# EFFECTS OF PRESCRIBED BURNING AT BUNCHGRASS MEADOW: AN ESTABLISHMENT REPORT AND BASELINE DATA

SUBMITTED TO THE MCKENZIE RANGER DISTRICT
WILLAMETTE NATIONAL FOREST, OREGON

**CHARLES B. HALPERN**
DIVISION OF ECOSYSTEM SCIENCES
COLLEGE OF FOREST RESOURCES
BOX 352100
UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195-2100

17 DECEMBER 1999

---

## BACKGROUND

Mountain meadows comprise a relatively small portion of the largely forested western Cascade landscape, but serve many important ecological and social functions. Meadows support a distinct and diverse assemblage of plant species, including rare and endemic taxa (Hickman 1968, 1976); provide habitat and forage for wildlife; and offer recreational opportunities for hikers who seek colorful displays of wildflowers and scenic vistas. Invasion of these meadows by trees represents a fairly recent, but widespread phenomenon (Franklin et al. 1971, Vale 1981, Halpern et al. 1984, Magee and Antos 1992, Rochefort et al.1994, Miller 1995, Miller and Halpern 1998). Our previous studies in the central Cascade Range of Oregon suggest that these invasions have been triggered by a variety of factors including changes in regional climate and cessation of sheep grazing during middle part of the century (Miller and Halpern 1998).

The role that fire has played in the maintenance of mountain meadows is less clear (Burke 1979, Vale 1981, Teensma 1987), but it is likely that periodic burning (of natural or anthropogenic origin) has been important in creating and maintaining openings, particularly on dry, south- and west-facing slopes and ridgetops. Studies of fire history in forests of the central, western Cascade Range suggest a complex history of burning (Agee 1993). During the last five centuries, fires of variable frequency, intensity and spatial extent occurred every 95-150 yr at lower elevations (i.e. western hemlock zone forests) (Teensma 1987, Morrison and Swanson 1990), but probably less often at higher elevations (Agee 1993). Although anthropogenic ignitions are known to have been important in maintaining open conditions in lowland valleys of western Oregon (Johannessen et al. 1971), evidence of aboriginal burning of mountain meadows is lacking for the central Cascades. During the post-European settlement period (ca. 1850-1890), human-induced fires are know to have occurred in association with road building, sheep grazing, and camping (Burke 1979, Vale 1981). Twentieth century fire suppression, however, may be permitting gradual succession of meadow to forest with profound consequences for local and regional patterns of plant diversity.

As a consequence, natural resource managers in the Pacific Northwest have begun to consider prescribed fire as a tool to "restore" meadow composition and structure—to reintroduce fire as a process that, historically, had contributed to the origin and long-term maintenance of these ecosystems. However, controlled experimental studies are necessary to understand the broader consequences of prescribed burning, and to guide the future implementation of these practices. Little is known about the responses of ground-layer communities to prescribed burning or about the effectiveness of prescribed fire for removing invasive trees in montane meadows. For example, it is unclear whether burning in areas that have experienced significant encroachment will promote reversion to open meadow or, conversely, will lead to renewed invasion by tree seedlings or to establishment of early successional species. There is also some concern that exotic plant species in or adjacent to these meadows may benefit from the effects of fire, e.g., through the creation of new germination sites, or through changes in competitive interactions with native forbs and graminoids. Exotic species commonly invade recently harvested and burned forests in this region (Halpern 1989, Schoonmaker and McKee 1988, DeFerrari and Naiman 1994, North et al. 1996) although few can persist once the forest canopy closes.

Our studies at Bunchgrass Meadow address these and other questions through long-term observations of vegetation responses to experimental burning. Our objectives are threefold: (1) to assess changes in the composition, structure, and diversity of forest and meadow communities in response to prescribed fire; (2) to examine the effectiveness of fire in inducing tree mortality and preventing future establishment; and (3) to assess changes in the distribution and abundance of exotic plant species in response to burning.

In coordination with the McKenzie Ranger District of the Willamette National Forest, Oregon, we have established a series of experimental plots in burned and unburned portions of Bunchgrass Meadow. Pre-treatment data were collected during summer 1999 and post-burning measurements will be made during summer 2000. In this establishment report we document our experimental and sampling designs, the locations of our study plots, and baseline vegetation conditions at Bunchgrass Meadow.

## STUDY AREA

The study area occupies the southwestern portion of Bunchgrass Meadow (McKenzie Ranger District, Willamette National Forest, Oregon; T15S R7E S10) (Fig. 1), more specifically, the southwestern section of the area designated as Zone 1W in the current management plan (Wilson et al. 1999). Slopes are gentle and south- to south-east facing and elevations range from 1220-1375 m (4000-4500 ft). Soils on this portion of the meadow are Typic Cryoborolls (Appendix D, Wilson et al. 1999)—moderately deep to deep mollisols with a loamy texture. Aerial photographs dating back to 1946 indicate that, although large portions of Bunchgrass Ridge have supported mature forest for much of this century, numerous meadow openings have experienced significant encroachment by trees. Current vegetation structure and composition in the southwestern portion of Bunchgrass are described in the sections that follow.

## EXPERIMENTAL DESIGN AND SAMPLING METHODS

We are studying vegetation responses in two common types of habitat at Bunchgrass Meadow:

MATURE FOREST.—These forests, characterized by high levels of mortality and many canopy gaps and small meadow openings, occupy the central portion of the study area (Fig. 1). This entire forest was targeted for prescribed burning on 10 Oct. 1999, however fuel moisture was too high and ignitions were very patchy, thus the area remained largely unburned. Prescribed burning may be attempted again during fall 2000. Vegetation responses will be assessed relative to initial (pre-treatment) conditions.

OPEN OR RECENTLY INVADED MEADOWS.—These communities, dominated by graminoids and forbs, occupy the northern portion and the western and southern perimeter of the study area (Fig. 1). Paired burned and unburned (control) areas (Fig. 1) were established and sampled prior to treatment (August 1999). Post-treatment sampling will occur in August 2000.

Sampling designs and analytical approaches differ in these habitats, as described below.

### MATURE FOREST TRANSECTS

Three transects were established in July 1999 to sample overstory and understory strata (Fig 1). Transects are 20 m wide but vary in length (Table 1) and each is grided into a series of 5 x 5 m subplots (Fig. 2). All transects run at an azimuth of 90°E (Table 1).

Overstory Measurements.—Within each uniquely numbered subplot all trees were measured either for diameter (trees ≥1.4 m tall) or height (trees 0.3-1.3 m tall). At the center of each subplot, canopy cover was estimated with a moosehorn densiometer. From the complete sample of trees, ca. 40 stems of varying diameter and height were cored to determine the range of tree ages (i.e., dates of establishment).

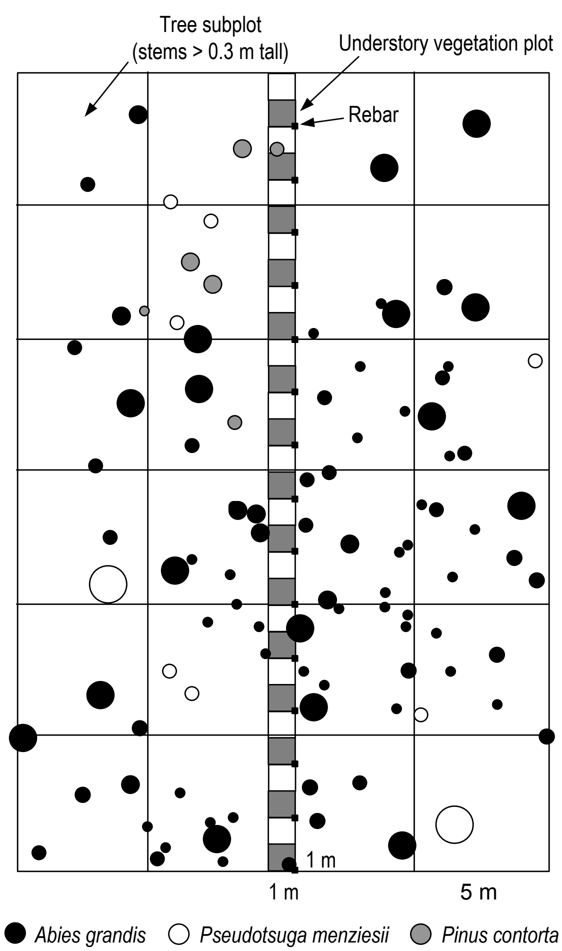



**Figure 2**. Schematic diagram of a 30-m long portion of a forest transect. Transects are a total of 20 m wide and 100-150 m long, grided into 5 x 5 m subplots. Within each subplot, all trees ≥0.3 m tall were identified to species and measured for height (stems 0.3-1.3 m tall) or diameter (stems ≥1.3 m tall). Overstory canopy cover was estimated at the center of each grid square using a moosehorn densiometer. A series of 1 x 1 m vegetation quadrats (grey squares at alternating meter marks) were used to sample understory vascular plant cover, ground surface conditions, and the density of tree seedlings (trees <0.3 m tall). Steel reinforcing bar (small dark squares) spaced 2 m apart marks the center line of each transect and the locations of the understory quadrats.

Understory Measurements.—To characterize understory vegetation composition, a series of 1 x 1 m quadrats was established on the north side of the central axis of each transect (Fig. 2). Steel reinforcing bar was placed at 2-m intervals (i.e., at meter marks 0, 2, 4, etc.) to permanently mark the understory quadrats, and a tall (>1 m) PVC pipe was placed at the start and end points of each transect. Within each understory quadrat we sampled the cover of all vascular plant species, the cover of common ground surface conditions (e.g., coarse woody debris, stone, mineral soil, litter), and the density of tree seedlings (trees < 0.3 m tall). Measurements were taken in even-numbered quadrats (i.e., between 0-1, 2-3, 4-5 m , etc.), but only for the first 80-90 m of transect, yielding a total of 41-45 understory quadrats per transect (Table 1). Nomenclature follows Hitchcock and Cronquist (1973).

**Table 1**. Characteristics of the three forest transects.

| Forest transect number | Transect length (m) | Transect width (m) | Transect azimuth (deg.)* | No. of understory quadrats |
|---|---|---|---|---|
| 1 | 100 | 20 | 90 | 45 |
| 2 | 150 | 20 | 90 | 41 |
| 3 | 145 | 20 | 90 | 41 |

* Azimuth is from m-mark 0 to transect end point (declination is 18.5 deg E)

## MEADOW TRANSECTS

To examine meadow community responses to burning, four pairs of transects were established at three locations (Table 2, Fig. 2) during July 1999; transects were sampled in late August 1999. One transect from each pair was burned on 10 Oct. 1999 while the second remained unburned. Transects are marked by steel reinforcing bar capped with PVC at 10-m intervals.

Ground-layer Vegetation.—To quantify changes in species frequency and abundance, a series of 1 x 1 m quadrats was established at alternating meter marks along each transect (as in the mature forest). For north-south trending transects (i.e., 1-E, 1-W, 2A-N, 2B-N and 2B-S), quadrats lie on the west side of the transect line. For east-west trending transects ( 3-S and 3-N), quadrats lie on the north side of the line. Within each quadrat we sampled the cover of all vascular plant species, the cover of common ground surface conditions (e.g., bare ground, litter, coarse woody debris), and the density of tree seedlings (trees <0.3 m tall). Measurements were taken in even-numbered quadrats (i.e., at 0-1, 2-3, 4-5 m, etc.) yielding a total of 20-30 quadrats per transect (Table 2). Nomenclature follows Hitchcock and Cronquist (1973).

**Table 2**. Characteristics of the four pairs (burned and unburned) of meadow transects.

| Location | —Treatment— | | Length (m)* | —Azimuth (deg)†— | | No. of understory quadrats | Width of tree plot (m) |
|---|---|---|---|---|---|---|---|
| | Unburned | Burned | | Unburned | Burned | | |
| Round Meadow | 1-E | 1-W | 60 | 40 | 38 | 25 | — |
| White Pine Meadow | 2A-S | 2A-N | 70 | 17 | 19 | 30 | — |
| | 2B-S | 2B-N | 40 | 9 | 1 | 20 | — |
| Lodgepole Meadow | 3-N | 3-S | 70 | 145 | 144 | 30 | 30 |

* Paired transects are of equal length; end points lie 11 m beyond the last sampled vegetation plot.

† Azimuth is from m-mark 0 to transect end point (declination is 18.5 deg E).

Measurements of Invasive Trees.— One sampling location, "Lodgepole Meadow" (Fig. 1), supports a large population of invading trees (primarily *Pinus contorta* and *Abies grandis*). To examine patterns of tree mortality and subsequent recruitment and growth, a 30-m wide grided tree plot was centered over each 70-m transect. Within each 5 x 5 m subplot all trees ≥ 0.3 m tall were identified to species and either measured for diameter (trees ≥1.4 m tall) or height (trees 0.3-1.3 m tall) (as in the mature forest).

Disturbance Assessment.— A disturbance assessment was conducted on 11 Oct. 1999, one day after the prescribed burn. Within each quadrat on the burned transects we estimated the proportion of vegetation burned. Consumption of litter was minimal and thus was not quantified.

Permanent Photo Points.—Permanent photo points were established at the start and end points of each meadow transect (burned and unburned). Pre-treatment photos were taken at two points during the growing season prior to burning (18 July and 23 August 1999) and immediately following burning (11 October 1999). The same photographs will be taken during one growing season following burning (August 1999). Additional photographs of a subset of 1 x 1 m quadrats (4 to 11 per transect) were taken on 11 Oct. 1999 to document the range of burning conditions within each transect.

## BASELINE VEGETATION CONDITIONS
## (JULY-SEPTEMBER 1999)

### MATURE FOREST COMMUNITIES

Overstory Composition and Structure.—Mature forests in the southwestern portion of Bunchgrass are dominated by *Abies grandis* (grand fir) representing a broad range of size classes (Fig. 3). The largest and oldest trees are *Pseudotsuga menziesii* (Douglas-fir) (maximum of 156 cm dbh on our transects), however these old remnants are relatively rare. Forests are characterized by an abundance of canopy gaps and larger openings resulting from tree mortality and windthrow; however, some of the larger forest openings showed no evidence of recent occupation by trees. Canopy cover (estimated by Moosehorn densiometer) averaged only 33-48% along the three forest transects sampled; in 40-60% of the subplots, cover did not exceed 10% (Fig. 4). Although regeneration of *Abies*, *Pseudotsuga,* and *Pinus contorta* was abundant (Fig. 3B), small tree seedlings (<0.3 m tall) were uncommon (0.17 per $m^2$) and patchy in their distribution.

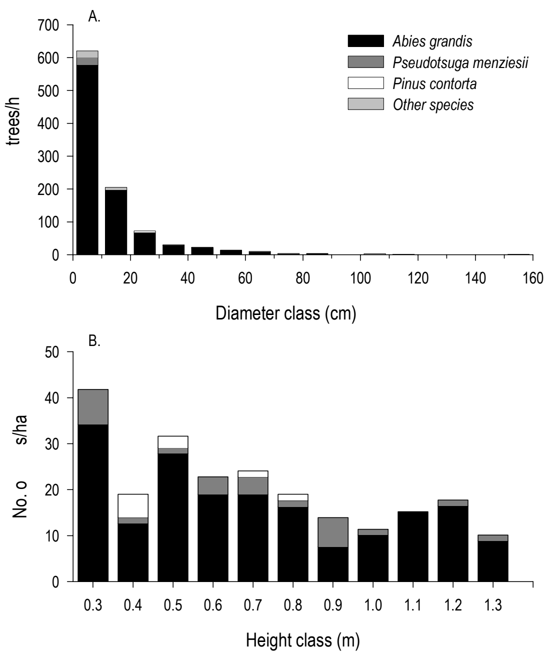



**Figure 3**. Size structure and species composition of trees in the mature forest in the Bunchgrass study area. Trees ≥1.4 m tall are summarized by diameter class (A) and trees 0.3-1.3 m tall by height class (B). "Other" species include *Abies procera* (noble fir*), Calocedrus decurrens* (incense cedar), *Tsuga heterophylla* (western hemlock), and *T. mertensiana* (mountain hemlock).

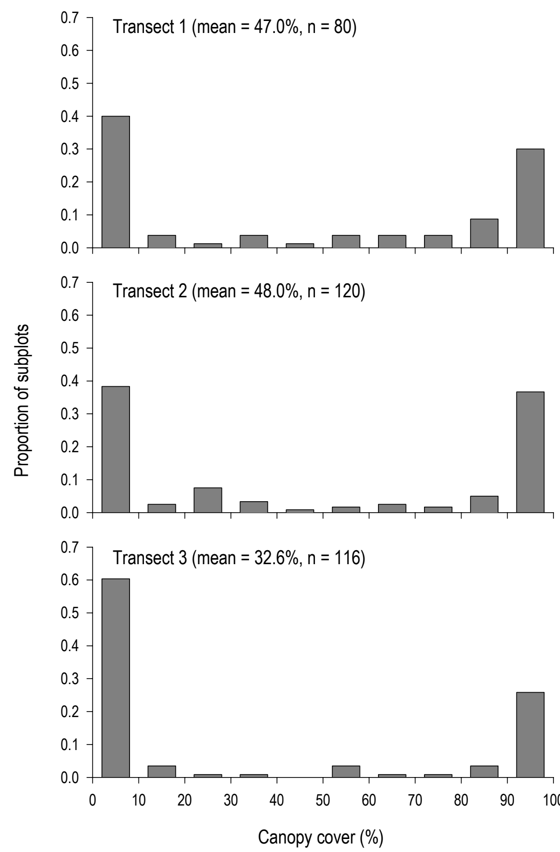



**Figure 4**. Frequency of overstory canopy cover (10% classes) in the 5 x 5 m subplots comprising each forest transect. Canopy cover was estimated at the center of each subplot. Average cover and the number of subplots sampled per transect (n) are in parentheses.

Tree Ages and Size-Age Relationships.— The oldest tree ages obtained (152 and 154 yr; Fig. 5B) were from *A. grandis*, however we were unable to core the largest, remnant *Pseudotsuga*, which are likely to be much older. The relationship between diameter and height was fairly linear for A*bies grandis*, but less so for *Pinus contorta* (Fig. 5A) which typically shows poorer apical dominance. Maximum ages for *Pinus contorta* were 52-56 yr. Relationships between *Abies grandis* age and diameter or height were not very strong (Figs. 5B, C)—not surprising for a species with a broad regeneration niche (i.e., capable of regenerating in the open and under the canopy).

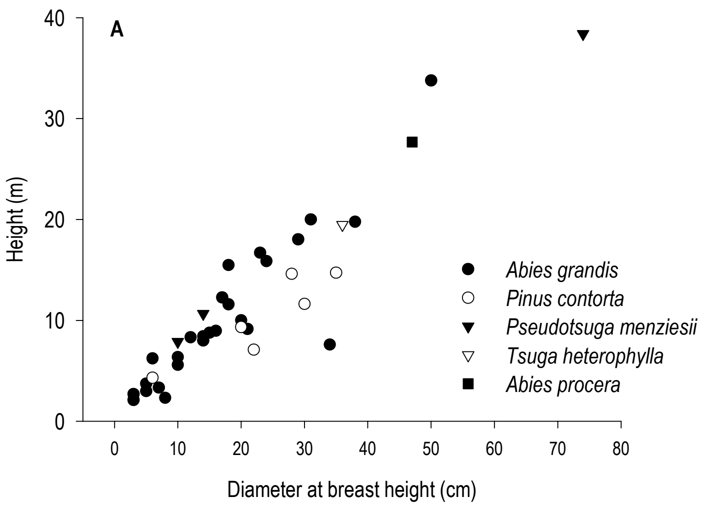
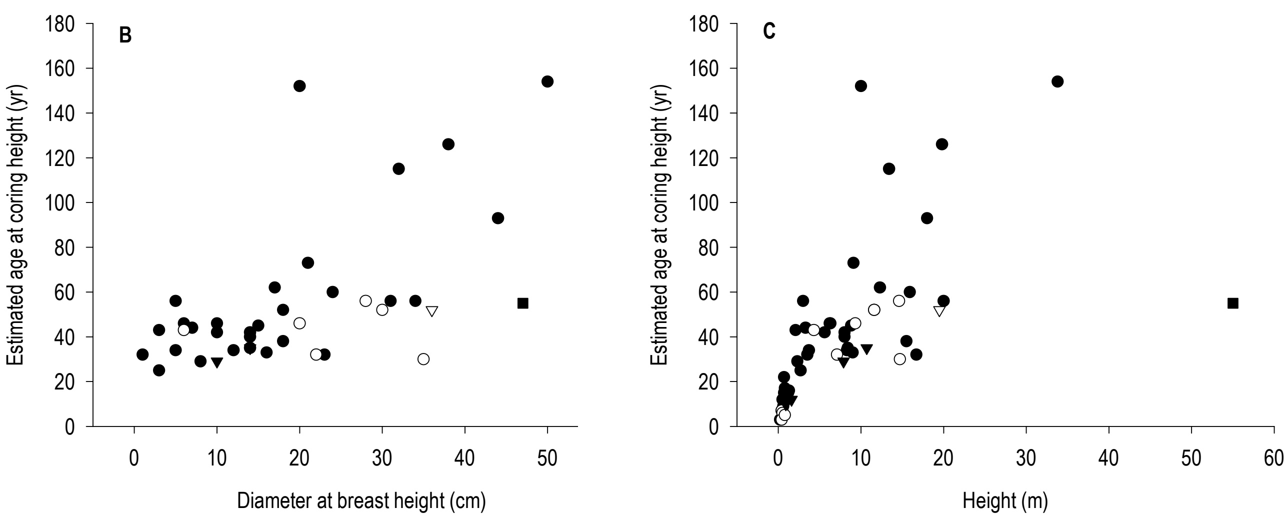



**Figure 5**. Height-diameter relationships (A), and size-age relationships (B and C), for a subset of trees at Bunchgrass. Trees smaller than 1.4 m tall and trees with broken tops were excluded from analyses of diameter-height relationships. Ages were derived from ring counts of increment cores (larger trees) and counts of terminal bud scale scars (small understory trees). Trees were cored as close to the base as possible (all but one at <10 cm from the ground); ages thus represent underestimates, but differences between estimated and true ages are probably small. Trees with incomplete increment cores were excluded from size-age analyses.



Understory Composition and Diversity.—Forest understories at Bunchgrass are characterized by a lush and floristically diverse assemblage of graminoids, herbs, and shrubs. A total of 86 understory taxa (excluding conifers) were identified in the 127 quadrats sampled (Table 3). On average we observed 16.1 species per quadrat and 64.3 species per transect. We noted only four exotic species (primarily in open areas) with the perennial herb, *Rumex acetosella*, the most common (Table 3).

Total understory cover (i.e., the sum of all non-tree species) averaged 120%, with forbs the dominant growth form (mean of 60% cover) (Table 3). Taxa that were both frequent and abundant included the graminoids, *Elymus glaucus*; the forbs, *Smilacina stellata, Galium oreganum*, *Fragaria virginiana/F. vesca*, and *Lathyrus nevadensis*; and the shrub *Symphoricarpos mollis* (Table 3). A second group of species were frequent but exhibited relatively low cover (*Bromus carinatus*, *Bromus vulgaris*, *Carex pensylvanica, Anemone oregana*, *Arenaria macrophylla*, *Galium oreganum*, and *Osmorrhiza chilensis*). A small group of taxa were patchily distributed with relatively low overall frequency but high cover where present (e.g., *Festuca rubra*, *Achlys triphylla*, and *Holodiscus discolor*) (Table 3).

**Table 3**. The frequency and mean cover (%) of understory species sampled in the forest transects between 21and 27August 1999. Frequency is the percentage of quadrats (n = 127) in which a species was found. The most common and/or abundant species are shaded; * indicates exotic species.

| GROWTH-FORM / Species | Frequency (%) | Cover (%) | GROWTH-FORM / Species | Frequency (%) | Cover (%) |
|---|---|---|---|---|---|
| GRASSES | | 26.89 | FORBS AND FERNS (CONT.) | | |
| *Agropyron repens** | 3.15 | 0.06 | *Aster ledophyllus* | 4.72 | 0.39 |
| *Agrostis scabra* | 13.39 | 0.35 | *Aster radulinus* | 7.87 | 0.84 |
| *Bromus carinatus* | 43.31 | 3.01 | *Campanula scouleri* | 31.50 | 0.68 |
| *Bromus vulgaris* | 49.61 | 2.80 | *Cerastium vulgatum* | 11.81 | 0.11 |
| *Elymus glaucus* | 49.61 | 15.66 | *Circaea alpina* | 48.82 | 3.51 |
| *Festuca idahoensis* | 8.66 | 0.46 | *Cirsium callilepes* | 29.92 | 0.85 |
| *Festuca rubra* | 20.47 | 4.09 | *Collinsia parviflora* | 1.57 | 0.00 |
| *Melica subulata* | 22.83 | 0.34 | *Commandra umbellata* | 4.72 | 0.06 |
| *Trisetum canescens* | 9.45 | 0.12 | *Dicentra formosa* | 3.15 | 0.01 |
| | | | *Dryopteris austriaca* | 1.57 | <0.01 |
| SEDGES AND RUSHES | | 5.02 | *Erigeron aliceae* | 14.96 | 0.23 |
| *Carex deweyana* | 8.66 | 0.33 | *Fragaria vesca/virginiana* | 87.40 | 9.40 |
| *Carex pensylvanica* | 48.03 | 4.62 | *Galium oreganum* | 84.25 | 4.41 |
| *Carex pachystachya* | 1.57 | 0.06 | *Galium triflorum* | 41.73 | 0.44 |
| *Luzula campestris* | 0.79 | 0.01 | *Geum macrophyllum* | 3.15 | 0.16 |
| *Luzula parviflora* | 0.79 | 0.01 | *Goodyera oblongifolia* | 5.51 | 0.07 |
| | | | *Hieracium albiflorum* | 12.60 | 0.16 |
| FORBS AND FERNS | | 60.15 | *Iris chrysophylla* | 20.47 | 0.94 |
| *Achillea millefolium* | 40.94 | 1.43 | *Lactuca muralis** | 9.45 | 0.16 |
| *Actaea rubra* | 3.94 | 0.06 | *Lathyrus nevadensis* | 59.84 | 5.10 |
| *Achlys triphylla* | 26.77 | 4.57 | *Listera sp.* | 0.79 | <0.01 |
| *Adenocaulon bicolor* | 11.81 | 0.31 | *Lupinus latifolius* | 3.15 | 0.12 |
| *Agoseris aurantiaca* | 0.79 | <0.01 | *Microsteris gracilis* | 0.79 | <0.01 |
| *Anemone deltoidea* | 9.45 | 0.27 | *Montia sibirica* | 6.30 | 0.06 |
| *Anaphalis margaritacea* | 0.79 | 0.01 | *Osmorrhiza chilensis* | 59.06 | 1.22 |
| *Anemone oregana* | 66.93 | 1.00 | *Phacelia heterophylla* | 18.90 | 0.14 |
| *Aquilegia formosa* | 15.75 | 0.58 | *Polygonum douglasii* | 4.72 | 0.03 |
| *Arenaria macrophylla* | 88.98 | 1.39 | *Polystichum munitum* | 0.79 | <0.01 |
| *Asarum caudatum* | 37.01 | 1.92 | *Pteridium aquilinum* | 12.60 | 1.66 |
| *Aster foliaceous* | 11.81 | 0.38 | *Pyrola picta* | 5.51 | 0.01 |

**Table 3**.—Continued.

| GROWTH-FORM / Species | Frequency (%) | Cover (%) | GROWTH-FORM / Species | Frequency (%) | Cover (%) |
|---|---|---|---|---|---|
| FORBS AND FERNS (CONT.) | | | LOW SHRUBS AND SUB-SHRUBS | | 19.73 |
| *Pyrola secunda* | 1.57 | <0.01 | *Berberis nervosa* | 3.94 | 0.23 |
| *Ranunculus uncinatus* | 21.26 | 0.14 | *Chimaphila menziesii* | 4.72 | 0.01 |
| *Rumex acetosella** | 20.47 | 0.42 | *Phlox diffusa* | 3.94 | 0.52 |
| *Satureja douglasii* | 1.57 | <0.01 | *Rubus ursinus* | 32.28 | 3.37 |
| *Smilacina stellata* | 44.88 | 13.84 | *Rubus lasiococcus* | 1.57 | 0.06 |
| *Stellaria calycantha* | 7.09 | 0.07 | *Symphoricarpos mollis* | 55.12 | 15.54 |
| *Stellaria crispa* | 3.94 | 0.01 | | | |
| *Stellaria* sp. | 0.79 | <0.01 | TALL SHRUBS | | 7.87 |
| *Taraxacum* sp. | 3.15 | 0.08 | *Acer circinatum* | 7.09 | 0.80 |
| *Tiarella trifoliata* | 7.87 | 0.13 | *Amelanchier alnifolia* | 1.57 | 0.07 |
| *Tragopogon dubius** | 0.79 | <0.01 | *Berberis aquifolium* | 1.57 | 0.03 |
| *Trientalis latifolia* | 34.65 | 0.71 | *Holodiscus discolor* | 12.60 | 6.26 |
| *Trillium ovatum* | 0.79 | <0.01 | *Rhamnus purshiana* | 4.72 | 0.14 |
| *Vicia americana* | 48.03 | 0.84 | *Ribes* spp. | 1.57 | <0.01 |
| *Viola glabella* | 74.80 | 1.20 | *Ribes lobbii* | 3.15 | 0.35 |
| *Viola nuttallii* | 2.36 | 0.01 | *Rosa gymnocarpa* | 5.51 | 0.22 |

## MEADOW COMMUNITIES

Ground-layer Vegetation.—Floristically, meadow communities at Bunchgrass are less diverse than are mature forest understories. We observed a total of 57 ground-layer taxa (Table 4) among the 8 transects and 210 quadrats sampled (compared with 86 taxa in 127 quadrats in the forest). Local (plot-level) diversity was also lower in the meadow—a mean of 13.2 species per quadrat compared with 16.1 in the forest (Table 5). Forbs were the most diverse growth-form (34 taxa), followed by grasses (11) and low/sub-shrubs (7) (Table 4).

Mean total plant cover (summed among non-tree species) averaged more than 140% but varied markedly among transects (Table 5). The dominant growth-forms were forbs (55% cover) and grasses (50% cover). Among the most frequent and abundant taxa were the grasses, *Festuca rubra* and *Bromus carinatus;* the sedge, *Carex pensylvanica*; and the forbs, *Achillea millefolium*, *Fragaria vesca/virginiana*, *Lupinus latifolius*, and *Aster radulinus.* Exotic species contributed minimally to the diversity and cover of the meadow vegetation (Table 4). The most abundant, non-native species was the grass, *Agropyron repens* (38% of quadrats, 1.3% cover). The remaining four species—*Agrostis alba* var. *stolonifera*, *Poa pratensis*, *Rumex acetosella* and *Tragopogon dubius*—occupied <1-10% of the quadrats with minimal cover. Bare ground was common, largely due to gopher activity, and was recorded in 78% of the quadrats samples with an average cover of 7.2%.

Undoubtedly, a number of spring ephemerals were completely missed in our August sampling (e.g., *Claytonia lanceolata,* which was observed at snow-melt in early June), and a number of common, early- (e.g., *Calochortus subalpinus*) and mid-season (e.g., *Lupinus* latifolius and *L. laxiflorus*) forbs had senesced in many quadrats. Thus our data do not represent a complete inventory of the plots, nor do they represent the peak biomass of all species. Our repeat photographs of the eight transects taken in July, August, and September, underscore the marked seasonal changes in meadow stature, composition, and cover. Unless burning differentially affects the performance of species with earlier phenologies, these seasonal trends should not affect our ability to detect the more general effects of prescribed burning.

**Table 4**. The frequency and mean cover (%) of species sampled in the meadow transects between 24 August and 03 September 1999. Proportions of transects and quadrats are based n = 8 and 210, respectively. The most common and/or abundant species are shaded; * indicates exotic species.

| GROWTH-FORM / Species | Proportion of transects (%) | Proportion of quadrats (%) | Cover (%) |
|---|---|---|---|
| **GRASSES** | | | 49.55 |
| *Agropyron repens** | 87.50 | 38.10 | 1.29 |
| *Agrostis scabra* | 87.50 | 18.10 | 0.12 |
| *Agrostis alba var. stolonifera** | 12.50 | 0.48 | 0.06 |
| *Bromus carinatus* | 100.00 | 87.62 | 8.63 |
| *Danthonia intermedia* | 100.00 | 69.05 | 3.04 |
| *Elymus glaucus* | 100.00 | 53.81 | 4.81 |
| *Festuca idahoensis* | 100.00 | 54.29 | 2.75 |
| *Festuca rubra* | 100.00 | 95.71 | 27.56 |
| *Poa pratensis** | 50.00 | 4.76 | 0.39 |
| *Stipa occidentalis* | 100.00 | 28.10 | 0.79 |
| *Trisetum canescens* | 25.00 | 3.81 | 0.11 |
| **SEDGES AND RUSHES** | | | 24.98 |
| *Carex pachystachya* | 12.50 | 0.48 | 0.01 |
| *Carex pensylvanica* | 100.00 | 97.62 | 24.97 |
| *Luzula campestris* | 12.50 | 0.95 | 0.00 |
| **FORBS** | | | 54.51 |
| *Achillea millefolium* | 100.00 | 94.29 | 8.73 |
| *Agoseris aurantiaca* | 50.00 | 9.05 | 0.06 |
| *Agoseris glauca* | 50.00 | 5.24 | 0.02 |
| *Anemone deltoidea* | 25.00 | 0.95 | 0.00 |
| *Anemone oregana* | 25.00 | 7.62 | 0.16 |
| *Arabis sp.* | 12.50 | 0.95 | 0.00 |
| *Arenaria macrophylla* | 75.00 | 23.81 | 0.46 |
| *Aster ledophyllus* | 25.00 | 4.76 | 0.18 |
| *Aster radulinus* | 87.50 | 48.57 | 5.69 |
| *Campanula scouleri* | 25.00 | 1.43 | 0.01 |
| *Calochortus subalpinus* | 25.00 | 1.43 | 0.01 |
| *Cirsium callilepes* | 100.00 | 67.62 | 1.73 |
| *Epilobium angustifolium* | 12.50 | 0.48 | 0.01 |
| *Erigeron aliceae* | 87.50 | 34.29 | 1.95 |
| *Erysimum asperum* | 37.50 | 1.90 | 0.01 |
| *Fragaria vesca/virginiana* | 100.00 | 57.62 | 14.75 |
| *Galium oreganum* | 25.00 | 0.95 | 0.07 |
| *Gnaphalium microcephalum* | 12.50 | 0.48 | 0.00 |
| *Hieracium gracile* | 100.00 | 72.38 | 4.63 |
| *Iris chrysophylla* | 100.00 | 41.90 | 2.49 |
| *Lathyrus nevadensis* | 87.50 | 15.24 | 1.68 |
| *Lomatium triternatum* | 37.50 | 2.86 | 0.02 |
| *Lupinus latifolius* | 100.00 | 74.29 | 5.52 |
| *Lupinus laxiflorus* | 12.50 | 2.86 | 0.02 |

**Table 4.**—Continued.

| GROWTH-FORM / Species | Proportion of transects (%) | Proportion of quadrats (%) | Cover (%) |
|---|---|---|---|
| **FORBS** (CONT.) | | | |
| *Mitella* sp. | 12.50 | 0.48 | 0.00 |
| *Orthocarpus imbricatus* | 37.50 | 23.33 | 1.35 |
| *Osmorhiza chilensis* | 25.00 | 0.95 | 0.01 |
| *Polygonum douglasii* | 62.50 | 4.76 | 0.01 |
| *Pteridium aquilinum* | 37.50 | 14.76 | 4.58 |
| *Ranunculus uncinatus* | 12.50 | 0.48 | 0.01 |
| *Rumex acetosella** | 50.00 | 9.52 | 0.13 |
| *Tragopogon dubius** | 12.50 | 0.48 | 0.00 |
| *Trientalis latifolia* | 12.50 | 0.48 | 0.00 |
| *Viola nuttallii* | 100.00 | 24.76 | 0.22 |
| **LOW SHRUBS AND SUB-SHRUBS** | | | 11.83 |
| *Commandra umbellata* | 100.00 | 36.67 | 0.46 |
| *Happlopappus greenei* | 12.50 | 0.48 | 0.05 |
| *Penstemon procerus* | 25.00 | 7.14 | 0.92 |
| *Phlox diffusa* | 75.00 | 45.24 | 9.09 |
| *Rubus ursinus* | 25.00 | 2.38 | 0.07 |
| *Symphoricarpos mollis* | 25.00 | 0.95 | 0.00 |
| *Vaccinium membranaceum* | 25.00 | 4.29 | 1.23 |
| **TALL SHRUBS** | | | 0.08 |
| *Amelanchier alnifolia* | 37.50 | 1.90 | 0.05 |
| *Prunus emarginata* | 12.50 | 0.95 | 0.03 |
| **CONIFERS** | | | 6.53 |
| *Abies grandis* | 25.00 | 8.10 | 3.81 |
| *Pinus contorta* | 25.00 | 5.71 | 1.80 |
| *Pseudotsuga menziesii* | 12.50 | 1.43 | 0.92 |

**Table 5.** Variation in plant species diversity and total cover among meadow transects sampled between 24 August and 3 September 1999. Values for "All transects" represent the means of all transects.

| | Transect | | | | | | | | All |
|---|---|---|---|---|---|---|---|---|---|
| Community measure (No. of quadrats) | 1-E (25) | 1-W (25) | 2A-N (30) | 2A-S (30) | 2B-N (20) | 2B-S (20) | 3-N (30) | 3-S (30) | transects (210) |
| No. species per transect | 34 | 31 | 28 | 25 | 29 | 24 | 33 | 36 | 30 |
| Mean no. species per plot | 13.1 | 14.7 | 11.9 | 12.2 | 14.4 | 14.3 | 12.3 | 12.7 | 13.2 |
| Total plant cover (%) | 165 | 122 | 117 | 151 | 174 | 171 | 89 | 138 | 141 |

Invasive Trees.—One of three meadow sampling locations (Lodgepole Meadow, Fig. 1) supports a large population of invading trees. Tree densities were higher in the control (Figs. 6A, B) than in the burned transect (Figs. 6C, D), although diameter distributions and species composition were fairly similar between transects. As in the mature forest, *Abies grandis* was the dominant species, however, *Pinus contorta* was also abundant, particularly in the 0-5 cm diameter class. The largest (and presumably oldest) invasive trees in both transects were *P. contorta*.

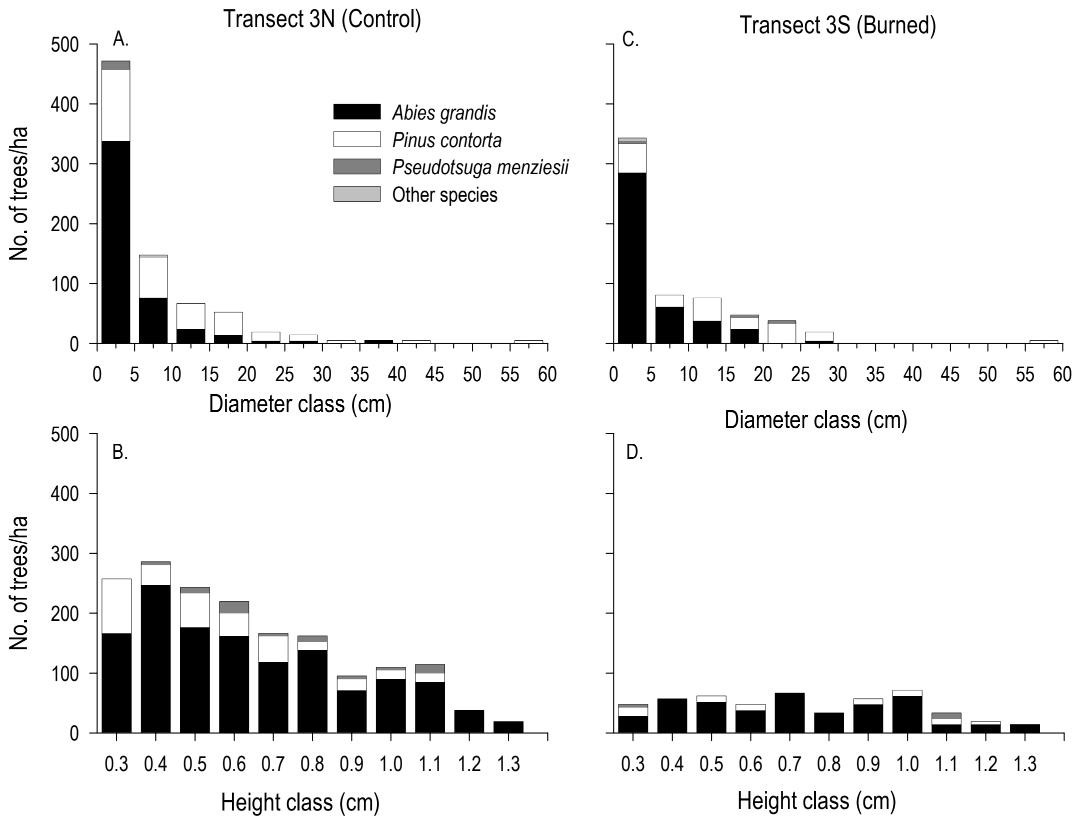



**Figure 6**. Size structure and species composition of invasive trees in the control (left) and burned (right) transects in "Lodgepole Meadow," prior to prescribed burning. Trees ≥1.4 m tall are summarized by diameter class (A, C), and trees 0.3-1.3 m tall by height class (B, D). "Other" species include *Taxus brevifolia* (yew) and *Calocedrus decurrens* (incense cedar).

DISTURBANCE ASSESSMENT

The prescribed burn on 11 October 1999 was light and patchy. In the meadow portions of the study area, duff consumption was minimal and vegetation consumption was largely limited to blackening of plant stems and foliage. Estimates of the proportion of vegetation burned within each quadrat varied widely within each transect (Fig. 7), facilitating future comparison of the relationship between burn characteristics and changes in species composition and diversity.

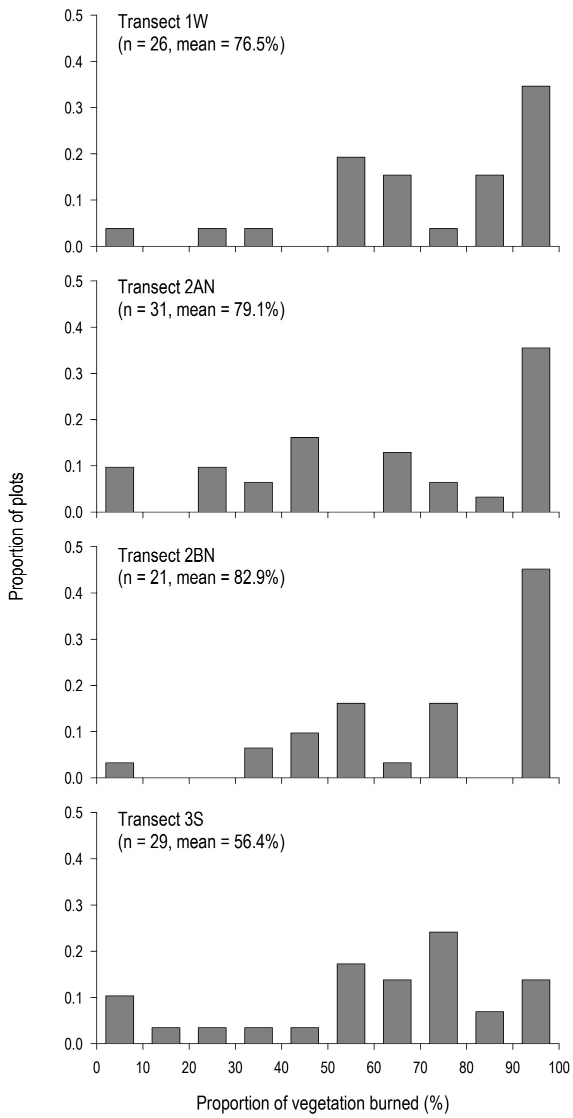



**Figure 7**. Histogram of the proportion of vegetation burned in quadrats representing each transect. The numbers of 1 x 1 m quadrats sampled per transect (n) and the transect-level means are in parentheses.

## FUTURE PLANS

Post-treatment sampling of meadow transects will be conducted during summer 2000. Because the mature forest study area experienced little to no burning, resampling of the forest transects for changes in understory composition or tree mortality will be postponed until a future burn causes greater tree mortality and/or consumption of ground-layer vegetation. Specific plans for further sampling and analysis of meadow vegetation are documented in the original grant proposal and will not be repeated here. Baseline data in electronic form or as hardcopy are available from the Principal Investigator upon request.


## ACKNOWLEDGEMENTS

Many individuals contributed to the collection of baseline data at Bunchgrass including Nick Otting and Danna Lytjen (meadow transects), Ann Lezberg and Reese Lolley (forest understory transects), and Kelvin Lloyd, Mark Swanson, and Lauren Schachner (forest plots). Joseph Antos assisted with the study design and transect establishment. Ann Lezberg and Kate Bicket assisted with data entry, verification, and database manipulations. Numerous individuals at the McKenzie Ranger District, Willamette National Forest have facilitated this research—special thanks to Nancy Wilson, Pat Ford, John Phillips, Jenny Lippert, Eric Bergland, Shane Kamrath, and John Allen. John Cissel of the Blue River Ranger District was instrumental in initiating the discussions that led to this collaborative arrangement.


## LITERATURE CITED


Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Island Press, Washington, D.C.

Burke, C.J. 1979. Historic fires in the central western Cascades, Oregon. M.S. thesis, Oregon State Univ., Corvallis, OR.

DeFerrari, C.M., and R.J. Naiman. 1994. A multi-scale assessment of the occurrence of exotic plants on the Olympic Peninsula, Washington. J. Veg. Sci. **5**: 247-258.

Franklin, J.F., W.H. Moir, G.W. Douglas, and C. Wiberg. 1971. Invasion of subalpine meadows by trees in the Cascade Range, Washington and Oregon. Arc. Alp. Res. 3: 215-224.

Halpern, C. B. 1989. Early successional patterns of forest species: interactions of life history traits and disturbance. Ecology 70:704-720.

Halpern, C.B., B.G. Smith, and J.F. Franklin. 1984. Composition, structure, and distribution of the ecosystems of the Three Sisters Biosphere Reserve/Wilderness Area. Final report to the U.S. Department of Agriculture. On file, PNW Research Station, For. Sci. Lab., Corvallis, OR.

Hickman, J.C. 1968. Disjunction and endemism in the flora of the central western Cascades of Oregon: An historical and ecological approach to plant distributions. Ph.D. dissertation, Univ. of Oregon, Eugene, OR.

Hickman, J.C. 1976. Non-forest vegetation of the central western Cascade Mountains of Oregon. Northw. Sci. 50:145-155.

Hitchcock, C.L., and Cronquist, A. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle, Wash.

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

Magee, T.K., and J.A. Antos.  1992.  Tree invasion into a mountain-top meadow in the Oregon Coast Range, USA.  J. Veg. Sci. 3: 485-494.

Miller, E.A.  1995.  The dynamics of forest-meadow ecotones in the Three Sisters Wilderness, Oregon: Variation across environmental gradients.  M.S. thesis, Univ. of Washington, Seattle, WA.

Miller, E.A., and C.B. Halpern.  1998.  Effects of environment and grazing disturbance on tree establishment in meadows of the western Cascade Range, Oregon, USA.  J. Veg. Sci. 9:265-282.

Morrison, P.H., and F.J. Swanson.  1990.  Fire history and pattern in a Cascade Range landscape. USDA For. Serv. Gen. Tech. Rep. PNW-GTR-254.

North, M., J. Chen, G. Smith, L. Krakowiak, and J. Franklin.  1996.  Initial response of understory plant diversity and overstory tree diameter growth to a green tree retention harvest.  Northw. Sci. 70:24-35.

Rochefort, R.M., R.L. Little, A. Woodward, and D.L. Peterson.  1994.  Changes in subalpine tree distribution in western North America:  A review of climatic and other causal factors.  The Holocene 4: 89-100.

Schoonmaker, P., and A. McKee.  1988.  Species composition and diversity during secondary succession of coniferous forests in the western Cascade Mountains of Oregon.  For. Sci. 34:960-979.

Teensma, P.D.A.  1987.  Fire history and fire regimes of the central western Cascades of Oregon.  Ph.D. dissertation, Univ. of Oregon, Eugene, OR.

Vale, T.R.  1981.  Tree invasion of montane meadows in Oregon.  Am. Midl. Nat. 105: 61-69.

Wilson, N., E. Bergland, P. Ford, S. Kamrath, and J. Phillips.  1999.  Bunchgrass Meadow special habitat area management plan.  Unpubl. management plan, U.S.F.S. Mckenzie Ranger District, Willamette National Forest, OR.