PATTERNS OF GRASSLAND, SHRUBLAND, AND WOODLAND VEGETATION ABUNDANCE IN RELATION TO LANDSCAPE-SCALE ENVIRONMENTAL AND DISTURBANCE VARIABLES, APPLEGATE WATERSHED SOUTHWEST OREGON

by

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To my loving wife, Sherry, without your patience, understanding, support, and encouragement this thesis would never have been undertaken or completed.

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ABSTRACT OF THESIS

PATTERNS OF GRASSLAND, SHRUBLAND, AND WOODLAND VEGETATION ABUNDANCE IN RELATION TO LANDSCAPE-SCALE ENVIRONMENTAL AND DISTURBANCE VARIABLES, APPLEGATE WATERSHED SOUTHWEST OREGON

by Eric Pfaff

Multivariate techniques were used to assess the relationship between environmental and disturbance variables and current vegetation composition of 425 stands from grassland, shrubland, and woodland vegetation types. Thirteen plant assemblages were defined and used to investigate general patterns on the landscape. Some assemblages were relatively distinctive in species composition, while others with more common species and/or habitats tended to overlap considerably. Disturbance (wildfire and fuels reduction treatments) appears to be a homogenizing force on the landscape that transforms various assemblages into a single assemblage based on similar species composition and abundance. Sixteen environmental and nine disturbance variables were regressed against ordination scores. Variables related to moisture and soils were most correlated to plant distribution. The most important variables were elevation, summer actual evapotranspiration, pH, annual precipitation, total silt, upper soil horizon depth, and total clay. Vegetation patterns

appear to be determined by a complex combination of edaphic, topographic, and climatic variables in addition to site history.

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INTRODUCTION

Landscape-level vegetation patterns are an expression of abiotic gradients, biotic processes, and disturbances (Urban et al. 2000). Investigating the correlations of environmental and disturbance variables with patterns of vegetation structure and composition can offer clues to the mechanisms that produce observed patterns (Levin 1992). Identifying the mechanisms of plant distribution may become even more important in light of potential climate changes, noxious weed invasions, and changes in land use (Corney et al. 2004) as well as aid in more accurate distribution models (Levin 1992).

Multiple drivers of vegetation patterns such as environmental and disturbance factors have seldom been investigated simultaneously (Wimberly and Spies 2001). Numerous studies have investigated the effect of environmental factors on plant assemblage distribution (e.g. Whittaker 1960; Chang et al. 2004, Vogiatzakis 2003). Considerably fewer studies, however, have simultaneously analyzed the effect of disturbance (e.g. Corney 2004; Wimberly and Spies 2001; Huebner and Vankat 2003). Considering environmental and disturbance predictor variables seems especially pertinent due to spatio-temporal variability on the landscape causing the transition of vegetation assemblages to different states dependent on changes in the frequency and intensity of disturbance (Botkin and Sobel 1975).

Grassland, shrubland, and woodland vegetation types are a major component of the landscape in the Applegate Valley of southwest Oregon. However, there is a paucity of data for this vegetation as a whole and especially for chaparral (Hosten 2006, Franklin and Dyrness 1973). Southwest Oregon's plant assemblages include species from northern California, the Pacific Northwest, and the Great Basin, which contribute to their unique species composition (Detling 1961). Previous gradient analyses of similar vegetation types in the region have been completed at different localities (e.g. Thilenius 1968, Sugihara et al. 1987, Meentemeyer et al. 2001, Erickson 2002), a coarser resolution (e.g. Ohmann and Spies 1998), over larger geographic areas (e.g. Whittaker 1960, Atzet et al. 1996) or were restricted to a single vegetation type (e.g. Thilenius 1968, Riegel et al. 1992, Meentemeyer et al. 2001, Erickson 2002).

The Ashland Resource Area of the Medford Bureau of Land Management is currently implementing thousands of hectares of fuels reduction treatments annually (USDI 2002). The purpose of the treatments is to reduce fire intensity and size, thereby increasing the ability to control wildfires, to protect homes and timber resources. The ecological impacts and efficacy of controlling fires via fuels reduction treatments within the woodland and shrubland vegetation types are still largely unknown. Further anthropogenic disturbances that affect these vegetation types include fire suppression, conversion to farms and ranches, livestock grazing, firewood harvesting, home construction, and introduction of non-native invasive plants.

The purpose of this study was to explore the relationship between environmental and disturbance factors and the distribution of grassland, shrubland, and woodland plant

assemblages. I sought to quantify the factors responsible for the current vegetation pattern in order to produce benchmark information to enable further understanding of vegetation dynamics and ecological processes and aid in the management and conservation of a little known vegetation type that is rapidly being altered.

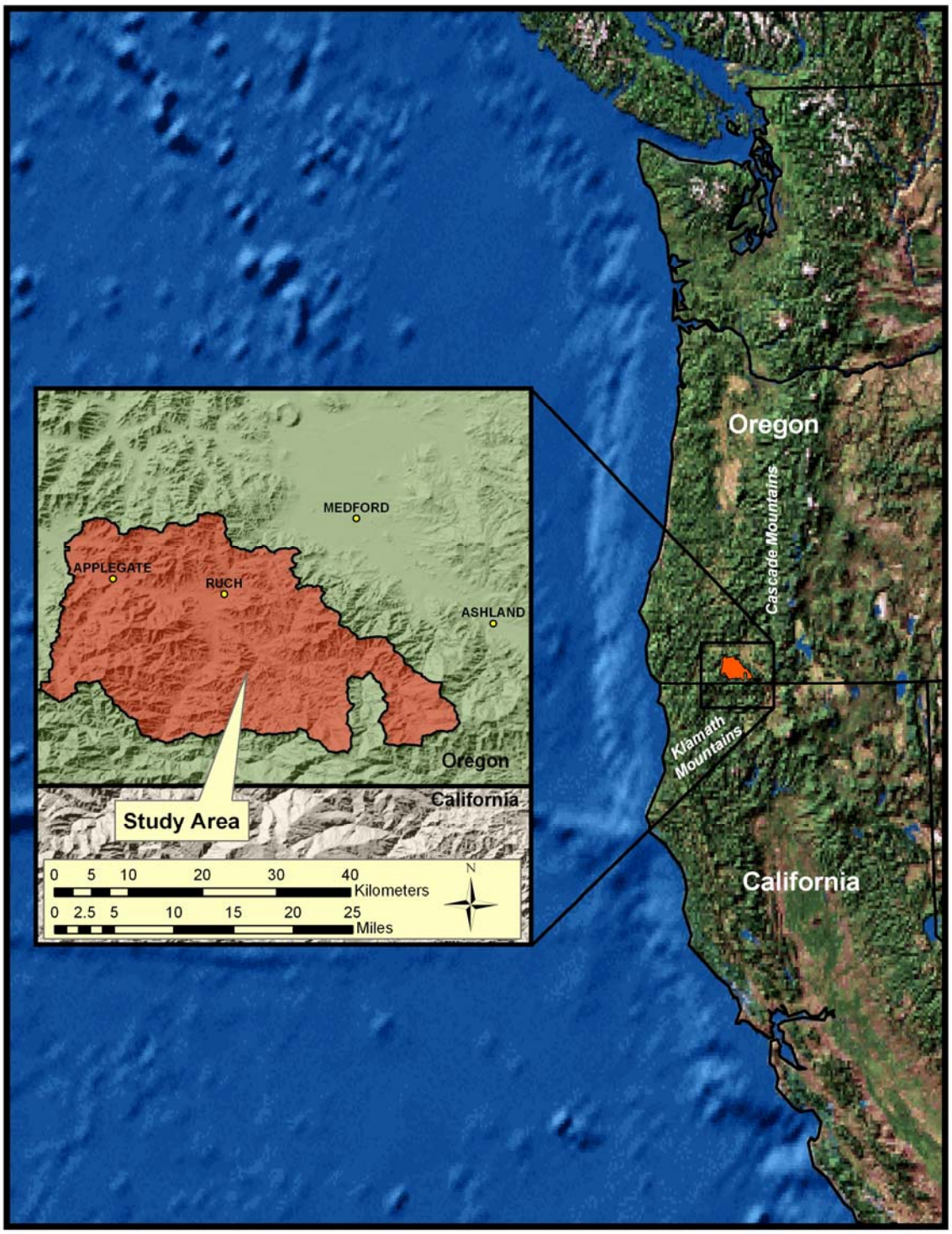
Study Area

The study area (Fig. 1.) lies within the Applegate Valley of southwestern Oregon on U.S. Department of Interior (USDI) Bureau of Land Management (BLM) lands in the Ashland Resource Area. The study area lies within the Klamath Mountains Physiographic Province.

The climate of the study area is west coast inter-mountain valley, which exhibits sclerophyllous vegetation often associated with Mediterranean climates. This climate has pronounced hot, dry summers (May to September) and cool rainy winters (October to April). The complex topography has produced an elaborate pattern of rain shadow effects (Riegel et al. 1992). The vegetation types studied average 904 mm of annual precipitation (Thornton 1997; http://www.daymet.org).

The geology of this area contains a diverse array of parent materials including metamorphosed sediments, volcanics, ultramafics, and granitic plutons. Geology has produced a diverse array of soil suborders (Riegel et al. 1992) and thus relatively high biological diversity. The study area includes 55 soil types (NRCS 2006).

Figure 1. Study Area Map. Study area shown in red within the Klamath Mountains of southwest Oregon.



The topography of the area is highly complex including broad valleys, adjacent foothills and steep mountains. Elevations in the study area range from 470 m (1540 ft) to 1597 m (5240 ft). Additionally, the east-west oriented Siskiyou Mountains within the Klamath Province have acted as a corridor between the north-south oriented Cascade and Coastal ranges allowing plant and animal species to migrate from adjacent regions.

The result of these and other influences is a unique and ecologically diverse area within the Pacific Northwest (Hosten et al. 2006) and perhaps one of the most biologically diverse areas in North America (USDI-USDA 1998). More than 100 rare plant species are found in the Applegate Adaptive Management Area (AMA; USDI-USDA 1998). The Klamath-Siskiyou ecoregion is considered a significant center for endemism and speciation (Whittaker 1961; Stebbins and Major 1965).

METHODS

Sampling Methodology

Potential survey areas were identified using rectified and geo-referenced digital aerial photographs, digital orthophoto quadrangles, in a geographic information system (GIS). Onscreen digitizing of polygons containing homogenous areas of vegetation was performed using these images in a GIS. Emphasis was placed on selecting stands that covered the range of variability of vegetation and environmental characteristics among stands. This strategy aimed at capturing the beta diversity within the study area (Chang et al. 2004; Corney et al. 2004). Urban et. al. (2002) found that a sampling strategy of clusters of samples stratified regularly throughout the study area was capable of capturing both fine and large scale variability, while still being feasible under logistic constraints of time and human resources. This sampling methodology allows collection of herbaceous plant cover data, which is often ignored or aggregated in landscape-level studies that use remote detection techniques such as telescopes (Meentemeyer 2001) or remote sensing (Dennison and Roberts 2003). As relatively large portions of a stand are covered it also reduces the potential for unrepresentative data such as that from a low density of point samples.

Field Data Collection

Data were collected from 426 stands over the summers of 2004 and 2005. A relevé style, rapid survey approach was used in which the surveyor collected data visually while walking through portions of a stand, which was a relatively homogenous area of vegetation (Braun-Blanquet 1932/1951). Phytosociological surveys using this method are typically employed when the intent of the study is to gain an understanding of variables responsible for the observed patterns of associated vegetation types and for the modeling and mapping of those vegetation associations (e.g. Riegel et al. 1992, Choler et al. 2001, Dirnbock et al. 2003). The use of plant assemblages allows a simplified, integrated method of analyzing site conditions (Erickson 2002).

Visual cover estimates were performed for tree, shrub, grass and herbaceous components both as physiognomic groups and as individual species for each stand. Size class data were collected for the dominant oak and shrub species in each stand in addition to the oak growth form (i.e. single or multi-stemmed). Visual estimates of ground cover (e.g. rock, soil, litter) were recorded. The presence of conifer snags, evidence of fire, and evidence of fuels reduction treatments were noted. Further information on field methods can be found in Appendix A.

Predictor Variables

Values for the 16 environmental (Table 1) and 9 disturbance (Table 2) variables that were hypothesized to drive the distribution of key species and assemblages were collected from various sources and standardized into a 30 m x 30 m raster format by

resampling with ArcToolbox in ArcGIS (ESRI 2006) using bilinear interpolation. Vector data were converted into raster format and were projected in NAD27 CONUS zone 10 Universal Transverse Mercator (UTM).

A Digital Elevation Model (DEM; USDI 2005) was the source of the elevation data. Slope shape was derived from the DEM using the curvature algorithm in ArcGIS Spatial Analyst (ESRI 2006) using a Z factor of 1. Watershed membership was derived by reclassifying named sixth field watersheds into numeric categories from a BLM sixth field watershed shapefile (USDI 2006). The heat load index was calculated in ArcView 3.2a (ESRI 2000) using equation 3 from an extension developed by Sean Parks based on an equation developed by Bruce McCune (McCune and Keon 2002). This heat load index estimates the accumulation of temperature based on aspect, slope, and latitude (McCune and Keon 2002). Heat load was used instead of aspect, as it is an environmental scalar that is more mechanistic and less location specific (Austin et al. 1984). A Topographic Position Index (TPI; Jenness 2006) extension was used in ArcView 3.2a (ESRI 2000) to derive 10 categories (Table 1) of topographic position from a seamless DEM (Gesch et al. 2002) using a small neighborhood circle of 500 map units and a large neighborhood circle of 2000 map units (Weiss 2001; slightly modified).

Table 1A. Environmental Variable Descriptions

Variable	Data type	Description of data	Source
TOPOGRAPHIC			
Slope shape	Quantitative	Shape of hill slope (e.g. concave, convex, flat) on continuous scale	Computed in GIS from DEM
Elevation	Quantitative	Elevation in meters	USDI Digital Elevation Model (DEM)
Sixth field watershed	Categorical	Sixth field watershed designation	Reclassified USDI shapefile
Topographic position index	Categorical	Topographic position (Mountain tops, high ridges; midslope ridges; local ridges; upperslopes; open slopes; plains; U-shaped valleys; upland drainages; midslope drainages; deeply incised streams)	Computed in GIS from DEM
Heat load	Quantitative	Amount of heat that occurs at a location on the earths surface; unitless index	Computed in GIS from DEM
CLIMATIC			
Actual annual evapotranspiration	Quantitative	Relative amount of moisture available to plant over a year in millimeters (averaged from 1980-1997)	USGS (Shafer unpublished)
Summer actual annual evapotranspiration	Quantitative	Average relative amount of moisture available to plant during June, July, and August in millimeters (averaged from 1980-1997)	USGS (Shafer unpublished)
Annual precipitation	Quantitative	Average annual precipitation from 1980-1997 in millimeters	DAYMET climatological

Table 1B. Environmental Variable Descriptions

Variable	Data type	Description of data	Source
EDAPHIC			
Cation exchange capacity	Quantitative	Average cation exchange capacity milliequivalents per hundred grams	SSURGO database
Total clay	Quantitative	Average percent of clay	SSURGO
Total silt	Quantitative	Average percent of silt	SSURGO
Total sand	Quantitative	Average percent of sand	SSURGO
Drainage class	Categorical	Drainage class (e.g. well drained)	SSURGO
Parent material	Categorical	Parent material (i.e. geology)	SSURGO
Upper soil horizon depth	Quantitative	Average depth of upper soil horizon in centimeters (i.e. A horizon)	SSURGO
pH	Quantitative	Average pH for soil mapping unit	SSURGO

Table 2. Disturbance Variable Descriptions

Variable	Data type	Description of data	Source
WILDFIRE			
Fire frequency	Quantitative	How often a wildfire has occurred at a site in last 110 years	USDI data
Maximum fire interval	Quantitative	Maximum amount of years between fires in last 110 years	USDI data
Years since a wildfire	Quantitative	Number of years since the last wildfire occurred in last 110 years	USDI data
MANAGEMENT			
Broadcast burn	Binary	Broadcast burn fuels reduction treatment	USDI data
Mechanical mastication	Binary	Mechanical mastication fuels reduction treatment	USDI data
Slash	Binary	Slash fuels reduction treatment	USDI data
Slash hand pile burn	Binary	Slash hand pile and burn fuels reduction treatment	USDI data
Underburn	Binary	Underburn fuels reduction treatment	USDI data
Scarification	Binary	Scarification fuels reduction treatment	USDI data

Precipitation data were from the DAYMET dataset for annual precipitation represented in monthly means for an 18-year time period (1980-1997) recorded in millimeters (Thornton 1997; http://www.daymet.org). This data was resampled from its original 1 kilometer resolution to a 30 m x 30 m grid to match the other data layers.

Actual annual evapotranspiration and actual summer evapotranspiration were acquired from the USGS (Shafer 2006). Evapotranspiration is an environmental scalar that provides information on the relative amount of moisture available to plants. It is based on temperature, precipitation, sunshine, and soil texture. Plant transpiration was held constant by using a generic vegetation type for the entire region (Shafer 2006). Actual annual evapotranspiration represents total annual evapotranspiration in millimeters. Summer actual annual evapotranspiration data correspond to actual annual evapotranspiration amounts in millimeters summed for June, July and August. The precipitation, temperature, and sunshine data used in the model are from the same data set for the same time period as the precipitation data used in this study (http://www.daymet.org).

Soil information was derived from the Natural Resources Conservation Service (NRCS) Soil Survey Geographic database (SSURGO) containing tabular and spatial data (NRCS 2006). Analysis was performed at the level of soil mapping unit (i.e. MUKEY). Soil characteristics (e.g. pH) were tabularly linked, collated and averaged for soil complexes if there were more than one soil type in a mapping unit. To simplify the analysis only the representative values (measure of central tendency) from the upper soil horizon (SSURGO category H1) were used as they were considered to have the greatest

effect on plant life history processes and hence distribution. Tabular data were then joined spatially in GIS and converted to rasters for pH, upper soil horizon depth, total clay, total sand, total silt, cation exchange capacity, and drainage class. Parent material was derived by reclassifying a geology layer (USDI 2006).

Fuels reduction treatment data were obtained from the Medford BLM Fire/Fuels Specialist (USDI 2006b). The polygons of different types of fuels reduction treatments were converted to raster files denoting the presence or absence of one of the following fuels reduction treatments: broadcast burn, mechanical mastication, slash, slash hand pile burn, and underburn. Wildfire data were obtained from the same source. This polygon data covered known wildfires from 1900 to the present. The data were converted to individual raster files based on each of the following wildfire attributes: fire interval (number of years between fires), fire frequency (number of times an area has burned), and number of years since last fire.

The GIS extension ‘Hawth tools’ (Beyer 2004) was used to randomly select five points within each of 425 stands to capture the within stand variability of each of the environmental and disturbance variables. The five values for each stand were used independently and collated into a sample point by variable data matrix. This matrix was used in the regression of predictor variables against ordination results, and in the autocorrelation test.

Statistical Analysis

Complementary Analysis

The use of ordination and classification in a concerted effort to investigate multivariate data is termed complementary analysis (Kent and Ballard 1988). Investigating the clustering of stands in ordination space has been suggested by Kent and Coker (1992) as a means of displaying the relationships between the two techniques and according to Urban et al. (2002) is a powerful tool for interpreting vegetation pattern. The method allows examination of both individual species patterns and group structure.

The distribution of the species abundance data confirmed that the data were non-normal as individual stands and species tended to be highly leptokurtic and positively skewed. For these reasons it was most appropriate to use non-parametric multivariate methods. PC ORD 4.0 (McCune and Mefford 1999) was used for all multivariate statistical methods. The matrices used had one outlying stand removed, used only known species, and only contained species that had an abundance of 1% or more in a minimum of one stand. Square root transformation (McCune and Grace 2002) displayed no overall improvement of species response curves, hence, no transformation or relativization was used. The final stand by species matrix included 425 stands with a total of 225 species.

Classification

Classification was used to group stands with similar species composition in order to simplify landscape-level vegetation analysis. Hierarchical agglomerative clustering using space conserving methods to avoid distortion were used to form plant assemblages based

on similar plant composition (McCune and Grace 2002). Species that were relatively rare in the data set were maintained, as they may be important for defining groups (Kent and Coker 1992). The number of known species found in only 5% of the stands was quite high (52%), which is indicative of high beta diversity. Cluster analysis using PC ORD software (McCune and Mefford 1999) was performed using the flexible beta linkage method (-0.25), which produces results similar to Ward's method, but is compatible with the Sorenson (Bray-Curtis) distance measure. The Sorenson distance measure puts weight on common species, which was desirable in this study (Kent and Coker 1992).

Indicator Species Analysis (ISA; Dufrene and Legendre 1997) was employed to aid in pruning cluster analysis dendograms and to describe groups based on fidelity of indicator species to stand clusters (McCune and Grace 2002). The Monte Carlo test within the ISA was conducted with 1000 runs starting at a random point. Species significant to $P<0.01$ were considered for describing assemblages. Assemblages were named with regards to defining species and/or physiognomy. Defining species were selected based on mean cover, constancy, and fidelity (indicator species value; McCune and Grace 2002) within the assemblage.

Ordination

Nonmetric multidimensional scaling (NMS) was utilized to investigate patterns of species composition with respect to dominant landscape gradients. The ability of NMS to analyze non-normal data and especially community data, which include many zero values, made it a desirable technique (Kruskal 1964, McCune and Grace 2002). NMS

was also used initially to find an outlier later eliminated from the analysis. The NMS ordination used to investigate patterns in the data and assemblage distribution in species space was run using the “medium” autopilot mode in PC ORD (McCune and Mefford 1999). The NMS ordination, which was regressed against environmental variables, used the “slow and thorough” autopilot mode. The Sorenson (Bray-Curtis) coefficient was chosen as a distance measure as it can be used with both qualitative and quantitative data (Kent and Coker 1992) and has been recommended for use with community data (McCune and Grace 2002). Relationships between predictor variables and species composition were investigated using overlays and joint plots superimposed on the “slow and thorough” ordination. The predictor variables that were regressed against the ordination were relativized by maximum value in order to scale the variables equally so that variables with high values did not obscure those with low values (McCune and Grace 2002). Coeffients of determination (r^2) were calculated to quantify the amount of variance explained by the predictor variables for the distribution of stands in ordination space. Individual species were regressed against ordination scores to better understand the distribution of species in ordination space.

Autocorrelation

Spatial autocorrelation has been considered a problem in spatial ecology, but has recently been reconsidered as simply a reality that needs to be addressed (Legendre 1993). This study investigates vegetation patterns in relation to environmental and disturbance factors. However, biotic processes that function in a contagious manner (e.g.

dispersal, competition, mutualism, herbivory) that are outside the scope of this study also drive landscape patchiness. This study tested for autocorrelation, which allowed an investigation of the “distance apart”, not simply location (Urban et al. 2002). This enabled comparisons between the spatial proximity of sample points and their species composition.

Simple Mantel tests (Mantel 1967) were used in PC ORD version 4 (McCune and Mefford 1999) to quantify the effect of spatial autocorrelation on the distribution of vegetation (Urban et al. 2002). Dissimilarity matrices of species composition versus environmental variables and species composition versus geographic distance apart were tested for significance of correlations between the corresponding matrices. Only environmental variables that produced an r^2 of 0.20 or higher from the regression against ordination scores were used in the environmental matrix as it has been stated that inclusion of weak factors can diminish the differences between sites (McCune and Grace 2002). The environmental matrix was relativized by maximum value. The Sorenson (Bray-Curtis) distance measure was used in conjunction with Mantel’s asymptotic approximation to calculate P-values.

Predictor Variable Ranges

Summary statistics (e.g. mean, median and range) were compiled for the thirteen plant assemblages in relation to the most important predictor variables. These statistics were produced to elucidate the distribution of assemblages along gradients.

RESULTS

Classification

Thirteen groups were chosen (Table 3) based on the relatively high number of significant indicator species (128; Figure 2) and the low average p value (0.14; Figure 3) compared to the other cluster analysis group designations (McCune and Grace 2002).

Table 3. Plant Assemblage Summary

ASSOCIATION NAME	TYPICAL SPECIES (common names)	PHYSIOGNOMIC GROUP
Fescue grassland	Fescue/St. Johns wort/ balsamroot	Grassland/bald
Buckbrush chaparral	Buckbrush/soft brome	Shrubland
Rabbitbrush/buckwheat bald	Rabbitbrush/arrowleaf and naked buckwheat	Grassland/bald
Manzanita/white oak	Whiteleaf manzanita/Oregon white oak	Woodland/shrubland
Oak woodland	Oregon white oak/Chinook brome/hedgehog dogtail/ spreading hedgeparsley	Woodland
Oat grass grassland	Oat grass/ medusa head/ Lemmon's needlegrass/ California poppy/lupine	Grassland/bald
Mountain mahogany/Brewer's oak	Mountain mahogany/Brewer's oak/serviceberry/seablush/ yarrow/lambstongue ragwort	Shrubland
Open oak/chaparral	Oregon white oak/grand collomia/California brome/ hedgehog dogtail	Woodland/shrubland
Black oak woodland	California black oak/blue wildrye/yellowleaf iris/beaked hazelnut	Woodland
Disturbance mediated woodland/chaparral	Madrone/white oak/buckbrush/ manzanita/cheatgrass/madia	Woodland/shrubland
Madrone woodland	Madrone/black oak/deerbrush/ blacksnakeroot	Woodland
Manzanita chaparral	Whiteleaf manzanita/ponderosa pine/white oak/blue dicks	Shrubland
Canyon live oak woodland	Canyon live oak/Douglas-fir/ bearbrush/Oregon grape/ honeysuckle	Woodland

Figure 2. Number of Significant Indicator Species. Number of significant indicator species from indicator species analysis for each assemblage.

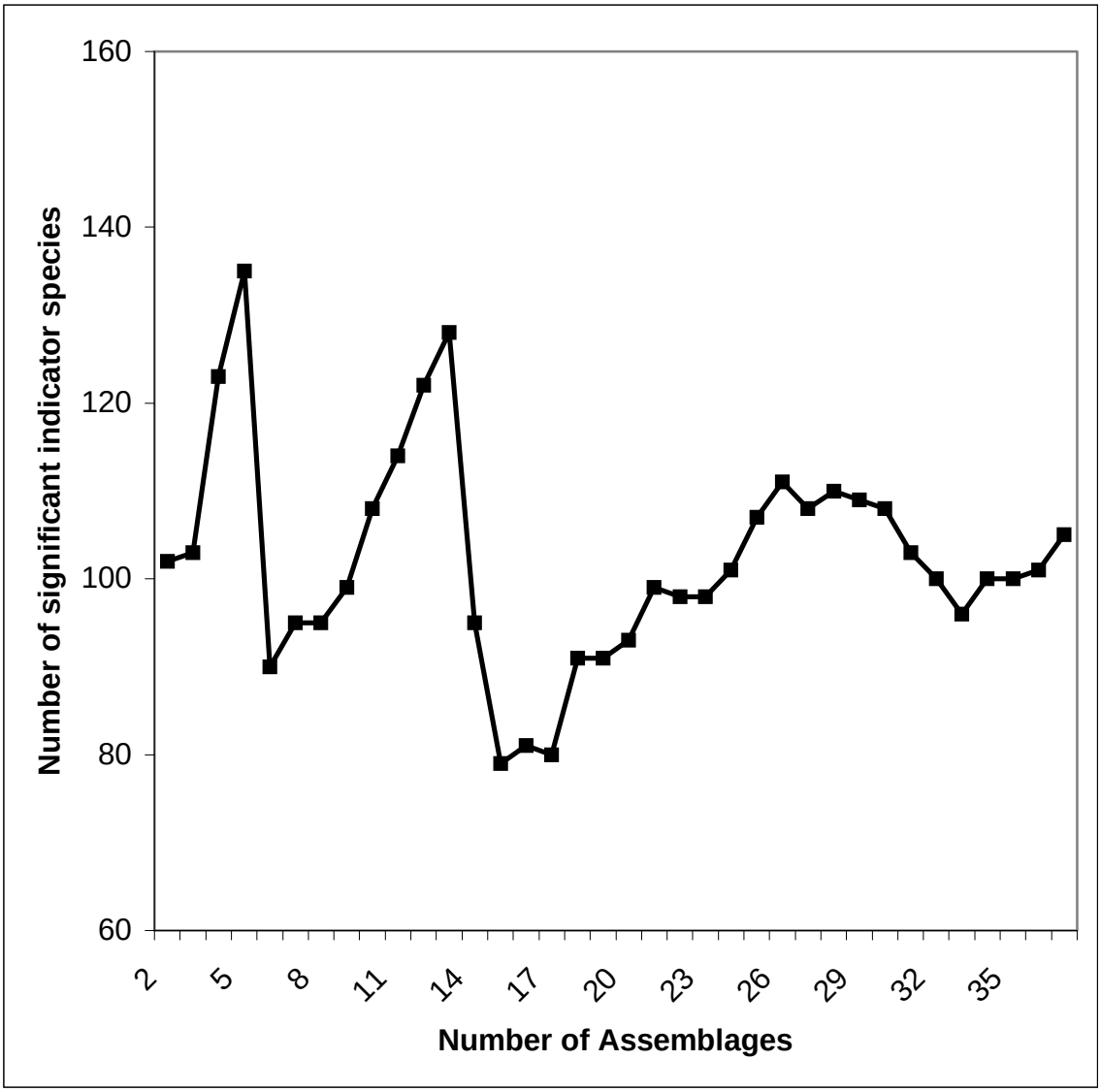
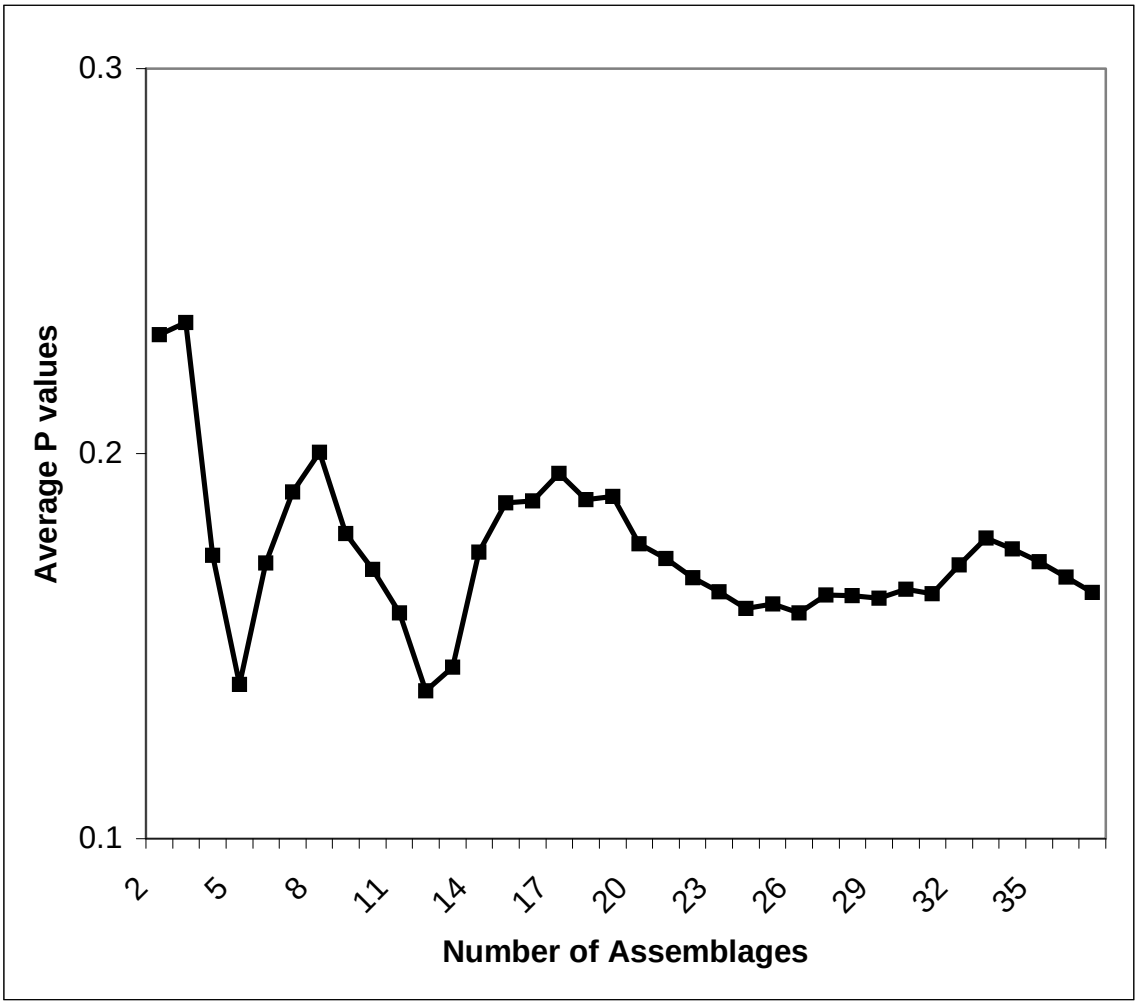


Figure 3. Average P Values from Indicator Species Analysis. Average P values from the indicator species analysis for each cluster analysis group.



Ordination

The nonmetric multidimensional scaling (NMS) ordination, using the “medium” autopilot mode, found three axes that explain the most variation in species abundance with the lowest stress (mean stress = 19.45). Coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space for axes 1, 2, and 3 respectively were: $r^2 = 0.23$, $r^2 = 0.29$, $r^2 = 0.22$ producing a cumulative r^2 of 0.74.

The NMS ordination, using the “slow and thorough” autopilot mode, found three axes that explain the most variation in species abundance data with the lowest stress (mean stress = 18.32). Coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space for axes 1, 2, and 3 respectively were: $r^2 = 0.20$, $r^2 = 0.32$, $r^2 = 0.22$ producing a cumulative r^2 of 0.74. Elevation, moisture, and soil variables appear most important as demonstrated by coefficient of determination (r^2) values for axis 2 (Table 4 and Figure 4) for the following variables: Elevation, summer actual evapotranspiration, pH, annual precipitation, total silt, upper soil horizon depth, and total clay. Axis 1 was weakly correlated with heat load and years since a wildfire suggesting heat accumulation and fire history to be marginally responsible for that axis. Fire interval maximum was the only variable that was more correlated with axis 3 than with the first two axes. Figure 4 is ordination diagrams displaying assemblages for each of the individual physiognomic groups. Within the shrubland physiognomic group assemblages were quite discrete (Figure 4). In most of the other physiognomic groups assemblages were clustered in ordination space, but often

overlapped with other assemblages. The disturbance mediated woodland/chaparral assemblage was more dispersed in ordination space than the other assemblages (Figure 4).

Individual species regression results corresponded to ordination results for the thirteen plant assemblages. The individual species most correlated to the ordination axes were dominants of the respective assemblages that were found in the same portion of ordination space (Table 5 and Figure 5).

Table 4. Correlations of Predictor Variables with Ordination Axes. Pearson's correlation coefficients (r) for the correlations of predictor variables with NMS ordination axes. Table sorted by maximum r^2 for each variable.

	Axis: 1		Axis: 2		Axis: 3	
Variable	r	r^2	r	r^2	r	r^2
Elevation	-0.062	0.004	0.691	0.478	0.283	0.080
Summer actual evapotranspiration	-0.028	0.001	0.549	0.302	0.284	0.081
pH	0.232	0.054	-0.534	0.285	0.010	0.000
Annual precipitation	-0.009	0.000	0.501	0.251	0.329	0.108
Percent silt	0.275	0.076	-0.487	0.237	-0.008	0.000
Upper soil horizon depth	-0.282	0.080	0.485	0.235	-0.064	0.004
Percent clay	0.248	0.062	-0.480	0.230	-0.003	0.000
Annual actual evapotranspiration	-0.102	0.010	0.426	0.181	0.211	0.044
Percent sand	0.266	0.071	-0.410	0.168	0.128	0.016
Cation exchange capacity	0.309	0.096	-0.286	0.082	0.112	0.013
Fire frequency	-0.186	0.035	0.088	0.008	0.052	0.003
Fire interval maximum	0.129	0.017	-0.072	0.005	-0.166	0.027
Slope shape	0.018	0.000	0.049	0.002	-0.034	0.001
Years since last wildfire	0.235	0.055	-0.012	0.000	0.089	0.008
Heat load	-0.234	0.055	0.008	0.000	-0.075	0.006

Figure 4. Plant Assemblage Joint Plots. NMS ordination classified by plant assemblages for each physiognomic group. Regression results are superimposed displaying the relationship of predictor variables to plant assemblage distribution. Joint plot uses a cutoff r^2 value of 0.05 and a vector scaling of 225%.

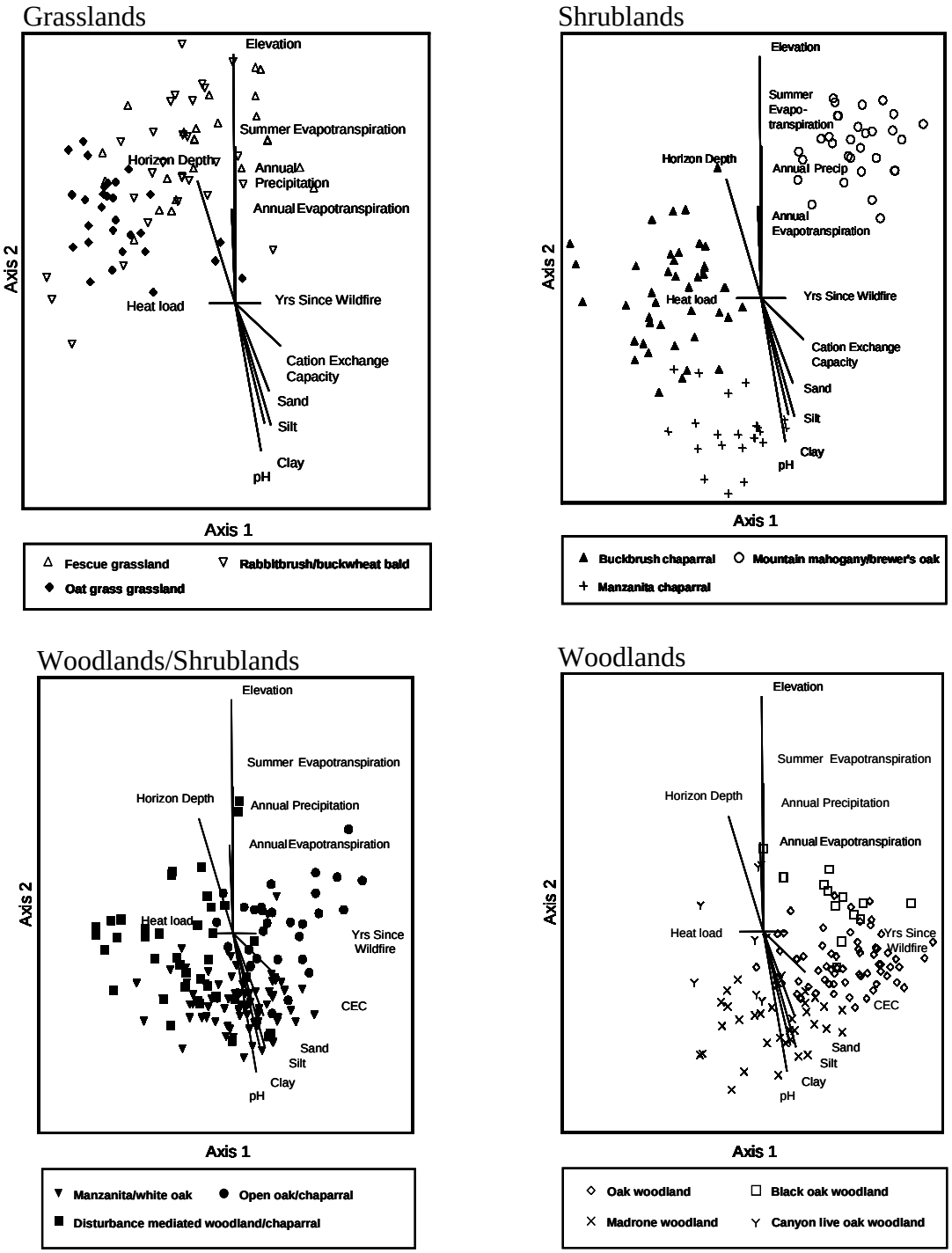
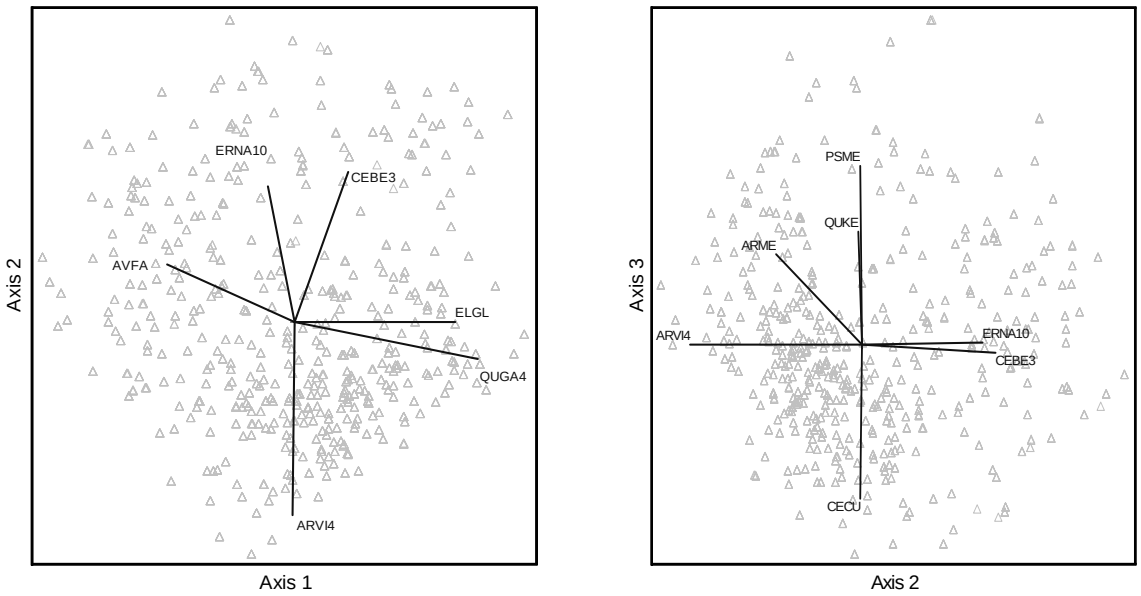


Table 5. Correlations Between Individual Species and Ordination Axes. Pearson's correlation coefficients (r) for correlations between individual species and NMS ordination axes. Individual species are sorted by (r^2) for each axis.

Species	Axis 1	Species	Axis 2	Species	Axis 3
QUGA4	0.59	ARVI4	-0.60	PSME	0.58
ELGL	0.55	CEBE3	0.53	CECU	-0.54
AVFA	-0.49	ERNA10	0.50	QUKE	0.46
TOAR	0.43	ARME	-0.42	ARME	0.41
BRHO2	-0.40	TODI	-0.39	QUCH2	0.36
FECA	0.39	BEPI2	0.38	BRHO2	-0.32
CECU	-0.37	LUPIN	0.36	QUGA4	-0.31
FERO	0.36	BRLA3	-0.34	VIAM	0.29
TACA8	-0.35	LOHI2	-0.34	SYAL	0.29
BRLA3	0.34	QUGAB	0.34	VUMI	-0.28

Figure 5. Individual Species Joint Plots. Individual species regressed against ordination scores from the NMS stand by species ordination. Vector angles and lengths correspond to the direction and strength of the relationship. Only species with a coefficient of determination of 0.20 or higher are included. Vector scaling is 200%



Autocorrelation

Mantel tests found a positive correlation (t = 43.18) between species composition dissimilarity and environmental dissimilarity (Standardized Mantel statistic of r = 0.29; p < 0.001). The test found a weaker positive correlation (t = 25.36) between species composition dissimilarity and spatial dissimilarity (i.e. distance apart) (Standardized Mantel r = 0.16; p < 0.001).

Relationships Between Species Composition and Predictor Variables

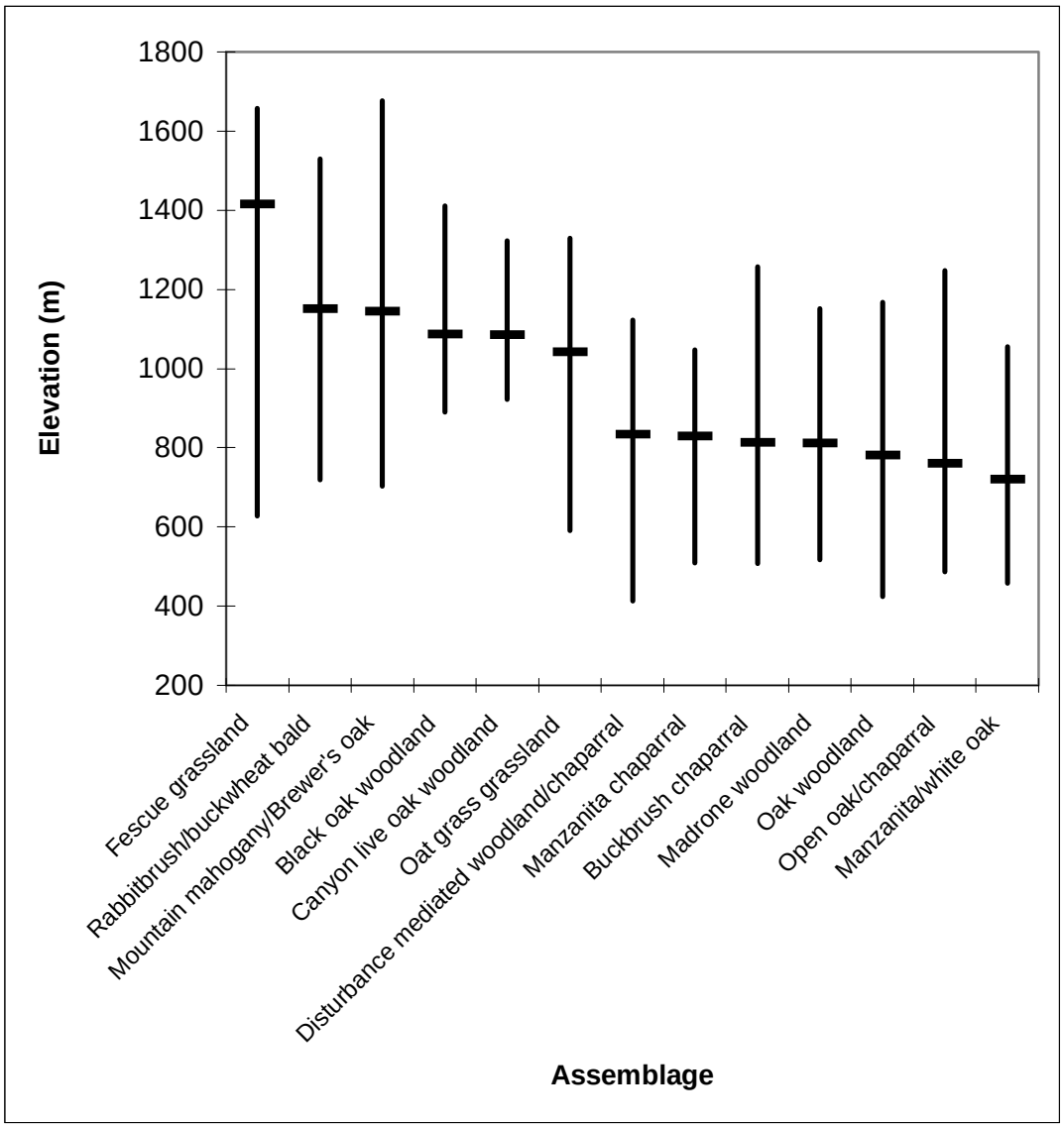
The use of summary statistics (e.g. range, median) for each assemblage in relation to environmental and disturbance variables summarize the position of the assemblages along individual gradients (Figures 6 – 14). Tables with all statistical parameters computed are found in Appendix B.

Environmental Variables

Annual precipitation and evapotranspiration are strongly correlated with elevation (Fig. 4), while heat accumulation is orthogonal to these variables. The direction and length of these moisture variables' vectors indicates that moisture is the primary component of the composite variable elevation. The low correlation of heat load to elevation suggests that heat has less to do with elevation's influence on species distributions (Table 4). Soil attributes seem intermediate in their association with axes 1 and 2. However, they are more closely aligned with axis 2, which is most explained by elevation (Table 4). This suggests that elevation and soil attributes covary, but do not have as strong a relationship as elevation and moisture variables.

Corroboration of the joint plot with summary statistics for plant associations clarified some trends. The assemblages with white oak, manzanita, or madrone as a dominant were found at the lowest elevations (Figure 6). Grassland associations and the mountain mahogany/Brewer's oak association occupy the highest elevation sites.

Figure 6. Elevation Ranges. Ranges of elevation for assemblages sorted by median.



Relationships between assemblages with regard to summary statistics for elevation (Figure 6) are reflected in both annual precipitation (Figure 7) and summer evapotranspiration (Figure 8). Most plant assemblages at high elevation sites also have high annual precipitation and high summer actual evapotranspiration, while assemblages at the low elevations typically have low annual precipitation and evapotranspiration.

Evaluation of median values showed that in respect to the other assemblages the manzanita/white oak community and the open oak/chaparral community were consistently the lowest in elevation, precipitation, and evapotranspiration. Median values for elevation, precipitation, and summer evapotranspiration varied for most of the other assemblages. Fescue grasslands, rabbit brush/buckwheat balds, canyon live oak woodlands, and black oak woodlands typically averaged the highest in regards to moisture. Assemblages that had a pronounced change between their assemblage's rank order in median elevation and their rank order in median precipitation and summer evapotranspiration were the canyon live oak, black oak, and oak woodland assemblages all of which moved up in rank order for summer evapotranspiration (Figures 6, 7, and 8). Canyon live oak, while not residing on the highest elevation sites, typically had the highest precipitation and summer evapotranspiration . The canyon live oak and black oak assemblages are two of the most mesic of the assemblages.

Figure 7. Annual Precipitation Ranges. Ranges of annual precipitation for assemblages sorted by median.

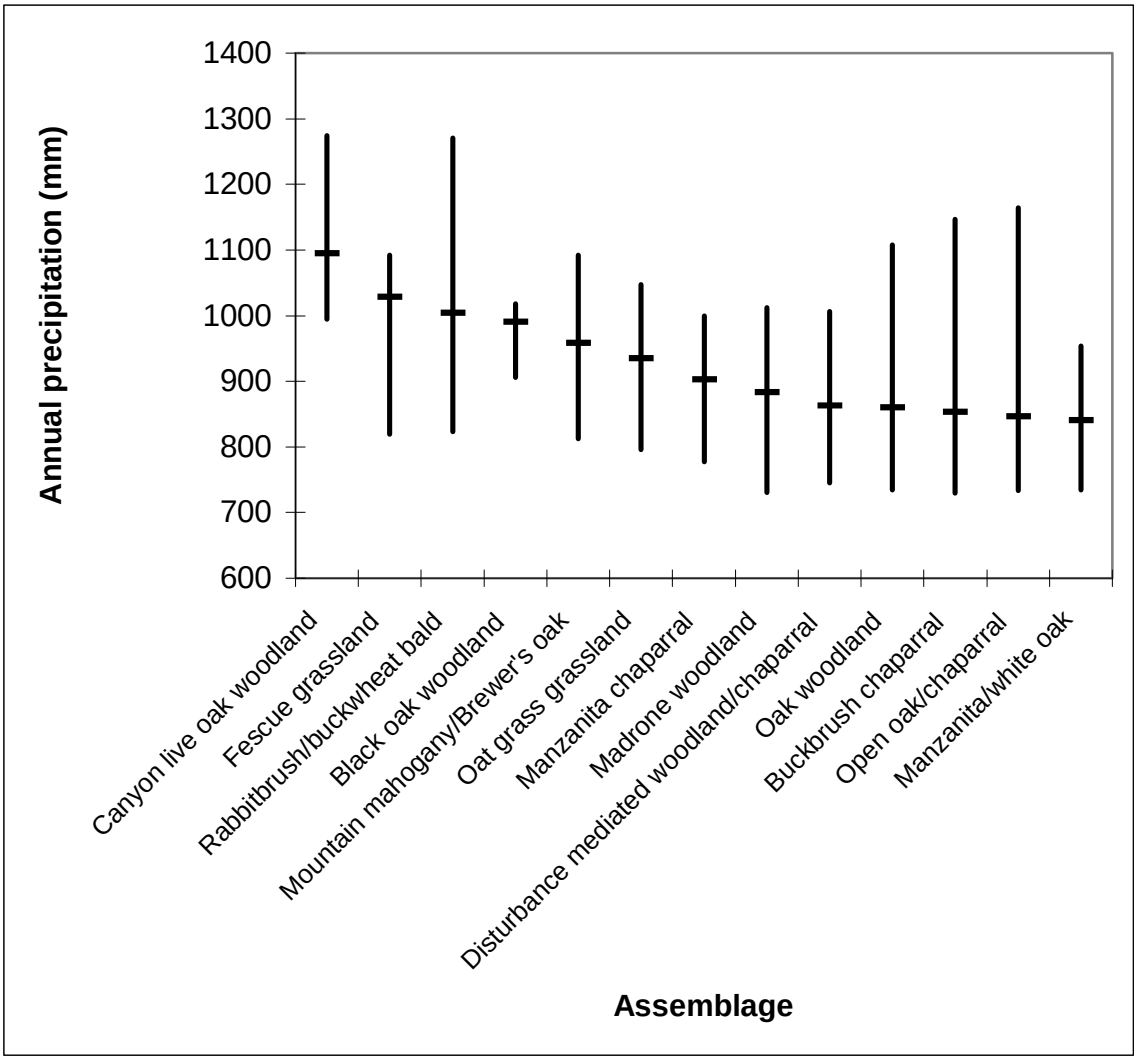
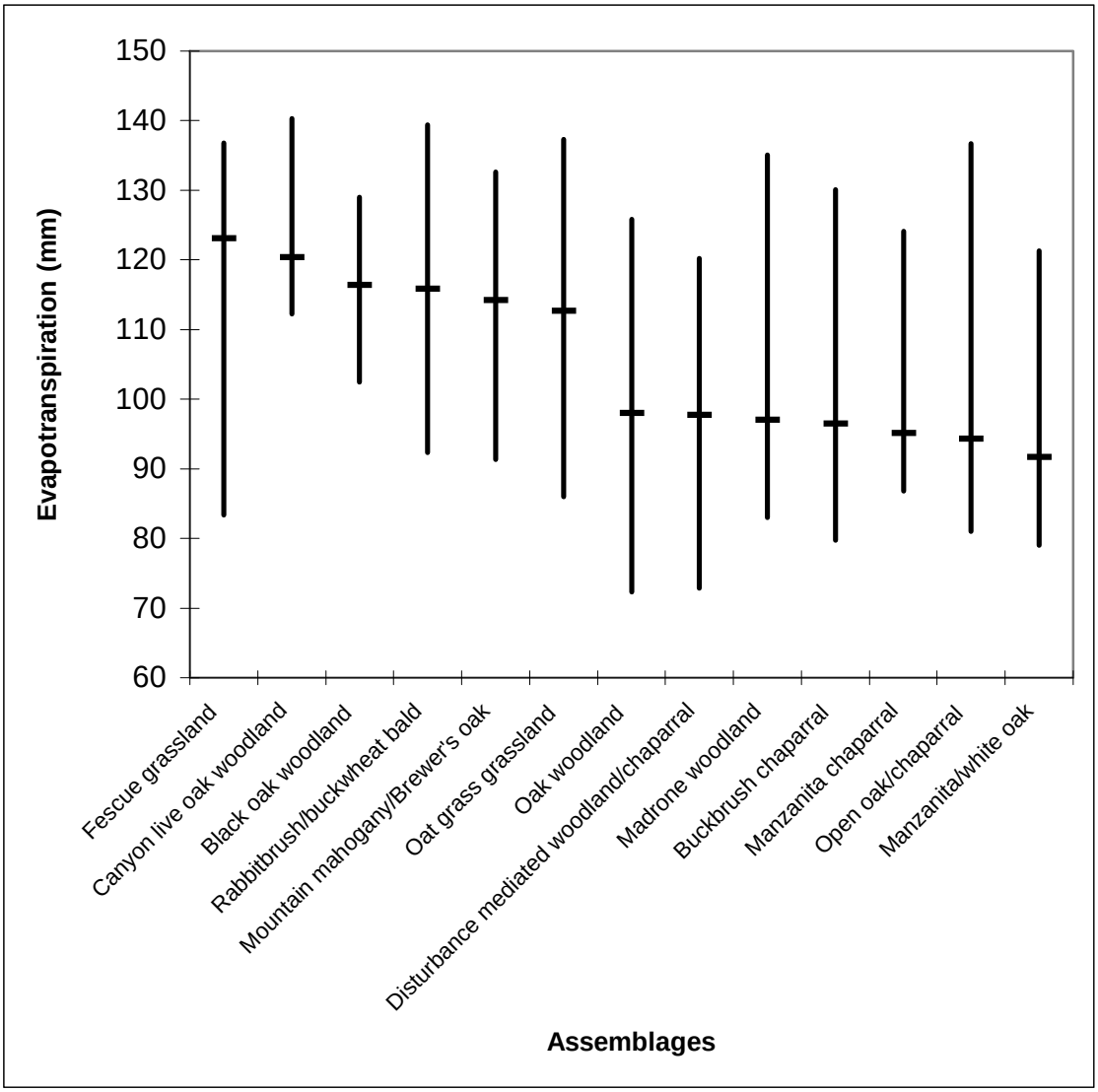
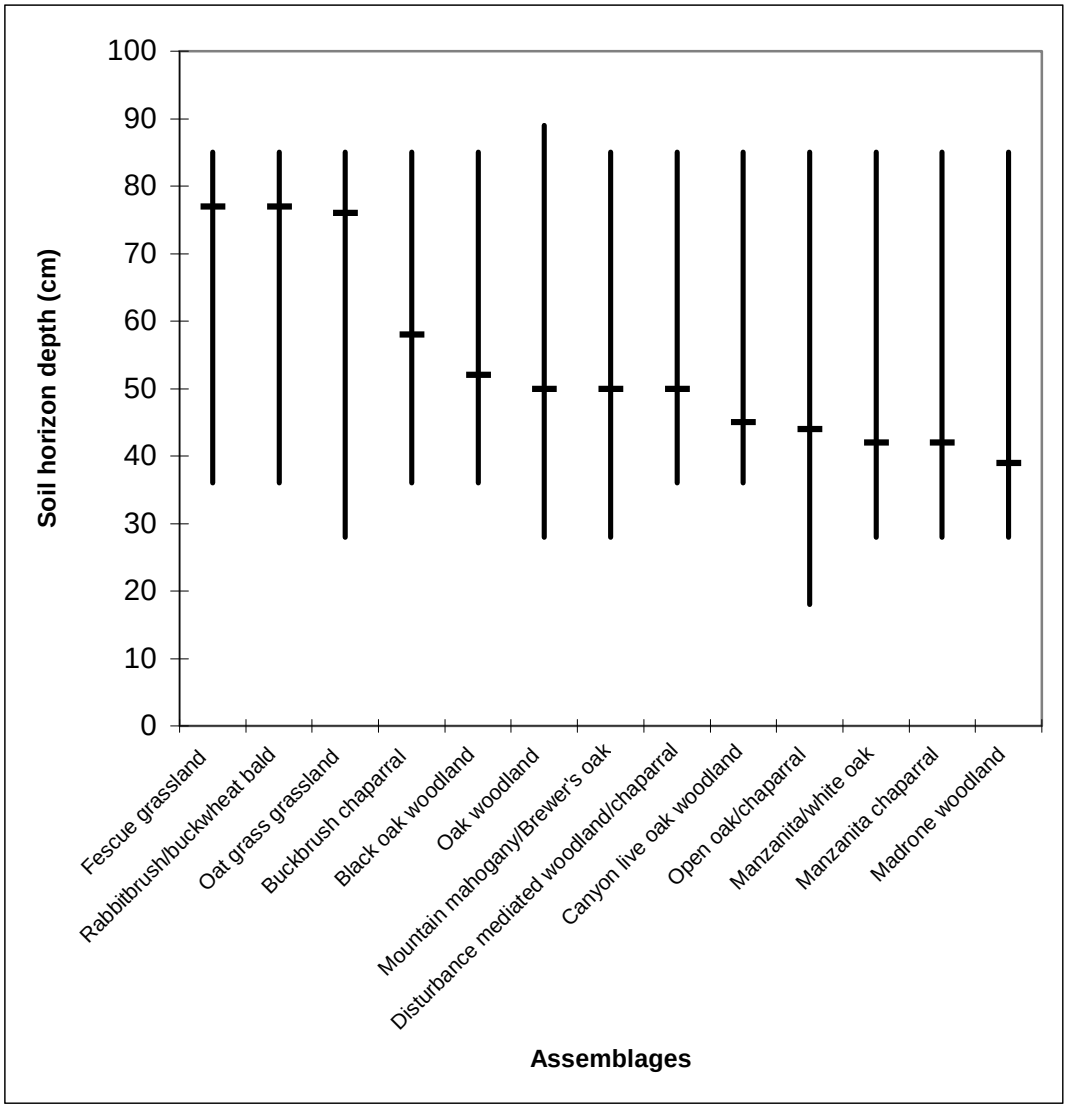


Figure 8. Summer Evapotranspiration Ranges. Ranges of summer evapotranspiration for assemblages sorted by median.



The grassland assemblages were found to be associated with the deepest upper soil horizons (Figure 9). The more mesic assemblages (canyon live oak, black oak, mountain mahogany/Brewer's oak and madrone woodlands) had the shallowest mean upper soil horizon depths. The plant assemblage with the lowest mean upper soil horizon depth is the madrone woodland association.

Figure 9. Upper Soil Horizon Depth Ranges. Ranges of upper soil horizon depth for assemblages sorted by mean.



Noticeably lower mean ph (Figure 10) and cation exchange capacity (CEC7; Figure 11) values were found in the grassland associations. Values for pH in the results are artificially low. This is hypothesized to be an artifact of zero pH values associated with rock outcrops. The woodland physiognomic group typically had the highest mean cation exchange capacity values (Figure 11).

Figure 10. pH Ranges. Ranges of pH for assemblages sorted by mean.

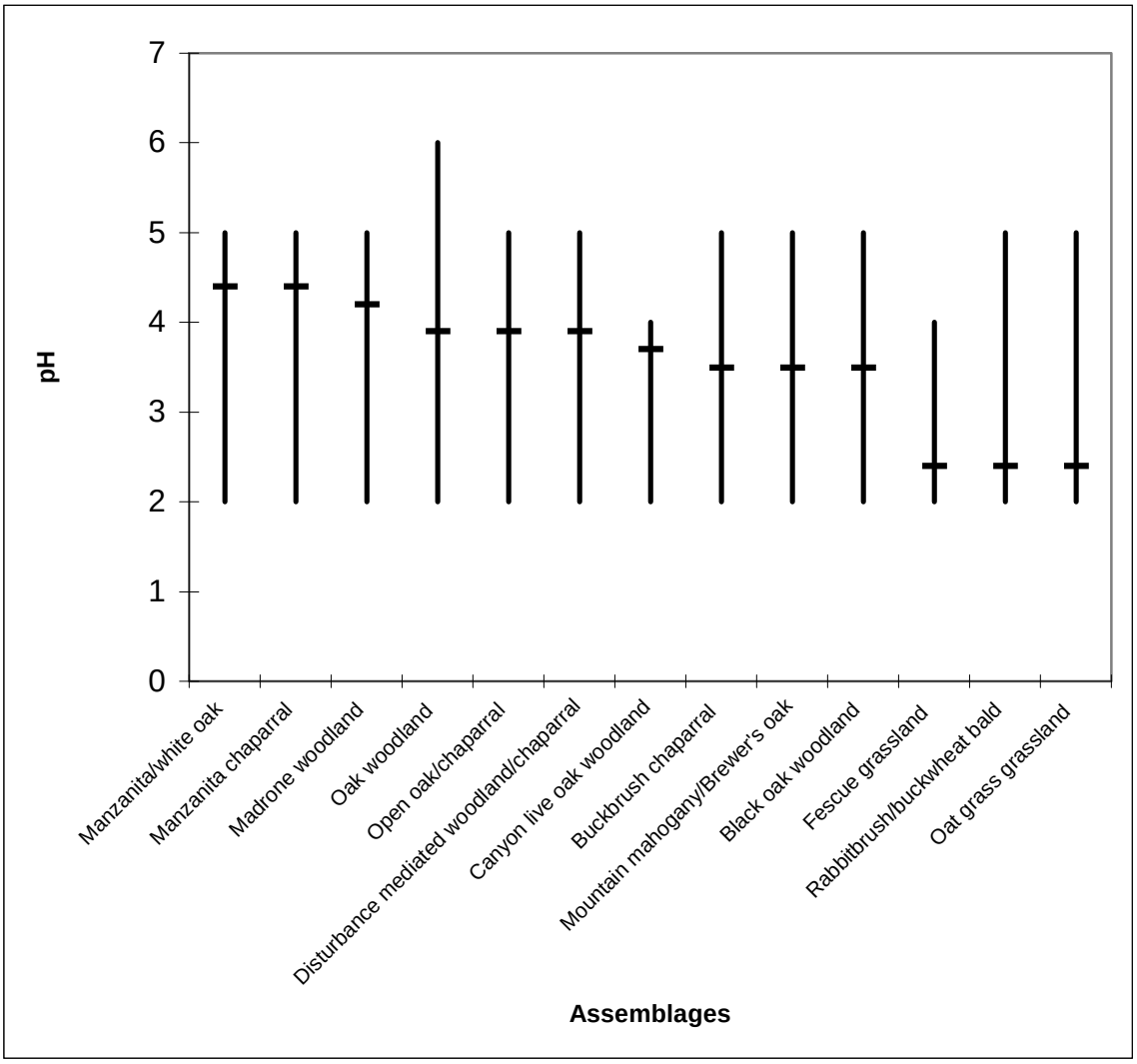
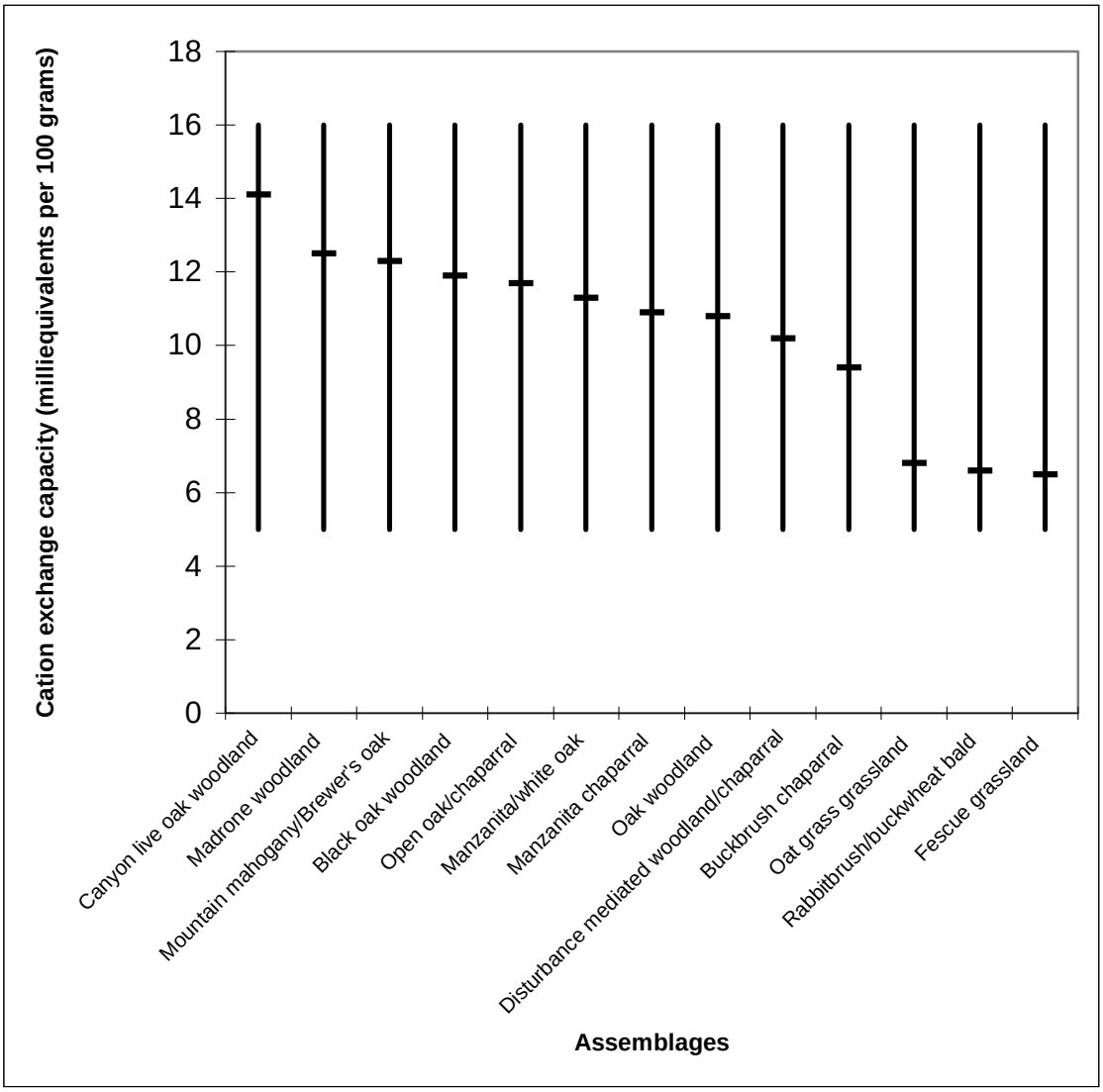


Figure 11. Cation Exchange Capacity Ranges. Ranges of cation exchange capacity for assemblages sorted by mean.



Soil textural differences between assemblages appear to be negligible for the most part, with about equal parts of silt and sand and lesser amounts of clay (Figures 12, 13, and 14). A noticeable exception to this is the three grassland assemblages. These assemblages occur in sites with considerably less of all three soil separates indicating that the soil has a considerable rock component.

Figure 12. Total Silt Ranges. Ranges of total silt for assemblages sorted by mean.

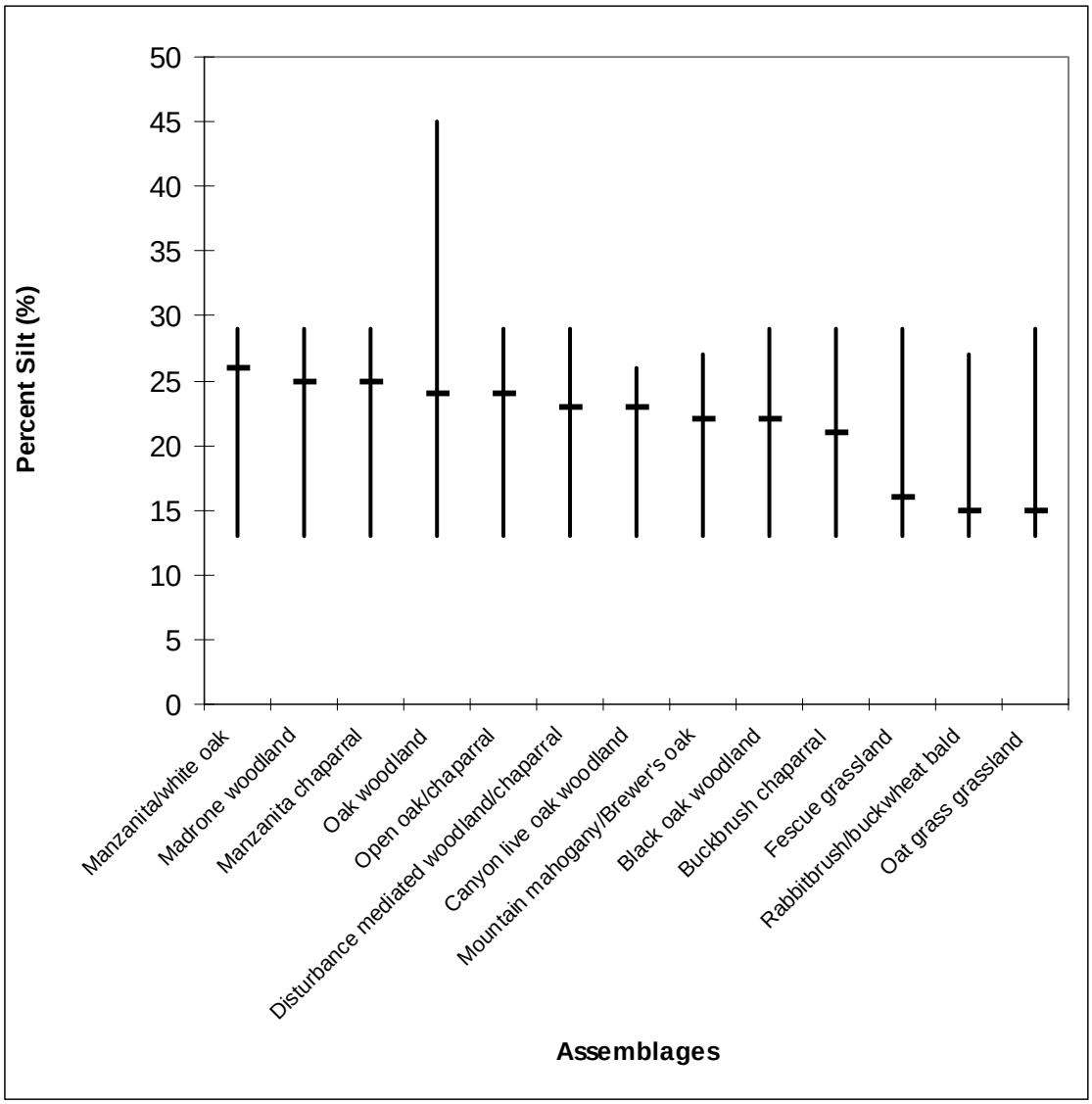


Figure 13. Total Sand Ranges. Ranges of total sand for assemblages sorted by mean.

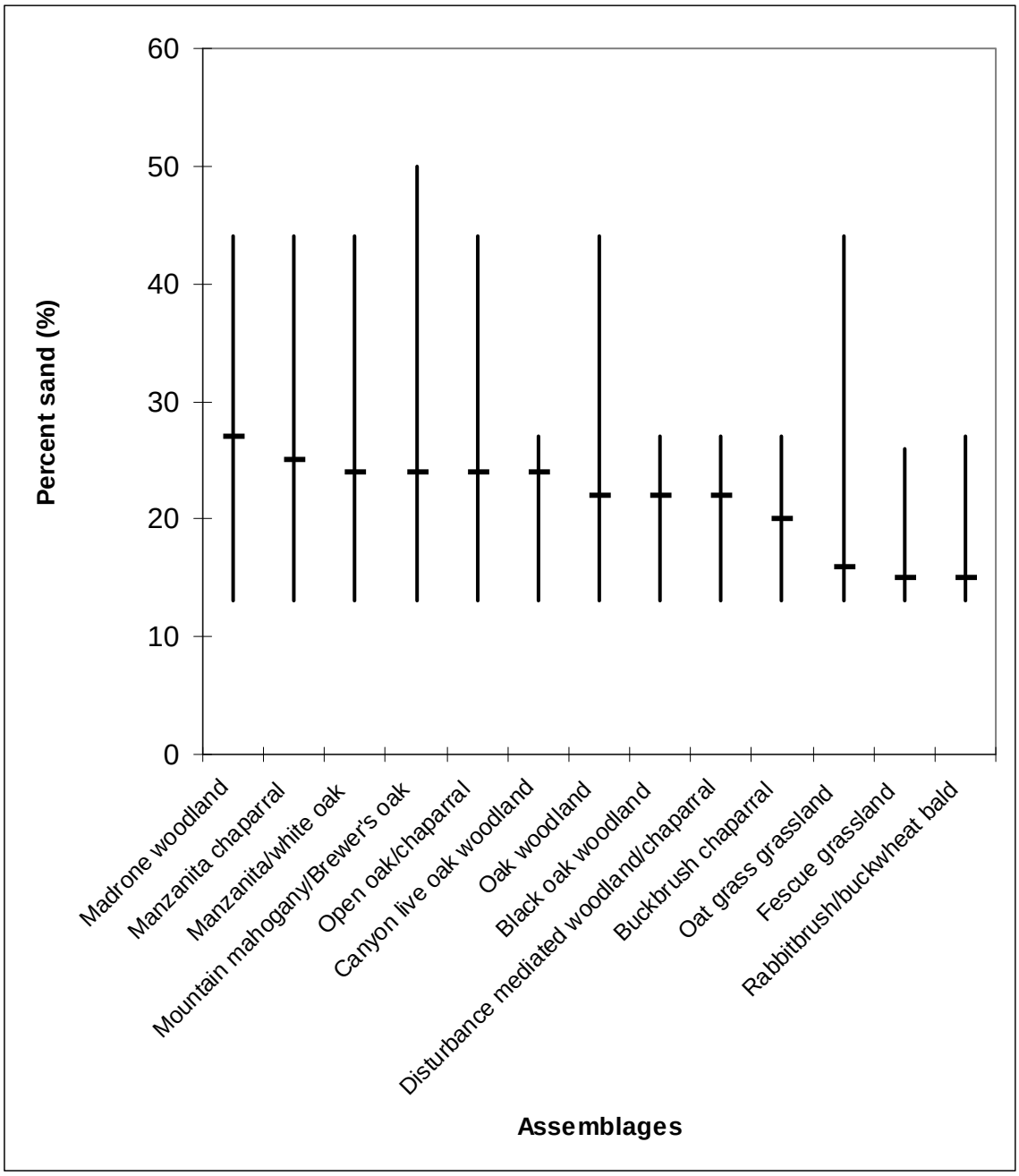
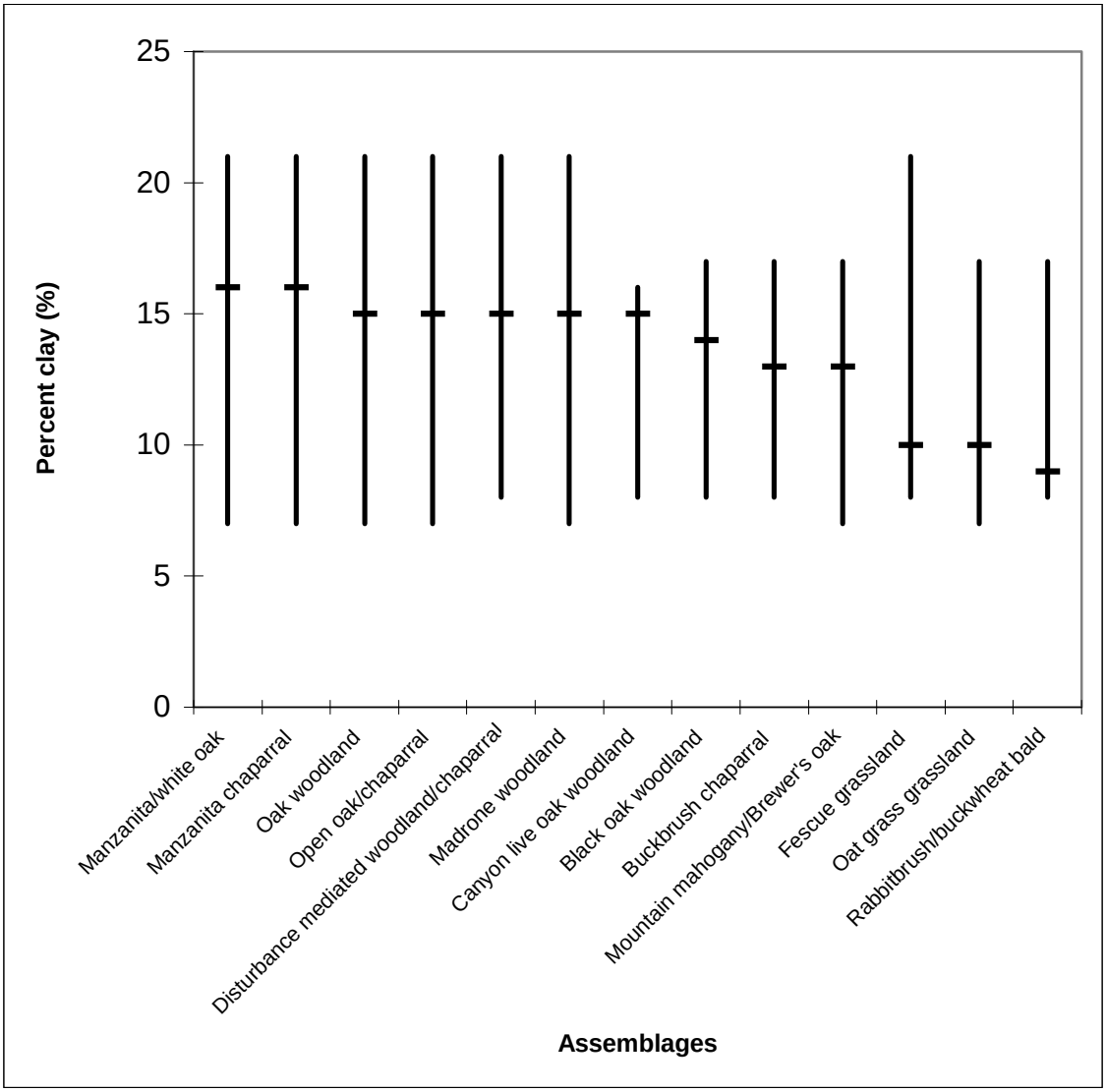


Figure 14. Total Clay Ranges. Ranges of total clay for assemblages sorted by mean.



Heat load was directly related to axis 1 and had no relationship to axis 2 (Figure 4 and Table 4). The correlation of heat load with plant distribution along axis 1 was quite weak, however, with an r^2 of 0.055. Although assemblages overlap there does appear to be differential placement of assemblages along axis 1 (Figure 4). Summary statistics for heat load do not reflect exactly the same pattern as the ordination diagram for the assemblages

likely due to the existence of outliers (Table 15). Heat load does, however, emulate their averages in elevation (a temperature surrogate). Differences between placement along axis 1 and rank order of summary statistics are a likely confirmation that some other variable explains a portion of axis 1. Overall there appears to be a trend of open canopy and/or xeric assemblages at one end of axis 1 and closed canopy mesic assemblages at the other end.

Disturbance

While it is difficult to quantify the influence of the categorical disturbance variables on vegetation patterning, the quantitative variables of fire interval maximum and years since last wildfire were weakly correlated with ordination axis 1 (Figure 4 and Table 4). Summary statistics for plant associations in relation to years since a fire showed that the fescue grassland, manzanita/white oak, oak woodland, mountain mahogany/Brewer's oak, and manzanita chaparral assemblages have all averaged approximately 90 years since a fire, which is longer than the other groups (Table 16). Associations with less time since a fire were the buckbrush, rabbit brush/buckwheat bald, disturbance mediated woodland/chaparral, and canyon live oak assemblages. The longest average fire intervals were in the manzanita/white oak, oak woodland, open oak/chaparral, and manzanita chaparral assemblages (Table 17). The shortest fire interval means were found in canyon live oak woodland, black oak woodland, fescue grassland, and oat grass grassland assemblages.

Assemblages with high heat loads typically experienced fewer mean years since a fire and lower mean fire interval maximums. Within the grassland and shrubland physiognomic groups the assemblages with the highest average heat loads had the shortest amount of time since a fire (Tables 15 and 16). This also was true for the woodland physiognomic group with the exception of the black oak woodland association. This trend is not clear for the disturbance mediated woodland/chaparral and manzanita/white oak associations.

The effect of fuels reduction treatments was difficult to quantify, as they are categorical variables. The methodology of using random points to obtain environmental and disturbance variable values in GIS was used to identify treatment types within the assemblages. With the exception of a few anomalies, likely due to mapping errors, results portray what would be expected based on current management practices for each respective assemblage. Scarification treatments were most associated with chaparral assemblages. The slash treatment occurred most often in the woodland/shrubland assemblages, but was also used in woodland assemblages. Mechanical mastication was applied mostly to the disturbance mediated woodland/chaparral and madrone woodland assemblages. Fire treatments were associated with most of the assemblages. Broadcast burns tended to be most associated with grasslands and underburn treatments were most commonly found in the woodland/shrubland assemblages. The comparison between associations and treatments was summarized by percentage of points that were classified as a specific treatment type within each association (Table 18).

DISCUSSION

Multivariate analysis identifies conditions to which grassland, shrubland and woodland vegetation are differentially adapted and distributed. Ordination results show that some assemblages are quite discrete such as the mountain mahogany/Brewer's oak assemblage, especially when examined by physiognomic group. Other assemblages overlap considerably in ordination space such as the disturbance mediated woodland/chaparral assemblage. Some assemblages are likely transitional states between other assemblages (Whittaker 1960), which may indicate disturbance-induced multiple stable states if more than one assemblage exists in similar environmental conditions (Huebner and Vankat 2003). Assemblages also vary in the range of habitat conditions they occupy. The black oak and canyon live oak assemblages typically exist in a narrow range of conditions along individual gradients. Conversely, the oak woodland assemblage is more general in its habitat requirements (Figures 6 – 14).

Moisture and soil variables were most important in the distribution of vegetation. These results agree with studies of similar vegetation types in other parts of the world, which found elevation/moisture and soil characteristics to be important (e.g. Vogitatkis et al. 2003, Corney et al. 2004). A study of oak woodlands in southwest Oregon found precipitation to be most important (Riegel et al. 1992), while a similar study within the region found soil variables to be most influential to assemblage distributions (Erickson 2002). Studies of chaparral vegetation in California have found soil moisture and solar

radiation to be most associated with shrub abundance (Meentemeyer et al. 2001). Disturbance appeared to have only a minor effect on plant assemblage distribution.

This study augmented past studies in the region by considering grasslands, shrublands, and woodlands and by studying a wider range of predictor variables including environmental and disturbance variables. While the findings of this study simply reflect correlation and not causation, the use of environmental scalars and variables related closely with natural history characteristics (e.g. water and nutrient availability) provide a basis for further experimental studies to gain a mechanistic understanding of specific requirements of these plants and associated assemblages.

Species composition was most highly correlated with elevation. However, as it is a proxy for moisture, temperature, and soil attributes (Urban et al. 2002) it is often difficult to interpret the possible mechanisms for the effect of elevation on current vegetation pattern. This study's inclusion of soil variables in addition to moisture and heat accumulation scalars (e.g. evapotranspiration and heat load) enabled interpretation of the underlying reasons for the importance of elevation. Ordination results regressed against environmental factors (Figure 4) indicate that within this data set elevation is principally a surrogate for moisture and to a lesser degree soils.

The importance of the elevational gradient to distribution seems especially pertinent in light of global climate change. If scenarios of altitudinal shifts occur certain high altitude habitats would likely diminish, while others would be lost altogether (Halpin 1997). These shifts could take place in the study area as regional predictions foresee temperatures increasing and summers becoming longer (Jones 2005). Precipitation is

expected to increase, however, much of the increase is forecasted to occur in the spring (CIG 2007). These climatic trends could cause changes in the distribution of plant assemblages. For example, within the fescue grassland assemblage were rare native grass dominated grasslands, which are only found at the highest elevations. These grasslands could be especially important for rare animal taxa such as the Mardon skipper (*Polites mardon*), which is known to prefer fescue-dominated grasslands (Black and Vaughan 2005). Similarly, within the mountain mahogany/Brewer's oak assemblage were nearly homogeneous Saskatoon serviceberry (*Amelanchier alnifolia*) stands, again only at the highest elevations. These relatively rare stand types could potentially be extirpated from the watershed or diminished in extent if regional climate change trends continue. Conversely, assemblages that inhabit low and mid-altitude ranges and are well adapted to long periods of high temperatures and little precipitation could expand in distribution.

As elevation is related to moisture, assemblages were distributed in similar ways in respect to elevation, summer evapotranspiration, and annual precipitation. Nevertheless different responses to these individual moisture related variables did exist. For example, the rank order of the canyon live oak, black oak, and oak woodland assemblages along the summer evapotranspiration gradient in respect to the other assemblages was higher than their respective rank order along the elevation gradient (Figures 8 and 6). This is likely a function of varied amounts of sunlight and/or different edaphic conditions on their associated sites.

Soil characteristics including upper soil horizon depth, pH, cation exchange capacity, and soil texture (sand, silt, clay) were found to have a strong correlation to plant

distribution (Table 4). These characteristics seemed most influential in segregating grasslands from shrublands and woodlands. The phenomenon of soil catena appears to partially explain this separation of vegetation types. Grassland assemblages typically occupy ridge top or upper slope positions that experience both colluvial and eluvial processes. The downhill movement of soil, clay particles, nutrients, and water all produce conditions which large woody plants have difficulty tolerating.

Results of upper soil horizon depth (Figure 9) initially seemed paradoxical as grassland assemblages had the deepest upper soil horizon depth and assemblages with relatively high tree cover had the shallowest upper horizon depths. The plausible explanation is that while soils associated with grasslands have deeper upper soil horizons the overall soil depth may be shallower and less developed. Vogiatzakis et al. (2003) in a study of Mediterranean vegetation found that both soil depth and soil formation/development were important to vegetation distribution with high mountain areas having shallow, rocky, immature soils.

Grasslands tended to occur on soils with low pH (Figure 10). These results are similar to findings from other localities. Corney et al. (2004) in a study of British woodlands found that upland communities occupied acid soils, while lowland woodland forests were found on base-rich soils. Low pH soils in that study were associated with relatively open, nutrient poor environments (Corney et al. 2004). Low pH soils can cause the soil to become more acidic over time through acidification. This can limit nutrient availability, stunt root development, and reduce a plants ability to tolerate drought (Ashman and Puri 2002). Cation exchange capacities were also considerably lower in the grassland

physiognomic group (Figure 11). Soils with low cation exchange capacities typically have low clay content and organic material, low buffering capacities to maintain an even pH, and limited nutrient availability (Ashman and Puri 2002).

Further evidence that grassland associations typically inhabit areas of undeveloped, rocky soils was found in the soil textural summary statistics (Figures 12, 13, and 14) and regression results (Figure 4). Figure 4 depicts the separation in ordination space of grasslands from the other plant assemblages along the soil textural gradient (Figure 4). The mountain mahogany/Brewer's oak and buckbrush assemblages also appear to be more closely related to grassland assemblages along this gradient. Grassland assemblage soils appear to have a considerable coarse fragment component as all three textural separates have relatively low average percentages. Summary statistics for soil texture suggest that the mountain mahogany/Brewer's oak assemblage's distribution on the gradient is mostly related to low clay content (Figure 14), while like the grasslands, buckbrush appears to be driven by the proportion of coarse fragments. The association of rocky soils to grasslands is consistent with the author's hypothesis that the zero values associated with these rocky soils lowered pH averages in the results. The presence of a considerable rock component and typically sandy loam soils produce fast draining soils that do not contain significant quantities of available water, especially during the summer. This makes these sites unsuitable to many plants. However, most grasses and forbs in the Applegate watershed cycle through their growth and reproductive cycles when moisture is available in the spring and early summer. This allows these herbaceous plants to inhabit and colonize water and nutrient limited sites. The low pH, low nutrient,

low organic material, fast draining, rocky soils of grassland sites appear unable to support more than low amounts of woody species. This low canopy cover condition provides ample sunlight, which facilitates high species richness of herbaceous plants.

Soils appear to have less effect on the segregation of shrubland and woodland assemblages from each other (Figure 4). The separation of these assemblages in ordination space appears to occur primarily along axis 1, which is not well explained. The axis does appear to transition from open canopy associations on one end to closed canopy associations on the other. A successional trajectory could be the reason for the transition from grassland to shrubland to woodland along axis1. This could also explain the high degree of community overlap in certain habitats. The variables most correlated with this axis are heat load (aspect and slope) and years since a wildfire, although they have low coefficient of determination values (r^2).

Associations with manzanita and white oak as dominants tended to have some of the highest average years since a fire and the longest mean fire intervals. Buckbrush and the rabbitbrush/buckwheat bald assemblage are associated with recent fire. This may be due to higher quantities of fine fuels in these assemblages. Trends in the fire data should be viewed with caution, however, as the fire history data is relatively brief (110 years) and may contain inaccuracies. Fire suppression may further complicate the situation.

Investigations in ordination space of the stands from the disturbance mediated woodland/chaparral assemblage produced some interesting trends. With the exception of one unrepresentative stand, all stands in this assemblage had either experienced wildfire or fuels reduction treatments. These stands have disturbance in common, but pretreatment

compositions vary, resulting in a widely dispersed assemblage in ordination space. This assemblage had stands with similar species composition to grassland, open oak/chaparral, buckbrush chaparral, and manzanita/white oak assemblages. Typically the stands with recent fire were similar in species composition to grassland associations. The modification of plant assemblages by disturbance appears to have a homogenizing effect on species composition and abundance. This is likely due to decreases in abundance of woody species, which allows increased growth of herbaceous plants.

A regression of individual species against ordination scores corroborated findings from the assemblage ordinations and predictor variable regression. Natural history characteristic trends emerged for the species most correlated to the ordination axes. Factors responsible for the distribution of assemblages and species along axis 1 are still unexplained. However, species distributions in ordination space confirm that the axis varies by canopy cover. The axis transitions from open canopy species associated with grassland and buckbrush chaparral assemblages (buckbrush and annual exotic grasses) to species that produce or inhabit areas of higher canopy (Oregon white oak and native bunchgrasses) (Figure 5). While correlations are low, environmental factors indicate a shift along the axis from shallow nutrient and water limited soils with high heatload and more frequent fires to more productive soils with lower heatload and less occurrence of fire (Table 4). Species most correlated to axis 2 reflect distributional differences related to elevation and moisture (Table 5). High elevation shrubs (rabbitbrush and mountain mahogany) are found at one end of axis 2 and lower elevation shrub and tree species occupy the other portion of the axis (manzanita and madrone) (Figure 5). While the

higher elevation habitats receive more moisture than most of the other grassland, shrubland, and woodland sites, they most likely have low tree abundance due to soil conditions. The species correlated to axis 3 confirm that the axis is most explained by differences in moisture (Table 5). Mesic tree species (Douglas-fir and California black oak) occupy one end of axis 3, while xeric species (buckbrush) are found at the other end of the axis (Figure 5).

Tests for spatial autocorrelation found distance between points and species composition to be positively correlated and statistically significant. Nevertheless, environmental and disturbance variables were found to be more correlated to species composition. These results suggest that while the chosen predictor variables explain much of the variability in species composition, spatial influences have an effect. Biotic processes such as dispersal, competition and facilitation (e.g. mycorrhizal fungi) and abiotic processes such as fluxes of energy and nutrients from adjacent communities (Polis et al. 2004) all could contribute to the distribution of species.

CONCLUSIONS

Grassland, shrubland, and woodland vegetation patterns in the Applegate Valley of southwest Oregon appear to be determined by the complex interplay of topographic, edaphic, and climatic variables in addition to site history. Moisture (elevation, summer evapotranspiration, and annual precipitation) and soils (pH, upper soil horizon depth, silt, and clay) variables were the most important determinants of vegetation distribution. These variables are related to the varying availability of water and nutrients among different habitats. Disturbance and spatial autocorrelation also appear to have some influence on vegetation distribution. Wildfire was not found to be an important factor influencing distribution, but this could be due to deficiencies in the fire history data or lack of recent fires. The implementation of fuels reduction treatments and the occurrence of wildfire have resulted in an entire assemblage defined by disturbance. This assemblage was the most dispersed in ordination space and hence species composition.

Complementary analysis produced important insights into vegetation pattern as it allowed data investigation within discrete and continuous response paradigms. Findings in respect to elevation, soils, and disturbance corroborate, quantify, and augment information from prior observations of grassland, shrubland, and woodland vegetation in southwest Oregon (Hosten 2006). Results of this study provide a more detailed knowledge of the factors responsible for the distribution of these vegetation types. This benchmark assessment should aid in conservation of the unique vegetation components

identified, understanding the diversity and relative abundance of assemblages, monitoring change over time, and the mapping of assemblages.

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APPENDIX A

DETAILED METHODS SECTION

Data were collected from 426 stands over the summers of 2004 and 2005. A relevé style survey approach was used in which the surveyor collected data while walking through a stand (a relatively homogenous area of vegetation). The author avoided taking data at the margins of the stand to avoid edge effects. Visual estimations of percent cover were collected for tree, shrub, overstory interspace, grass and herbaceous components both as groups and as individual species for each stand. High resolution color aerial photos were used to assess tree and shrub cover for the stand as a whole to aid in making the overall survey more objective. Visual estimates were initially calibrated using estimation aids found in the U.S. Department of Agriculture (USDA) Forest Service Field Inventory and Analysis manual (USDA 2002). Vegetation layering may cause shrub and tree cover totals to be over 100%. Herbaceous cover totals were always under 100% as there is interspace cover counted in that vegetation layer (e.g. total forb 30% + total grass 30% + interspace within herbaceous layer 40% = 100%). Unidentifiable species were collected as voucher specimens with a unique name. In addition, structural class data were collected for the dominant oak species and shrub species in each stand, including the form of the oaks if present (i.e. single or multi-stemmed). This included diameter at breast height (dbh) classes for the dominant oaks and height/life stage classes for the dominant shrub species. Ocular estimates of substrate cover were also taken including:

rock, exposed soil, litter (e.g. leaves, previous seasons herbaceous), and downed woody material (DWM). Evidence of fuel treatments, fires or erosion; presence of conifer snags; presence of wildlife observed either by sight, sound or scat; and any other notes that I felt were pertinent were also collected. Stands were digitized into a GIS and given a unique name denoting watershed and stand number (e.g. LICK01 = Lick Gulch stand 1). Photos were taken at a representative point or points within each stand. These points were marked with a Garmin GPS and given a name corresponding to the stand (LICK01A). If possible easily recognizable landscape features were included in the photos to make them repeatable. Fuel loading estimates were made for each stand using the Ottmar photo series (Ottmar et al. 2004). This method uses a photo to represent plot data on fuel loading denoted in tons/acre of live and dead fuels. Plants considered to be noxious weeds were also marked with a GPS and identified. Spatial data were collected and used in the field with ArcPad software on a handheld computer and later transferred to and organized in ArcGIS 9.2 (ESRI 2006). Stand data were collected in the field using a hand held computer with Excel and then organized into a stand by species matrix for statistical analysis. Plant species abundance and separately stand structural characteristics and other stand data were organized into a stand by species matrix in a format useable by PC ORD 4.0 (McCune and Mefford 1999). Any data that were not originally numerical were assigned a numeric code. Plant species names were standardized according to the USDA plants data base (USDA 2006). Data were also summarized in plant functional groups based on whether the species were native or exotic, plant form (tree, shrub, grass, forb) and life form (annual or perennial).

APPENDIX B

PREDICTOR VARIABLE SUMMARY STATISTICS

Table 6. Elevation Sorted by Median for the Assemblages

	Elevation (m)				
Assemblage	mean	median	mode	min	max
Fescue grassland	1315	1416	1432	628	1658
Rabbitbrush/buckwheat bald	1135	1151	1178	719	1530
Mountain mahogany/Brewer's oak	1140	1145	1223	703	1676
Black oak woodland	1099	1088	1050	890	1411
Canyon live oak woodland	1107	1085.5	1003	922	1322
Oat grass grassland	1014	1043	1105	590	1329
Disturbance mediated woodland/chaparral	801	835	959	413	1122
Manzanita chaparral	788	829	973	509	1048
Buckbrush chaparral	840	813	1086	508	1257
Madrone woodland	797	812	650	517	1152
Oak woodland	756	781	820	425	1168
Open oak/chaparral	768	761	624	487	1247
Manzanita/white oak	727	720	632	458	1055

Table 7. Annual Precipitation Sorted by Median for the Assemblages

	Annual Precipitation Daymet (mm)				
Assemblage	mean	median	mode	min	max
Canyon live oak woodland	1105.9	1095.4	1001	994.8	1274.7
Fescue grassland	1007.1	1028.5	1073.4	819.4	1091.8
Rabbitbrush/buckwheat bald	1016.5	1004.5	972.7	823.6	1270.6
Black oak woodland	978.5	990.7	#N/A	906	1017.7
Mountain mahogany/Brewer's oak	957.9	958.5	977.3	812	1091.7
Oat grass grassland	932.6	935	933.5	795.5	1047.3
Manzanita chaparral	894.7	902.9	913.5	777.2	999.9
Madrone woodland	892.4	883.9	982.6	731	1012.1
Disturbance mediated woodland/chaparral	869.8	863.1	933.1	745.3	1006.4
Oak woodland	879.2	860	836.7	734.1	1107.3
Buckbrush chaparral	891.2	853.7	878.8	729.2	1146.5
Open oak/chaparral	860.6	846.8	871.4	733.3	1164
Manzanita/white oak	842.6	840.5	917.9	734.3	953.5

Table 8. Summer Evapotranspiration Sorted by Median for the Assemblages

	Summer Evapotranspiration (mm)				
Assemblage	mean	median	mode	min	max
Fescue grassland	120.7	123.1	123.5	83.4	136.8
Canyon live oak woodland	124.1	120.4	116.2	112.2	140.3
Black oak woodland	117.1	116.4	#N/A	102.5	129
Rabbitbrush/buckwheat bald	116.6	115.9	101.1	92.3	139.4
Mountain mahogany/Brewer's oak	113.7	114.2	103.7	91.3	132.6
Oat grass grassland	109.4	112.7	106.6	86	137.3
Oak woodland	98.1	98	98	72.3	125.8
Disturbance mediated woodland/chaparral	97.4	97.8	94.5	72.9	120.2
Madrone woodland	98.9	97	113.5	83	135.1
Buckbrush chaparral	100.7	96.5	101.6	79.7	130.1
Manzanita chaparral	101.3	95.1	112.4	86.8	124.1
Open oak/chaparral	96.6	94.3	99.6	81	136.7
Manzanita/white oak	93.3	91.7	109.9	79	121.3

Table 9. Upper Soil Horizon Depth Sorted by Mean for the Assemblages

	Upper Soil Horizon Depth (cm)				
Assemblage	mean	median	mode	min	max
Fescue grassland	77	85	85	36	85
Buckbrush chaparral	58	40	85	36	85
Rabbitbrush/buckwheat bald	77	85	85	36	85
Manzanita/white oak	42	40	40	28	85
Oak woodland	50	40	36	28	89
Oat grass grassland	76	85	85	28	85
Mountain mahogany/Brewer's oak	50	36	36	28	85
Open oak/chaparral	44	40	36	18	85
Black oak woodland	52	36	36	36	85
Disturbance mediated woodland/chaparral	50	40	40	36	85
Madrone woodland	39	36	36	28	85
Manzanita chaparral	42	40	40	28	85
Canyon live oak woodland	45	36	36	36	85

Table 10. pH Sorted by Mean for the Assemblages

	pH				
Assemblage	mean	median	mode	min	max
Manzanita/white oak	4.4	5	5	2	5
Manzanita chaparral	4.4	4	5	2	5
Madrone woodland	4.2	4	4	2	5
Oak woodland	3.9	4	4	2	6
Open oak/chaparral	3.9	4	4	2	5
Disturbance mediated woodland/chaparral	3.9	4	4	2	5
Canyon live oak woodland	3.7	4	4	2	4
Buckbrush chaparral	3.5	4	2	2	5
Mountain mahogany/Brewer's oak	3.5	4	4	2	5
Black oak woodland	3.5	4	4	2	5
Fescue grassland	2.4	2	2	2	4
Rabbitbrush/buckwheat bald	2.4	2	2	2	5
Oat grass grassland	2.4	2	2	2	5

Table 11. Cation Exchange Capacity Sorted by Mean for the Assemblages

	CEC (milliequivalents per 100 grams)				
Assemblage	mean	median	mode	min	max
Canyon live oak woodland	14.1	16	16	5	16
Madrone woodland	12.5	10	10	5	16
Mountain mahogany/Brewer's oak	12.3	16	16	5	16
Black oak woodland	11.9	16	16	5	16
Open oak/chaparral	11.7	10	10	5	16
Manzanita/white oak	11.3	10	10	5	16
Manzanita chaparral	10.9	10	10	5	16
Oak woodland	10.8	10	10	5	16
Disturbance mediated woodland/chaparral	10.2	10	10	5	16
Buckbrush chaparral	9.4	10	5	5	16
Oat grass grassland	6.8	5	5	5	16
Rabbitbrush/buckwheat bald	6.6	5	5	5	16
Fescue grassland	6.5	5	5	5	16

Table 12. Percent Silt Sorted by Mean for the Assemblages

	Total silt (%)				
Assemblage	mean	median	mode	min	max
Manzanita/white oak	26	27	27	13	29
Madrone woodland	25	26	27	13	29
Manzanita chaparral	25	27	27	13	29
Oak woodland	24	26	27	13	45
Open oak/chaparral	24	26	26	13	29
Disturbance mediated woodland/chaparral	23	27	27	13	29
Canyon live oak woodland	23	25	25	13	26
Mountain mahogany/Brewer's oak	22	25	26	13	27
Black oak woodland	22	25	25	13	29
Buckbrush chaparral	21	25	13	13	29
Fescue grassland	16	13	13	13	29
Rabbitbrush/buckwheat bald	15	13	13	13	27
Oat grass grassland	15	13	13	13	29

Table 13. Percent Sand Sorted by Mean for the Assemblages

	Total Sand (%)				
Assemblage	mean	median	mode	min	max
Madrone woodland	27	26	24	13	44
Manzanita chaparral	25	24	24	13	44
Manzanita/white oak	24	24	24	13	44
Mountain mahogany/Brewer's oak	24	26	26	13	50
Open oak/chaparral	24	24	26	13	44
Canyon live oak woodland	24	27	27	13	27
Oak woodland	22	24	24	13	44
Black oak woodland	22	26	27	13	27
Disturbance mediated woodland/chaparral	22	24	24	13	27
Buckbrush chaparral	20	24	13	13	27
Oat grass grassland	16	13	13	13	44
Fescue grassland	15	13	13	13	26
Rabbitbrush/buckwheat bald	15	13	13	13	27

Table 14. Percent Clay Sorted by Mean for the Assemblages

	Total Clay (%)				
Assemblage	mean	median	mode	min	max
Manzanita/white oak	16	17	17	7	21
Manzanita chaparral	16	17	17	7	21
Oak woodland	15	16	17	7	21
Open oak/chaparral	15	16	16	7	21
Disturbance mediated woodland/chaparral	15	17	17	8	21
Madrone woodland	15	16	16	7	21
Canyon live oak woodland	15	16	16	8	16
Black oak woodland	14	16	16	8	17
Buckbrush chaparral	13	16	8	8	17
Mountain mahogany/Brewer's oak	13	16	16	7	17
Fescue grassland	10	8	8	8	21
Oat grass grassland	10	8	8	7	17
Rabbitbrush/buckwheat bald	9	8	8	8	17

Table. 15 Heat Load Sorted by Median for the Assemblages

	Heat load (unitless index)				
Assemblage	mean	median	mode	min	max
Canyon live oak woodland	9335	9744	9744	6406	9997
Rabbitbrush/buckwheat bald	9381	9625.5	9910	6231	9997
Buckbrush chaparral	9280	9619	9658	6005	9999
Oat grass grassland	9342	9550	8954	7065	9999
Manzanita chaparral	9393	9497	9211	7919	9998
Manzanita/white oak	9047	9442.5	7141	5496	9998
Fescue grassland	9129	9281	9136	7275	9994
Disturbance mediated woodland/chaparral	8956	9254	9975	5531	9986
Madrone woodland	8660	9248	9595	4768	10000
Open oak/chaparral	8652	9180	9897	4426	9993
Oak woodland	8853	9125	9834	5209	9999
Mountain mahogany/Brewer's oak	8577	9027	5461	5085	9998
Black oak woodland	8836	8941	#N/A	6163	9985

Table 16. Years Since Last Wildfire Sorted by Mean for the Assemblages

	Years since last wildfire				
Assemblage	mean	median	mode	min	max
Manzanita/white oak	92	110	110	3	110
Mountain mahogany/Brewer's oak	92	110	110	3	110
Fescue grassland	91	91	91	69	110
Manzanita chaparral	89	105	110	3	110
Oak woodland	88	105	110	3	110
Open oak/chaparral	85	91	110	3	110
Black oak woodland	85	69	69	69	110
Oat grass grassland	82	69	69	33	110
Madrone woodland	81	69	110	3	110
Canyon live oak woodland	76	69	69	18	110
Rabbitbrush/buckwheat bald	74	69	69	3	110
Buckbrush chaparral	71	69	69	3	110
Disturbance mediated woodland/chaparral	71	69	110	3	110

Table 17. Fire Interval Maximum Sorted by Mean for the Assemblages

	Fire interval maximum (years)				
Assemblage	mean	median	mode	min	max
Manzanita chaparral	102	100	100	12	110
Manzanita/white oak	101	110	110	4	110
Oak woodland	101	100	110	4	110
Open oak/chaparral	101	100	100	22	110
Rabbitbrush/buckwheat bald	100	100	100	66	110
Mountain mahogany/Brewer's oak	96	110	110	22	110
Buckbrush chaparral	95	100	100	22	110
Disturbance mediated woodland/chaparral	91	100	110	12	110
Madrone woodland	90	100	110	4	110
Oat grass grassland	88	100	100	22	110
Fescue grassland	85	100	100	4	110
Black oak woodland	85	100	100	22	110
Canyon live oak woodland	74	100	100	22	110

Table 18. Percentage of GIS Sample Points Within Fuel Treatment Categories by Assemblage

Association name	Scari-fication	Slash and handpile	Slash	Mechanical mastication	Under-burn	Broadcast burn
Fescue grassland	0	0	0	1	0	5
Buckbrush chaparral	13	3	3	5	2	2
Rabbitbrush/ buckwheat bald	0	8	8	0	4	26
Manzanita/ white oak	1	28	28	8	12	1
Oak woodland	0	12	12	7	6	12
Oat grass grassland	0	1	1	0	18	19
Mountain mahogany/ Brewer's oak	0	2	2	0	24	4
Open oak/ chaparral	3	5	5	6	18	0
Black oak woodland	0	6	6	0	9	3
Disturbance mediated woodland/ chaparral	2	18	18	28	29	11
Madrone woodland	0	9	9	25	3	13
Manzanita chaparral	10	8	8	0	0	3
Canyon live oak woodland	0	13	13	0	0	0

APPENDIX C

PLANT SPECIES LIST

Plant species list for all known species within the data set. Species records are sorted alphabetically by scientific name. Names and codes follow the USDA PLANTS database (USDA 2006).

Scientific name	Common name	Family	Species code
Abies concolor X *grandis*	white fir	Pinaceae	ABCO
Achnatherum lemmonii	Lemmon's needlegrass	Poaceae	ACLE8
Acer macrophyllum	bigleaf maple	Aceraceae	ACMA3
Achillea millefolium	common yarrow	Asteraceae	ACMI2
Agoseris sp.	agoseris	Asteraceae	AGOSE
Agoseris retrorsa	spearleaf agoseris	Asteraceae	AGRE
Agropyron sp.	sterile wheatgrass	Poaceae	AGROPST
Ailanthus altissima	tree of heaven	Simaroubaceae	AIAL
Aira caryophyllea	silver hairgrass	Poaceae	AICA
Allium sp.	onion	Liliaceae	ALLIU
Alopecurus pratensis	meadow foxtail	Poaceae	ALPR3
Amelanchier alnifolia	Saskatoon serviceberry	Rosaceae	AMAL2
Amsinckia menziesii var. *intermedia*	common fiddleneck	Boraginaceae	AMIN3
Amsinckia menziesii	Menzies' fiddleneck	Boraginaceae	AMME
Anthriscus caucalis	burr chervil	Apiaceae	ANCA14
Apocynum androsaemifolium	spreading dogbane	Apocynaceae	APAN2
Arabis sp.	rockcress	Brassicaceae	ARABI2
Arbutus menziesii	Pacific madrone	Ericaceae	ARME
Arctostaphylos patula	greenleaf manzanita	Ericaceae	ARPA6
Arctostaphylos viscida	sticky whiteleaf manzanita	Ericaceae	ARVI4
Astragalus accidens	Rogue River milkvetch	Fabaceae	ASAC
Aspidotis densa	Indian's dream	Pteridaceae	ASDE6
Aster radulinus	roughleaf aster	Asteraceae	ASRA
Asclepias speciosa	showy milkweed	Asclepiadaceae	ASSP
Aster sp.	aster	Asteraceae	ASTER

Astragalus sp.	milkvetch	Fabaceae	ASTRA
Athyrium filix-femina	common ladyfern	Dryopteridaceae	ATFI
Avena fatua	wild oat	Poaceae	AVFA
Balsamorhiza deltoidea	deltoid balsamroot	Asteraceae	BADE2
Berberis nervosa	Cascade barberry	Berberidaceae	BENE2
Berberis piperiana	hollyleaved barberry	Berberidaceae	BEPI2
Boschniakia sp.	groundcone	Orobanchaceae	BOSCH
Bromus carinatus	California brome	Poaceae	BRCA5
Bromus diandrus	ripgut brome	Poaceae	BRDI3
Brodiaea elegans	harvest brodiaea	Liliaceae	BREL
Bromus hordeaceus	soft brome	Poaceae	BRHO2
Bromus laevipes	Chinook brome	Poaceae	BRLA3
Briza maxima	big quakinggrass	Poaceae	BRMA
Bromus sp.	brome	Poaceae	BROMU
Bromus rubens	red brome	Poaceae	BRRU2
Bromus tectorum	cheatgrass	Poaceae	BRTE
Calocedrus decurrens	incense cedar	Cupressaceae	CADE27
Calystegia sp.	false bindweed	Convolvulaceae	CALYS
Calystegia occidentalis	chaparral false bindweed	Convolvulaceae	CAOC6
Castilleja pruinosa	frosted Indian paintbrush	Scrophulariaceae	CAPR14
Campanula prenanthoides	California harebell	Campanulaceae	CAPR15
Carex sp.	sedge	Cyperaceae	CAREX
Castilleja sp.	indian paintbrush	Scrophulariaceae	CASTI2
Castilleja tenuis	hairy Indian paintbrush	Scrophulariaceae	CATE26
Calochortus tolmiei	Tolmie star-tulip	Liliaceae	CATO
Cercocarpus betuloides	birchleaf mountain mahogany	Roaceae	CEBE3
Ceanothus cuneatus	buckbrush	Rhamnaceae	CECU
Ceanothus integerrimus	deerbrush	Rhamnaceae	CEIN3
Centaurea melitensis	Maltese star-thistle	Asteraceae	CEME2
Centaurea solstitialis	yellow star-thistle	Asteraceae	CESO3
Cheilanthes sp.	lipfern	Pteridaceae	CHEIL
Chondrilla juncea	hogbite	Asteraceae	CHJU
Chlorogalum sp.	soapplant	Liliaceae	CHLOR3
Chimaphila umbellata	pipsissewa	Pyrolaceae	CHUM
Cirsium cymosum	peregrine thistle	Asteraceae	CICY
Cirsium occidentale	cobwebby thistle	Asteraceae	CIOC
Cirsium sp.	thistle	Asteraceae	CIRSI
Cirsium vulgare	bull thistle	Asteraceae	CIVU
Clarkia sp.	clarkia	Onagraceae	CLARK

Clinopodium douglasii	yerba buena	Lamiaceae	CLDO2
Claytonia perfoliata	miner's lettuce	Portulacaceae	CLPE
Clarkia purpurea	winecup clarkia	Onagraceae	CLPU
Clarkia purpurea	winecup clarkia	Onagraceae	CLPU2
Clarkia rhomboidea	diamond clarkia	Onagraceae	CLRH
Corylus cornuta	beaked hazelnut	Betulaceae	COCO6
Collomia grandiflora	grand collomia	Polemoniaceae	COGR4
Collinsia linearis	narrowleaf blue eyed Mary	Scrophulariaceae	COLI
Collinsia sp.	blue eyed Mary	Scrophulariaceae	COLLI
Crepis sp.	hawksbeard	Asteraceae	CREPI
Cryptantha sp.	cryptantha	Boraginaceae	CRYPT
Cryptogramma sp.	rockbrake	Pteridaceae	CRYPT3
Cynosurus echinatus	bristly dogstail grass	Poaceae	CYEC
Cynoglossum grande	Pacific hound's tongue	Boraginaceae	CYGR
Daucus carota	Queen Anne's lace	Apiaceae	DACA6
Dactylis glomerata	orchardgrass	Poaceae	DAGL
Delphinium sp.	larkspur	Ranunculaceae	DELPH
Dichelostemma congestum	ookow	Liliaceae	DICO19
Dipsacus sp.	teasel	Dipsacaceae	DIPSA
Dodecatheon hendersonii	mosquito bills	Primulaceae	DOHE
Dryopteris carthusiana	spinulose woodfern	Dryopteridaceae	DRCA11
Elymus elymoides	squirreltail	Poaceae	ELEL5
Elymus glaucus	blue wildrye	Poaceae	ELGL
Epilobium brachycarpum	tall annual willowherb	Onagraceae	EPBR3
Epilobium sp.	willowherb	Onagraceae	EPILO
Eriodictyon californicum	California yerba santa	Hydrophyllaceae	ERCA6
Eriogonum compositum	arrowleaf buckwheat	Polygonaceae	ERCO12
Erigeron inornatus	California rayless fleabane	Asteraceae	ERIN2
Eriogonum sp.	buckwheat	Polygonaceae	ERIOG
Eriophyllum lanatum	common woolly sunflower	Asteraceae	ERLA6
Ericameria nauseosa	rubber rabbitbrush	Asteraceae	ERNA10
Eriogonum nudum	naked buckwheat	Polygonaceae	ERNU3
Eriogonum nudum var. *westonii*	Weston's buckwheat	Polygonaceae	ERNUW
Eriogonum umbellatum	sulphur-flower buckwheat	Polygonaceae	ERUM
Eriogonum vimineum	wickerstem buckwheat	Polygonaceae	ERVI5

Eschscholzia californica	California poppy	Papaveraceae	ESCA2
Festuca californica	California fescue	Poaceae	FECA
Festuca occidentalis	western fescue	Poaceae	FEOC
Festuca roemeri	Roemer's fescue	Poaceae	FERO
Fraxinus latifolia	Oregon ash	Oleaceae	FRLA
Fragaria vesca	woodland strawberry	Rosaceae	FRVE
Galium ambiguum	Yolla Bolly bedstraw	Rubiaceae	GAAM2
Galium aparine	stickywilly	Rubiaceae	GAAP2
Garrya fremontii	bearbrush	Garryaceae	GAFR
Galium sp.	bedstraw	Rubiaceae	GALIU
Gastridium phleoides	nit grass	Poaceae	GAPH2
Geranium robertianum	Robert geranium	Geraniaceae	GERO
Gilia capitata	bluehead gilia	Polemoniaceae	GICA5
Gnaphalium sp.	cudweed	Asteraceae	GNAPH
Hieracium albiflorum	white hawkweed	Asteraceae	HIAL2
Hieracium sp.	hawkweed	Asteraceae	HIERA
Holodiscus discolor	oceanspray	Rosaceae	HODI
Horkelia sp.	horkelia	Rosaceae	HORKE
Hypericum perforatum	common St. Johnswort	Clusiaceae	HYPE
Iris chrysophylla	yellowleaf iris	Iridaceae	IRCH
Juniperus occidentalis	western juniper	Cupressaceae	JUOC
Koeleria macrantha	prairie Junegrass	Poaceae	KOMA
Lactuca serriola	prickly lettuce	Asteraceae	LASE
Lithophragma affine	San Francisco woodland-star	Saxifragaceae	LIAF
Ligusticum grayi	Gray's licorice-root	Apiaceae	LIGR
Lilium washingtonianum	Washington lily	Liliaceae	LIWA
Lomatium californicum	California lomatium	Apiaceae	LOCA3
Lonicera ciliosa	orange honeysuckle	Caprifoliaceae	LOCI3
Lomatium dissectum	fernleaf biscuitroot	Apiaceae	LODI
Lonicera hispidula	pink honeysuckle	Caprifoliaceae	LOHI2
Lolium sp.	ryegrass	Poaceae	LOLIU
Lomatium macrocarpum	bigseed biscuitroot	Apiaceae	LOMA3
Lomatium sp.	desertparsley	Apiaceae	LOMAT
Lotus micranthus	desert deervetch	Fabaceae	LOMI
Lonicera sp.	honeysuckle	Caprifoliaceae	LONIC
Lomatium nudicaule	barestem biscuitroot	Apiaceae	LONU2
Lomatium tracyi	Tracy's desertparsley	Apiaceae	LOTR

Lupinus albifrons	silver lupine	Fabaceae	LUAL4
Lupinus sp.	lupine	Fabaceae	LUPIN
Luzula sp.	woodrush	Juncaceae	LUZUL
Madia citriodora	lemonscented madia	Asteraceae	MACI1
Madia citriodora	lemonscented madia	Asteraceae	MACI2
Madia sp.	tarweed	Asteraceae	MADIA
Madia elegans	common madia	Asteraceae	MAEL
Madia exigua	small tarweed	Asteraceae	MAEX
Madia gracilis	grassy tarweed	Asteraceae	MAGR
Madia gracilis	grassy tarweed	Asteraceae	MAGR3
Madia madioides	woodland madia	Asteraceae	MAMA
Madia minima	oppositeleaved tarweed	Asteraceae	MAMI
Marah oreganus	coastal manroot	Cucurbitaceae	MAOR3
Maianthemum racemosum ssp. *Amplexicaule*	feathery false lily of the	Liliaceae	MARAA
Melica harfordii	Harford's oniongrass	Poaceae	MEHA2
Micropus californicus	q tips	Asteraceae	MICA
Monardella odoratissima	mountain monardella	Lamiaceae	MOOD
Navarretia sp.	pincushionplant	Polemoniaceae	NAVAR
Oemleria cerasiformis	Indian plum	Rosaceae	OECE
Osmorhiza depauperata	bluntseed sweetroot	Apiaceae	OSDE
Osmorhiza sp.	sweetroot	Apiaceae	OSMOR
Pedicularis densiflora	Indian warrior	Scrophulariaceae	PEDE
Penstemon deustus	scabland penstemon	Scrophulariaceae	PEDE4
Pentagramma triangularis	goldback fern	Pteridaceae	PETRT
Phleum alpinum	alpine timothy	Poaceae	PHAL2
Phacelia corymbosa	serpentine phacelia	Hydrophyllaceae	PHCO3
Phacelia heterophylla	varileaf phacelia	Hydrophyllaceae	PHHE2
Philadelphus lewisii	Lewis' mock orange	Hydrangeaceae	PHLE4
Pinus lambertiana	sugar pine	Pinaceae	PILA
Pinus ponderosa	ponderosa pine	Pinaceae	PIPO
Piperia unalascensis	slender-spire orchid	Orchidaceae	PIUN3
Plagiobothrys sp.	popcornflower	Boraginaceae	PLAGI
Plectritis ciliosa	longspur seablush	Valerianaceae	PLCI
Plectritis congesta	shortspur seablush	Valerianaceae	PLCO4
Plectritis macrocera	longhorn plectritis	Valerianaceae	PLMA4
Poa brachyglossa	Sandberg bluegrass	Poaceae	POBR
Poa bulbosa	bulbous bluegrass	Poaceae	POBU
Potentilla glandulosa	sticky cinquefoil	Rosaceae	POGL9
Polystichum munitum	western swordfern	Dryopteridaceae	POMU

Poa secunda	Sandberg bluegrass	Poaceae	POSE
Prunus emarginata	bitter cherry	Rosaceae	PREM
Prunus subcordata	Klamath plum	Rosaceae	PRSU2
Prunus sp.	plum	Rosaceae	PRUNU
Prunus virginiana	chokecherry	Rosaceae	PRVI
Pseudognaphalium canescens	Wright's cudweed	Asteraceae	PSCAM
Pseudotsuga menziesii	Douglas-fir	Pinaceae	PSME
Pseudoroegneria spicata	bluebunch wheatgrass	Poaceae	PSSP6
Pteridium aquilinum	western brackenfern	Dennstaedtiaceae	PTAQ
Quercus chrysolepis	canyon live oak	Fagaceae	QUCH2
Quercus garryana	Oregon white oak	Fagaceae	QUGA4
Quercus garryana var. *breweri*	Oregon white oak	Fagaceae	QUGAB
Quercus kelloggii	California black oak	Fagaceae	QUKE
Ranunculus occidentalis	western buttercup	Ranunculaceae	RAOC
Rosa canina	dog rose	Rosaceae	ROCA3
Rosa gymnocarpa	dwarf rose	Rosaceae	ROGY
Rubus armeniacus	Himalayan blackberry	Rosaceae	RUAR9
Sanicula crassicaulis	Pacific blacksnakeroot	Apiaceae	SACR2
Salix sp.	willow	Salicaceae	SALIX
Sambucus mexicana	common elderberry	Caprifoliaceae	SAME
Sambucus mexicana	common elderberry	Caprifoliaceae	SAME5
Sedum sp.	stonecrop	Crassulaceae	SEDUM
Senecio integerrimus	lambstongue ragwort	Asteraceae	SEIN2
Silene hookeri	Hooker's silene	Caryophyllaceae	SIHO
Sidalcea malviflora	dwarf checkerbloom	Malvaceae	SIMA2
Silene vulgaris	maidenstears	Caryophyllaceae	SIVU
Solidago californica	California goldenrod	Asteraceae	SOCA5
Solidago sp.	goldenrod	Asteraceae	SOLID
Stachys	hedgenettle	Lamiaceae	STACH
Stephanomeria virgata	rod wirelettuce	Asteraceae	STVI2
Symphoricarpos albus	common snowberry	Caprifoliaceae	SYAL
Taeniatherum caput-medusae	medusahead	Poaceae	TACA8
Thinopyrum intermedium	intermediate wheatgrass	Poaceae	THIN6
Torilis arvensis	spreading hedgeparsley	Apiaceae	TOAR
Toxicodendron diversilobum	Pacific poison oak	Anacardiaceae	TODI
Tragopogon dubius	yellow salsify	Asteraceae	TRDU

Triteleia hendersonii	Henderson's triteleia	Liliaceae	TRHE
Trichostema lanceolatum	vinegarweed	Lamiaceae	TRLA4
Vaccinium sp.	blueberry	Ericaceae	VACCI
Verbena lasiostachys	western vervain	Verbenaceae	VELA
Verbascum thapsus	common mullein	Scrophulariaceae	VETH
Vicia americana	American vetch	Fabaceae	VIAM
Vitis californica	California wild grape	Vitaceae	VICA5
Vicia sp.	vetch	Fabaceae	VICIA
Vinca major	bigleaf periwinkle	Apocynaceae	VIMA
Vulpia microstachys	small fescue	Poaceae	VUMI
Vulpia myuros	rat-tail fescue	Poaceae	VUMY
Zigadenus exaltatus	giant deathcamas	Liliaceae	ZIEX
Zigadenus sp.	deathcamas	Liliaceae	ZIGAD
Zigadenus venenosus	meadow deathcamas	Liliaceae	ZIVE