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Vegetation of the Gregory-Long Canyon Watershed

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Abstract:

Five vegetation units were found within our study area in the Gregory-Long Canyon watershed. On the south-facing slope, a *Pinus ponderosa-Schizachyrium scoparium* community type was identified. The north-facing slope was represented by a *Pseudotsuga menziesii-Jamesia americana* community type. In the valley bottom, three community types were identified, including a *Prunus americana-Salix bebbiana* community type, an *Elymus canadensis-Dactylis glomerata* community type, and a *Corylus cornuta-Betula fontinalis* community type. Six shared exotic taxa were present between the *Pinus-ponderosa-Schizachyrum scoparium* community type and riparian stands.

Analysis of forest stand structure indicated that *Pinus ponderosa* dominates south-facing slopes where it was the only tree species found in our samples. *Pseudotsuga menziesii* dominates north-facing slopes with over twice the density of *Pinus ponderosa* (1050.8 trees/ha for *Pseudotsuga menziesii* as opposed to 473.8 trees/ha for *Pinus ponderosa)* but only 8.7% greater mean basal area (12.6 m^2/ha for *Pseudotsuga menziesii* and 11.5 m^2/ha for *Pinus ponderosa*). Analysis of the *Corylus cornuta-Betula fontinalis* valley bottom syntaxon revealed that *Populus tremuloides* is probably a climax species for that community type, whereas *Pseudotsuga menziesii* is probably a successional species.

Direct ordinations revealed that there is a positive relationship between soil moisture and the cover value of tall shrubs (r^2=0.625 p=0.003). *Pinus ponderosa* was found to increase in cover with increasing southern exposure of the plot, while *Pseudotsuga menziesii* had the greatest cover values on sites that face north. *Mahonia repens* was found to correlate positively with drier site conditions, north-facing slopes, and acidic soils.

The first axis of the DCA (eigenvalue = 0.652) described a moisture gradient from subxeric to mesic. This axis also separated all five of the plant communities defined from the sorted table analysis from each other with the exception of plot nine, which was grouped with the *Pseudotsuga menziesii-Jamesia americana* syntaxon.

Introduction

Vegetation analysis was conducted within the Gregory -Long Canyon watershed in Boulder Mountain Parks on the east slope of the Front Range in Boulder, Colorado. The valley is approximately 4 km long and rises 1000 m from the base of Gregory Canyon to the head of Long Canyon. This study was restricted to Gregory Canyon and the lower portion of Long Canyon in order to avoid disturbance to *Betula papyifera,* which is rare within Colorado and is disjunct from its main distribution which is hundreds of miles to the north (Hogan, 1993). This canyon generally runs in an eastward direction with steep slopes on both the north and south sides. This variation in topography has been shown to have a large effect on the vegetation in the region (Marr, 1961; Peet, 1981). The primary purpose of this study was to identify plant community types, differential taxa among plant communities, and important trends of species distribution between sample stands as related to site environmental conditions. In addition, we hypothesized that as elevation increases, the north and south-facing slopes become more similar in their species composition. Three types of analysis were conducted as part of this study: classification, ordination to relate the vegetation to environmental gradients, and forest stand structure.

Previous research on montane Rocky Mountain forests have shown that the forests are dominated by two forest types, depending on topography. In the monograph *Ecosystems of the East Slope of the Front Range, Colorado*; Marr (1961) describes stand complexes typical of the Front Range at different elevational zones. One stand (A-3) Marr describes is the *Pinus ponderosa* stand complex, which is one of the major stand types of the lower montane forest climax region at an elevation between 6000 and 7700 feet. Marr characterized this stand as a mosaic of different-sized patches of *Pinus ponderosa* and herbs (Marr, 1961). Peet (1981) notes that grasses and composites are particularly important in Ponderosa Pine woodlands. Peet also found that *Artemesia frigida* and *Muhlenbergia montana* respond more strongly to moisture related aspects than to temperature at around 2000 m, and that these two species are found only on dry, exposed sites.

Marr characterized his Douglas Fir- Ponderosa Pine stand (A-2) as being successional and stated that eventually *Pinus ponderosa will* become less abundant and the herb layer will thin out, giving rise to a DouglasFir topographic climax stand. Peet's (1981) foothills ravine forest is characterized by *Pseudotsuga menziesii* dominating the tree stratum with *Pinus ponderosa* also being present but not as the dominant species. Shrub cover in this forest is contributed by *Jamesia americana, Juniperus communis* and *Arctostaphylos ura-ursi.* A similar type is Baker's (1984) *Pseudotsuga menziesii-(Pinus ponderosa)/Jamesia americana-Physiocarpus monogynus* association. Peet (1981) found *Jamesia americana* to be confined largely to cool, north facing slopes around 2000 m

Materials and Methods

Plot selection and sampling

Eleven plots were established within Gregory Canyon: four plots on north-facing slopes, four plots on south-facing slopes, and three plots on the valley bottom (Figures 1-6). Plots were 15 m by 15 m and were subjectively located in areas of fairly homogeneous vegetation. The plot shape was varied on some riparian plots to insure that the entire plot was within the floodplain. In March 1996, the plots were sampled by listing all plant species present with an estimate of their percent cover. Portions of each species were collected, and 300 ml soil samples were collected at 10 cm below ground level. Due to the timing of the surveys (when most species were dormant and snow often covered the ground), it is likely that many species growing on the plots were not recorded. Nomenclature of plant species follows Weber (1995). At each plot, estimates were made of percent cover of nine growth forms, bare ground, rock, and water. Field estimates were also made of site moisture, slope, aspect, topographic position, exposure, site stability, moisture, animal disturbance, exposed rocks, and depth of O and A soil horizons (see Table 4 for descriptions of variables)

Laboratory analysis

Samples of each plant collected in the field were brought to the University of Colorado Herbarium for verification of taxonomy. The soil samples, which were frozen after collecting, were thawed and weighed with field moisture, dried at 110 degrees and reweighed to determine percent soil moisture, and ashed at 450 degrees and weighed to determine organic matter (Nelson and Sommers 1982). Gravimetric moisture and volumetric moisture were determined following methods outlined by Gardener (1986). Soils were also tested for bulk density, pH (McLean 1982) and color (Munsell Color 1994).

Classification

A sorted table analysis was accomplished following Mueller-Dombois and Ellenberg (1974). Differentiating species were determined based on rules set by Daniels (1982), which for our data set stated that a species had to be present in at least two plots within the syntaxa, while not being present in any other syntaxa. Exceptions were made for species with only a rare presence in other syntaxa. In addition, when it became clear that there were three different community types in the valley bottom, some community types consisted of only one plot. In these circumstances, species with high cover were selected as characteristic taxa.

Forest Structure

At each of the 15 m by 15 m plots; tree density, basal area, and frequency were determined for trees greater than two meters in height . Basal area was determined by calculating the cross-section of the trunks at breast height per hectare, density was the number of trees per hectare and frequency was the proportion of plots within each aspect contained each species (Mueller-Dombois and Ellenberg 1974).

Ordination

A variety of direct ordinations were performed in order to observe changes in the importance of individual species and of the various growth forms along directly measurable environmental gradients. Direct ordinations were limited by the fact that many species occurred in only one or two sites. Therefore, direct ordination data is presented only for species and growth forms found at many sites.

The vegetation data were also ordinated using detrended correspondence analysis (DCA) with a downweighting of the rare species using the program PC-ORD. The resulting ordination was related to the plant syntaxa defined in the sorted table analysis and Spearman rank correlations were calculated for the first two axes with all site variables measured.

Vegetation Mapping

The Gregory-Long Canyon watershed was delineated on an aerial photograph, and physiognomic classes that could be distinguished from the photo were marked on a mylar overlay. These map units were identified: closed forests, woodlands, shrublands, riparian forests, grassland, and bare rock. Each area on the overlay was shaded according to its physiognomic class. In addition, the site locations were marked along with roads and topographical lines. The relative area of each of the physiognomic types was determined by overlaying a fine-mesh graph paper over the completed map, and counting the squares within each physiognomic type. This map was prepared from a single perspective aerial photograph and therefore artificially increases areas at the margins.

Results

Classification

Five vegetation units were defined through sorted table analysis (Table 1). On the south-facing slope, a *Pinus ponderosa-Schizachyrium scoparium* community type was identified (Figures 1,2,3). On the north-facing slopes, a *Pseudotsuga menziesii-Jamesia americana* community type was identified (Figure 4). In the valley bottom, three community types were identified, including a *Prunus americana-Salix bebbiana* community type, an *Elymus canadensis-Dactylis glomerata* community type, and a *Corylus cornuta-Betula fontinalis* community type (Figure 5,6).

Differential taxa are listed for each community type in order of cover abundance. The differential taxa for the *Pinus ponderosa-Schizachyrium scoparium* plant community are: *Schizachyrium scoparium*, *Grindelia squarrosa*, *Artemisia frigida*, *Opuntia compressa*, *Muhlenbergia montanum*, *Andropogon gerardii*, *Chondrosum gracile*, *Yucca glauca*, *Astragalus* *spp*, *Pascopyrum smithii*, *Silene scouleri*, and *Erysimum capitatum*. Differential taxa for the *Pseudotsuga menziesii-Jamesia americana* plant community are *Jamesia americana*, *Allium textile*, and *Drymocallis fissa*. In the valley bottom, differential taxa for the *Prunus americana-Salix bebbiana* plant community are *Prunus americana and Salix bebbiana*.. In *Elymus canadensis-Dactylis glomerata* plant community, *Elymus canadensis*, *Dactylis glomerata*, and *Rhamnus cathartica* are differential taxa. Finally, the differential taxa for the *Corylus cornuta-Betula fontinalis* plant community are *Corylus cornuta*, *Betula fontinalis*, *Hippochaete hyemalis*, *Populus tremuloides*, and *Poa pratensis*. Two constant taxa were present within all eleven stands: *Mahonia repens* and *Pinus ponderosa*..

Six exotic taxa (as determined by Weber (1995)) were shared between the *Pinus ponderosa-Schizachyrum scoparium* community type and riparian community type stands, and were not present in the *Pseudotsuga menziesii-Jamesia americana* community type. The exotic species, listed in order of their cover abundance, are: *Phleum pratense, Bromopsis lanatipes, Alyssum minus, Verbascum thapsus, Bromus tectorum* and *Cichorium intybus*.

Forest Structure

On the south-facing slope, *Pinus ponderosa* is the only tree species present in our samples, with a frequency of 0.75 (Table 2). All south-facing plots except for plot six (which contained only saplings) contain *Pinus ponderosa.* On the north-facing slope, *Pinus ponderosa* and *Pseudotsuga menziesii* are both present in all of the plots sampled. *Pseudotsuga menziesii* (1050.8 trees/ha) has over twice the density of *Pinus ponderosa,*(473.8 trees/ha). Basal area, however, is higher for *Pseudotsuga menziesii* by 8.7% (basal area for *Pseudotsuga menziesii* is 12.6 m^2/ha, whereas basal area for Pinus *ponderosa* is 11.5 m^2/ha). In the valley bottom, four tree species are present: *Pinus ponderosa* (frequency of 0.75), *Pseudotsuga menziesii* (frequency of 0.66), *Populus tremuloides* and *Juniperus scopulorum* (each with a frequency of 0.5). In the *Corylus cornuta-Betula fontinalis* community type, the dominant tree species is *Populus tremuloides* with an average basal area of 10.5 m^2/ha and an average density of 621.6 trees/ha. Also present in the *Corylus cornuta-Betula fontinalis* community type are *Pseudotsuga menziesii*

(199.8 trees/ha, 3.3 m^2/ha) and *Pinus ponderosa* (66.7 trees/ha, 6.95 m^2/ha). The only tree species in plot five are *Pinus ponderosa* (88.9 trees/ha, 14.5 m^2/ha) and seedling *Pseudotsuga menziesii* (44.4 trees/ha). In plot nine, only *Pinus ponderosa* (44.4 trees/ha, 5.6 m^2/ha) and *Juniperus scopulorum* (44.4 trees/ha, negligible basal area) are present. Tree data are summarized in Table 2, and graphs of basal area, density, and frequency are in Figure 7.

Growth Forms

There were large differences in the percent cover of most of the different growth form types among the three aspects, but due to the low sample size, only a few of these differences can be considered significant (Table 3). There was a greater cover of trees on north-facing slopes than on south-facing slopes, more tall shrubs on the valley bottoms than on both of the other aspects, and fewer graminoids on the north-facing slope than on the other aspects.

Environmental Data

In the Gregory-Long Canyon watershed, the environmental variables are arranged in a complex manner based in large part on aspect (Table 4, Figure 8). Note that the scale of the values presented on the y-axis of figure 8 varies with the environmental variable being measured. Several of the measured soil characteristics do vary together, with pH, plasticity, grit, Munsell soil color, A horizon depth, and subjective soil moisture all having their maximal values on valley bottoms. O horizon depth, however, was greatest on south-facing slopes. In addition, the north-facing slopes and south-facing slopes are significantly steeper than the valley bottom slopes.

Ordination

The ordinations reveal that there is a significant positive relationship between soil moisture and the importance of tall shrubs (Figure 9). Linear regression analysis resulted in an $r^2=0.625$ ($p=0.0038$). At the same time there is no such relationship between moisture and coverage by trees (Figure 9) ($r^2=0.176$ and $p=0.605$). There appears to be a weak positive relationship between soil moisture and coverage by medium shrubs (Figure 10) ($r^2=0.20$ and $p=0.167$). Dwarf shrubs show a negative relationship with soil moisture ($r^2=.314$ and $p=0.047$) indicating that they have a higher percent coverage on dry sites than on wet sites (Figure 10). The direct ordinations for two of the most common species, *Pinus ponderosa* and *Pseudotsuga menziesii* , show correspondence with the aspect angle of the sample plot (Figures 11 and 12). *Pinus ponderosa* increases in cover with increasing southern exposure. In contrast, *Pseudotsuga menziesii* has its greatest cover on sites that face north. The other common species for which direct ordinations were carried out was *Mahonia repens* . This dwarf shrub shows the same correlation with drier sites that the other dwarf shrubs do. It also shows statistically insignificant correlations with north facing slopes and with acidic soils (figure 13 and figure 14). Although these ordinations are not statistically significant with our small sample size, the trends observed suggest a need for further investigation.

The first axis of the DCA (eigenvalue = .652) described a moisture gradient from subxeric to mesic and was positively correlated with grittiness of the soil, percent cover of tall shrubs, percent cover of open water, site moisture, gravimetric soil moisture, and volumetric soil moisture. The first axis of the DCA was negatively correlated with percent cover of cacti, rocks and lichens, and slope (Figure 15). This axis separated all five of the plant communities defined from the sorted table analysis from each other with the exception of plot nine, which was grouped with the *Pseudotsuga menziesii-Jamesia americana* community. The second axis (eigenvalue = .349) added very little extra information, except for the separation of plots seven and nine from each other. This axis was positively correlated with percent cover of trees and dwarf shrubs and negatively correlated with site exposure. The two axes together were sufficient to separate the five community types from each other. There were no significant correlations between either of the axes with elevation or any of the soil variables.

<u>Vegetation Mapping</u>

The majority of the Gregory-Long Canyon watershed is dominated by coniferous forests (Figure 16).. The closed forest and open woodland cover 49.8% and 45.9% of the watershed area respectively. Of less spatial importance are bare rock covering 2.6% of the area, grasslands covering 0.7%, Riparian zones covering 0.5%, Shrublands covering 0.2% of the area and roads and parking lots occupying 0.4% of the watershed surface.

Discussion

Classification

The sorted table (Table 1) illustrates the trends of species distribution between the sample stands. *Mahonia repens* and *Pinus ponderosa* occur in all stands, illustrating their broad ecological range. Their species cover abundance values, however, do differ among stands, with *Mahonia repens* coverage highest on north-facing slopes and *Pinus ponderosa* coverage highest on south-facing slopes.

The *Pinus ponderosa-Schizachyrium scoparium* plant community includes species that are typical of xeric tallgrass prairie, such as *Andropogon gerardii* and *Schizachyrium scoparium* ; and species typical of montane woodland (Baker 1984), such as *Opuntia compressa*, *Grindelia squarrosa*, *Yucca glauca*, and *Muhlenbergia montanum*. This may indicate that soil moisture is a controlling factor on the herbaceous understory of south-facing slopes.

The data suggest that a *Corylus cornuta-Betula fontinalis* plant community exists that may be unique to valley bottom stands in the Gregory-Long Canyon area. All differential taxa for this community type had a cover-abundance value ranging from 5% to 50%. In addition, all of the differential species except *Poa pratensis* are considered common along streams in the foothills of Colorado (Weber, 1976).

The other two valley bottom community types both had high cover abundance values for all their differential species, but there was no repetition of these community types in the sampling. This is a reflection of the low number of stands sampled in the valley bottoms. More samples are needed to represent the variety of communities that occupy the riparian habitats.

Most of the exotic species in the study were confined to either south-facing slopes or valley bottoms. North-facing slopes, which are intermediate on the moisture scale, had the fewest exotic species. This may be a result of the closed canopy of the forests on the north-facing slopes compared to the relatively more open vegetation on the other sites.

Our original hypothesis, which stated that as elevation increases, north and south-facing slopes become more similar in their species composition, was inconclusive. There were two similar taxa between north and south-facing slopes at lower elevations and three at higher elevations. The similarity of the percent cover of the species that were in common showed a 0.5 percent increase from low to high elevations. This change was not statistically significant because of the low number of similar taxa and the low percentage of change with an increase in elevation.

Forest Structure

South-facing slopes generally receive more sun than the north-facing slopes, which causes the water to evaporate more quickly. The trees are probably competing for water, rather than sun, on the south-facing slope, so they have a lower density. This allows the rooting system of each tree to extend further in search of water. On the north-facing slope and valley bottom, in contrast, water is not evaporated so readily, and the trees can crowd closer together. A side effect of the trees being able to grow more densely on the northern slope and valley bottom is that the mean basal area is lower for the valley bottom and the north-facing slope that it is on the southern slope.

The dry southern slope may also be more susceptible to fires than the northern slope or valley bottom. The thick bark of *Pinus ponderosa* protects mature individuals from fire, while *Pseudotsuga menziesii* has no such protection. The dominance of *Pinus ponderosa* on the southern aspect may be due to *Pseudotsuga menziesii* species being killed in fires while mature *Pinus ponderosa* species survive. The large mean basal area for *Pinus ponderosa* on the southern slope may be due to the fact that younger species of *Pinus ponderosa* were killed by fires.

The mean basal area of *Pinus ponderosa* on the northern slope is also large. Although the density of *Pseudotsuga menziesii* on the northern aspect is over twice that of *Pinus ponderosa*, the basal area of *Pseudotsuga menziesii* is only 8.7% greater than that of *Pinus ponderosa.* This may indicate that the *Pinus ponderosa* are older than *Pseudotsuga menziesii.* In Colorado's dry climate, *Pseudotsuga menziesii* prefers to germinate in the shade of other trees. The *Pseudotsuga menziesii* stands probably germinated when the *Pinus ponderosa* were large enough to provide shade. *Pinus ponderosa*, in contrast, does not germinate well in shade, explaining the shortage of young *Pinus ponderosa* on the shaded northern aspect.

Although plot 6 has no trees other than sapling *Pinus ponderosa*, this plot is still part of the woodland habitat. Although there were no large trees on the plot itself, trees grow along the edges (see Figure 3).

Peet (1981) states that *Populus tremuloides* can be found as a successional stand in both wet and dry habitats and can be found as a climax vegetation in poorly drained areas. Of our two plots which have *Populus tremuloides*, plot three appears to have older trees, with mean basal areas of 7.8, 5.6, and 20.3 m^2/ha respectively for *Pinus ponderosa, Pseudotsuga menziesii,* and *Populus tremuloides*. Plot twenty-one, in contrast, has mean basal areas of 6.1, 0.9, and 0.8 m^2/ha for *Pinus ponderosa, Pseudotsuga menziesii* and *Populus tremuloides*. Plot three has a higher density of *Populus tremuloides* (843.6 trees/ha, as opposed to 399.6 trees/ha for plot 21), while plot 21 has a higher density of *Pseudotsuga menziesii* (355.2 trees/ha as opposed to 44.4 trees/ha for plot 3). This suggests that in Gregory-Long Canyon, *Populus tremuloides* is an important part of the climax vegetation of the *Corylus cornuta-Betula fontinalis* syntaxon, while only a few individuals of *Pseudotsuga menziesii* survive to become part of the climax vegetation.

Growth Forms

The physiognomy of the three aspects was as different as the plant communities were. The south-facing slopes were dominated by graminoids with significant cover added by trees and lichens. The north-facing slopes had a very dense tree canopy, and an understory dominated by dwarf shrubs. The valley bottoms were co-dominated by tall shrubs and graminoids with significant cover added by trees, medium shrubs, and forbs.

Environmental Data

There are several environmental variables which we were not able to measure in the short period of time in which this study was conducted. These include variables which may have important roles in controlling vegetation distribution such as solar intensity, temperature, relative humidity and, potential evapotranspiration. However the variables which were measured do reveal some controlling factors. South facing slopes are steep and receive more direct sun which results drier soil, thus restricting water demanding species. The north-facing slopes are shaded for a greater proportion of both the day and the year, which provides an advantage for species that need more moisture and less sun. Valley bottoms receive water and nutrients from the surrounding steep slopes. These inputs result in more highly developed soil with a nearly permanent supply of water available to roots at depth. Therefore, the valley bottoms, although they represent a very small proportion of the total surface area of the Gregory-Long Canyon complex, contain a significant proportion of the biodiversity present in the watershed.

We only sampled three different elevations for each aspect and these elevation differences were not large. The lack of significant variation in elevation did not allow us to determine if the vegetation of north and south facing slopes is more similar at high elevation than at low elevation in the Gregory-Long Canyon complex. In order to address this hypothesis fully further research will need to be carried out with a larger sample size.

Ordination

The number of samples upon which our direct ordinations were performed was very small. This small sample size limits the conclusions which can be drawn from our study. Clearly the aspect angle of a slope has a very large impact on the survival of all the species living there. This is probably due to differences in incident solar radiation found on slopes with different aspects. The influence of solar radiation extends to soil moisture where it acts with soil composition to determine water availability to plants. The success of trees appears to not depend directly upon moisture in the upper layers of the soil. Because trees often have extensive rooting systems, soil moisture in the top 10 cm of the soil directly adjacent to a tree may not be an adequate indicator of water availability to a tree. For shrubs however, it can be seen that there is a competitive interaction taking place in which shrubs that receive enough water to grow tall dominate their environments, excluding smaller shrubs. As the water availability becomes the limiting factor, rather than competition, the smaller plants are able to persist and co-dominate their environments.

Information about the response of *Mahonia repens* to variation in pH leads one to believe that pH may be an important controlling factor in the distribution of other species.

The indirect ordination in general verified the groupings of the sorted table analysis and the dominance of site moisture as a factor controlling vegetation in the area. The dry end of the moisture gradient correlated with cacti, lichens, and bare rocks, while the moist end of the gradient correlated with tall shrubs, gritty soil, and several measures of moisture. For determination of the effect of elevation and soil on the hillslopes, many more plots would need to sampled.

Conclusions:

More sampling is needed to adequately describe the range of vegetation variability and environmental variability occurring in the three sampled habitats. Here are the conclusions drawn from the limited sampling that was done:

Classification

Five syntaxa were defined in our study area. On the south-facing slopes, a *Pinus ponderosa-Schizachyrium scoparium* community type was identified. The north-facing slope was represented by a *Pseudotsuga menziesii-Jamesia americana* syntaxon. In the valley bottom, three community types were identified, including a *Prunus americana-Salix bebbiana* community type, an *Elymus canadensis-Dactylis glomerata* community type, and a *Corylus cornuta-Betula fontinalis* community type. The *Corylus cornuta-Betula fontinalis* plant community may be unique to valley bottom stands in the Gregory-Long Canyon area.

Most of the exotic species in the study were confined to either south-facing slopes or valley bottoms. Six shared exotic taxa were present between the south-facing slopes and the valley bottoms: *Phleum pratense, Bromopsis lanatipes, Alyssum minus, Verbascum thapsus, Bromus tectorum* and *Cichorium intybus*.

Two constant taxa were present within all eleven stands: *Mahonia repens* and *Pinus ponderosa*.

Forest Structure

In our samples, *Pinus ponderosa* is the only tree species present on the south-facing slope. On the north-facing slope, *Pinus ponderosa* and *Pseudotsuga menziesii* are both present in all of the plots sampled. *Pseudotsuga menziesii* has over twice the density of *Pinus ponderosa* on north-facing slopes, but its basal area is higher than that of *Pinus ponderosa* by just 8.7%.

In *Corylus cornuta-Betula fontinalis* community type of the valley bottom, the density and mean basal area of *Populus tremuloides* and *Pinus ponderosa* were found to increase with increased age of the stand. The density of *Pseudotsuga menziesii* decreased with age of the stand, but its mean basal area increased.

Ordination

A positive correlation was found between soil moisture and the cover values for tall and medium shrubs, while a weak negative relationship was shown between soil moisture and dwarf shrubs. No relationship was found between the moisture gradient and coverage of trees.

Direct ordinations for *Pinus ponderosa* and *Pseudotsuga menziesii* show that *Pinus ponderosa* increases with increasing southern exposure of the plot while *Pseudotsuga menziesii* has its greatest cover on sites that face north. *Mahonia repens* shows the same correlation with drier sites that the other dwarf shrubs do; it also shows a correlation with north-facing slopes and with acidic soils.

The first axis of DCA corresponded with a moisture gradient from subxeric to mesic and was positively correlated with grittiness of the soil, percent cover of tall shrubs, percent cover of open water, site moisture, gravimetric soil moisture, and volumetric soil moisture. The first axis of DCA was negatively correlated with percent cover of cacti, rocks and lichens, and slope. This axis separated all five of the plant communities defined from the sorted table analysis with the exception of plot nine, which was grouped with the *Pseudotsuga menziesii-Jamesia americana* community. The second axis of DCA was positively correlated with percent cover of trees and dwarf shrubs and negatively correlated with site exposure.

Vegetation Mapping

The Gregory-Long Canyon complex is spatially dominated by a *Pseudotsuga menziesii-Pinus ponderosa* Closed Forest community covering 49.8% of the watershed surface area and a *Pinus ponderosa* Woodland community type covering 45.9% of the watershed area.

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Figure 1. Plot 2, south-facing slope. *Pinus ponderosa-Schizachyrium scoparium* Community type.

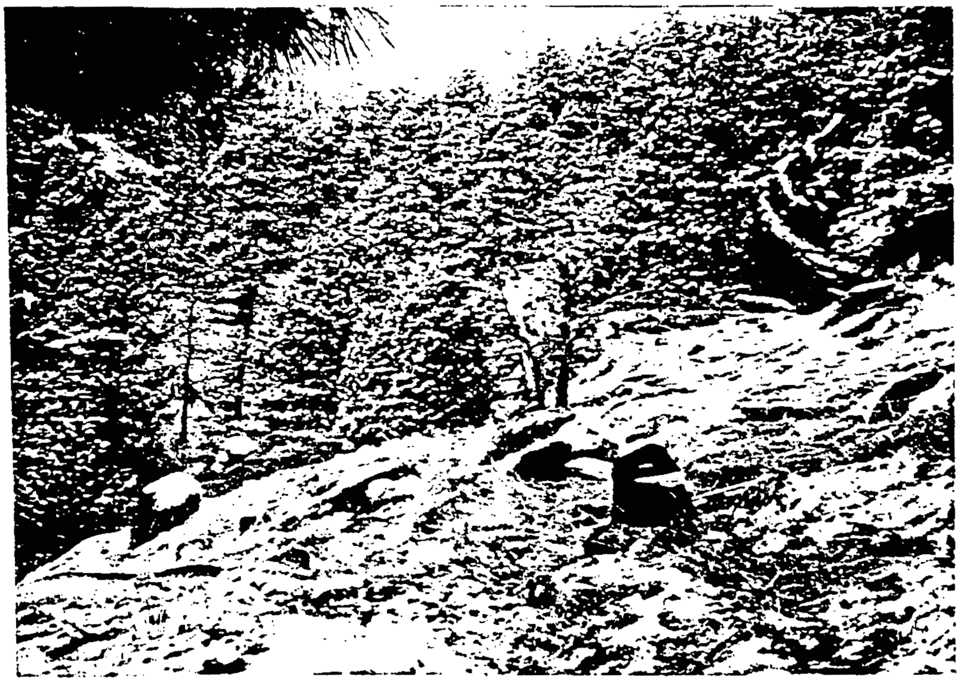


Figure 2. Plot 4, south-facing slope. *Pinus ponderosa-Schizachyrium scoparium* community type.

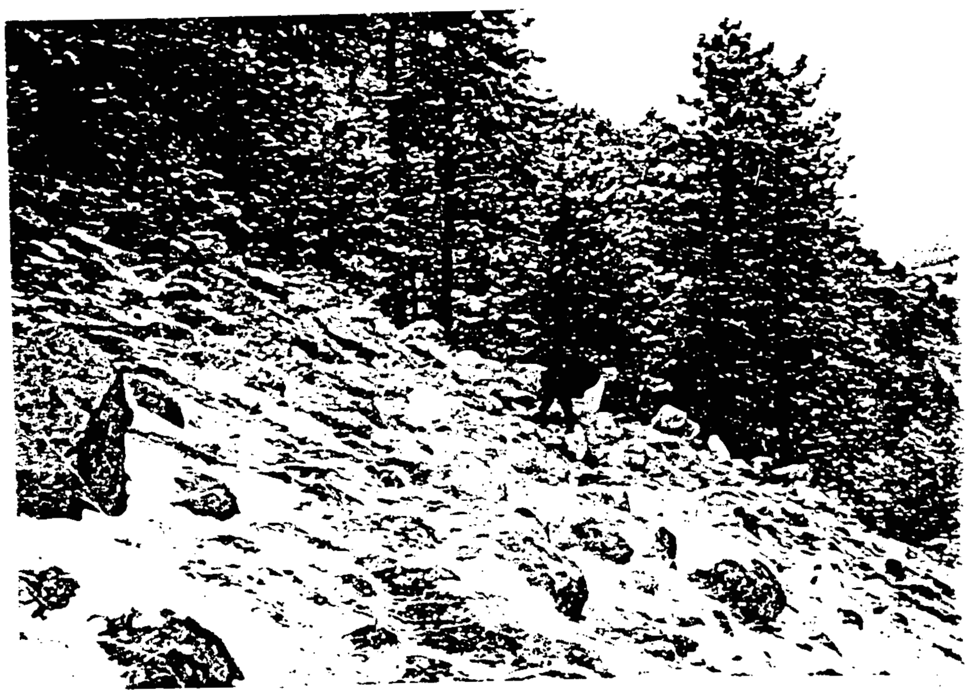


Figure 3. Plot 6, south-facing slope. *Pinus ponderosa-Schizachyrium scoparium* community type.

Figure 4. Plot 20, north-facing slope *Pseudotsuga menziesii-Jamesia americana* community type.

plot 20

Figure 5. Plot 3, valley bottom. *Corylus cornuta-Betula fontinalis* community type.

Figure 6. Plot 21, valley bottom. *Corylus cornuta-Betula fontinalis* community type.

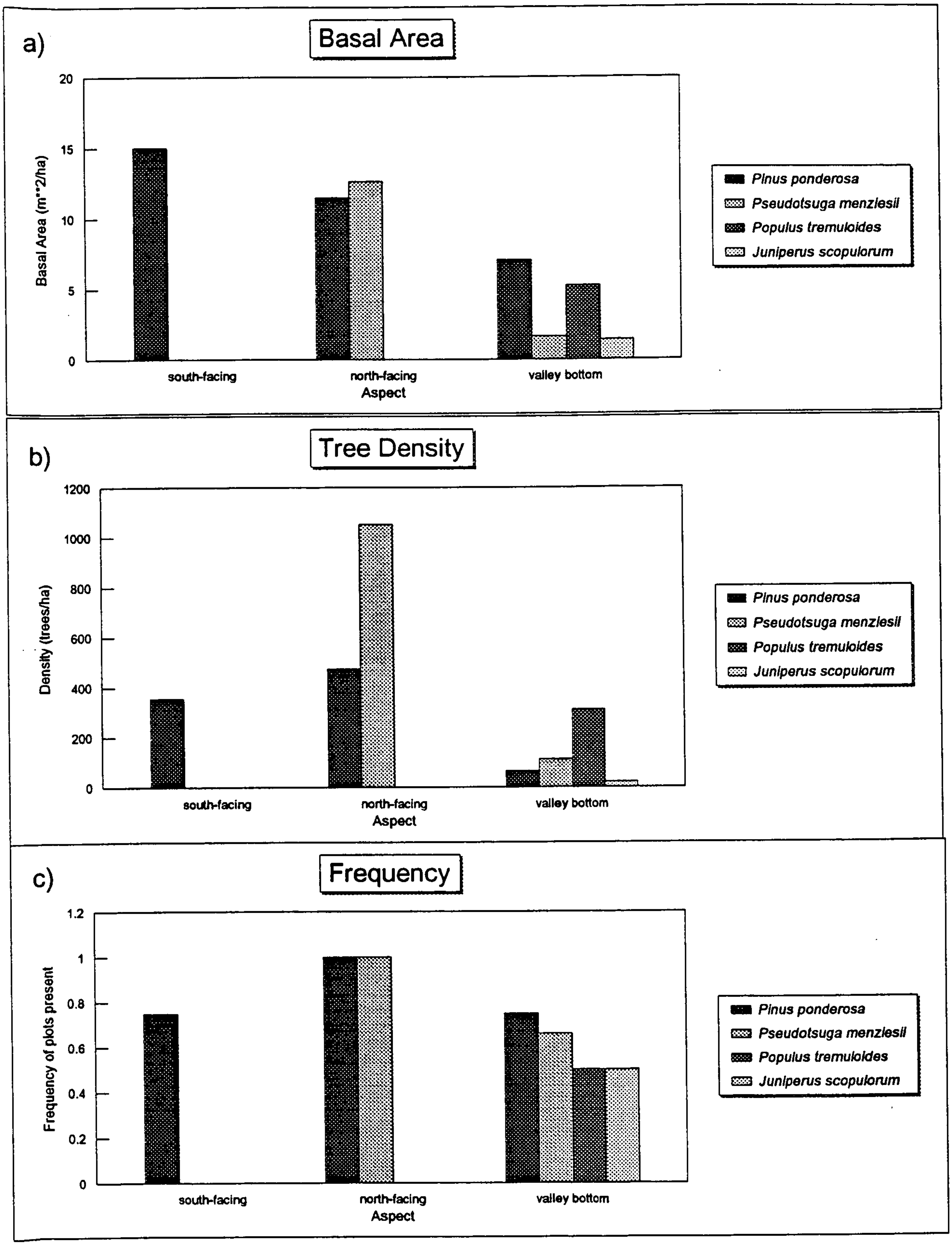


Figure 7 Forest structure data for trees sampled in 11 plots in Gregory Canyon. Fig. 7a shows the basal area per hectare Fig 7b the density of the trees per hectare, and 7c the frequency of each species in 15 m by 15m plots.

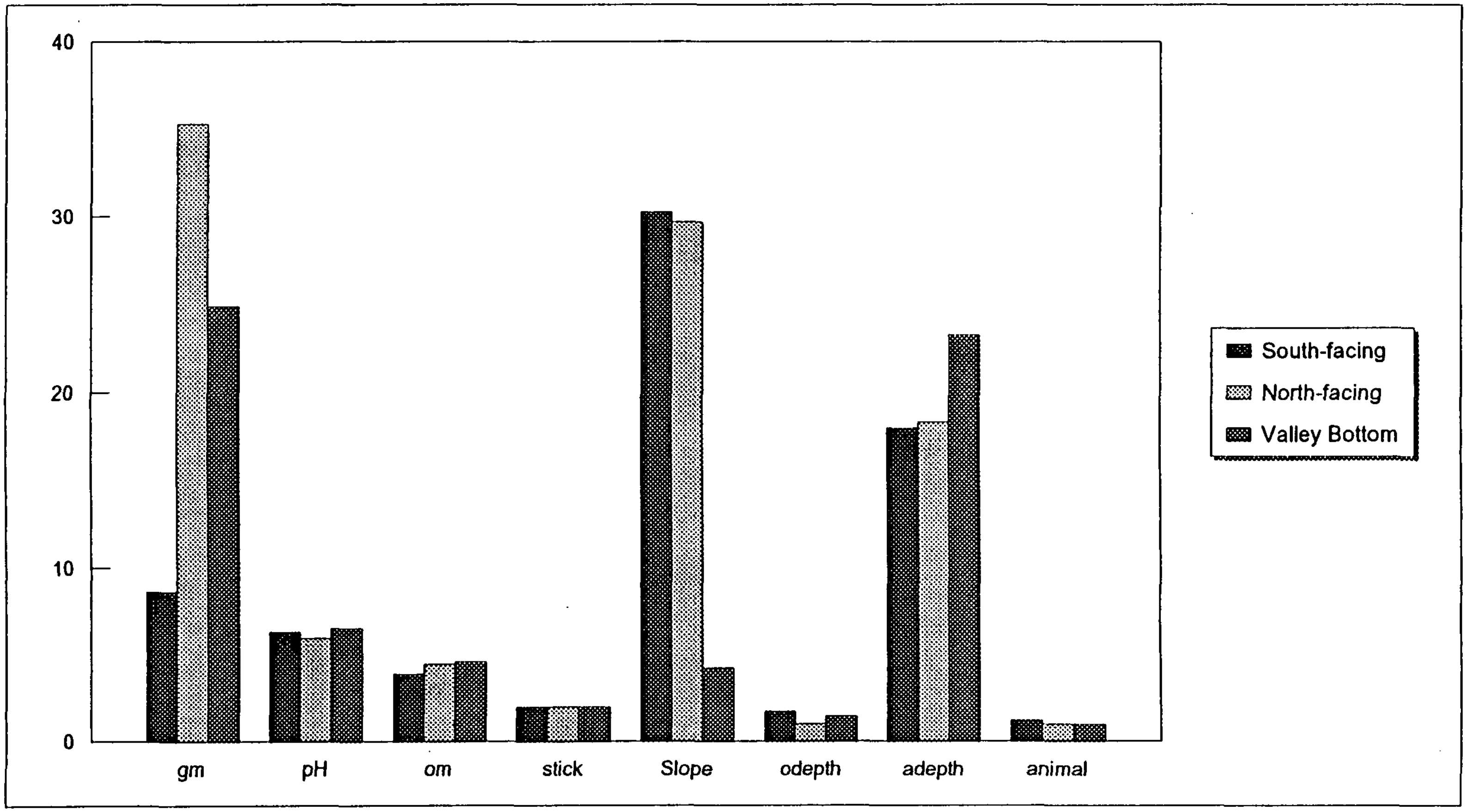
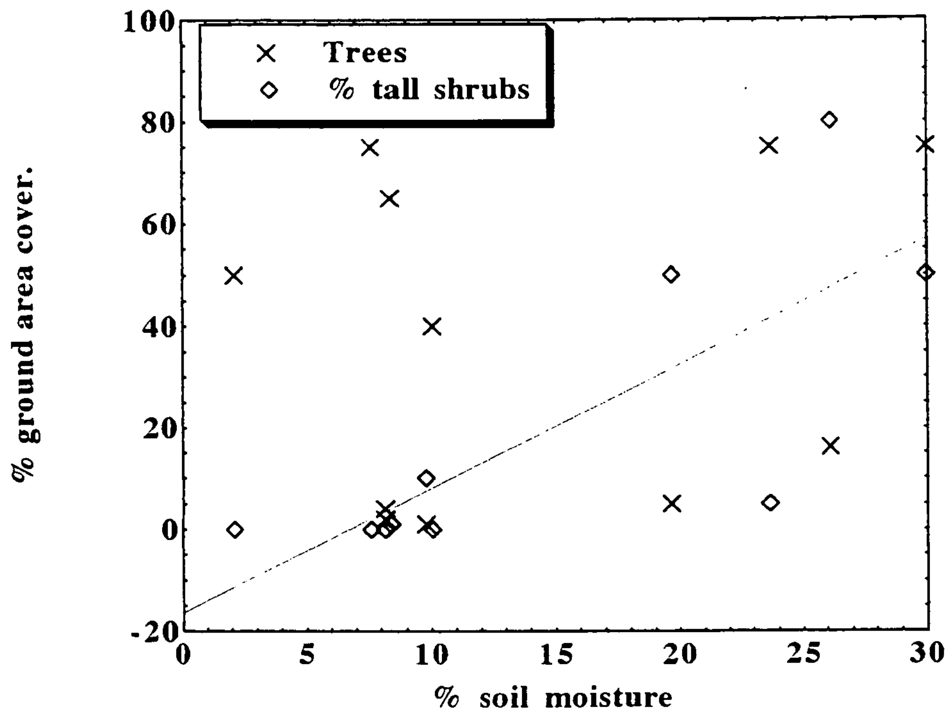


Figure 8 . Summary of environmental data of the Gregory Canyon plots. Gm is percent gravimetric moisture content of soil, pH the acidity of the soil, om the percent organic matter in the soil, stick a subjective measure of the stickiness of the soil (a measure of clay content), slope the degrees of the slope, odepth the depth of the O soil horizon, adepth the depth of the soil A horizon, and animal a subjective measure of animal disturbance.



Firgure 9. Direct ordination of tree and tall shrub cover with respect to % soil moisture.

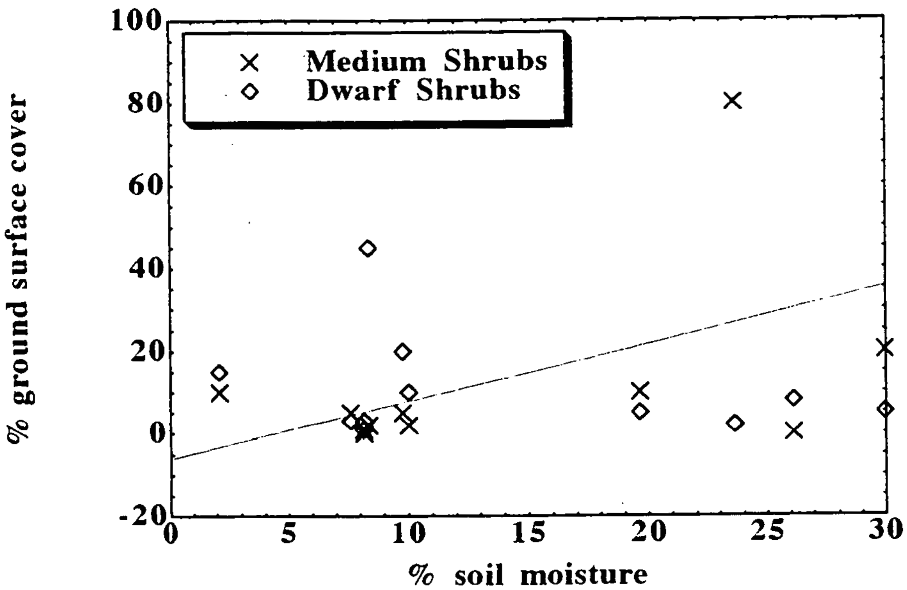


Figure 10. Direct ordination of cover of medium shrubs and dwarf shrubs with respect to % soil moisture.

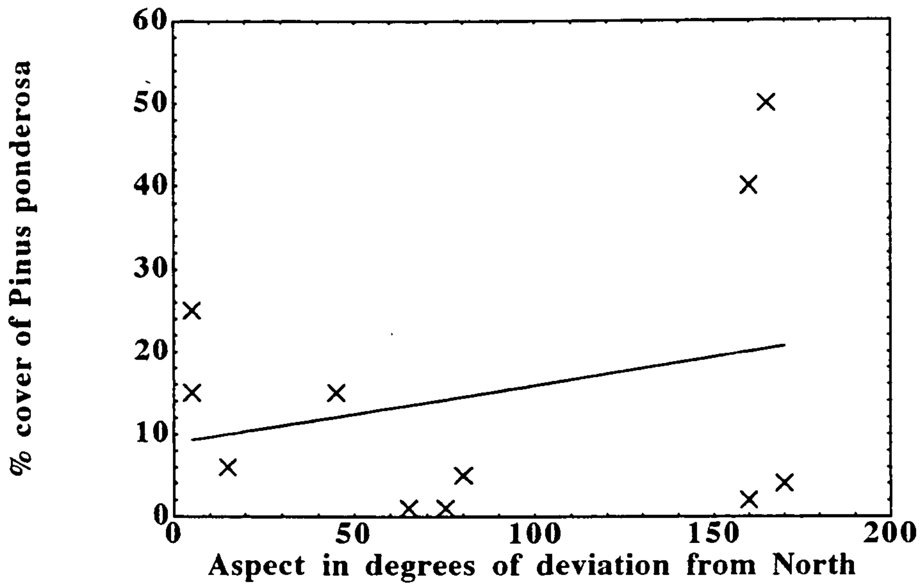


Figure 11. The % cover of
Pinus ponderosa as a function of
the aspect angle of sample plot.

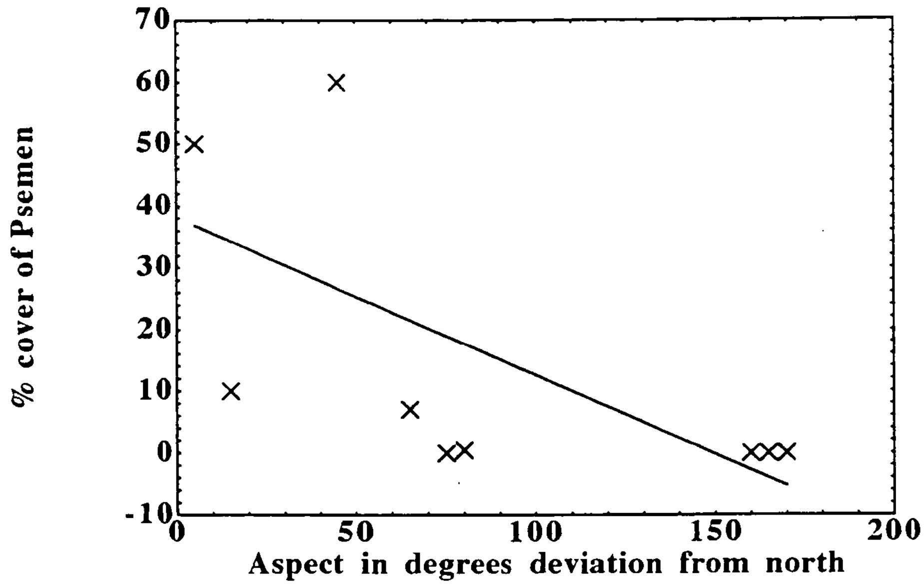


Figure 12. Percent cover of Pseudotsuga menzeisii with respect to the aspect angle of sample plot.

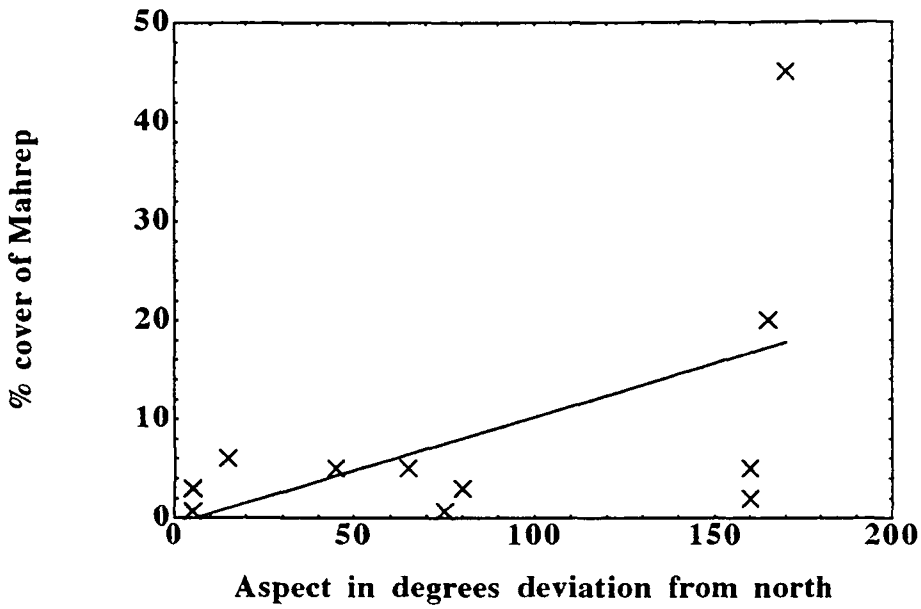


Figure 13 Percent cover of Mahonia repens as a function of aspect angle of sample plot.

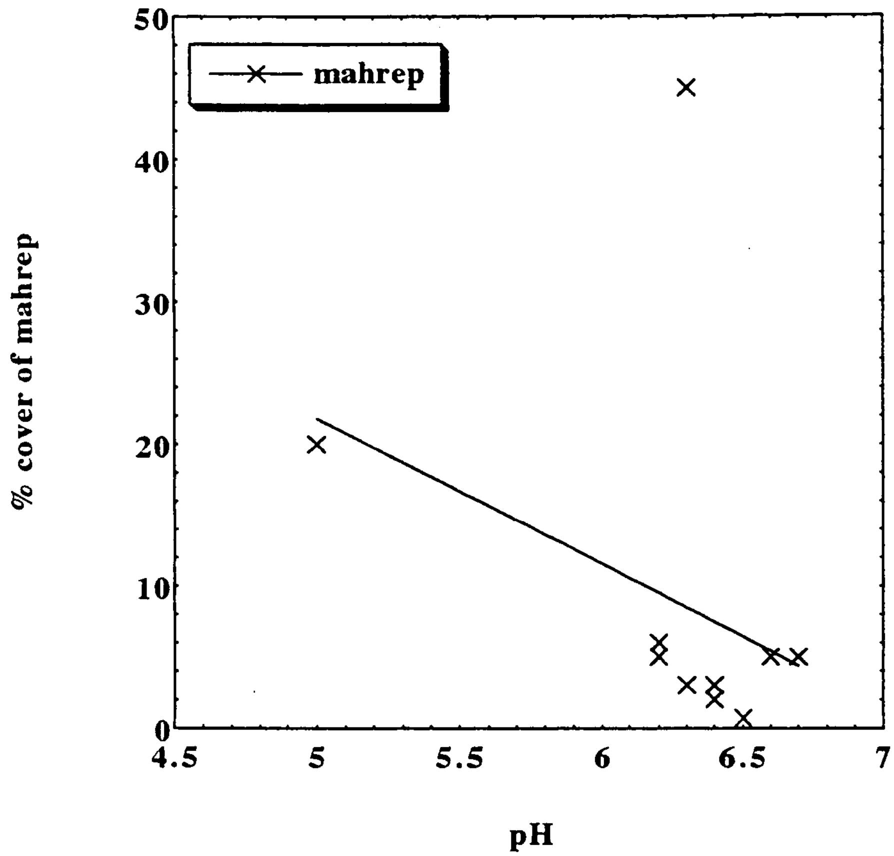


Figure 14. This figure shows the direct ordination of pH and cover by Mahonia repens.
r^2=0.125 p=0.28

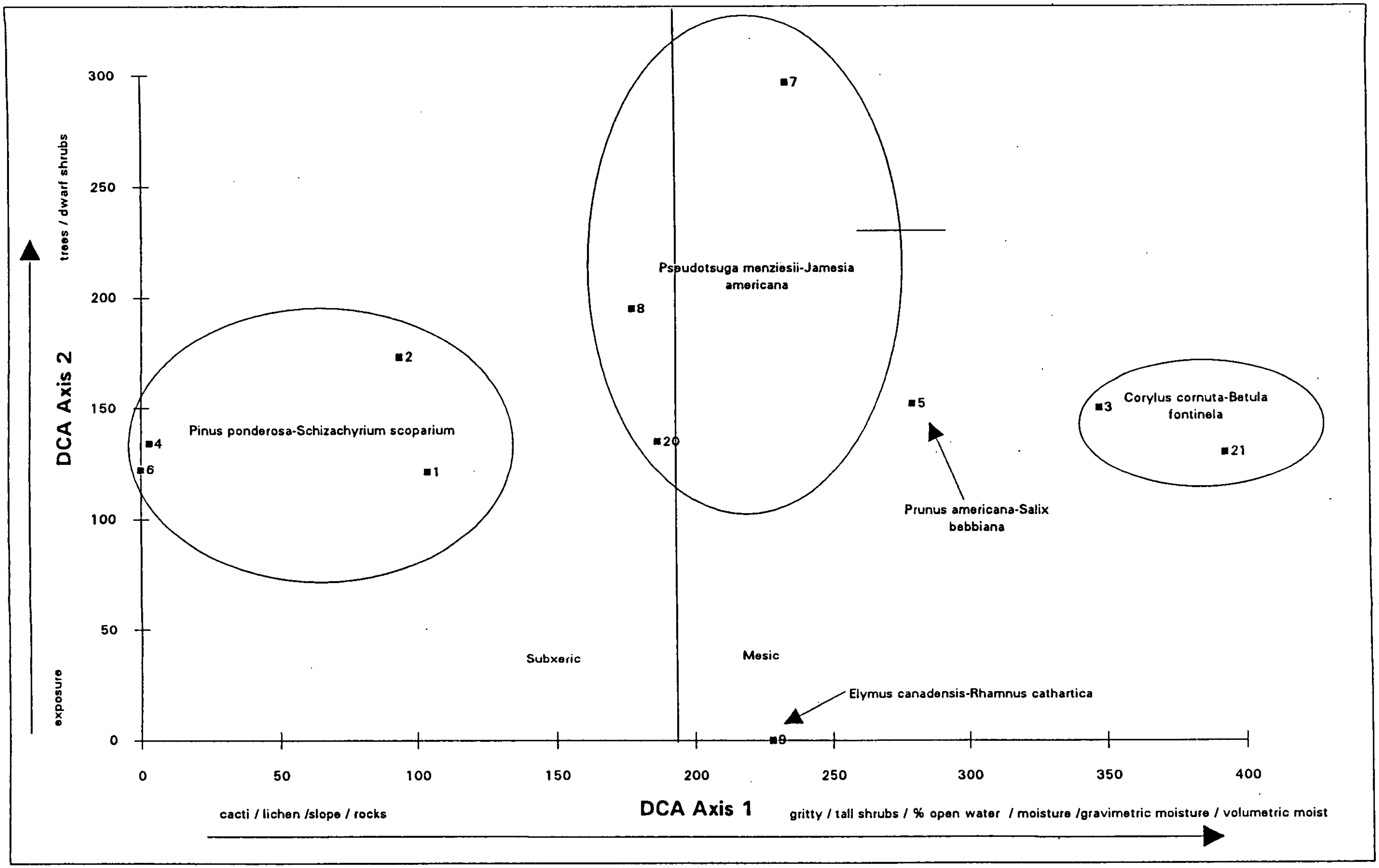
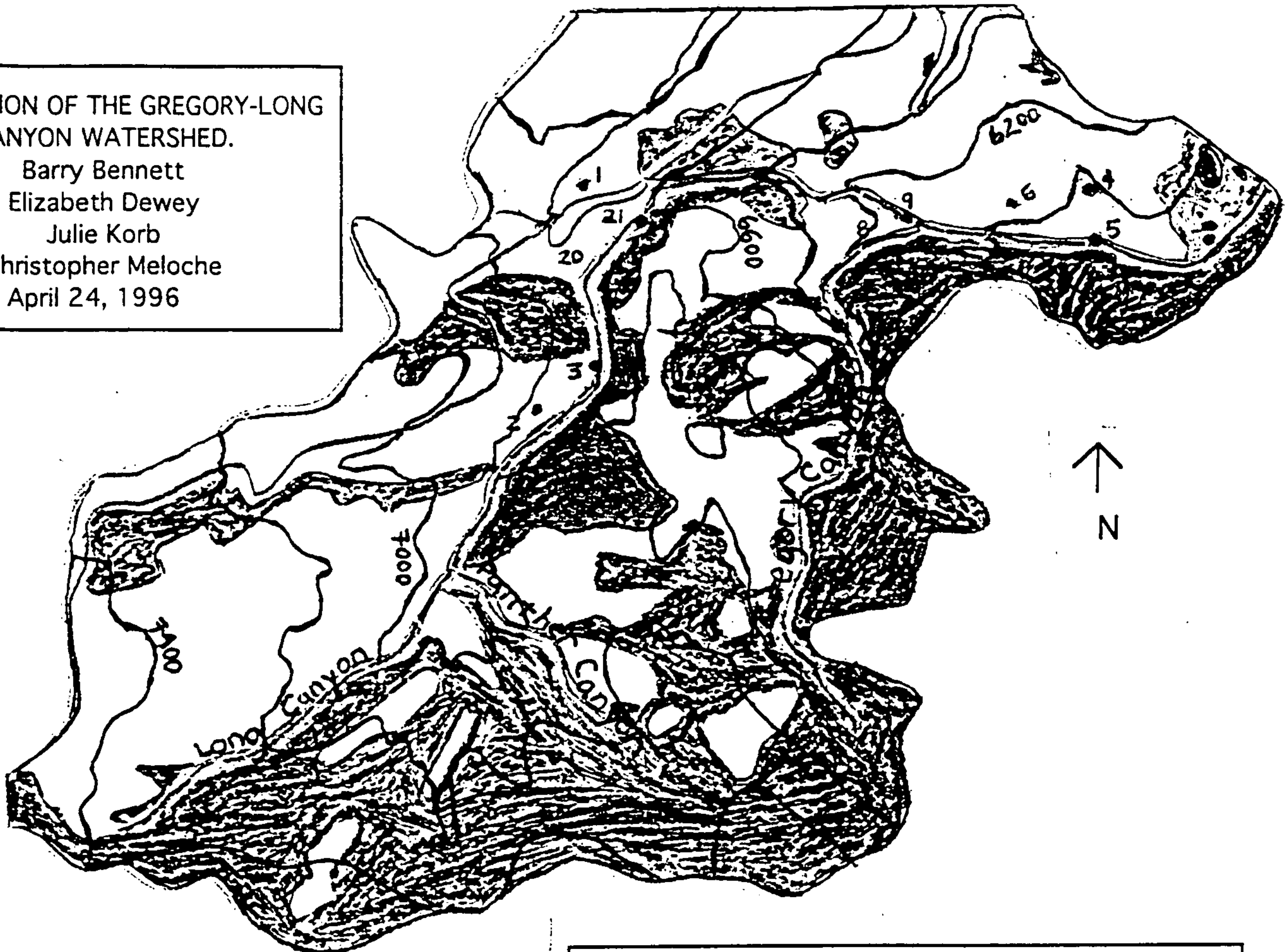


Figure 15 Detrended Correspondence Analysis.
Detrended correspondence analysis of Gregory-Long Canyon stands using downweighting of rare species. Community types defined from sorted table analysis are enclosed by elipses. The vertical line separates plots defined as mesic form those defined as subxeric.

VEGETATION OF THE GREGORY-LONG CANYON WATERSHED.
Barry Bennett
Elizabeth Dewey
Julie Korb
Christopher Meloche
April 24, 1996



Areal Coverage of Vegetation Types	
49.8%	Pseudotsuga menziesii-Pinus ponderosa forest
45.9%	Pinus ponderosa woodland
2.6%	Bare rock
0.7%	Grasslands
0.5%	Riparian Zone
0.4%	Paved road
0.2%	Shrublands

LEGEND

- *Pinus ponderosa* Woodland
- *Pseudotsuga menziesii-Pinus ponderosa* Closed Forest
- Riparian Woodlands & Shrublands
- Other Shrublands
- Grasslands
- Rock
- Road
- Stream
- Releve Site
- Watershed Boundary

Scale 1: 31,250
1 km
1 mi

Note: Area estimates are approximate, because this map has not been registered to a controlled base map.

Figure 16 Vegetation of the Gregory-Long Canyon Watershed

Table 1. Sorted table classification of Gregory-Long Canyon. Numbers in the table are percent coverage estimates. Listed at the top of the table are the five community types found within the eleven stands samples. Pinpon-Schsco represents the *Pinus ponderosa-Schizachyrium scoparium* stands. Psemen-Jamame represents the *Pseudotsuga menziesii-Jamesia americana* stands. Pruame-Salbeb represents the *Prunus americana-Salix bebbiana* stand. Elycan-Rhacat represents the *Elymus canadensis-Rhamnus cathartica* stand. Corcor-Betfon represents the *Corylus cornuta-Betula fontinela* stands. The stands are arranged left to right from xeric to mesic stands. The constancy of each species is also listed in the far right-hand column of the table along with the number of taxa total for each species at the end of the table.

COMMUNITY TYPE	Pinpon-Schsco				Psemen-Jamame			Pruame-Salbeb	Elycan Rhacat	Corcor-Betfon		CONS
RELEVE #	s1	s2	s4	s6	s7	s8	s20	s5	s9	s3	s21	
CONSTANT TAXA												
Mahonia repens	2	5	6	3	20	45	+	5	+	5	3	11
Pinus ponderosa	40	40	4	2	25	15	15	8	1	6	7	11
DIFFERENTIAL TAXA SHARED BY PINPON-SCHSCO & PSEMEN-JAMAME												
Eriogonum umbellatum	+	+	.	.	+	r		.	.	.	.	4
Heterotheca villosa	.	+	2	1	.	.	+	.	.	.	.	4
Achillea lanulosa	+	.	.	.	.	r	+	.	.	.	.	3
Sedum lanceolatum	+	.	.	.	.	r	1	.	.	.	.	3
DIFFERENTIAL TAXA FOR PINPON-SCHSCO												
Schizachyrium scoparium	+	25	1	1	.	.	.	.	.	.	.	4
Grindelia squarrosa	+	r	+	1	.	.	.	.	.	.	.	4
Artemisia frigida	+	+	2	.	.	.	.	.	.	.	.	3
Opuntia compressa	+	.	1	1	.	.	.	.	.	.	.	3
Muhlenbergia montanum	+	+	1	.	.	.	.	.	.	.	.	3
Andropogon gerardii	.	.	6	2	.	.	.	.	.	.	.	2
Chondrosum gracile	.	.	1	5	.	.	.	.	.	.	.	2
Yucca glauca	.	2	.	1	.	.	.	.	.	.	.	2
Astragalus spp	.	.	1	1	.	.	.	.	.	.	.	2
Pascopyrum smithii	.	.	1	1	.	.	.	.	.	.	.	2
Silene scouleri	+	.	.	+	.	.	.	.	.	.	.	2
Erysimum capitatum	.	r	r	.	.	.	.	.	.	.	.	2
DIFFERENTIAL TAXA SHARED BY PSEMEN-JAMAME & RIPARIAN PLOTS												
Pseudotsuga menziesii	.	.	.	.	50	50	60	r	.	10	1	6
Acer glauca	.	.	.	.	5	.	.	+	.	5	.	3
DIFFERENTIAL TAXA FOR PSEMEN-JAMAME												
Jamesia americana	.	.	.	.	.	2	5	.	.	.	.	2
Allium textile	.	.	.	.	.	+	+	.	.	.	.	2
Drymocallis fissa	.	.	.	.	+	+	.	.	.	.	.	2
DIFFERENTIAL TAXA SHARED BY RIPARIAN PLOTS												
Rosa woodsii	.	.	.	.	.	.	+	5	1	5	1	5
Juniperus scopulorum	.	.	.	.	.	.	.	.	r	.	1	2
Symphoricarpos occidentalis	.	.	.	.	.	.	.	+	+	.	.	2
Heracleum sphondylium	.	.	.	.	.	.	.	.	+	+	.	2
DIFFERENTIAL TAXA FOR PRUAME-SALBEB												
Prunus americana	.	.	.	.	.	.	.	40	.	.	.	1
Salix bebbiana	.	.	.	.	.	.	.	15	.	+	.	2
DIFFERENTIAL TAXA FOR ELYCAN-RHACAT												
Elymus canadensis	.	.	.	.	.	.	.	.	40	.	.	1
Dactylis glomerata	.	.	.	.	.	.	.	.	30	.	.	1
Rhamnus cathartica	.	.	.	.	.	.	.	.	25	.	.	1
DIFFERENTIAL TAXA FOR CORCOR-BETFON												
Corylus cornuta	.	.	.	.	.	.	.	+	.	15	30	3
Betula fontinalis	.	.	.	.	.	.	.	.	.	12	50	2
Hippochaete hyemalis	.	.	.	.	.	.	.	.	.	15	10	2
Populus tremuloides	.	.	.	.	.	.	.	.	.	15	5	2
Poa pratensis	.	.	.	.	.	.	.	.	.	5	10	2

COMMUNITY TYPE	Pinpon-Schsco				Psemen-Jamame			Pruame-Salbeb	Elycan Rhacat	Corcor-Betfon		CONS
RELEVE #	s1	s2	s4	s6	s7	s8	s20	s5	s9	s3	s21	
SHARED EXOTIC TAXA BETWEEN PINPON-SCHSCO & RIPARIAN PLOTS												
Phleum pratense	+	.	.	.	.	.	.	.	5	1	.	3
Bromopsis lanatipes	.	1	.	.	.	.	.	.	.	5	.	2
Alyssum minus	.	.	+	2	.	.	.	.	+	.	.	3
Verbascum thapsus	+	+	.	.	.	.	.	.	+	.	.	3
Bromus tectorum	+	.	.	.	.	.	.	.	+	.	.	2
Cichorium intybus	.	r	.	.	.	.	.	.	.	+	.	2
NONDIFFERENTIATING TAXA												
Bromus japonicus	+	.	.	.	.	.	5	.	.	.	.	2
Ceanothus fendleri	+	.	.	.	.	.	+	.	.	.	.	2
Padus virginiana	+	.	.	.	.	1	.	.	.	.	.	2
Poa compressa	.	.	1	.	.	.	+	.	.	.	.	2
Juniperus communis	.	.	.	.	.	.	2	.	.	.	5	2
Campanula rotundifolia	.	.	.	.	.	+	.	.	+	.	.	2
Artemisia ludoviciana	.	+	1	1	.	.	1	+	.	.	.	5
Aster laevis	+	.	.	.	15	+	1	.	1	.	.	5
Bromopsis inermis	.	.	5	8	.	10	.	.	+	.	.	4
Cerastium strictum	+	.	.	.	.	.	+	r	1	.	.	4
Monarda fistulosa	.	+	.	.	r	.	.	.	+	1	.	4
Ribes cereum	+	.	.	.	+	.	.	+	.	+	.	4
Arctostaphylos uva-ursi	4	.	.	.	.	.	.	.	.	.	.	1
Carex rossii	1	.	.	.	.	.	.	.	.	.	.	1
Juncus sp.	+	.	.	.	.	.	.	.	.	.	.	1
Stipa comata	+	.	.	.	.	.	.	.	.	.	.	1
Sisymbrium altissimum	+	.	.	.	.	.	.	.	.	.	.	1
Pterogonum alatum	.	+	.	.	.	.	.	.	.	.	.	1
Centaurea diffusa	.	.	1	.	.	.	.	.	.	.	.	1
Koeleria macrantha	.	.	+	.	.	.	.	.	.	.	.	1
Opuntia polyacantha	.	.	.	1	.	.	.	.	.	.	.	1
Viola spp	.	.	.	.	+	.	.	.	.	.	.	1
Pteridium aquilinum	.	.	.	.	.	1	.	.	.	.	.	1
Claytonia lanceolata	.	.	.	.	.	+	.	.	.	.	.	1
Penstemon virens	.	.	.	.	.	+	.	.	.	.	.	1
Pulsatilla patens	.	.	.	.	.	+	.	.	.	.	.	1
Selaginella densa	.	.	.	.	.	+	.	.	.	.	.	1
Elymus longifolius	.	.	.	.	.	r	.	.	.	.	.	1
Antennaria neglecta	.	.	.	.	.	.	5	.	.	.	.	1
Harbouria trachypleura	.	.	.	.	.	.	1	.	.	.	.	1
Hedeoma hispidum	.	.	.	.	.	.	1	.	.	.	.	1
Heuchera bracteata	.	.	.	.	.	.	+	.	.	.	.	1
Pterospora andromedea	.	.	.	.	.	.	+	.	.	.	.	1
Asclepias subverticillata	.	.	.	.	.	.	.	+	.	.	.	1
Galium septentrionale	.	.	.	.	.	.	.	+	.	.	.	1
Parthenocissus inserta	.	.	.	.	.	.	.	+	.	.	.	1
Glycyrrhiza lepidota	.	.	.	.	.	.	.	r	.	.	.	1
Clematis ligusticifolia	.	.	.	.	.	.	.	.	3	.	.	1
Rhus glabra	.	.	.	.	.	.	.	.	1	.	.	1

COMMUNITY TYPE	Pinpon-Schsco				Psemen-Jamame			Pruame-Salbeb	Elycan Rhacat	Corcor-Betfon		CONS
RELEVE #	s1	s2	s4	s6	s7	s8	s20	s5	s9	s3	s21	
Collinsia parviflora	.	.	.	.	.	.	.	.	+	.	.	1
Taraxacum officinale	.	.	.	.	.	.	.	.	+	.	.	1
Toxicodendron rydbergii	.	.	.	.	.	.	.	.	+	.	.	1
Muhlenbergia racemosa	.	.	.	.	.	.	.	.	r	.	.	1
Solidago canadensis	.	.	.	.	.	.	.	.	.	1	.	1
Osmorhiza depauperata	.	.	.	.	.	.	.	.	.	+	.	1
Cynoglossum officinale	.	.	.	.	.	.	.	.	.	r	.	1
Rumex crispus	.	.	.	.	.	.	.	.	.	r	.	1
Agrostis exarata	.	.	.	.	.	.	.	.	.	.	5	1
Equisetum arvense	.	.	.	.	.	.	.	.	.	.	2	1
Cirsium ochrocentrum	.	.	.	.	.	.	.	.	.	.	+	1
Fragaria vesca	.	.	.	.	.	.	.	.	.	.	+	1
Populus deltoides	.	.	.	.	.	.	.	.	.	.	+	1
Number of taxa	25	16	19	15	10	19	21	16	24	21	16	

Table 2. Forest Structure of Gregory-Long Canyon. Basal area (m/ha), density (trees/ha), and frequency are given for all tree species sampled within the eleven stands. Pinpon represents *Pinus ponderosa*, Psemen represents *Pseudotsuga menziesii*, Poptre represents *Populus tremuloides*, and Junsco represents *Juniperus scopulorum*

	Basal Area (m **2 /ha)					**Density (trees/ha)**				
	pinpon	psemen	poptre	junsco	total	pinpon	psemen	poptre	junsco	total
S1	31.8				31.8	843.6				843.6
S2	23.7				23.7	488.4				488.4
S3	7.8	5.6	20.3		33.7	88.9	44.4	843.6		976.9
S4	4.7				4.7	88.9				88.9
S5	14.5				14.5	88.9	44.4			133.3
S6					0					0
S7	9.8	7.8			17.6	532.8	1021.2			1554
S8	8.7	22.5			31.2	532.8	710.4			1243.2
S9	5.6			very small	5.6	44.4			44.4	88.8
S20	16	7.6			23.6	355.2	1420.8			1776
S21	6.1	0.9	0.8	very small	7.8	44.4	355.2	399.6	44.4	843.6
averages:										
south-facing	15.05				15.1	355.225				355.2
north-facing	11.5	12.63			24.1	473.6	1050.8			1524.4
valley bottom	8.5	1.625	5.275		15.4	66.65	111	310.8	22.2	510.7
corcor-betfon	6.95	3.3	10.5		20.8	66.7	199.8	621.6	22.2	910.3

	Frequency			
	pinpon	psemen	poptre	junsco
south-facing	0.75	0	0	0
north-facing	1	1	0	0
valley-bottom	0.75	0.66	0.5	0.5
corcor-betfon	1	1	1	0.5

Table 3 Estimates of the percent cover of various growth forms on the Gregory Canyon plots. Different letters following averages denote significant differences between aspects using Mann-Whitney U-test. Averages with no letters have no significant differences.

Plot#	Trees	Tall Shrubs	Med. Shrubs	Dwarf Shrubs	Graminoids	Cacti	Forbs	Bryophyte	Lichens	Bare Ground	Water
s1	50	0	10	15	60	0.7	2	0	0	10	0
s2	40	0	2	10	60	0	5	0	0	10	0
s4	4	0	0	3	50	1	15	1	20	1	0
s6	2	0	1	1	25	2	5	0	60	5	0
s7	75	5	5	20	1	0	5	10	0	0	0
s8	65	0	2	45	10	0	1	1	1	0	0
s20	75	0	5	3	10	0	3	15	5	20	0
s3	75	50	20	5	40	0	25	0	0	0	3
s5	5	50	10	5	30	0	25	0	0	1	3
s9	1	10	80	2	75	0	2	1	1	1	5
s21	16	80	0	8	15	0	11	2	0	1	2
<u>Averages</u>											
South-facing	24.0 a	0 a	3.3	7.3	48.7 a	0.9	6.8	0.3	20.0	6.5	0.0
North-facing	71.6 b	1.6 a	4.0	22.7	7 b	0.0	3.0	8.6	1.9	6.7	0.0
Valley Bottom	24.2 a,b	47.5 b	27.5	5.0	40 a	0.0	15.8	0.8	0.2	0.8	3.3

Table 4. Environmental site characteristics of Gregory Canyon plots.

Plot#	gm	pH	om	bd	vm	plast	stick	grit	Color	Hue	Chroma	Slope	Aspect	elev	odepth	adept	topo	expos	stable	moist	animal
s1	2.3	6.4	4.4	1.1	2.39	1	1	1	10.0	2	2	34	175	6755	2	18	2	2	2	4	2
s2	12.3	6.2	4.5	1.0	12.46	2	2	1	10.0	2	2	22	160	6800	3	25	2	2	2	4	1
s4	11.7	6.2	3.7	1.2	14.16	2	3	1	5.0	3	4	30	170	6000	1	20	2	2	2	4	2
s6	8.2	6.4	3.1	1.4	11.42	1	2	1	10.0	3	2	35	160	6400	1	9	2	2	2	4	0
s7	12.2	5	3.4	1.3	15.71	2	2	1	7.5	3	2	30	355	6120	0	28	2	1	1	6	0
s8	83.8	6.3	6.9	0.9	72.06	1	2	1	10.0	2	2	34	0	6300	1	12	2	1	3	4	1
s20	9.9	6.5	3.1	1.4	13.82	1	2	1	7.5	4	4	25	315	6880	2	15	2	1	3	5	2
s3	30.0	6.6	7.1	1.0	28.45	3	3	2	10.0	3	2	2	15	6710	1	35	3	1	2	6	0
s5	19.9	6.7	4.6	1.2	23.83	2	2	1	10.0	3	3	7	90	5860	2	35	3	1	2	6	2
s9	23.6	6.5	2.7	1.2	27.65	2	1	1	7.5	3	4	5	90	5900	1	8	3	2	4	4	1
s21	26.1	6.3	4.1	1.2	31.32	2	2	2	10.0	3	3	3	65	6800	2	15	3	2	2	6	1
Averages																					
South-facing	8.6	6.3	3.9	1.2	10.1	1.5	2.0	1.0	8.8	2.5	2.5	30.3	166.3	6489	1.8	18.0	2.0	2.0	2.0	4.0	1.3
North-facing	35.3	5.9	4.5	1.2	33.9	1.3	2.0	1.0	8.3	3.0	2.7	29.7	223.3	6433	1.0	18.3	2.0	1.0	2.3	5.0	1.0
Valley Bottom	24.9	6.5	4.6	1.1	27.8	2.3	2.0	1.5	9.4	3.0	3.0	4.3	65	6318	1.5	23.3	3.0	1.5	2.5	5.5	1.0

gm	% gravimetric soil moisture.
om	% soil organic matter
bd	bulk density of soil
vm	% volumetric soil moisture
plast	subjective plasticity of soil 1 = not plastic 2 = slightly plastic 3 = plastic 4 = very plastic
stick	subjective stickiness of soil 1 = not sticky 2 = slightly sticky 3 = sticky 4 = very sticky
grit	subjective grittiness of soil 1 = gritty 2 = smooth
color	From Munsell soil chart
hue	From Munsell soil chart
chroma	From Munsell soil chart
slope	Degrees of slope
aspect	in degrees
elevation	in feet
odepth	depth of O horizon in cm
adepth	depth of A horizon
topo	topographic position 1 = hill crest/shoulder 2 = mid-slope 3 = canyon bottom
expos	subjective exposure scale 1 = protected 2 = moderate exposure 3 = exposed to wind 4 = very exposed
stable	subjective site stability scale 1 = stable 2 = occasional disturbance 3 = slow/prolonged disturbance 4 = annually disturbed
moist	subjective moisture scale 4 = sub-xeric 5 = sub-xeric to mesic 6 = mesic
animal	subjective animal disturbance scale 1 = scattered sign 2 = abundant sign 3 = very abundant sign (>25% cover)