

Recent (5 to 30 years) and historic changes in plant community composition in the Cascade-Siskiyou National Monument, southwest Oregon

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Abstract

According to memoirs and historical anecdotes, weedy species replaced native bunchgrasses at many locales in the Cascade-Siskiyou National Monument during the late 1800s and early 1900s under high use, season-long grazing by sheep, cattle, and horses. Starting in the 1950s, improved management reduced the spread of medusahead (*Taeniatherum caput-medusae*) and replaced weedy annual grasses with non-native perennial bulbous bluegrass (*Poa bulbosa*). Anecdotes reported that native perennial grasses increased in response to improved management of the livestock. Recent inventories verify continued increase of native bunchgrass under modern range management practices at certain locations. Re-examination of 15 to 30 year old stand inventories indicates changes in extent and abundance of individual species and life-forms at the landscape level. Non-native perennial forbs, native or non-native grasslike plants (including sedges), and non-native perennial grasses have increased in extent over time. Only one non-native perennial forb occupies fewer stands than previously. Native and non-native perennial grasses were the only life-forms that changed significantly in cover abundance over time. Individual species showing the most consistent increases in cover abundance over time include short-lived non-native perennial grass bulbous bluegrass, and Douglas-fir (*Pseudotsuga menziesii*). Black oak (*Quercus kelloggii*) was the only species that showed consistent declines in cover abundance across the landscape. Spatial patterns of non-native annual grass reflected the influence of topography, soils and historic livestock grazing. Declines in annual grasses at some locations were matched by increases in abundance at other locations. Indirect evidence from patterns of bulbous bluegrass abundance suggests that livestock promote non-native grass invasion of the landscape, but its decrease on a site with increased grazing indicates that livestock may also reduce bulbous bluegrass with spring grazing. Topographic and edaphic factors influence vegetation composition relative to current livestock-induced changes in species composition. Recent change in herbaceous species extent and cover abundance reflect the invasion of non-native species introduced in seeding trials in the 1960s and 1970s. Increase in Douglas-fir and decline of black oak are consequences of natural succession in the absence of fire.

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Introduction

The proclamation for the Cascade-Siskiyou National Monument mandated studies to determine potential impacts by livestock on objects of biological interest, including plant communities and ecological processes (White House 2000). The history of livestock grazing in the area of the Monument dates back to the 1850s (Hosten *et al.* 2007b). Large herds of horses, cattle, and sheep grazed the area from the Klamath River to the Dead Indian Plateau. During this period of unregulated use, overgrazing caused severe damage to rangeland resources. Comments about grazing, repeat historic photos, and knowledge about past stocking rates indicate that areas of heavy utilization were more widespread than they are now. Factors including fencing, creation of riparian and elk forage reserves, improved livestock control, and reduced stocking rates reduced grazing severity. Livestock grazing in the Monument is managed as nine grazing allotments, two of which are currently vacant. Five of the active allotments account for 97% of the authorized grazing in the Monument (Figure 1). The Soda Mountain and Keene Creek Allotments contain most of the Animal Unit Months (AUMs) in the Monument. Existing grazing leases authorize a total of 2,714 active AUMs within the CSNM boundary during the grazing season. This number includes 99% of the Soda Mountain Allotment and 44% of the Keene Creek Allotment that are within the CSNM. The average actual use for the Soda Mountain and Keene Creek Allotments between 1985 and 2006 is 58%. (63% for Soda Mountain and 49% for Keene Creek Allotments). Grazing season generally is May through October. Hosten *et al.* (2007b) describe historic and current grazing in the Monument in detail.

Cascade-Siskiyou National Monument

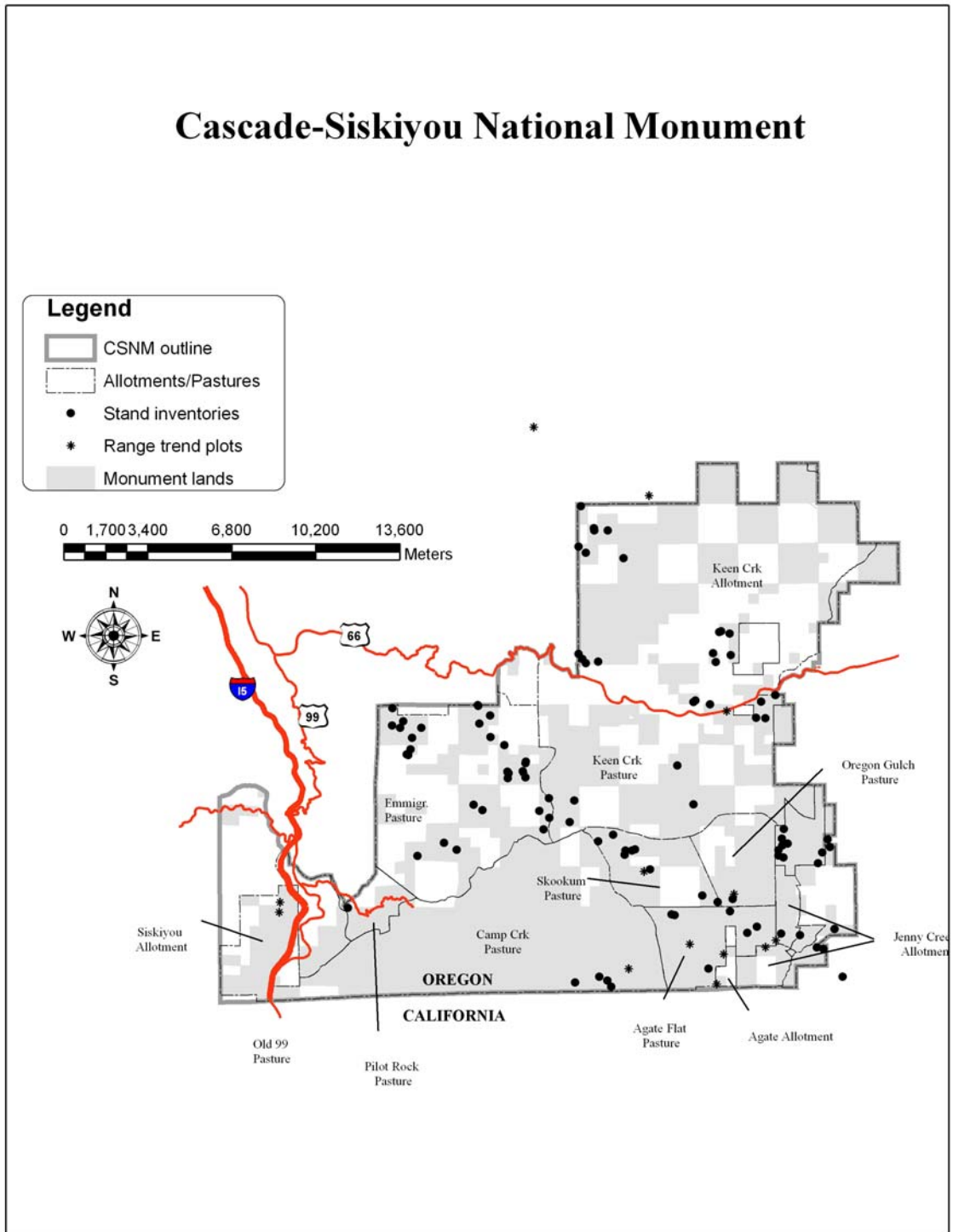


Figure 1. Map of the Cascade-Siskiyou National Monument showing research sites.

The ecological and biological richness of the Monument area (Carroll *et al.* 1998, Detling 1961, Prevost *et al.* 1990) is due in part to the convergence of three ecoregions: Cascade, Klamath, and eastern Cascade slope (Pater *et al.* 1997a). Whittaker (1960, 1961) described southwestern Oregon vegetation as having elements of the floras of California, the coast, and the interior Oregon, which together with a high level of endemism, creates regionally distinct plant communities. Soil depth, texture, drainage, aspect, and topographic position are important factors in determining vegetation; arid communities often associate with shallow soils, south to west-facing slopes, and lower elevations. The area of grasslands, shrublands, and open woodlands is estimated at 19,741 acres mainly in the southern portion of the Monument.

Grasslands usually occupy poorly drained bottomlands or dry upland sites with shallow soils or soils of expanding clay (vertisol). Grasslands at lower or mid elevations may include minor amounts of *Eriogonum sp.*, *Ericameria nauseosa*, *Ceanothus cuneatus*, *Amelanchier alnifolia*, *Purshia tridentata* and *Cercocarpus betuloides*. Patches of chaparral (shrubland dominated by species with sclerophyllous leaves) occur at lower elevations throughout the southern part of the Monument, but are generally restricted to an ecological named “Shrubby Scabland” (USDA 1993).

Oak savanna stands, usually *Quercus garryana* (seldom *Quercus kelloggii*), are narrowly restricted by site conditions. Savanna persists on the Medford valley floor, low elevation slopes, and foothills where vertisol clays, seasonal wetness, or shallow soils limit expansion by *Quercus garryana* and encroachment by other species. At higher elevations, there are dense oak woodlands (with closed canopy) that have a dense shrub component and grass understory. The shrub component may include *Prunus subcordata*, *Amelanchier alnifolia*, *Symphoricarpos sp.*, *Cercocarpus betuloides*, and *Juniperus occidentalis*. *Ceanothus cuneatus* and *Purshia tridentata* grow on gentle lower elevation slopes in more open white oak-juniper stands, often with *Pinus ponderosa* on more clayey soils. Oak woodlands and meadows at higher elevations are restricted to soils that do not support conifer growth.

More mesic areas are dominated by mixed coniferous forests, which support a variety of trees, including *Pseudotsuga menziesii*, *Abies concolor*, *Pinus ponderosa*,

Pinus lambertiana, *Calocedrus decurrens*, and *Taxus brevifolia*. White fir forests occur at higher and colder elevations in the northern part of the Monument.

A literature review of livestock influence on vegetation change

Methods using exclosures or a chrono-sequences identified a decline in palatable perennial grasses with livestock grazing (Anderson and Holte 1981; Brotherson and Brotherson 1981; Rose and Miller 1993; Robertson 1971; Pearson 1965; Arnold 1950; Peters *et al.* 1993; Yorks *et al.* 1992; Eckert and Spencer 1986, 1987). Others showed maintenance of perennial grass during utilization by livestock (Sneva *et al.* 1984; West *et al.* 1984; Saunders and Voth 1983). Relict perennial grass stands in the coastal range of Monterey County, California, withstood different levels of historic grazing by livestock (Stromberg and Griffen 1996). Three common grasses were more productive on moderately grazed sites than ungrazed sites in New Mexico (Daddy *et al.* 1988). While the interaction of livestock and fire has been demonstrated in the Great Basin to allow conversion of shrub-grass to annual domination, other studies show that annual grass increase after fire can be short-term (West and Hassan 1985; Hassan and West 1986, Hosten 1995; Hosten and West 1994). Both palatability and grass stature influenced the response of grasses to livestock use. Taller statured grasses can out-compete shorter statured grasses (Mclean and Tisdale 1972). Short-statured grasses are generally more resistant to livestock impact (Tueller and Platou 1981; Mclean and Tisdale 1972). Individual perennial grasses may respond differently to livestock grazing (Mack and Thompson 1982). Menke and Trlica (1981) attributed differing abilities of recovery from defoliation to carbohydrate reserve cycles. Shrubs and grasses that maintain lower carbohydrate reserves for more of the growing season recovered more slowly from defoliation events. Hayes and Holl (2003) found that *Danthonia californica* directed more resources towards vegetative tillering following defoliation. Four years of livestock exclusion failed to change the frequency of non-native annual grasses or native perennial grass abundance at 30 grazed sites in the Cascade-Siskiyou National Monument (Menke and Kaye 2006). While several authors have noted the association of annual grasses (notably *Bromus tectorum*) with grazing by livestock (Hosten 1995, Tueller and Platou

1991, Brotherson and Brotherson 1981), others demonstrated its ability to establish in the absence of fire or grazing in Idaho (Anderson and Inouye 1988).

The accumulation of litter on the soil surface may influence vegetation composition by ameliorating physical conditions such as soil surface temperatures and bulk density (Rice 1986, Heady 1966). Higher soil surface temperatures favor higher abundance of forbs over annual grasses. Forbs declined with grazing (Rose and Miller 1993) Possibly because rosette-forming forbs prevent perennial grass seedlings from emerging, and reduce seedling growth rates (Menke 1992). Based on an understanding of these patterns of growth, Menke (1992) suggests the use of prescribed fire and livestock as a restoration tool by manipulating soil surface conditions and other factors. A test of prescribed fire and intense short-duration grazing in a *Nassella pulchra* grassland in California found a short term increase in perennial grass seedling recruitment, but few survived beyond one year (Dyer *et al.* 1996). Grazing and prescribed fire treatments led to increased seed size and longer-term viability (Dyer 2002). Holechek and Stevenson (1983) imply that historic grazing by sheep removed the forb component of plant communities.

Shrubs show a mixed response to livestock influence. Pearson (1965) found increased shrubs with reduced livestock influence. Rose and Miller (1993) show shrubs to remain static with livestock use, while several authors show less shrub abundance with reduced livestock influence (Hosten 1995, Youtie *et al.* 1988). Mclean and Tisdale (1972) show a loss of half shrubs (*Antennaria*) with a reduction of grazing. Tueller and Platou (1991) show reduced bitterbrush phytomass production in the absence of grazing. Duncan *et al.* 1987 show moderate season-long grazing by cattle maintaining a buckbrush-free open blue oak woodland following fire in comparison to ungrazed areas of the San Joaquin Experimental Range, Central California.

Although many of these studies were conducted in the Great Basin, a generalized model of plant community dynamics within an oak woodland environment supports common plant community changes, especially in regard to annual and perennial grass dynamics. George *et al.* (1992) associates annualization of grasslands in an oak woodland environment with poor livestock management and identifies the difficulty of restoring “Mediterranean” grasslands back to native perennial domination. Lack of change in 20

small exclosures paired with moderately grazed plots indicates that this is true for annual-dominated portions of the CSNM (Menke and Kaye 2006).

Livestock have been shown to increase the abundance of bare soil (Platts and Nelson (1989). Clary (1995) tried to separate the effects of defoliation and soil compaction by examining the effects of simulated grazing and compaction on a variety of riparian sites in Idaho and Oregon. Results showed that the effects of soil compaction were more consistent across study areas than vegetation response to defoliation. Defoliation varied by plant species, plant community, and grazing intensity. The most consistent vegetative response to grazing was a reduction in height and biomass following compaction treatments. A grass (*Agrostis gigantea*) community maintained or increased above-ground production following spring or spring-fall defoliation, while *Carex* communities maintained or declined production following spring, mid summer, or late summer defoliation (Clary 1995). The increased height in control plots indicated that soils were still recovering from compaction prior to experimental compaction. Several studies noted an increase in plant vigor or height with the cessation of grazing. Possible factors include a reversal of soil compaction and accompanying changes in soil moisture and organic matter (Orodho et al. 1990; Rauzi and Smith 1973), and plant retention of biomass previously lost to herbivory (Clary 1995; Patten 1993; Painter and Belsky 1993).

The pattern of decreasing bare soil and moss inside exclosures is similar to the findings of past studies (Hulme *et al.* 1999). Tall vegetation would shade out moss, while closely cropped stubble allows enough light for moss to thrive.

Past studies of gopher mound abundance across a grazing intensity gradient showed mixed results. Tevis (1956), Beuchner (1942), Phillips (1936), and Garlough (1937) reported more gopher mounds in grazed areas while Hunter (1991) and Stromberg and Griffin (1996) reported more gopher mounds in ungrazed areas, though these two studies occurred in annual grasslands where a large percentage of the available biomass was removed by cattle each year. McLean and Tisdale (1972) associated annual grasses with increased gopher activity within exclosures. It was speculated gophers within exclosures were protected from predators by the increase in cover. In an annual grass dominated environment, Ratliff and Westfall (1971) suggest that gophers are more active near the surface of soils compacted in the late winter and spring. Livestock compacted

the soil loosened by gopher activity. Stromberg and Griffen (1996) found that recovery of native grasses were dependent on a range of environmental factors including soil texture, gopher abundance and slope. The germination of perennial grasses was reduced relative to annual grasses on gopher diggings.

Objective

This paper examines spatial and temporal patterns of vegetation change to determine how the influence of ecological forces (grazing by ungulates, the introduction of weeds, fire exclusion, and others) have influenced composition and successional processes across the diverse ecological sites of the Cascade-Siskiyou National Monument.

Methods And Materials

Historic Anecdotes

Historic anecdotes describing vegetation and past livestock management in the Monument area were collected from local memoirs and minutes of meetings of grazing associations (Table 2).

Range Trend Plots

Fourteen transects in the nine allotments and pasture subdivisions of the Monument (Figure 1) were established in the early 1990s. Nested frequency was derived from 100 nested plots (Plot 1, 5x5 cm; Plot 2, 25x25 cm; Plot 3, 25x50 cm; Plot 4, 50x50 cm) along a 100-foot transect (the macro-plot). Data was collected for ten frames along mini-transects (alternating left and right) every 3.5 feet along a 35 foot transect. Each time the quadrat frame was placed on the ground, the observer recorded the smallest size plot within which a species occurred. This allowed determination of frequency for three plot sizes.

Individual macroplots were representative of local conditions, defined by ecological site (slope, soil, aspect) and past management practices. Each plot size was analyzed for significant change by species for individual transects using Chi-square analysis comparing the oldest to the most recent data collection. Data were examined to see if vegetation responded differently between early season low elevation grazing, late season high elevation grazing, and no grazing. Chi-square analysis was used to examine presence and absence within individual plots for comparison years following Elzinga *et al.* (1998), and considered significant at a probability level of 0.1. The probability value used to ascertain statistical significance was adjusted by the number of species tested resulting in a Bonferroni adjustment.

SVIM/NRCS Stand Examinations

Two historic vegetation surveys were conducted at the stand level to serve as a baseline to evaluate plant community changes over the past two decades: the Soil-Vegetation-Inventory-Method (SVIM) assessments and surveys conducted by the Soil

Conservation Service (now Natural Resource Conservation Service, NRCS). SVIM inventories date from 1979 to 1982, while NRCS vegetation surveys were conducted between 1970 and 1995. Both surveys were plotless cover estimates. In the NRCS data, old and new assessments (up to 25 years apart) were completed by the same technician. To optimize repeatability of data collection in the SVIM data, small clearly delineated stands were selected. Canopy cover was estimated for individual species and summarized by life-form and origin (native or non-native). Plot locations were recorded using a Global Position System (GPS) for spatial analysis by plot location in a Geographic Information System (GIS). The NRCS surveys are a better replicated set of stand data (n = 85) spanning 30 years, but the repeatability was lower due to the subjective nature of the data. Before the data were analyzed, problem stand inventories (e.g., SVIM sites that straddled two or more ecological sites) were deleted. Three aspects of the data were examined: presence/absence of species on old versus new plots (also described as change in extent); the number of plots showing significant changes in cover between the original inventory and the 2000 inventory; and plant community change relative to environmental (edaphic, biological, and management) using multivariate techniques.

Data were summarized by ecological site with three or more representatives. The ecological sites examined include grass/forb dominated sites (Aspen-sedge Meadow, Biscuit-scabland, Dry Meadow, Hellebore Meadow, High Mountain Shallow Grassland, Semi-wet Meadow, Wet Meadow), non-conifer woody dominated sites (Loamy Juniper Scabland, Oak Fescue, Oak Juniper Fescue, Oak Mahogany Fescue, Oak Pine Oatgrass, Shrubby Scabland), and conifer sites (Douglas-fir Forest, Douglas-fir Mixed Pine Sedge, Douglas-fir Mixed Pine Sedge (marginal), Mixed conifer Chinquapin sedge, Mixed fir Dogwood (Dry), Mixed fir Oceanspray forest, Mixed Fir serviceberry, Mixed Fir yew, Pine Douglas-fir Fescue, Pine Oak Fescue, and White Fir Forest)(Tables 10 and 11).

Data sets were entered in EXCEL and analyzed in PCORD and HYPERNICHE to provide a plant community perspective based on the collective individual species or life-forms relative to environmental variables.

Multivariate techniques were conducted using the Bray Curtis similarity index to favor more common species in the formulation of similarity indices between plots/stands. Hybrid Multi-Dimensional Scaling was used as ordination technique because of its

robustness with highly variable data. Jointplots were used to identify the relative loading of species values or environmental factors on ordination axes. A measure of change between temporal data was determined by examining the relative positions of repeat data in ordination space. This interpretation was aided by vectors joining repeat data collections to create a trajectory over time.

Additional ordinations were created using differences between repeat data collections using Principal Components Analysis (PCA). Ordination of differences detected patterns of change across the landscape .

All community data was analyzed in the context of environmental data including topographic (slope, heatload, and elevation), edaphic (soil composition and depth), biotic (vegetation cover, plant community, and NRCS ecological site descriptions), and management (past treatments, distance from water, average utilization, and maximum utilization) factors (Table 1 and Hosten et al. 2007b).

Nonparametric Multiplicative Regression (NPMR) as implemented in HYPERNICHE (McCune 2006) was used to derive best-fit models describing the pattern of the above defined response variables relative to predictor variables. The Local Mean form of the NPMR regression enables the incorporation of binary or quantitative data. The modeling process includes an initial screening for variables of interest followed by an exhaustive modeling approach. As the number of predictor variables increases, a stepwise search is initiated. All predictor variables are assessed in one variable models to determine the best one-variable model. Additional variables are added stepwise assessing improvement at each step. This approach evaluates all possible combinations of predictors and tolerances.

In addition to identifying important variables, the modeling process also provides several measures for assessing importance of individual variables and overall model quality.

When a response variable is declared as quantitative, model quality is evaluated in terms of the size of the cross validated residual sum of squares in relation to the total sum of squares. The HYPERNICHE manual calls this the “cross r^2 ” (xr^2) because the calculation incorporates a cross validation procedure. The xr^2 value is considered a measure of variability captured by the best fit model.

Sensitivity analysis provides a measure of the relative importance of individual quantitative predictors in NPMR models. The sensitivity measure used in this paper refers to the mean absolute difference resulting from nudging the predictors, expressed as a proportion of the range of the response variable. The greater the sensitivity, the more influence that variable has in the model. With the sensitivity measure employed in this paper, a value of 1.0 implies a change in response variable equal to that of change in a predictor. A sensitivity of 0.5 implies the change of response variable magnitude is half that of the predictor variable. A sensitivity of 0.0 implies that nudging the value of a predictor has no detectable effect on the response variable.

NPMR models can be applied in the same way that traditional regression models are used (McCune 2006). A major difference is that estimates from the model require reference to the original data. Three dimensional plots of select predictor and response variables provide a visual assessment of how important predictor variables relate to response variables. The modeling approach as utilized by HYPERNICHE works well with variables defined in GIS as ASCII grids, allowing the formulation of probability estimate maps for response variables.

Table 1. Description of predictor variables

Variable	Source	Description
Topographic variables		
heatload	NRCS database	calculated from digital elevation data
elevation	digital elevation data	derived from digital elevation data
slope	digital elevation data	derived from digital elevation data
Edaphic variables		
% clay	NRCS database	average percent clay by soil horizon, then by soil component
% sand	NRCS database	average percent sand by soil horizon, then by soil component
% silt	NRCS database	average percent silt by soil horizon, then by soil component
soil depth	NRCS database	soil depth
vertisol	NRCS database	
Biotic variables		
Woody cover	Satellite imagery	Woody vegetation cover
Management variables		
last grazed	BLM grazing records	years of rest since most recent population assessment
average utilization	BLM grazing records	running average forage utilization for years when forage was mapped
maximum utilization	BLM grazing records	maximum recorded forage utilization for years when forage was mapped
distance from water	BLM riparian inventory	distance from perennial and long-duration intermittent water (100 m increments)
distance from road	BLM road inventory	distance from road (100 m increments)
non-conifer disturbance	BLM records	non-conifer management compiled from BLM records
Conifer change	Satellite imagery	Conifer cover change

Results

Historic anecdotes

In an interview (anon 1991) and undated memoirs, Mark Lawrence, who started work in the BLM range and silviculture program in 1957, recounted that old-timers had observed sheep grazing in the glades west of Soda Mountain, where the peavine (thought to be *Lathyrus* sp.) was as high as their backs. At that time, Agate Flat was already dominated by medusahead, ostensibly brought in by sheep from Roseberg Country in the 1870s. Medusahead rye spread rapidly throughout the open range of northern California and Jackson and Klamath counties. Sheep left the range in 1918. Lawrence commented that old-timers recalled that the open areas of the Greensprings area were bunchgrass range. Remnants on rocky areas along the Greensprings Highway and the road to Yreka indicate that bluebunch wheatgrass (*Pseudoroegneria spicata*) with an understory of Sandberg bluegrass (*Poa secunda*), Junegrass (*Koeleria macrantha*), and Idaho fescue (*Festuca roemerii*) was common, with patches of Great Basin wild rye (*Leymus cinereus*) along creek bottoms. This plant community was known to “not stand up under extremely heavy, and particularly year-long, grazing. It soon starts giving way to annuals such as cheat grass, medusahead and various weeds such as star thistle” (Lawrence 1973).

Table 2. Anecdotes describing historic vegetative condition of the Monument and adjacent landscape. The Wright reminiscences (Wright unpublished) include anecdotes about his grandfather, father, and his own years as a buckaroo and therefore span the years from early the 1870's to the 1950's.

Shrub references	
"Mr Mulloy said that by the time the fence was built the brush would take over. He also suggested it would be better to wait and see if cattle drift excessively before putting up the fence."	Peterson 1953
"Brushy gulch always called brushy gulch ... though not as much brush as other gulches"	Wright unpubl
"Middle forks of camp creek always brushy ... likely a lot worse today ..."	Wright unpubl
In reference to a fire that started on the 30 th may 1925 and put out on the 6 th June 1925, Wright records that: "... fire burned many thousands of acres of grassland, some timber, cattle, and horses as well as wildlife in its path. ... many cattle and even some horses starved after the lack of fire because of the lack of feed."	Wright unpubl
"When I was a boy my father and others told me that on the north side of the knoll was where the grizzly bears dug holes in the hillside in the mahogany brush to den up during the winter."	Wright unpubl
"There is a couple of nice springs on the Bench, lots of brush such as scrub oak, with a few little open glades."	Wright unpubl
Local ranchers mention that it is now more difficult to ride their horses on Keene ridge above the bench due to increase presence of brush	Miller (pers. Comm.)
Grass/weed references	
In reference to the Left fork of Camp Creek, west of bald mountain and around Timber Spring ... " In days gone by I could always find a grassy spot to stake out my horse for the night. Now the grass is about gone and is becoming, like many other things, just a memory."	Wright unpubl
On lone pine ridge ... "the side facing pine creek is fairly open by steep. The area in the early days was a fine winter and spring range for cattle and horses because there was always a good supply of bunch grass growing on the hillsides. Roaming bands of horses depleted the bunch grass but most of them have been rounded up so may be the good old bunchgrass will get a second chance."	Wright unpubl
On timber mountain ... p48 ... in the area of timber spring ... " The sheep killed about all of the good grass that used to grow around that part of Timber Mountain. The area was over grazed year after year by both sheep and cattle and it became more dust than anything else. After the grass was gone weeds had a chance to get a foothold and now the woods have taken the place of the grass that used to grow so abundantly."	Wright unpubl
" The Bald Mountain area was a wonderful place for grass but the sheep men would herd their sheep there year after year until the grass was killed out. Weeds of different kinds have taken the place of the grass."	Wright unpubl
"About 1923, after the sheep had ruined the range ..."	Wright unpubl
Wright notes that the first record of extensive salting for livestock occurred in 1916 in the currently named Salt Creek ... p 52	Wright unpubl
"It used to be a good place for deer and many big bucks have been taken there in past years. The upper part of the ridge was a good horse range but since the fine bunch grass has been killed out on the knolls and ridges the range horses are about a thing of the past."	Wright unpubl
Cold spring butte ... " ... On the west side it is too rocky for cattle and horses to go and get the nice bunchgrass which grows there."	Wright unpubl
Wright describes "the bench" below Keen Ridge as: "There is a couple of nice springs on the Bench, lots of brush such as scrub oak, with a few little open glades. There used to be lots of nice grass growing in the glades, but not near so much now days."	Wright unpubl
" The skookum ridge area in the early days was a good cattle range but due to over grazing its not near as good now."	Wright unpubl
Area of goat camp ... " This area was a fine cattle range in the early days, but too many goats and cattle killed out most of the grass. Like the balance of the range land, it's been overgrazed by cattle, horses, goats and sheep. It is goodbye to the free and open range, goodbye to the horned cattle and all the rest, the old goes and the new comes, good and bad."	Wright unpubl
About Keen creek ... p 80 ... " Around 40 or more years ago that was fine cattle range, but its not near so good now."	Wright unpubl
" Crooked Pine Spring Area (along Soda Mountain Road between Hobart Lake and Soda Mountain) was a fine cattle range, but it was grazed with sheep and cattle till its not much more than a dust pile today". "On Agate Flat a broadcasting and harrowing of bulbous bluegrass did very well and was quite successful in replacing the Medusa rye. It is not the best grass but is definitely superior to Medusa rye grass" (Lawrence).	Lawrence unpubl
"After the fencing was completed and the heavy congregation of cattle in many areas was eliminated, we began to note the return of the original perennial grasses"	Lawrence unpubl
General Township/Range descriptions	
FRACTIONAL TOWNSHIP 41 SOUTH, RANGE 1 EAST. This fractional township consists of spurs and canyons projecting southward from the Siskiyou Range. The forest along the lower slopes is of excellent quality and proportion, and is remarkable for the large percentage of incense cedar of large growth which it contains. The upper slopes have been badly overrun by fires in recent times, and are thinly covered with forest in the midst of dense brush growths.	Leiberg 1900

<p>FRACTIONAL TOWNSHIP 41 SOUTH, RANGE 2 EAST.</p> <p>The central and southern portions of this township are situated on the summit and southern slopes of the Siskiyou Range. The township is very thinly forested, consisting largely of grassy or brushy semiarid slopes. The northern portion of the township contains scattered stands of timber much damaged by fires and of little commercial value</p>	Leiberg 1900
<p>FRACTIONAL TOWNSHIP 41 SOUTH, RANGE 3 EAST.</p> <p>This township consists of steep hills very sparsely forested, but covered with dense brush growths as the result of fires. Most of the timber was burned in recent times. There is no reforestation. The mill timber, scattered among the brush heaps, is of poor quality and practically inaccessible.</p>	Leiberg 1900
<p>FRACTIONAL TOWNSHIP 41 SOUTH, RANGE 4 EAST.</p> <p>The greater portion of this township consists of steep ridges bordering Jenny Creek, with a plateau-like tract in the northeastern area. The southern areas of the township are timbered with light, open stands interspersed with many oak copses. The northern portions bear a forest of moderate density, easy of access, with stands of timber of good quality and body.</p>	Leiberg 1900
<p>TOWNSHIP 40 SOUTH, RANGE 1 EAST.</p> <p>This township consists chiefly of high rocky combs and ridges culminating in Siskiyou Peak. It forms the larger portion of the Ashland Forest Reserve. Along the higher slopes the forest occurs in scattered stands, largely composed of noble fir. The lower areas bear good stands of yellow and sugar pine. The red fir is mostly of small growth. Fires have run throughout the forest in the township. The summit of the ridge near Siskiyou Peak has been burned to the extent of 75 per cent within the last two or three years. Although a forest reserve for the purpose of supplying the town of Ashland with pure water, sheep are permitted to graze on the high slopes, defiling the water.</p>	Leiberg 1900
<p>TOWNSHIP 40 SOUTH, RANGE 2 EAST.</p> <p>This township is situated on the northern slopes of the Siskiyou Mountains and consists of rocky, broken hills rising in the east and south to join the main range. Fires have run through the forest in recent times, burning 30 percent of the timber and badly searing the remainder. The stands are light and scattered among bare, rocky flats and glades and dense brush growths. The larger portion of the timber consists of small-growth red fir of little commercial value.</p>	Leiberg 1900
<p>TOWNSHIP 40 SOUTH, RANGE 3 EAST.</p> <p>This township consists of ridges and canyons projecting eastward from the Siskiyou Mountains, and forms a portion of the Jenny Creek drainage basin. It is a very broken region, with the forest mostly burned up long ago and in its place dense brush growths or here and there grassed over slopes. The mill timber is of small growth and of little value.</p>	Leiberg 1900
<p>TOWNSHIP 40 SOUTH, RANGE 4 EAST.</p> <p>The eastern areas of this township consist of portions of the large lava plateau which flanks the main summit of the Cascade Range north of the Klamath River. The western portions of the township comprise broken, unevenly forested ridges draining into Jenny Creek. The mill timber in the eastern sections forms heavy stands, is excellent in quality, and easy of access. Fires have marked the entire forest stand in the township, and have mostly suppressed the young growth; hence the forest is of an open character, with but little undergrowth.</p>	Leiberg 1900
<p>TOWNSHIP 39 SOUTH, RANGE 1 EAST.</p> <p>The extreme western portions of this township consist of low, sparsely timbered slopes, with heavier stands in the ravines; the central portions comprise agricultural and grazing lands while the eastern mainly include semiarid, rocky, nonforested slopes. The forest is of poor quality throughout. Since the first settlement of the region it has been culled and burned repeatedly. Private holdings have conserved some of the better portions. In general the timber is of little commercial value.</p>	Leiberg 1900
<p>TOWNSHIP 39 SOUTH, RANGE 2 EAST.</p> <p>This township consists mostly of steep rocky breaks rising abruptly from Bear Creek Valley toward the Siskiyou-Cascades junction in the east. A large proportion of the region is naturally nonforested. The forested areas bear thin stands of scattered yellow pine and red fir mixed with copses of oak. The timber is all of poor quality.</p>	Leiberg 1900
<p>TOWNSHIP 39 SOUTH, RANGE 3 EAST.</p> <p>This township covers the areas at the junction of the Siskiyou and the Cascade ranges, and consists of rocky flats and ridges forming the upper drainage basin of Jenny Creek. The forest contains a large quantity of red fir, small in growth and badly damaged by the numerous fires which have overrun the township in recent times. The yellow pine is short bodied, as is the usual condition on the rocky areas of this region. Where fires have burned all the timber, brush growths are the rule.</p>	Leiberg 1900
<p>TOWNSHIP 39 SOUTH, RANGE 4 EAST.</p> <p>This township comprises most of the eastern areas of the Jenny Creek watershed and consists, in its eastern portion, of a level or gently rolling plateau region; in its western sections of hilly and broken ground. Its central areas contain Johnson Prairie, a large glade with many small ramifications. Fires have run throughout the entire extent of the township. The northern areas are very badly burned, extensive tracts being completely covered with brush growth as a result. The central and southern portions carry a heavy forest of yellow pine, excellent in quality and easy of access. The red fir is inferior in growth and quality, due to the many fires in the region.</p>	Leiberg 1900
<p>TOWNSHIP 40 SOUTH, RANGE 4 EAST</p> <p>The land in this township is rolling and generally second rate soil. It is timbered with the finest quality of Sugar and Yellow Pine, Fir, Cedar, and Oak. There is some first rate land along Jenny Creek bottom. There is a large soda spring in sec. 8."</p>	General Land Office (various)
<p>TOWNSHIP 41 SOUTH, RANGE 3 EAST</p> <p>The eastern half of this township is mostly smooth bald hills covered with bunch grass and very well watered with springs and small streams. Along the streams are found many small flats suitable for agriculture have good soil. Timber is not plenty but enough is found for all purposes of settlement. It has the appearance of having been extensively used for grazing for many years. The west half is on the Siskiyou Mountains is generally barren and</p>	General Land Office (various)

rocky and being unfit for agriculture or grazing purposes is unsurveyed.	
TOWNSHIP 41 SOUTH, RANGE 4 EAST This township is situated on what is known as Jenny Creek Flats and with the exception of section 1 which corners on a wooded mountain is comparatively level. Rich grass is very abundant, and along the stream noted as Fall Creek there is considerable of fertile grassy land. Jenny Creek is a rapid stream flowing through the Township in a southerly direction. Sections 3 and 7 contain a number of very large springs of pure water which give rise to large streams. It is contains much fine timber consisting of Sugar and Yellow Pine, Cedar, and Oak and a number of beautiful prairies.	General Land Office (various)

Range Trend Transects

All individual range trend plots showed significant change in frequency for individual species over time (Table 3).

Vacant Allotments

Agate Allotment. Even though the Agate Allotment is officially vacant, use by livestock was evident. An increase in *Ceanothus cuneatus* and weedy species (*Madia* sp. and *Poa bulbosa*) and decline of short-statured native perennial grass (*Poa secunda*) was unexpected in an area rested from grazing.

Siskiyou Allotment. The two plots in the ungrazed Siskiyou Allotment show disparate changes. The first plot shows an increase in two perennial grasses (*Festuca roemerii* and *Achnatherum lemmonii*) at the expense of two annual grasses (*Taeniatherum caput-medusae* and *Bromus tectorum*). The second plot, a weedier site, showed a mixed response by short-lived non-native perennial and annual grasses.

Grazed Allotments

Jenny Creek Allotment. In the North Pasture of the Jenny Creek Allotment in 1983, palatable perennial grasses increased and less palatable annual grasses decreased. An increase in a less palatable perennial grass (*Achnatherum lemmonii* over *Festuca roemerii*) in the south pasture may have been caused by development of a new (1990) livestock water source near the established trend plot. Short-lived perennial grasses (*Elymus elymoides*, *Poa bulbosa*), annual grasses (*Taeniatherum caput-medusae*, *Bromus hordeaceus*), and a forb (*Clarkia* sp.) also declined in frequency.

Soda Mountain Allotment. A trend plot in Agate Flat that was strongly influenced by fence-line-induced grazing showed a loss of *Danthonia californica* and increased abundance of *Poa bulbosa* and *Madia* sp. A trend plot in Camp Creek likely experienced considerably less use by livestock in recent years. *Bromus hordeaceus* and *Poa bulbosa*

were replaced by *Centaurea solistialis* and *Madia* spp. It appeared that grasses were misidentified in the plot for Emigrant Creek, so it was omitted. The trend plot in Keene Pasture showed a strong increase in *Danthonia californica* with attendant loss of *Bromus hordeaceus*. In the Oregon Gulch plot, two perennial grasses, *Festuca roemerii* and *Elymus elymoides*, increased and a third, *Achnatherum lemmonii*, declined, accompanied by an increase in the weedy grasses *Bromus hordeaceus* and *Poa bulbosa*. In Skookum Pasture, palatable *Festuca roemerii* and two annual grasses (*Taeniatherum caput-medusae* and *Bromus tectorum*) were replaced by *Madia* sp. and *Poa bulbosa*.

Keene Creek Allotment. The trend plot at Wildcat Glade of Keene Allotment is partially located on an old road grade, but shows a loss of *Carex* species and forbs (*Trifolium* sp., *Achillea millefolium* and *Perideridia*). *Elymus glaucus*, a pioneer species on mesic sites, was replaced by longer-lived perennial grasses (*Achnatherum lemmonii* and *Bromus carinatus*). In the other plot in the Keene Allotment, there was a strong increase in long-lived perennial grasses (*Bromus carinatus* and *Achnatherum lemmonii*) and *Eriophyllum lanatum* at the cost of *Madia* sp.

Summary of Range Trend Transects

Species with the highest number and most consistent direction of change in abundance over time (Table 3) included *Madia* sp. (6 increases, 2 declines), *Bromus hordeaceus* (5 increases, 2 declines), and *Poa bulbosa* (7 increases, 2 declines). No native perennial grass species showed a consistent pattern of change; at the native life-form level, 13 increased and 8 declined in frequency. Other life-forms showing more increases than declines were native annual forbs, native perennial forbs, and non-native perennial grasses. Only non-native annual forbs declined in percent frequency. Non-native annual grasses, grasslike plants and woody species showed no consistent pattern of change.

Several plots showed a balance between annuals and perennials. Agate Allotment, Agate Flat pasture 1, Oregon Gulch pasture, and Skookum pasture had an increase in weedy species at the cost of perennial grasses, while in Cottonwood Glades, Emigrant pasture, Keene Creek pasture, and Siskiyou Allotment perennial grasses increased at the cost of annual species (Table 2). In one trend plot in South pasture there was a mixed

response by weedy species (decline in *Poa bulbosa* and increase in two annual grasses) with an increase in native perennial grass *Achnatherum lemmonii*.

Table 3. Herbaceous plant species showing significant frequency of occurrence change within individual range trend plots of Allotments and Pastures within the Cascade-Siskiyou National Monument. Dates indicate the season of grazing. E = exotic, n = native, increase = statistically significant increase within a range trend plot, decrease = statistically significant decrease within a range trend plot. The final two columns sum the number of significant increases and decreases for individual species and native/exotic life forms across all range trend plots

Common Name	Life-form	native/exotic	Agate Allotment (vacant)	Agate Flat Pasture (5/01-6/06)	Agate Flat Pasture (5/01-6/06)	Camp Crk Pasture (6/15-7/03)	Cottonwood Glades (6/16-10/15)	Emigrant Pasture (7/04-10/15)	Keene Crk Pasture (7/04-10/15)	North Pasture (7/06-7/10)	Oregon Gulch Pasture (7/04-10/15)	Siskiyou Allotment (vacant)	Siskiyou Allotment (vacant)	Skookum Pasture (6/07-7/15)	South Pasture (5/16-6/30)	Wildcat Glades (6/16-10/15)	Increase/decrease of individual species	Increase/decrease of native/exotic life-forms	
<i>Brassica</i> sp.	Annual forb	e	0	0	0	0	0	0	0	0	0	-46	0	0	0	0	0	0/1	1/3
<i>Vicia</i> sp.		e	0	0	0	0	0	0	0	0	0	-21	-38	0	0	0	0	0/2	
<i>Centaurea solstitialis</i>		e	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	1/0	
<i>Phlox gracilis</i>		n	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	1/0	7/2
<i>Madia</i> sp.		n	12	93	0	20	-79	25	0	0	19	0	-18	91	0	0	0	6/2	
<i>Cynosurus echinatus</i>	Annual grass	e	0	0	0	0	0	0	0	0	0	95	0	0	0	0	0	1/0	9/8
<i>Bromus tectorum</i>		e	0	0	0	0	0	0	0	0	0	-100	0	-15	0	0	0	0/2	
<i>Taeniatherum caput-medusae</i>		e	0	0	0	0	0	0	23	0	0	-29	0	-30	11	0	0	2/2	
<i>Bromus hordeaceus</i>		e	0	0	0	-43	0	0	-42	27	16	17	0	52	24	0	0	5/2	
<i>Melilotus</i> sp.	frb	u	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	1/0	1/2
<i>Lotus</i> sp.		u	0	0	0	0	0	0	0	-14	0	0	0	0	0	-41	0/2		
<i>Eriophyllum lanatum</i>	Perennial	n	0	0	0	0	36	0	0	0	0	0	0	0	0	0	0	1/0	
<i>Achillea</i>		n	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-35	0/1	

<i>millefolium</i>																	
<i>Clarkia sp.</i>	n	0	0	0	0	0	0	0	0	0	0	0	0	0	-21	0	0/1
<i>Brodiaea elegans</i>	n	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	1/0
<i>Perideridia oregana</i>	n	0	0	24	0	0	0	47	24	0	0	0	0	0	0	-24	3/1
<i>Potentilla gracilis</i>	n	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0	1/0
<i>Sanguisorba occidentalis</i>	n	0	0	0	0	0	0	-18	0	0	0	0	0	0	0	0	0/1
<i>Ranunculus occidentalis</i>	n	0	0	0	0	0	0	0	38	0	0	0	0	0	0	0	1/0
<i>Triteleia hyacinthina</i>	n	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	1/0
<i>Poa bulbosa</i>	e	21	25	0	-25	0	36	0	34	37	0	14	11	-14	0	7/2	
<i>Thinopyrum intermedium</i>	e	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	1/0
<i>Thinopyrum intermedium</i>	e	0	0	0	0	0	-53	0	0	0	0	0	0	0	0	0	0/1
<i>Elymus glaucus</i>	n	0	0	0	0	0	0	0	0	0	21	0	0	0	0	-13	1/1
<i>Poa sp.</i>	n	-25	0	0	0	0	11	-23	0	0	0	0	0	0	18	0	2/2
<i>Bromus carinatus</i>	n	0	0	0	0	43	0	0	0	0	0	0	0	0	0	0	1/0
<i>Danthonia californica</i>	n	0	-90	0	0	0	97	34	0	0	0	0	0	0	0	0	2/1
<i>Festuca roemerii</i>	n	0	0	0	0	0	-20	0	0	33	49	0	-80	0	0	0	2/2
<i>Achnatherum lemmonii</i>	n	0	0	0	0	18	0	0	0	-29	0	0	0	22	27	3/1	
<i>Koeleria macrantha</i>	n	0	0	0	0	0	0	0	0	-19	0	0	0	0	0	0	0/1
<i>Elymus elymoides</i>	n	0	0	0	0	0	0	0	0	11	13	0	0	0	0	0	2/0
<i>Juncus sp.</i>	n	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0	1/0
<i>Carex sp.</i>	n	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-33	0/1
<i>Luzula sp.</i>	n	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	1/0
<i>Ceanothus cuneatus</i>	shrb	n	19	0	0	0	0	0	0	0	0	0	0	0	0	0	1/0
<i>Quercus garryana</i>	tree	n	0	0	0	0	0	0	0	0	15	0	0	0	0	0	1/0

Multivariate analysis

The overlay of vectors (stippled lines) indicating direction and magnitude of change over time and biplots showing major patterns of individual species change allow the characterization of change in the context of all plots (Figure 2). The joint-plots identify species change in ordination space due to perennial grasses (*Danthonia californica* (DACA), *Festuca roemerii* (FEID), *Achnatherum lemmonii* (ACLE8), *Poa bulbosa* (POBU), and other *Poa* sp., annual grasses (*Taeniatherum caput medusae* (TACA8), *Bromus tectorum* (BRTE), *Bromus hordeaceus* (BRHO)), and annual forbs (*Madia* sp.). *Taeniatherum caput-medusae* and *B. hordeaceus* share the same slope and are orthogonal to *A. lemmonii*, indicating a pattern of replacement (Figure 2a and b). *F. roemerii* and *P. bulbosa* also share a trajectory. The vectors identify a large range in the magnitude and direction of change, indicating that site plays a large role in the pattern of community change at individual stands.

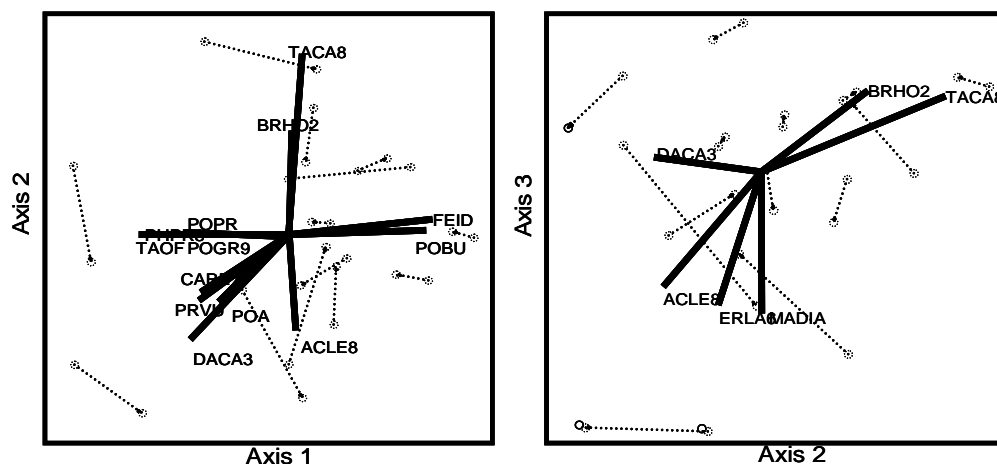


Figure 2. Ordination space defined by all plots (new and old) with overlays of vectors (indicating direction and magnitude of individual plot change over time in ordination space) and biplots to indicate species correlation with axes; the line forms the hypotenuse (h) of a right triangle with the two other sides being r values between the variable and the two axes. Cross r^2 values determine relative scaling; only species with a cross $r^2 > 0.3$ are shown; overall scaling on biplots is magnified by 150% to improve visibility.

Repeat SVIM/NRCS Stand Data

Species richness

The average species richness for new plots is 35.7 compared to 27.5 for old plots. Of the 85 plots evaluated for species richness, 71 increased and 14 did not change. At the landscape level, total species richness for new (277) and old plots (276) were similar (Table 4). Except for annual forbs, species richness for life-forms were similar in the two years of data collection. The ephemeral nature of annual forbs may have resulted in a reduced species count during drought year of 2000.

Table 4. Total species richness by life-form for old and new (2000) vegetation plots.

life-form and origin	old plots	2000
annual forb, native	50	39
annual forb, non-native	5	5
annual grass, native	5	4
annual grass, non-native	8	11
grasslike plant	4	3
perennial forb, native	120	125
perennial forb, non-native	7	11
perennial grass, native	21	23
perennial grass, non-native	10	10
shrub	30	29
tree	25	31
total herbaceous	230	231
unknown	1	1

Presence/absence

All life-forms increased in the number of stands occupied over time (Table 5). Sedges and rushes increased the most, followed by non-native perennial forbs, non-native grasses, non-native annual forbs, native annual grasses, and non-native perennial grasses. Native annual forbs, native perennial forbs, and native perennial grasses remained relatively unchanged in the number of plots occupied.

Table 5. The number of stands occupied by native versus non-native life-forms across the CSNM landscape (* denotes statistical significance, Chi-square, p=0.1).

life-form and origin	old plots	new plots
annual forb, native	83	85
annual forb, non-native	21	31
perennial forb, native	83	85
perennial forb, non-native	18*	35*
annual grass, native	51	61
annual grass, non-native	35	45
sedges and rushes	25*	46*
perennial grass, native	83	85
perennial grass, non-native	23*	44*
shrub	81	82
tree	81	81
unknown	2	1
total herbaceous	85	85

A number of species increased in the number of sites occupied (Table 6). Native perennials *Elymus glaucus* and *Carex* species showed the largest increase in site occupation, while native grasses *Trisetum canescens* and *Achnatherum lemmonii* had a moderate increase in the number of occupied sites. Of the non-native annual grasses, bulbous bluegrass shows the greatest increase in the number of sites occupied, followed by *Cynosurus echinatus*. Several native perennial forbs (*Agoseris* sp., *Perideridia* sp, *Perideridia gairdneri*, and *Lomatium nudicaule*) increased in number of sites occupied while non-native *Taraxacum officianale* declined. One shrub (*Amelanchier pallida*) increased in extent. Six trees that increased in extent were components of the understory, though only in *Pinus ponderosa* and *Quercus garryana* was the change statistically significant.

Table 6. Stands occupied by individual species; * denotes statistical significance, Chi-square, $p = 0.1$.

species	lifeform	old	2000	difference
<i>Epilobium minutum</i>	annual forb, native	12	35	23*
<i>Polygonum cascadense</i>	annual forb, native	8	28	20*
<i>Collomia</i> sp.	annual forb, native	13	32	19*
<i>Collinsia</i> sp.	annual forb, native	2	16	14*
<i>Madia</i> sp.	annual forb, native	20	34	14
<i>Galium triflorum</i>	annual forb, native	20	31	11
<i>Arenaria</i> sp.	annual forb, native	33	43	10
<i>Tragopogon</i> sp.	perennial forb, non-native	5	29	24*
<i>Taraxacum officinale</i>	perennial forb, non-native	13	1	-12*
<i>Cynosurus echinatus</i>	annual grass, non-native	6	18	12
<i>Carex</i> sp.	sedge (graminoid)	18	43	25*
<i>Perideridia</i> sp.	perennial forb, native	5	28	23*
<i>Agoseris</i> sp.	perennial forb, native	12	33	21*
<i>Perideridia gairdneri</i>	perennial forb, native	5	25	20*
<i>Lomatium nudicaule</i>	perennial forb, native	0	14	14*
<i>Aster</i> sp.	perennial forb, native	7	20	13
<i>Hieracium albiflorum</i>	perennial forb, native	34	44	10
<i>Elymus glaucus</i>	perennial grass, native	36	67	31*
<i>Achnatherum lemmonii</i>	perennial grass, native	16	30	14
<i>Trisetum canescens</i>	perennial grass, native	16	30	14
<i>Poa bulbosa</i>	perennial grass, non-native	9	34	25*
<i>Berberis aquifolium</i>	shrub	41	55	14
<i>Symphoricarpos albus</i>	shrub	49	60	11
<i>Amelanchier pallida</i>	shrub	1	11	10*
<i>Pinus ponderosa</i> (u)	tree	26	46	20*
<i>Quercus garryana</i> (u)	tree	8	25	17*
<i>Juniperus occidentalis</i> (u)	tree	11	26	15
<i>Calocedrus decurrens</i> (u)	tree	26	41	15
<i>Pseudotsuga menziesii</i> (u)	tree	37	48	11
<i>Abies concolor</i> (u)	tree	33	43	10

Number of plots with significant change

The increase and decrease in cover of native and non-native perennial grass species were significant (Table 7).

Table 7. Number showing Change in life-form cover across the CSNM landscape (* denotes statistical significance, chi-square, $p = 0.1$).

Life-form and origin	Stands showing change	
	Decreases	Increases
annual forb, native	2	0
annual forb, non-native	1	0
annual grass, native	0	2
annual grass, non-native	3	7
grasslikes (sedges, rushes)	0	1
perennial forb, native	4	1
perennial forb, non-native	0	0
perennial grass, native	1*	11*
perennial grass, non-native	1*	14*
shrub	6	8
tree	29	31
total herbaceous	10	29
unknown	0	0

Poa bulbosa was the only herbaceous species to show consistent increases in cover abundance over time across the CSNM (Table 8).

Table 8. Individual plant species with more than four instances of significant decrease or increase in cover ranked by number of instances of decreased cover.

Vascular plant name	Lifeform	Decreases	Increases	Difference
<i>Abies concolor</i>	tree (overstory)	7	5	2
<i>Abies concolor</i>	tree (understory)	3	3	0
<i>Pinus ponderosa</i>	tree (overstory)	4	3	1
<i>Poa bulbosa</i>	perennial grass, non-native	0	13	13
<i>Pseudotsuga menziesii</i>	tree (overstory)	9	13	4
<i>Pseudotsuga menziesii</i>	tree (understory)	3	8	5
<i>Quercus kelloggii</i>	tree (overstory)	7	0	7

Few new noxious weeds appeared in new plots. Three additional plots contained *Centaurea solistalis*, while the number of stands including *Cirsium arvense* remained unchanged (Table 9).

Table 9. Incidence of broadleaved noxious weeds.

species	Lifeform	Old plots	2000
<i>Centaurea solistalis</i>	Non-native annual forb	1	4
<i>Cirsium arvense</i>	Non-native perennial forb	1	1

Summary by ecological site

Festuca roemerii cover abundance was static or declined within Semi-wet Meadows, Oak fescue, Douglas-fir Mixed Pine, and pine Douglas-fir Fescue. *Festuca roemerii* showed mixed response within Oak Juniper Fescue and Shrubby scablands (Table 10). *Bromus tectorum* was static or declined in cover abundance within Semi-wet Meadows, Oak Fescue, Oak Juniper Fescue, Shrubby Scabland, Douglas-fir Mixed Pine Sedge. A mix of increased and decreased cover abundance is found in Loamy Juniper Scabland. *Poa bulbosa* increased in cover abundance in all grassland and non-conifer dominated ecological sites except Oak fescue. *P. bulbosa* also increases in abundance within Douglas-fir Mixed Pine Sedge. *Tainiatherum caput-medusae* shows increased and decreased cover abundance in Semi-wet Meadow, Loamy Juniper Scabland, and Oak Juniper Fescue, though increased abundance is usually greater in magnitude than declines in abundance. Shrubby scablands shows only increases in cover abundance by *Taeniatherum caput-medusae*.

Table 10. Average cover, minimum cover, and maximum cover for herbaceous key species and species showing significant change in cover at the landscape level.

Ecological site (number of representative sites)	<i>Festuca roemerii</i> Native Perennial grass	<i>Bromus tectorum</i> Exotic annual grass	<i>Poa bulbosab</i> Exotic short-lived perennial grass	<i>Tainiatherum caput medusae</i> Exotic annual grass
Semi-wet Meadow (4)	(-0.5 / 0 / -2)	(-1 / 0 / -4)	(5.5 / 19 / 0)	(7 / 30 / -2)
Loamy Juniper Scabland(3)	(0 / 0 / 0)	(-2 / 4 / -5)	(19.7 / 25 / 15)	(0.3 / 2 / -1)
Oak Fescue (3)	(-0.3 / 0 / -1)	(-0.3 / 0 / -1)	(0 / 0 / 0)	(0 / 0 / 0)
Oak Juniper Fescue (8)	(3.3 / 15 / -12)	(-1.6 / 0 / -5)	(9.6 / 15 / 3)	(4.9 / 22 / -2)
Shrubby Scabland (3)	(-1.7 / 1 / -5)	(-7 / -2 / -15)	(27.3 / 37 / 20)	(11 / 20 / 5)
Douglas-fir Forest (6)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)
Douglas-fir Mixed Pine Sedge (4)	(-1.2 / 0 / -5)	(-0.2 / 0 / -1)	(1.3 / 5 / 0)	(0 / 0 / 0)
Douglas-fir Mixed Pine Sedge (marginal) (6)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)
Mixed conifer Chinquapin sedge (8)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)
Mixed fir Oceanspray forest (1)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)
Mixed Fir serviceberry (6)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)
Pine Douglas-fir Fescue (6)	(-0.3 / 0 / -1)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)
White Fir Forest (6)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)

Conifers (canopy and understory) showed no change in abundance in non-conifer communities, and also lacked clearly defined patterns of increased or decreased cover abundance in conifer communities at this level of analysis. The mixed response (both increased and decreased canopy cover) within many ecological sites is likely due to past logging activities (Table 11). *Quercus kelloggii* was found in both conifer and non-conifer communities. It declined in cover abundance through all non conifer communities (Semi-wet Meadow, Oak Fescue, Oak Juniper Fescue), a mixed response in Douglas-fir Forest, Douglas-fir Mixed Pine Sedge, Mixed fir Oceanspray forest, Pine Douglas-fir Fescue; and static and declines in abundance in Douglas-fir Mixed Pine Sedge, Mixed conifer Chinquapin sedge, Mixed Fir serviceberry.

Table 11. Average cover, minimum cover, and maximum cover abundance for tree species showing significant change in cover at the landscape level.

Ecological site	<i>Abies concolor</i> (overstory)	<i>Abies concolor</i> (understory)	<i>Pseudotsuga menziesii</i> (overstory)	<i>Pseudotsuga menziesii</i> (understory)	<i>Quercus kelloggii</i> (overstory)
Semi-wet Meadow (4)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(-0.5 / 0 / -2)
Loamy Juniper Scabland (3)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)
Oak Fescue (3)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(-3.3 / 0 / -10)
Oak Juniper Fescue (8)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(-1.6 / 0 / -7)
Shrubby Scabland (3)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)	(0 / 0 / 0)
Douglas-fir Forest (6)	(-0.3 / 0 / -2)	(-0.8 / 0 / -5)	(-0.8 / 15 / -10)	(1.7 / 4 / 0)	(-0.3 / 1 / -3)
Douglas-fir Mixed Pine Sedge (4)	(0 / 0 / 0)	(0 / 0 / 0)	(-8.8 / 10 / -45)	(13.5 / 25 / 0)	(1 / 5 / -1)
Douglas-fir Mixed Pine Sedge (marginal) (6)	(0.2 / 1 / 0)	(0 / 0 / 0)	(2.5 / 20 / -15)	(7 / 25 / -5)	(-7.2 / 0 / -13)
Mixed conifer Chinquapin sedge (8)	(-3.7 / 0 / -13)	(-5.2 / 0 / -12)	(5.6 / 20 / -20)	(1 / 25 / -15)	(-2 / 0 / -9)
Mixed fir Oceanspray forest (1)	(-4.7 / 35 / -50)	(0.5 / 10 / -20)	(2.2 / 60 / -25)	(0.4 / 2 / 0)	(0.1 / 1 / -1)
Mixed Fir serviceberry (6)	(0.3 / 17 / -25)	(3.3 / 20 / -10)	(2 / 45 / -60)	(-1.7 / 3 / -15)	(-5 / 0 / -30)
Pine Douglas-fir Fescue (6)	(0 / 0 / 0)	(-0.3 / 0 / -1)	(10.8 / 20 / 0)	(-0.8 / 3 / -4)	(-17.3 / 3 / -40)
White Fir Forest (6)	(-15.8 / 5 / -70)	(-0.7 / 10 / -15)	(-0.3 / 0 / -2)	(4.2 / 25 / 0)	(0 / 0 / 0)

Summary in PCORD and HYPERNICHE

Pattern of stands in ordination space based on individual species abundance

Ordination of all data from conifer and non-conifer stands (Figure 3) reveals two general patterns of change over time defined by magnitude and direction of change. Longer lines indicate large magnitude of plant community change are more strongly associated with axis 2 (vertical) while the smaller magnitude change show an association with both axis one and two. The larger magnitudes of change are associated with non-

livestock-induced disturbance (scarification, seedings, etc) while shorter magnitudes are associated with change in the absence of disturbance. In general, the magnitudes of change are greater in non-conifer than conifer communities.

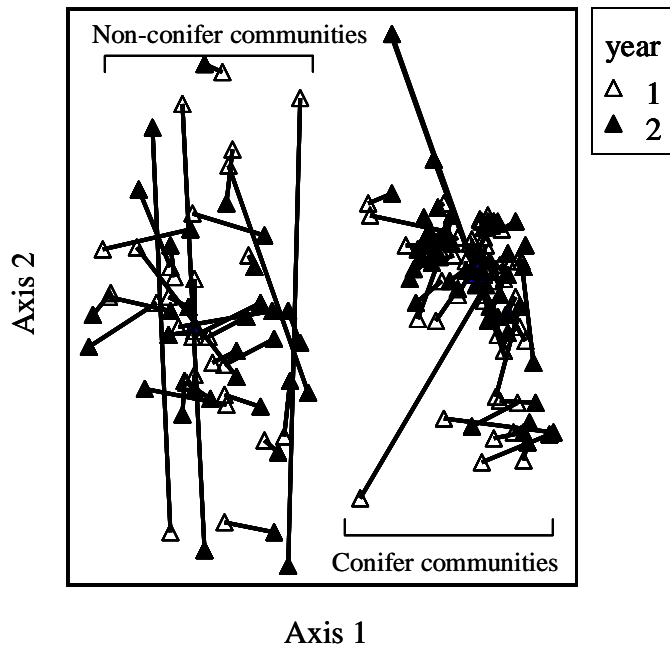


Figure 3. Ordination and overlay of vectors of change for repeat conifer and non-conifer stand data. The length of the vector is indicative of the magnitude of plant community change within ordination space.

For the above ordination, twenty-three species correlate with the first axis of ordination. The mix of species includes overstory trees [*Pseudotsuga menziesii* overstory (+), *Abies concolor* overstory (+) and understory (+), *Juniperus occidentalis* *(-), *Quercus garryana* (-)], *Ceanothus cuneatus* (shrub) and herbs. The herbs included native and non-native grasses and forbs. Non-native grasses (*Taeniatherum caput-medusae*, *Bromus tectorum*, *Bromus hordeaceus*) feature prominently, as do native perennial grasses (*Poa secunda*, *Achnatherum lemmonii*, and *Festuca roemerii*). Environmental factors include topographic descriptors (three measures of slope), and management descriptors (two measures of utilization). The signs of correlation of native and non-

native grasses to the first ordination axis are both negative, while the environmental factors are all positive (including measures of livestock use).

Three plant species correlated with the second ordination axis: *Abies concolor* (+), *Pseudotsuga menziesii* (-), and *Quercus garryana* (+). There were no significant correlations of environmental factors with the second ordination axis (Figure 4).

Closer examination of non-conifer stands identified major components of change identified by biplots (solid lines), and direction and magnitude of temporal within individual stands. Biplots verify that the annual grasses *Bromus tectorum* (BRTE), *Taeniatherum caput-medusae* (TACA8), and *Bromus commutatus* (BRCO) and the non-native perennial grass *Poa bulbosa* (POBU) constituted major components of change in ordination space (Figure 4a and 4b). *Festuca roemerii* (FEID), *Phleum pratense* (PHPR3), and *Carex* species were associated with the third ordination axis. Mesic species (*Carex* species and *Phleum pratense*) appear orthogonal to *Festuca roemerii*.

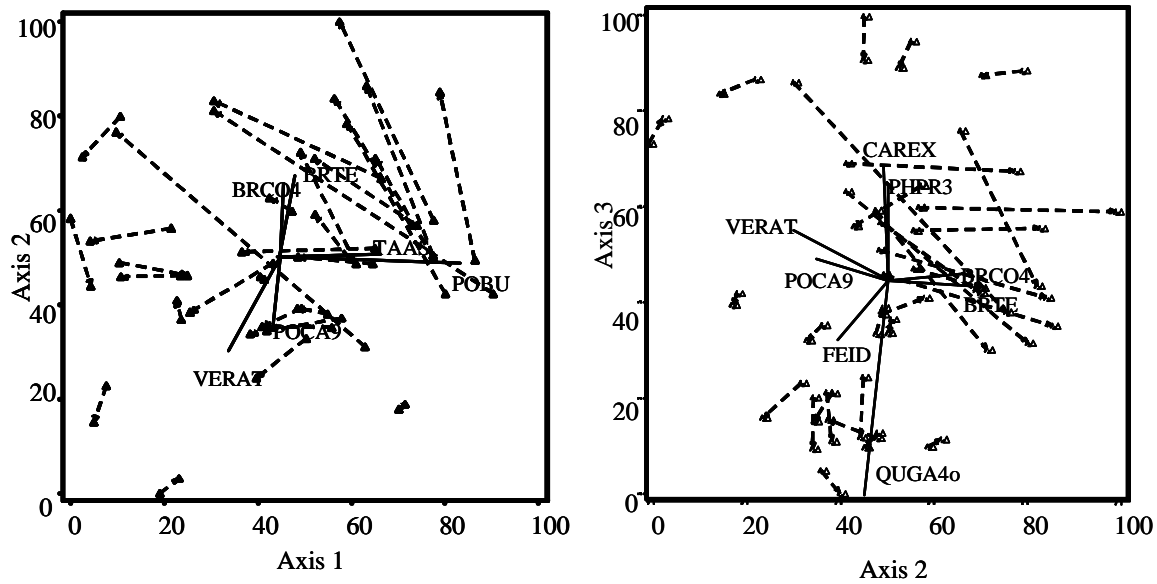


Figure 4. Ordination space defined by non-conifer plots (new and old) with vectors indicating direction and magnitude of individual plot change over time in ordination space and biplots to indicate species correlation with axes; the line forms the hypotenuse (h) of a right triangle with the two other sides being r values between the variable and the two axes. Cross r^2 values determine relative scaling, only species with a cross $r^2 > 0.3$ are shown; overall scaling on biplots is magnified by 150% to improve visibility.

Spatial pattern modeling

Consistent changes in bulbous bluegrass and the ability of life-form abundance to summarize community changes across the landscape lead to their inclusion in a model using HYPERNICHE to describe patterns of cover abundance (Table 11). In addition to the model of *Poa bulbosa* abundance, 6 of 11 life-form datasets submitted for modeling yielded models with r^2 of 0.3 or greater. Commonly included variables include heatload (3), elevation (4), slope (4), soil depth (2), soil texture (3), cover (6), utilization (5), and years since last grazed (3). Three dimensional plots of selected model variables and their relation to the object of interest (*Poa bulbosa* and life forms) depict the influence of management and environmental factors (Figures 5 to 8).

Table 11. Best fit models for *Poa bulbosa* and life-form abundance. Life-forms resulting in xr^2 values less than 0.3 were omitted (native perennial grasses, shrub, native annual forbs, annual grasses, non-native annual forbs).

Variable	Life form						
	Poa bulbosa cover	Tree	Non-native perennial grasses	Non-native annual grasses	Grasslike	Non-native perennial forbs	Perennial forbs
Cross r^2	0.7	0.6	0.6	0.6	0.5	0.5	0.3
Size	3.7	5.2	5.1	3.7	3.6	5.7	3.7
Count	8.0	5.0	6.0	4.0	8.0	5.0	7.0
var1	heatload	heatload	slope	elevation	elevation	soil depth1	heatload
var2	elevation	slope	soil depth	slope	% clay	% sand	elevation
var3	slope	woody cover	Conifer change	woody cover	% silt	woody cover	soil depth
var4	% silt	non-conifer disturbance	woody cover	average utilization	% sand	average utilization	woody cover
var5	Woody cover	last grazed	distance from water		woody cover		maximum utilization
var6	average utilization		average utilization		distance from water		average utilization
var7	last grazed				maximum utilization		last grazed
var8					average utilization		

Graphic interpretation

Poa bulbosa abundance was associated with lower elevations and higher heatload (Figure 5a). While soil composition is included in the model of *P. bulbosa* abundance, the relationship is weak (Figure 5c). Since the areas of rest are not interspersed with grazed areas (Figure 1), the relationship of years since last grazed with *Poa bulbosa* must be considered as spatially confounded (Figure 5c). The inverse relation of *Poa bulbosa* with slope (Figure 5c) provides indirect evidence that livestock facilitate this weed, on the assumption that steeper slopes are avoided by cattle (Hosten et al .2007b).

The three-dimensional figure of annual grass with slope and elevation shows an inverse relationship of cover abundance with slope and elevation (Figure 6a), verifying a preference for hotter and drier habitats with gentle slopes more likely to be grazed by livestock. Annual grass abundance is lowest at the highest cover value derived from satellite imagery, and shows a modal response to average utilization, with highest annual grass cover at intermediate livestock utilization levels (Figure 6b).

Non-native perennial grass abundance is negatively associated with slope and soil depth (Figure 7a). Non-native perennial grasses are abundant under more open

conditions, a relationship slightly favored by proximity to water (Figure 7b). Non-native perennial grasses increase with average utilization and with distance from water. The distribution of grasslike plants (including sedges and rushes) is inversely associated with satellite-derived cover throughout the elevation range (Figure 9a). Higher abundance of grasslike plants is associated with high average utilization and proximity to water (Figure 8c).

Perennial forbs are more abundant at higher elevations (Figure 9a), at moderate canopy closure (Figure 9b), and in areas preferred by livestock (Figure 9c). The relationship of perennial forb cover with heatload (Figure 9a), soil depth (Figure 9b), and time since last grazed (Figure 9c) appears weak.

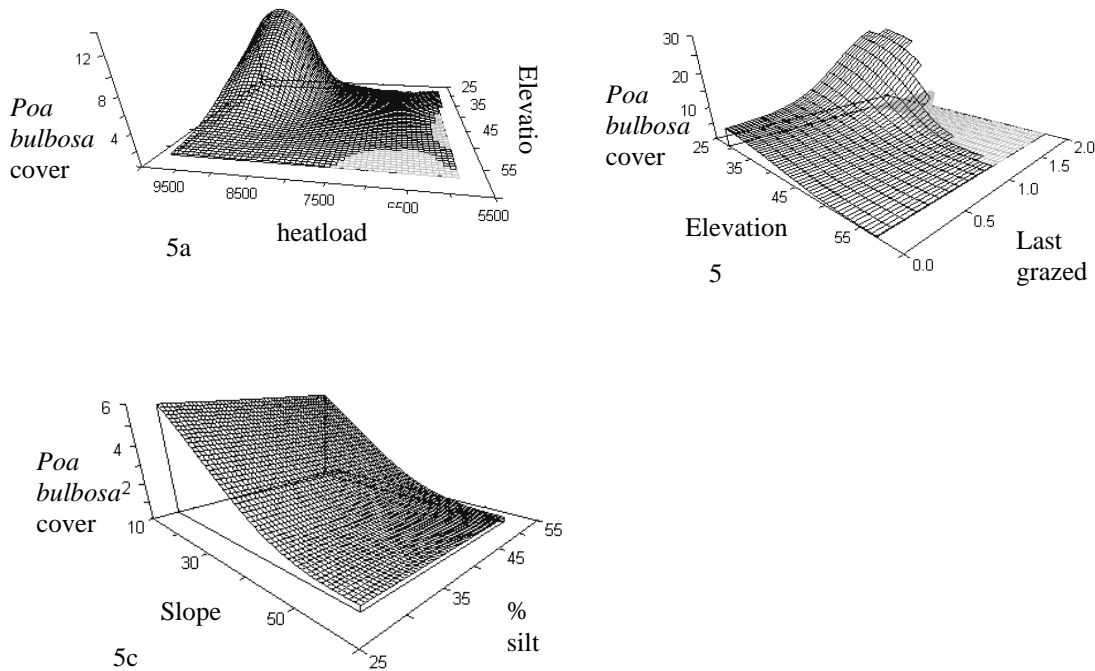


Figure 5a, b, c. Three dimensional representations of *Poa bulbosa* as a response variable to environmental and management predictor variables.

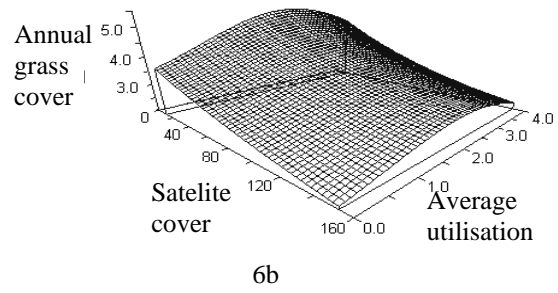
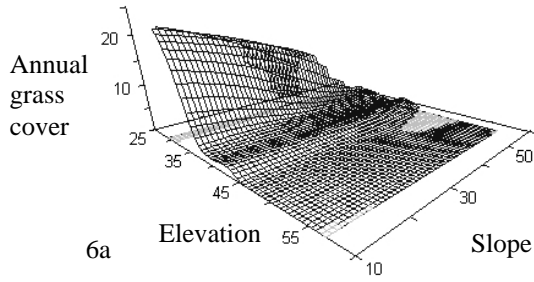


Figure 6a, b. Three dimensional representations of annual grass as a response variable to environmental and management predictor variables.

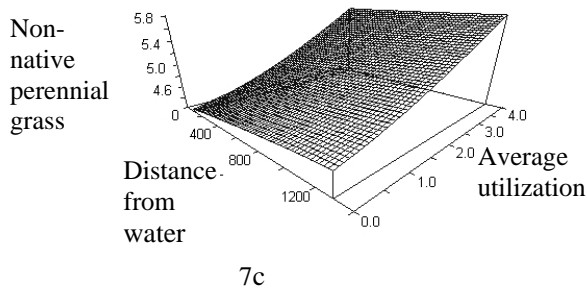
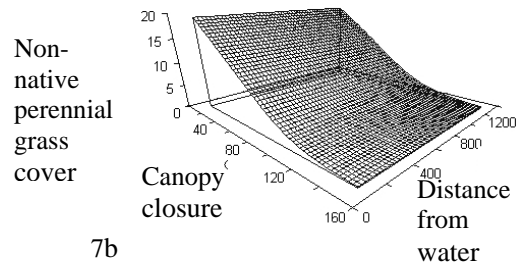
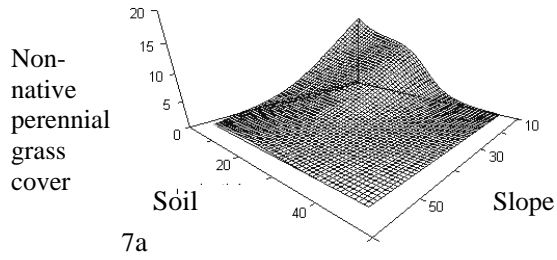
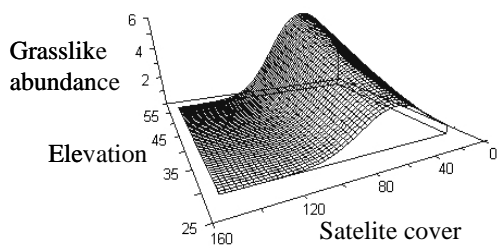
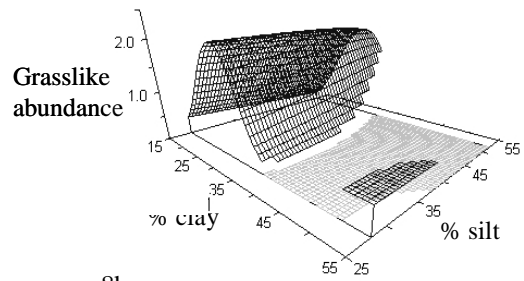


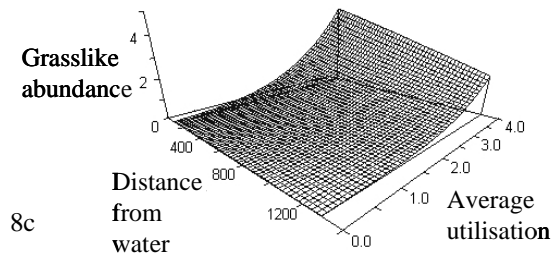
Figure 7. Three dimensional representations of non-native perennial grass as a response variable to environmental and management predictor variables.



8a

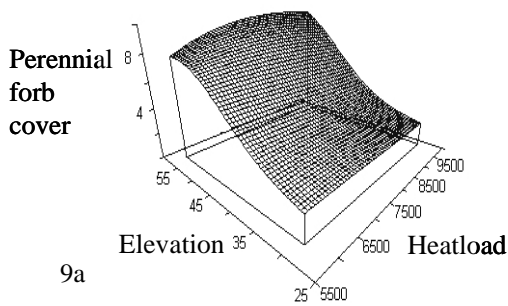


8b

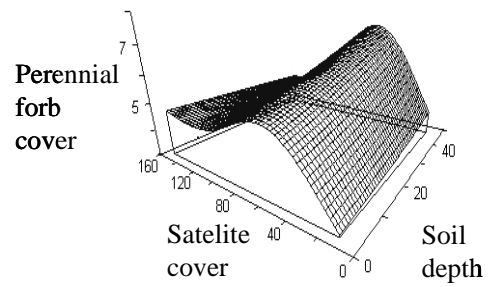


8c

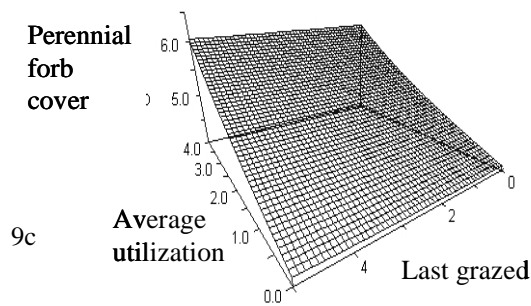
Figure 8a, b, c. Three dimensional representations of grasslike abundance as a response variable to environmental and management predictor variables.



9a



9b



9c

Figure 9a, b, c. Three dimensional representations of native perennial forbs as a response variable to environmental and management predictor variables.

Discussion

Historic anecdotes

General descriptions of the Monument area by Township and Range indicate a very early influence by Europeans on the landscape. Wright (unpublished) refers to livestock grazing on currently secluded portions of the Monument by cattle in the late 1860s, while early notes from the General Land Office indicate a heavily utilized landscape in the 1870s. The broad description of Township 39 South Range 1 East indicates that Europeans may have used fire even more frequently than Native Americans immediately prior to the time of contact, a concept supported also for other portions of the Siskiyou Mountains (Lalande 1995) that form the backbone of the Monument. Vegetation descriptions (Leiberg 1900) consistently refer to the prevalence of recent and historic fire. Historic observation of livestock facilitating the establishment of woody vegetation in areas of high livestock use in the Umpqua drainage (Hosten et al. 2007a) lends credibility to observation (Wright unpublished) of livestock induced conversion from bunchgrass to ‘brush’ within the CSNM. Other anecdotes suggest that livestock can also suppress shrub recovery following fire. The many references to the conversion of bunchgrass to weeds (Wright unpublished) and to subsequent management actions to eradicate annual grasses demonstrate widespread changes in herbaceous composition in areas without shrub cover. Other anecdotes by Lawrence (unpublished) record the introduction of *Poa bulbosa* with the intent to replace annual grasses, and the perception that native perennial grasses were returning with more restricted livestock management practices.

Range Trend Data

The Range Trend plots represent the grazed portions of the Monument. Chi-squared analyses revealed significant changes in annual and perennial grasses at many individual transects. However, not all changes can be attributed to livestock management. Many changes are influenced by other management activities. For example, the Agate Flat pasture in the Soda Mountain Allotment has had many restoration projects including

scarifications, seeding of non-native grasses (including *Poa bulbosa*) to replace annual grasses and was also influenced by the 1974 fire and subsequent restoration projects including seeding of *Thinopyrum intermedium*. The presence of perennial non-native pasture grasses (including *Phleum pretense*) in Keene, Emigrant, and Wildcat Glade transects indicates that these sites have been seeded, a common management activity of the past (Hosten et al. 2007b). Other observed changes may also have been influenced by proximity to roads, fences, and livestock water.

Several individual species consistently increase in frequency of occurrence across Range Trend Plots (native *Madia exigua*, and non-native weedy grasses), and none consistently decline. At the life-form level of biological organization, native perennial grasses, annual forbs, and perennial forbs and non-native perennial grasses show more increases than decreases in percent frequency of occurrence across the landscape. Counter to expectations, annual grass decline in frequency was matched by increases in frequency at other locations on the landscape. Only non-native annual forbs show more consistent declines than increases in percent frequency.

Patterns of community change showing a balance between annuals and perennials are supported by ordination diagrams. In particular, the non-native annual grass *Taeniatherum caput-medusae* appears negatively associated with native perennial grass *Achnatherum lemmonii*. Non-native *Poa bulbosa* is positively associated with the native perennial grass *Festuca roemerii*.

Poor replication of trend plots across the landscape and lack of controls preclude an interpretation of causal relationship between vegetation change and livestock utilization. However, the plots demonstrated a balance between annual and perennial grasses with change in seasonality/intensity of livestock use. A few trend-plots demonstrate that high livestock utilization favors annual grasses over perennial grasses. Other plots show a replacement of annual grasses by perennial grasses under ongoing grazing by livestock or no-grazing (transect 1 of Siskiyou Allotment). Transect 2 of the Siskiyou Allotment and cage studies associated with *Calochortus greenii* (Menke and Kaye 2006) demonstrate the static nature of annual grass dominated sites regardless of livestock influence.

Repeat Stand Data

The repeat stand data represents a wider range of utilization levels and plant communities than the Range Trend Plots. Individual species change across the landscape is characterized by changes in extent (presence/absence of individual species and life-forms within stands) and by changes in abundance (canopy cover). Herbaceous species showing the greatest changes in extent include mesic oak woodland conifer pioneer species such as blue wildrye (*Elymus glaucus*) and weeds such as bulbous bluegrass (*Poa bulbosa*). *Poa bulbosa* was the only herbaceous species that consistently increased in abundance across the stands examined. Multivariate analyses provide inference about the balance between annuals by bunchgrasses and woody species. Ordinations indicate that the major components of herbaceous change across the landscape involve annual grasses, *Poa bulbosa*, and *Festuca roemerii*. While native species appear to be recovering from historic livestock impact, introduced non-native perennials continue to expand their range and abundance. Annual grasses appear to be remaining static on the landscape, showing little change in extent. Localized increases in annual grasses were balanced by declines elsewhere on the landscape.

Of the woody species, the understory component of *Pinus ponderosa*, *Quercus garryana*, *Juniperus occidentalis*, and *Calocedrus decurrens* showed the greatest increase in extent. *Pseudotsuga menziesii* showed a moderate number of increases in abundance, while *Quercus kelloggii* showed consistent decline. Changes in extent and abundance of woody species are consistent with the literature on hardwood and conifer dynamics in the absence of fire.

Several native species show a mixed response in terms of direction of change in cover abundance. *Festuca roemerii* increased at some sites, perhaps as a consequence of improved range management. Declines are unlikely to be due to livestock considering the improvements in management over the past several decades. Increased cover by woody species may reduce native grass abundance through competition for resources. Changes in conifer cover likely reflect timber harvest, natural succession subsequent to the last disturbance. Tree species with different shade tolerances are likely displacing each other across ecological gradients in the absence of disturbance. *Poa bulbosa* has increased in cover abundance in all occupied ecological sites.

The modeling of environmental and management variables to *Poa bulbosa* and plant life forms verifies the importance of environmental factors, both topographic (slope, heatload, and elevation) and edaphic (soil depth and composition) in the expression of individual species and life-form abundance. Management factors appear to be of secondary importance, and usually weakly associated with species or life-form abundance. However, several patterns of native and non-native life-form abundance reflect the influence of livestock on the landscape (for example, increased abundance on more gentle and livestock accessible slopes), though the separation of current from historic patterns remains a problem. Non-native annual and perennial grasses are thus more abundant on shallower slopes favored by livestock.

CONCLUSIONS

Historic anecdotes identify the deterioration of the range under early season-long grazing conditions at high stocking rates. These changes include the loss of native bunchgrass species and invasion by annual grasses such as *Bromus tectorum* and *Taeniatherum caput-medusae*, or shrubs and hardwoods on other ecological sites. Early Forest Service employees of the region commonly recognized an increase in shrubs following the loss of perennial grasses (Hosten *et al.* 2007a). A literature review finds increased woody vegetation in grazed conifer stands to be a common observation (Belsky and Blumenthal 1997). Such changes are commonly ascribed to reduced competition following the loss of deep rooted perennial grasses, though the loss of fine fuels and loss of the native American lifestyle are also implicated.

Improved control of livestock resulted in an increased perennial grass cover since the mid-1900s at certain sites. Range trend plots and repeat observations of stands identify increases and decreases in native herbaceous domination at the site level. The landscape-wide increase in grasses includes native perennial grasses, as well as the introduced short-lived perennial grass *Poa bulbosa*. Although a decline in annual grasses was expected, both the rangeland trend plots and repeat stand inventories indicated that localized declines in annual grasses are offset by increases elsewhere on the landscape.

Some spatial patterns of life-form abundance support generally perceived patterns of vegetation change associated with livestock grazing, such as increased cover of annuals on gentle slopes where livestock tend to congregate. Although impacts of historic livestock grazing cannot be separated from more recent impacts, the identification of patterns of change within range trend plots indicate that livestock continue to influence vegetation dynamics, albeit on a more localized area compared to historic times. This is supported by the patterns of broadleaved noxious weeds described by Hosten (2007).

Other changes observed in the datasets reflect the absence of fire. Stands (especially the understory component) show an accumulation of woody vegetation even within the relatively short time-span of the repeated inventories. *Quercus kelloggii* commonly declines in mixed conifer stands in the absence of fire.

The disparate vegetation dynamics of individual range trend plots and stands of vegetation is indicative of the richness of ecological sites and variable response of individual species to environmental and management factors. Observed change supports few of the literature-derived patterns of vegetation change described in the introduction of this paper. It seems most likely that the intensity and temporal control of livestock are not stringent enough to elicit the described patterns of vegetation change.

Other management activities (scarification, seeding, and fire suppression) have played a role in local vegetation dynamics. The introduction of bulbous bluegrass appears to have had greater impact than current livestock use.

Perhaps George Wright said it best: “This area was a fine cattle range in the early days, but too many goats and cattle killed out most of the grass. Like the balance of the range land, it’s been overgrazed by cattle, horses, goats and sheep. Its goodbye to the free and open range, goodbye to the horned cattle and all the rest, the old goes and the new comes, good and bad.”

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