis, J.T. and M.L. Partch. 1948. Effect of fire on the competition between bluegrass and certain prairie plants. Amer. Mid. Nat. 39:437-443.

Cwynar, L.C. 1987. Fire and the forest history of the north Cascade Range. Ecology 68:791-802.

Dahl, T.E. 1990. Wetlands losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service. Washington, D.C. 21 pp.

Daubenmire, R. 1968. Ecology of fire in grasslands. pp. 209-266. In: J.G. Cragg (ed.), Advances in Ecological Research. Academic Press, New York.

Detling, L.E. 1968. Historical background of the flora of the Pacific Northwest. Bulletin Museum of Nat. Hist., Univ. of Oregon. No. 13. 57p.

Dicken, S.N., and E.F. Dicken. 1979. Two Centuries of Oregon Geography. Volume I. The Making of Oregon: A Study in Historical Geography. Oregon Historical Society, Portland, Oregon.

Dix, R.L. and J.E. Butler. 1954. The effects of fire on a dry, thin-soil prairie in Wisconsin. J. Range Manage. 7:265-268.

Duever, M.J., J.E. Carlson, J.F. Meeder, L.C. Duever, L.H. Gunderson, L.A. Riopelle, T.R. Alexander, R.L. Myers, and D.P. Spangler. 1986. The Big Cypress National Preserve. Research report No. 8. National Audubon Society. N.Y. 444p.

Duever, M. J., J. F. Meeder, and L. C. Duever. 1984. Ecosystems of the Big Cypress Swamp. pp. 294-303. In: Ewel, K. C. and H. T. Odum (eds.) Cypress swamps, Univ. of Florida Press, Gainesville, Fl.

Evans, R.A. and J.A. Young. 1970. Plant litter and establishment of alien weed species in rangeland communities. Weed Sci. 18:697-702.

Fenner, R.L. and J.R. Bentley. 1960. A simple pyronometer for measuring soil temperatures during wildland fires. USFS-Pacific Southwest Forest and Range Experiment Station. Misc. Paper #45.

Finley, K.K. 1994. Hydrology and related soil features of three Willamette Valley wetland Prairies. MS Thesis. Oregon State University. 94 p.

Franklin, J. F. and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA Forest Service General Technical Report. PNW-8, Pacific Northwest Forest Range Experiment Station. Portland, Oregon.

French, D. 1965. Ethnobotany of the Pacific Northwest Indians. Economic Botany 19:378-382.

Frenkel, R.E., and E.R. Heinitz. 1987. Composition and structure of Oregon ash (*Fraxinus latifolia*) forest in William L. Finley National Wildlife Refuge, Oregon. Northwest Science 61:203-212.

Frenkel, R.E. and E.H.G. McEvoy. 1983. Assessment of vegetation prior to and after burning of Willamette prairie in William L. Finley National Wildlife Refuge, Oregon. Unpublished interim report on file at W.L. Finley Wildlife Refuge, Corvallis, Oregon.

Frenkel, R.E and R. Streatfeild. 1994. Effects of fire on vegetation of the Willamette Floodplain Research Natural Area, W.L. Finley National Wildlife Refuge, 1991. Unpublished report on the first year of study. On file at W.L. Finley National Wildlife Refuge, Corvallis, Oregon.

Gibson, D.J. 1988. Regeneration and fluctuation of tallgrass prairie vegetation in response to burning frequency. Bulletin of the Torrey Botanical Club 115(1):1-12.

Glendening, G.E. 1942. Germination and emergence of some native grasses in relation to litter cover and soil moisture. J. Am. Soc. Agron. 797-804

Goldsmith, F.B., C.M. Harrison, and A.J. Morton. 1986. Description and analysis of vegetation. In: P.D. Moore and S.B. Chapman (eds.). Methods in plant ecology. Blackwell Scientific Publi. 589 pp.

Grime, J.P. 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. Am. Naturalist 111:1167-1194.

Habeck, J.R. 1961. The original vegetation of the mid-Willamette Valley. Northwest Sci. 35:65-77.

Habeck, J. R. 1962. Forest succession in Monmouth Township, Polk County, Oregon since 1850. Proceedings of the Montana Academy of Sciences 21:7-17.

Habeck, R.J. 1991. *Crataegus douglasii*. In: Fischer, W.C, compiler. The fire effects information system [Data base]. Missoula, MT: U.S. Depart. of Agr., Forest Service, Intermountain Research Station, Intermountain Fire Sciences Laboratory.

Habeck, R.J. 1992. *Rhamnus purshiana*. In: Fischer, W.C, compiler. The fire effects information system [Data base]. Missoula, MT: U.S. Depart. of Agr., Forest Service, Intermountain Research Station, Intermountain Fire Sciences Laboratory.

Hadley, E.B. 1970. Net productivity and burning response of native eastern North Dakota prairie communities. Am. Midl. Nat. 84:121-135.

Hadley, E.B. and B.J. Kiekhefer. 1963. Productivity of two prairie grasses in relations to fire frequency. Ecology 44:389-395.

Halverson, N.M., R.D. Lesher, and R.H. McClure, Jr. 1986. Major indicator shrubs and herbs on National Forests of western Oregon and southwestern Washington. USDA Forest Ser., PNW Region. R6-TM-229-1986.

Hansen, H.P. 1942. A pollen study of lake sediments in the lower Willamette Valley of western Oregon. Bull. of the Torrey Bot. Club. 69(4):262-280.

Hansen, H.P. 1947. Postglacial forest succession, climate, and chronology in the Pacific Northwest. Trans. of the Am. Phil. Soc. 37(1):??

Hansen, H.P. 1967. Chronology of postglacial pollen profiles in the Pacific Northwest (U.S.A.). Rev. of Palaeobot. and Palynology. 4:103-105.

Hardison, J.R. 1957. Chapter VII. Disease problems in forage seed production and distribution. In: Wheeler, W.A. and D.D Hill (eds.) Grassland seeds. Van Nostrand-Reinhold. Princeton, New Jersey.

Harper, J.L. 1977. Population biology of plants. New York, NY: Academic Press: 892 p.

Hervey, D.F. 1949. The reaction of a California plant community to fire. J. Range Manage. 2:116-121.

Hickerson, J. 1986. *Amelanchier alnifolia*. In: Fischer, W.C, compiler. The fire effects information system [Data base]. Missoula, MT: U.S. Depart. of Agr., Forest Service, Intermountain Research Station, Intermountain Fire Sciences Laboratory.

Hill, G.R. and W.J. Platt. 1975. Some effects of fire upon a tall grass prairie plant community in northwestern Iowa. pp.103-113 In: Wali, M.K. (ed.) Prairie: A Multiple View. The Univ. of North Dakota Press, Grand Forks.

Hitchcock, C. L., A. Cronquist, M. Ownbey, and J. W. Thompson. 1969. Vascular Plants of the Pacific Northwest. University of Washington Press, Seattle.

Hopkins, H.H. 1954. Effects of mulch upon certain factors of the grassland environment. J. Range Mgmt. 7:255-258.

Horn, E.L. 1972. Wildflowers 1: The Cascades. The Touchstone Press, Beaverton, Oregon. 160 p.

Howard, J.L. 1992. *Quercus garryana*. In: Fischer, W.C, compiler. The fire effects information system [Data base]. Missoula, MT: U.S. Depart. of Agr., Forest Service, Intermountain Research Station, Intermountain Fire Sciences Laboratory.

Hulbert, L.C. 1969. Fire and litter effects in undisturbed bluestem prairie in Kansas. Ecol. 50:874-877.

Hulbert, L.C. 1988. Causes of fire effects in tallgrass prairie. Ecol. 69:46-58.

Humphrey, L.D. 1984. Patterns and mechanisms of plant succession after fire on *Artemisia*-grass sites in southeastern Idaho. Vegetatio 57:91-101.

Johannessen, C.L., W.A. Davenport, A. Millet, and S. McWilliams. 1971. The vegetation of the Willamette Valley. Assoc. Amer. Geog. Annals 61:286-302.

Kauffman, J.B. 1990. Ecological relationships of vegetation and fire in Pacific Northwest forests. pp. 39-52. In: Walstad, J. D., S. R. Radosevich, and D. V. Sandberg (eds.) Natural and prescribed fire in Pacific Northwest forests. Oregon Sate Univ. Press, Corvallis, Oregon.

Kauffman, J.B. and R.E. Martin. 1990. Sprouting shrub response to different seasons and fuel consumption levels of prescribed fire in Sierra Nevada mixed conifer ecosystems. Forest Science 36:748-764.

Keeley, J.E. 1984. Factors affecting germination of chaparral seeds. Bull. Southern Calif. Acad. Sci. 83:113-120.

Keeley, J.E. 1988. Role of fire in seed germination of woody taxa in Calif. chaparral. Ecol. 68:434-443.

Keeley, J.E. and S.C. Keeley. 1987. Role of fire in the germination of chaparral herbs and suffructescents. Madrono 34:240-249.

Kilgore, B.M. 1981. Fire in ecosystem distribution and structure: Western forests and scrublands. In: H.A. Mooney, T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, and W.A. Reiners (Tech. Coords.). Fire Regimes and Ecosystem properties. USDA Gen. Tech. Rep. WO-26. pp. 58-89.

Kucera, C.L. 1981. Grasslands and fire. In: In: Mooney,, H.A., T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, W.S. Reiners (eds.) Fire Regimes and Ecosystem Properties. USDA For. Serv. Gen. Rep.WO-26.

Kucera, C.L., R.C. Dahlman, and M.R. Koelling. 1967. Total net productivity and turnover on an energy basis for tallgrass prairie. Ecol. 48:536-541.

Kucera, C.L. and M. Koelling. 1964. The influence of fir on composition of central Missouri prairie. Am. Midl. Nat. 72:142-147.

Kutiel, P. and Z. Naveh. 1987. The effect of fire on nutrients in a pine forest soil. Plant and Soil 104:269-274.

Lippert, B. E., and D. L. Jameson. 1964. Plant succession in temporary ponds of the Willamette Valley, Oregon. Am. Midl. Nat. 71:181-197.

Macdonald, C., undated. Final report of fire effects on a *Stipa lemmonii-Rhacometrium canescens* grassland community. The Nature Conservancy, Portland, Oregon.

Mackey, H. 1974. The Kalapuyans - a sourcebook on the Indians of the Willamette Valley. Mission Mill Museum Association, Inc. Salem, Oregon. 165 p.

Magee, T. K. 1986. Vegetation monitoring at Wren Prairie Preserve: I. Initial response of grassland vegetation to controlled burning. Unpublished report on file at the Oregon Field Office of The Nature Conservancy, Portland, Oregon.

Martin, R.E. 1982. Fire history and its role in succession. pp. 92-99. In: J.E. Means (ed.). Forest succession and stand development research in the Northwest: Proceedings of a Symposium. Corvallis, OR.

Martin, R.E. and C.T. Cushwa. 1966. Tall Timbers Fire Ecol. Conf. Tallahasee, Fl.

McCune, B. 1991. Multivariate Analysis on the PC-ORD System. Oregon State University, Corvallis, Oregon.

McNaughton, S.J., M.B. Coughenour, and L.L. Wallace. 1982. Chapter 7: Interactive processes in grassland ecosystems. pp. 168-193. In: J.R. Estes, R.J. Tyrl and J.N. Brunken. Grasses and Grasslands. Univ. of Oklahoma Press. Norman, Ok.

Meentemeyer, V. 1978. Macroclimate and lignin control of litter decomposition rates. Ecol. 59:465-472.

Minor, R., K.A. Toepel, and S.D. Beckman. 1981. Cultural resource overview of the Eugene BLM District, west-central Oregon. Report submitted to the Eugene District, U.S. Bureau of Land Management. Eugene, Oregon. 350p.

Mitsch, W.J. and J.G. Gosselink. 1986. Wetlands. Van Nostrand Reinbold Co., N.Y. 539p.

Moir, W., and P. Mika. 1972. Prairie vegetation of the Willamette Valley, Benton Co., Oregon. Report on file at Forest Science Lab, 3200 Jefferson Way, Corvallis, Oregon.

Mooney, H.A. and J.A. Drake. 1987. The ecology of biological invasions. Envir. 29:10-37.

Mooney, H.A. and M. Godron (eds.) 1983. Disturbance and ecosystems. Ecological Studies No. 44. Springer-Verlag, N.Y. 292p.

Morris, W.G. 1934. Forest fires in western Oregon and western Washington. Ore. Hist. Quart. 35:313-339

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. Wiley & Sons. 547 p.

Munford, K. April 28, 1982. Corvallis was once unforged wilderness.. Gazette-Times, Corvallis, Oregon.

Nelson, J.C. 1919. The grasses of Salem, Oregon, and vicinity. Torreya 19:216-227.

Oregon Natural Heritage Program. 1983. Survey of Willamette Valley 1981-1983 (A report to the Mason Trust). The Nature Conservancy. Portland, Oregon.

Orr, E. L., W. N. Orr, and E. M. Baldwin. 1992. Geology of Oregon. 4th edition. Kendall Hunt Publishing Co., Dubuque, Iowa.

Parmeter, J.R. 1977. Effects of fire on pathogens. Proc. Symp. Environ. Consequences of Fire Fuel Mgmt. of Mediterranean Ecosystems. USDA - Forest Service Gen. Tech. Rep. WO03. pp. 58-64.

Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. J. of Theoretical Biology 13:131-144.

Pojar, J. and A. MacKinnon. 1994. Plants of the Pacific northwest coast; Washington, Oregon, British Columbia and Alaska. Ministry of Forests and Lone Pine Publishing. 526 p.

Rasmussen, G.A. and H.A. Wright. 1988. Germination requirements of flameleaf sumac. J. Range Manage. 41:48-52.

Redman, R.E. 1978. Plant and soil water potentials following fire in a northern mixed grassland. J. Range Manage. 31:443-445.

Reed, W.R. 1993. *Rosa nutkana*. In: Fischer, W.C, compiler. The fire effects information system [Data base]. Missoula, MT: U.S. Depart. of Agr., Forest Service, Intermountain Research Station, Intermountain Fire Sciences Laboratory.

Rice, E.L. and R.L. Parenti. 1978. Causes of decreases in productivity in undisturbed tall grass prairie. Am J. Bot. 65:1091-1097.

Risser, P.G. 1988. Diversity in and among grasslands. In: Wilson, E.O. and M. Peter (eds.) Biodiversity. National Academy Press. Wa.,D.C. pp. 176-180.

Risser, P.G., E.C. Birney, H.D. Blocker, S.W. May, W.J. Parton, and J.A. Wiens. 1981. The true prairie ecosystem. Hutchenson Ross Publ. Co.

Rohlf, D.J. 1989. The endangered species act - a guide to its protections and implementation. Stanford Environmental Law Society. Stanford, California.

Ross, C.R. and H. Hayes. 1975. Trees to know in Oregon. Oregon State Univ. Extension Service and the State Department of Forestry. Bull. 697.

Rothermal, R.C., and J.E. Deeming. 1981. Measuring and interpreting fire behavior for correlation with fire effects. USDA-For. Ser. Gen. Tech. Rep. INT-93. Ogden, UT. 4 pp.

Rundel, P.W. 1981. Structural and chemical components of flammablity. pp. 183-207. In: Mooney, H. A., T. M. Bonnieksen, N. L. Christensen, J. E. Lotan, and W. A. Reiners (Tech. Coords.) Proc. of the Conference on Fire Regimes and Ecosystem Properties. USDA For. Ser. Gen. Tech. Rep. WO-26. Washington, D.C.

Sampson, A.W. 1944. Plant succession on burned chapparral lands in northern California. Calif. Agric. Exp. Station Bulletin 635:1-144.

Sapsis, D.B. 1990. Ecological effects of spring and fall prescribed burning on basin big sagebrush/Idaho fescue-bluebunch wheatgrass communities. M.S. Thesis, Oregon State Univ., Corvallis, OR. 106 p.

Scotter, D.R. 1970. Soil temperatures under grass fires. Aust. J. Soil Res. 8(3):273-279.

Shannon, C.E. and W. Weaver. 1949. The mathematical theory of communication. Univ. Illinois Press. Urbana, Illinois.

Sharrow, S.H. and H.A. Wright. 1977. Effects of fire, ash, and litter on soil nitrate, temperature, moisture and tobosagrass production in rolling plains. J. Range Manage. 30:266-270.

Sheldon, S.P. 1986. The effects of short-term disturbance on a freshwater macrophyte community. J. Freshwater Ecol. 3:309-317.

Smith, J. E. 1949. Natural vegetation in the Willamette Valley, Oregon. Science 109:41-42.

Smith, L.M. and J.A. Kadlec. 1984. Effects of prescribed burning on nutritive quality of marsh plants in Utah. J. Wildl. Manage. 48:285-288.

Smith, L.M. and J.A. Kadlec. 1985. Fire and herbivory in a Great Salt Lake marsh. Ecol. 66:259-265.

Sousa, W.P. 1984. The role of disturbance in natural communities. Ann. Rev. Ecol. Syst. 15:353-391.

Sprague, F.L., and H.P. Hansen. 1946. Forest succession in the McDonald Forest, Willamette Valley, Oregon. Northwest Sci. 20:89-98.

Stone, E.C. 1951. The stimulative effect of fire on the flowering of the golden Broadiaea (*Brodiaea ixioides* Wats. var. *lugens* Jeps.). Ecol. 32:534-537.

Streatfeild, R.A. 1995. Ecological survey and interpretation of the Willamette Floodplane Research Natural Area, W.L. Finley National Wildlife Refuge, Oregon. M.S. Thesis, Oregon State Univ., Corvallis, OR. 134 p.

Thilenius, J.F. 1968. The *Quercus garryana* forest of the Willamette Valley, Oregon. Ecol. 49:1124-1133.

Thompson, R.S., C. Whitlock, P.J. Bartlein, S.P. Harrison, and W.G. Spaulding. 1993. Climatic changes in the Western United States since 18,000 yr B.P. pp. 468-513. In: Wright, H.E. Jr. et. al. (eds.). Global climates since the last glacial maximum. Unv. Minnesota Press, Minneapolis, Minnesota.

Tirmenstein, D. 1989. *Rubus discolor.* In: Fischer, W.C, compiler. The fire effects information system [Data base]. Missoula, MT: U.S. Depart. of Agr., Forest Service, Intermountain Research Station, Intermountain Fire Sciences Laboratory.

Toepel, K.A. 1991. Chapter 3: The western interior. pp.15-20. In: Buan, C.M. and R. Lewis (eds.). The first Oregonians; an illustrated collection of essays on traditional lifeways, Federal-Indian relations, and the State's Native People today.

Towle, J. C. 1982. Changing geography of Willamette Valley woodland. Oregon Hist. Quart. 83:66-87.

Turner, R. B. 1969. Vegetation changes of communities containing medusahead (*Taeniatherum asperum* (Sim.) Nevski) following herbicide, grazing, and mowing treatments. Ph.D thesis. Oregon State University, Corvallis.

USDA - Soil Conservation Service. 1987. Soil survey of Lane County area, Oregon. USDA.

Van Wagner. 1973. Height of crown scorch in forest fire. Can. J. For. Res. 3:373-378.

Vogl, R. J. 1973. Effects of fire on the plants and animals of a Florida wetland. Amer. Midl. Nat. 89:334-347.

Vogl, R.J. 1974. Effects of fire on grasslands. In: Kozlowski, T.T. and C.E. Ahlgren (eds.). Fire and Ecosystems. pp. 139-194. Academic Press, New York.

Volland, L.A., and J.D. Dell. 1981. Fire effects on Pacific Northwest forest and range Vegetation. USDA-Forest Service Northwest Region. Portland, Oregon.

Walker, D. 1982. The development of resilience in burned vegetation. pp. 27-43. In: E.I. Newman (ed.) The plant Community as a working mechanism.

Weaver, J.E. and N.W. Rowland. 1952. Effects of excessive natural mulch on development, yield, and structure of native grassland. Bot. Gaz. 114:1-19.

Wells, P.V. 1969. The relation between mode of reproduction and extent of speciation in woody genera of the California chaparral. Evol. 23:264-267.

White, P.S. 1979. Pattern, process, and natural disturbance in vegetation. Bot. Rev. 45:229-299.

Whitlock, C. 1992. Vegetational and climatic history of the Pacific Northwest during the last 20,000 years: implications for understanding present-day biodiversity. NW Envir. Journ. 8:5-28.

Willms, W.D., S. Smoliak, and A.W. Bailey. 1986. Herbage production following litter removal on Alberta native grasslands. J. Range Mgmt. 39:536-540.

Wright, E. 1931. The effect of high temperatures on seed germination. J. Forestry 29:679-687.

Wright, H.A., and A.W. Bailey. 1982. Fire Ecology - western United States and Canada. Wiley and Sons, New York. pp. 501.

Wright, H. E. and M. L. Hinselman. 1973. The ecological role of fire in natural conifer forests of western and northern North America: Introduction. Quaternary Research 3:319-328.

Young, R.P. 1983. Fire as a vegetation management tool in rangelands of the Intermountain Region. In: Managing Intermountain Rangelands - Improvement of range and wildlife habitats. Symp. Proc., USDA For. Serv. Gen. Tech. Rept. INT-157.

Young, R.P. and R.F. Miller. 1985. Response of *Sitanion hystrix* (Nutt.) J.G. to prescribed burning. Amer. Midl. Nat. 113:182-187.

Zar, J. 1984. Biostatistical analysis, 2nd edition. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Zedler, P.H., C.R. Gautier, and G.S. McMaster. 1983. Vegetation change in response to extreme events: the effect of a short interval between fire in California chaparral and coastal scrub. Ecology 64:809-818.