

**Ungulate Herbivory on Ponderosa pine and Douglas fir along an
Elevational gradient in the National Bison Range**

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Abstract:

A study in 2003 by Rooney and Waller on herbivore-plant relations termed the idea of “indirect effects” in ungulate herbivory. Rooney and Waller’s study of herbivores and the indirect effects resulted from herbivore selectivity; provide results that support herbivore selectivity as the main controller of foraging and when combined with differential plant responses. Following Rooney and Waller, I conducted a survey in the National Bison Range’s Ponderosa pine and Douglas fir stand on the herbivory of saplings by ungulates. Like Rooney and Waller the survey explored possible controlling factors that could possibly influence ungulate sapling herbivory selectivity. My survey of herbivore selectivity evaluated the relationship between herbivore, plant and there environment. As stated earlier the research involved ungulate herbivores on the Bison Range and saplings of two tree species *Pinus ponderosa* (Ponderosa pine) and *Pseudotsuga menziesii*. Through my surveys I will test (1) is there a relationship between sapling herbivory and elevation within the forest stands,(2) is there a change ungulate herbivory and sapling abundance between sites,(3) what conditions affects herbivore selectivity on the two saplings. This survey measured quantitative characteristics of saplings and ungulate presences along a 100 x 5m transect; it ran through montane forest in the Bison Range following an elevational gradient through three sites. Douglas fir and Ponderosa pine displayed a significant differences between the two species across the three study sites Bitter Root ($P < 0.001$; Tower 3, $p=0.011$; Trisky, $p= 0.042$) (Figure 1). However; abundances compared across all three sites resulted with no significance values. This stepwise regression resulted with herbivory signs at each transect being significant ($p=0.001$) (Table 3). Douglas fir versus the same variables resulted in a single significant of herbivory sign at each transect ($p= 0.001$). When running a multivariable regression many of the variables were found as insignificant because browsing intensity in space and time is highly variable, and so are individual tree responses. Mechanisms causing the observed browsing patterns are seldom understood, and ungulates are only one if usually the most evident of several factors that drive population dynamics in a complicated interplay (Senn et. al. 2000).

Keywords: Herbivory, Ungulate, Saplings, Winter Foraging, Ponderosa pine, Douglas fir, Herbivore-Plant relations, Elevational Gradient.

I. Introduction

Ungulates are known to exert a profound influence on forest ecosystem processes, by modifying nutrient cycling, primary productivity and disturbance regimes (Hobbs et al. 1996). In the last 5 to 10 years, there have been a growing number of studies on the herbivore-plant relationship of ungulates. This research has demonstrated that herbivores can directly limit plant abundance and distribution (Kleintjes et al. 2007). In many cases

herbivory influences growth, recruitment, and mortality rates of plants which directly correlates with the plant's density and frequency (Huntly et al. 1991). Moreover, herbivory may increase, offset, or generate reciprocal negative interactions among plants (Huntly et al. 1991). This strong influence over plant population and vegetation, exemplifies the importance of levels of selective feeding by forest animals. Over browsing can result in complete changes in the structure, composition and productivity of the forest (Raedeke et al 1988). Literature reviews in referring to forest ecology clearly indicate the important role of herbivory not only in modifying the composition of plant communities but of ecosystems. The effect of herbivory on an ecosystem is a widely accepted hypothesis and is certainly visible to the untrained eye in overgrazed forest ecosystems. In a study in 1997 by Healy on herbivore-plant relationships, white-tailed deer disrupted the progression of stand development and stunned understory dynamics in eastern oak forests. The literature review of Alverson and Waller (1997) further explained that white-tailed deer greatly alters plant communities; shaping vegetation pattern in coniferous forests of the Northwestern plant communities.

A study in 2003 by Rooney and Waller on herbivore-plant relations termed the idea of "indirect effects" in ungulate herbivory. This encompasses the relationship or direct influences of herbivores on a plant species that are transmitted to surrounding "receiver species". Rooney and Waller's study of herbivores and the indirect effects resulted from herbivore selectivity; provide results that support herbivore selectivity as the main controller of foraging and when combined with differential plant responses.. Therefore, using this understanding of herbivore-plant relationship when conducting herbivore dependent study the relevant underlining question should not be 'does

herbivores influence plant species?’ but instead ‘what conditions affect herbivore selectivity of plants communities?’.

Following Rooney and Waller, I conducted a survey in the National Bison Range’s montane Ponderosa pine and Douglas fir stand on the herbivory of saplings by ungulates. Like Rooney and Waller the survey explored possible controlling factors that could possibly influence ungulate sapling herbivory selectivity. By doing so this will determine factors relevant to forest and plant assemblages and growth dynamics along with physical measures effecting ungulate behavior and preference. Some examples from similar scientific research performed on selectivity factors included abundance in areas such as open space, forest gaps, and edges. These areas are often locations of herbivory importance for two reasons: (1) vegetation developing after disturbance is often more palatable to ungulates than that available on undisturbed sites (Asherin et al.1976), and (2) forage production in recently disturbed areas is often greater than in surrounding forest communities with dense canopies (McConnell and Smith 1970, Klinka et al. 1996). There have been significant relationships between herbivores and areas that are characterized by relatively high biomass of palatable food resources; thus, we can expect to find more foraging activity in recently disturbed areas.

Manipulations that decrease canopy cover may accelerate the decline in nutritional quality of forage. Svejcar and Vavra (1985) explored the connection of decreasing canopy cover and soil moisture because when sunlight reaches the soil surface it warms the soil rapidly in the spring and dries it more in the summer, thus impacting plant phenology. Also, depending on density, Ponderosa pine communities have the potential to provide security, cover and foraging habitat for ungulates (Lyon et al. 1976).

In locations on the National Bison Range, human presence was constantly within close proximity to ungulate foraging habitat in tourist season. Elk distributions are expected to shift to allow avoidance of human visited areas (Wisdom et al. 2004). Specifically, road density and traffic rates in areas open to vehicular travel negatively influence elk distribution; elk avoid habitats near roads open to traffic (Rowland et al. 2000, Wisdom et al. 2004). Additionally, Lyon (1976) found that elk used habitats with greater canopy closure in areas of higher road density. And certainly site specific variables such as aspect, soil depth, and annual precipitation have an influence on understory production of ponderosa pine and Douglas fir communities.

My research conducted on the National Bison Range was along an elevational gradient inside of montane stands. Environmental gradients such as elevation can also be a controlling factor of ungulate selectivity because of its documented effects on plant composition. Louda (1982) documented that the shrub *Haplopappus squarrosus* was more abundant at inland sites than at sites close to the coast. By excluding pre-dispersal seed-feeders on plants across this gradient, Louda (1982) found that herbivory on *H. squarrosus* was intense at all sites, but that insect exclusion led to greater gains in recruitment at coastal versus inland sites. Thus, herbivory appeared to drive the pattern in plant abundance across this geographical gradient. Research along an elevational gradient will further evaluate the herbivore-plant relationship and may show a significant relationship in herbivore selectivity or sapling abundance.

My survey of herbivore selectivity evaluated the relationship between herbivore, plant and there environment. As stated earlier the research involved ungulate herbivores on the Bison Range and saplings of two tree species, *Pinus ponderosa* (Ponderosa pine)

and *Pseudotsuga menziesii* (Douglas fir). Through my surveys I will test (1) is there a relationship between herbivory and elevation within the forest stands, (2) is there a change ungulate herbivory and sapling abundance between sites, (3) what conditions affects herbivore selectivity on Ponderosa pine and Douglas fir saplings.

II. Materials and Methods

II. 1 Study Site

My survey area was three northerly facing forest stands on the National Bison Range located in Missoula, MT (47°19'50.09"N, 114°14'4.54"W). Site 1 was located near the Bitter Root Trail; Site 2 was located in Tower 3 and Site 3 was located at Triskey Point. The elevation of the sites ranged from 3500-4500 feet above sea level. These were locations found across the National Bison Range in areas that were accessibility by vehicle or by hiking, furthermore each transects were located in areas that were not visible from the public road by the request of UNDERC West and the National Bison Range. Ten transects were surveyed along the gradient of elevations during three research weeks in July and August of 2007. Each survey was conducted during daylight hours. Placement of transect was determined by a topographic map and aerial photos view on Google Earth Plus ® in order to get a relative equal elevation distribution.

II. 2 Study design

This survey measured quantitative characteristics of saplings and ungulate presences along a 100 x 5m transect; it ran through montane forest in the Bison Range following an elevational gradient. Transects were separated altitudinal by a difference of ~100 meters and were distributed longitudinal by a random distance greater than 10 meters. (Figure. 8) The stands were mixed Ponderosa pine and Douglas fir and were

greater than >200 meters in diameter. The saplings quantified were defined as alive Ponderosa pine and Douglas fir between 0.5 and 3.0 meters in height.

II. 3 Transect Measures

Along each transect relative abundance of species, sapling height, branches clipped vs. non-clipped branches, distance along transect, canopy cover, and herbivore signs were quantified for each sapling found.

Species Transect Abundance: Species abundance was represented as a count of Douglas fir and Ponderosa pine by presence of the species within 5 meters on either side of the 100m transect. Sapling height was measured in centimeters from the base of the sapling to maximum standing height. The relative individual sapling ratio of herbivory (clipped/non-clipped) was defined as the total amount of branches attached to the main stem with evidence of a single or multiple clean herbivore snips divided by the total number of branches attached to main stem.

Sapling Distances Along Transect: The distance of sapling from a transect's point A (start) was measured by the location a sapling occurred along the 100 meter tape.

Ungulate Signs: Large herbivore presence was totaled based on signs along the transect five meters along each side. Herbivore signs include all large ungulate herbivores excluding buffalo signs. Signs included scat, antler rubbings, bedding, deer runs, and sapling herbivore observation.

Aspect/Slope: Using a compass and a colorimeter aspect and slope was recorded at each transect from the starting location.

II. 4 Aerial Photo, GIS Software Transect Analysis

Aerial photos were used from Google Earth Plus ® Software to determine the distance from the road and distance from the edge. Points A and B (transect start and end) marked from a GPS handheld device at each transect. The points were loading to Google Earth Plus ® and the distance from the road and edge was measured from the closest point.

II. 5 Data Formation

Herbivory Index: An index was created in order to weigh the percent herbivory data for each species for each transect. In order to weigh the values of percent herbivory at each transect the number of clipped branches was divided by the estimated overall branches based on sapling abundance per transect. This value was then multiplied by the proportion of saplings on any given transect to make sure that transects with only a few saplings did not create unrealistic patterns within the data.

Data Transformation: A second data set was created for the subtotals and averages for each species per transect. All data collected as ratios was transformed in to ARCSIN values to normalize the point's distribution. Aspect was converted from degrees to radians in order change data in to a linear value compare to other variables in analysis.

II. 6 Statistical Analysis

A Wilcoxon Rank Sign Test was used to test variation between species abundances at each site. A series of stepwise multivariable regressions, with ungulate herbivory or abundance was conducted as the response variable comparing two species factors such as abundance against elevation, canopy, slope, aspect, herbivory sign, transect to edge and etc.

III. Results

The graph displaying species abundance of Douglas fir and Ponderosa pine displayed a significant differences between the two species across the three study sites Bitter Root ($P < 0.001$; Tower 3, $p=0.011$; Trisky, $p= 0.042$) (Figure 1). However; abundances compared across all three sites resulted with no significance values. (Bitter Root \rightarrow Tower 3, $p= 0.477$; Bitter Root \rightarrow Triskey, $p= 0.799$; Tower 3 \rightarrow Trisky, $p= 0.359$). The abundance of species at each of the three sites displays and moderately even ratio or difference between the two sapling species. The Bitter Root stand had slightly higher value of abundance for each species than Tower 3 and Triskey. The p-values for this analysis were derived using the non-parametric Wilcoxon Test to analyze between species abundances at each site. Within each stand the abundance density function of the distance between saplings shows that over 80% of the saplings sampled were within 5 meters of another sapling (Figure 3) The herbivory index varied differently between sites and among species (Figure 2). A 2-way analysis of variance (ANOVA) indicated a significant interaction term, meaning more Douglas fir was consumed than Ponderous pine at some sites but not at others. Stands did not differ significantly in total herbivory but Douglas fir was eaten more than Ponderous pine.

Multivariable Regressions A multivariable regression was ran on the percent herbivory on each plant for both species combined (# branches clipped / total number branches on each plant) vs. height, sapling to neighbor, canopy, slope, sapling to edge, and sapling to public road no significant variable was found (Table 1). Similarly when each variable was run separately no significant variables were found. The closest variable to significance were percent canopy and height of plant ($p=0.152$, $p=0.156$). When

running a stepwise regression of overall sapling abundance against elevation, canopy, slope, aspect, herbivory sign, transect to edge. The significant values found was the aspect ($p=0.051$) and the distance from transect to edge of the stand ($p=0.033$) (Table 2a). A stepwise regression of Douglas fir abundance against the same conditions resulted in no significant values were found; herbivore sign was approaching significance with a p-value of 0.093 (Table 2c). However no variables were approaching significance when ran with Ponderosa pine abundance.

Analyzing the herbivory index with a stepwise regression versus elevation, canopy, slope, aspect, herbivory sign, transect to edge. This stepwise regression resulted with herbivory signs at each transect being significant ($p=0.001$) (Table 3). The total herbivory index versus the number of herbivory signs expressed graphically shows a positive trend (Figure 3). The extremely high point was an outlier where very high herbivory occurred and a high number of scat were present. A stepwise regression of the herbivory index on Douglas fir versus the same variables resulted in a single significant of herbivory sign at each transect ($p= 0.001$); however, slope at each transect was approaching a level of significance ($p= 0.089$) (Table 4). When expressed graphically the herbivory index and herbivory sign show a strong positive trend (Figure 4a.); and slope also shows a positive tread when graphed (Figure 4b).

Herbivory index for Ponderosa pine stepwise regression vs. elevation, canopy, slope, aspect, herbivory sign, transect to edge. The significant value found in this regression was elevation at each transect ($p=0.002$) and the canopy at each transects were approaching a level of significance ($p=0.145$) (Table 5). The Ponderosa pine herbivory index by the number of herbivory signs linear regression. has an extremely high outlier

where very high herbivory occurred at a high elevation (Figure 5a). Even with this outlier, the trend is still strongly positive. The Ponderosa pine herbivory index by percent canopy resulted in a slight negative trend (Figure 5b).

Linear regressions were ran on herbivory index and distance from the road. The total herbivory index by distance to road, regression resulted in a value approaching significance ($p=0.091$) (Table 6b). The linear regression of herbivory index for Douglas fir by distance to road, regression is significant ($p=0.049$); however, when a regression was ran for Ponderosa pine distance to the road was found insignificant. This regression shows that Ponderosa pine has an extremely high point where very high herbivory occurred; the trend has an upward positive trend (Figure 7).

IV. Discussion

Studies have commonly demonstrated strong spatial variation in the magnitude of herbivory across gradients in elevation; even levels of plant defense can also vary across elevation gradients (Galen et. al. 1990). The survey resulted that herbivory on Ponderosa pine increase as elevation increase (Table 5) (Figure 5a). This did not occur with Douglas fir because it was eaten across all gradients. High elevation may affect selectivity of an ungulate; however, further investigation is needed to fully understand this dynamic.

It is fully known that ungulate herbivory shapes vegetation pattern in coniferous forests of the Northwestern U.S. (Schreiner et al. 1996). Previous research done indicated that ungulates maintained a reduced standing crop, increased species richness of forbs, and determined the distribution, morphology, and reproductive performance of several species of shrubs. (Woodward et al. 1994) However the extent to which herbivores can

change forest ecosystem processes may depend on the scale and magnitude of other disturbances. Herbivory by wild and domestic ungulates has its greatest potential to impact vegetation dynamics following rehabilitation efforts on ponderosa pine ecosystems. Changes to productivity and structure may be the most pronounced herbivory effects on ponderosa pine ecosystems.

Differences in vegetation patterns were noticed in the National Bison Range between the three sites and two species. Species abundance of Douglas fir and Ponderosa pine displayed significant differences between the two species across the three study sites; however, each site had the same ratio of species to species (Figure 1). Therefore Ponderosa pine and Douglas fir occurred in different amounts at each site but that difference was the same across the three sites. Within each stand the density function of the distance between saplings shows that over 80% of the saplings sampled were within 5m of another sapling (Figure 3). Meaning that saplings tend to grow in groups in forests ecosystems; this could be due to a controlling factor such as nitrogen, soil moisture or canopy cover. The herbivory index varied differently between sites and among species (Figure 2). The survey showed that more Douglas fir was consumed than Ponderous pine at some sites but not across all others. There was no significant difference in total herbivory even so it was noticeable that Douglas fir was eaten more than Ponderous pine. Herbivory occurred more on Douglas fir because of their abundance within each site making it a common food source for ungulates. Douglas fir also has more branches creating new growth; ungulates prefer this soft palatable growth. Ponderosa has high sap content which defers the herbivory from the species' buds and branches.

Since herbivory is highly variable in space and in time there fore there was not any sapling characteristic that significantly influence ungulate herbivory (Table 1). Ungulate behavior is also extremely unpredictable and varies from location to location. Therefore ungulate selectivity is highly variable; to determine what conditions cause behaviors can be difficult. However, in the Bison Range the effects of human disturbance may have some effect on the selectivity. Increased human access to an area can change ungulate distributions; there range can be expected to shift, avoiding areas with increased access (Wisdom et. al. 2004). Specifically, road density and traffic rates in areas open to vehicular travel negatively influence ungulate distribution; elk avoid habitats near roads open to traffic (Rowland et. al. 2000). The influence is not demonstrably linear; however, with roads having no apparent influence at zero or very low traffic rates. On the Bison Range this was noticed with Douglas Fir, herbivory was higher further from the public roads (Figure 7) (Table 6b). Since Douglas fir is the main winter food source for ungulates Ponderosa pine would be eaten only in time of Douglas fir scarcity. Making the location of the sapling not relevant when survival is the ungulate's concerning factor. Analyzing the herbivory index with a stepwise regression versus elevation, canopy, slope, aspect, herbivory sign, transect to edge. This stepwise regression resulted with herbivory signs at each transect being significant ($p=0.001$) (Table 3). Douglas fir versus the same variables resulted in a single significant of herbivory sign at each transect ($p= 0.001$) (Table 4). And when expressed graphically the herbivory index and herbivory sign show a strong positive trend (Figure 4a). Meaning that the presence of herbivores increases with the amount of herbivory at that location; therefore, we can conclude that ungulates tend to stay in location longer when they're feeding there.

Ungulate herbivores interfere with tree growth and survival mainly during the sapling stage. However, browsing intensity in space and time is highly variable, and so are individual tree responses. Mechanisms causing the observed browsing patterns are seldom understood, and ungulates are only one if usually the most evident of several factors that drive population dynamics in a complicated interplay (Senn et. al. 2000). Even when sapling loss by browsing has been accurately quantified, it is often not possible to determine why one sapling was eaten more than another. When conducting a survey with in a complex ecosystem one can only hope to find and answer to a prevailing question. Survey such as these will eventual lead to the full understating of a system's dynamics and help determine management techniques and plans for forest managers.

V. Acknowledgements

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VI. References

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IV. Tables and Figure.

Figure 1. Abundance differences between Douglas fir and Ponderosa pine: P values were derived using the non-parametric Wilcoxon stat to test between species abundances at each site.

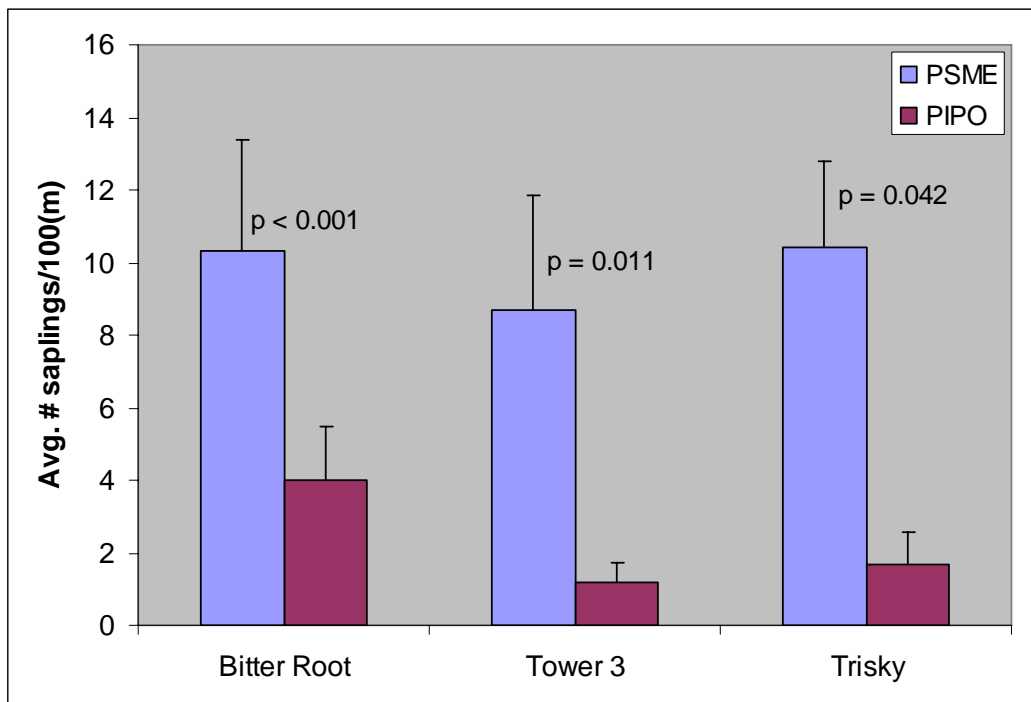


Figure 2. Herbivory index varied differently between sites and among species. A 2-way ANOVA indicates a significant interaction term, meaning more fir was consumed than PP at some sites but not at others. Stands did not differ significantly in total herbivory but Douglas fir was eaten more than Ponderous pine.

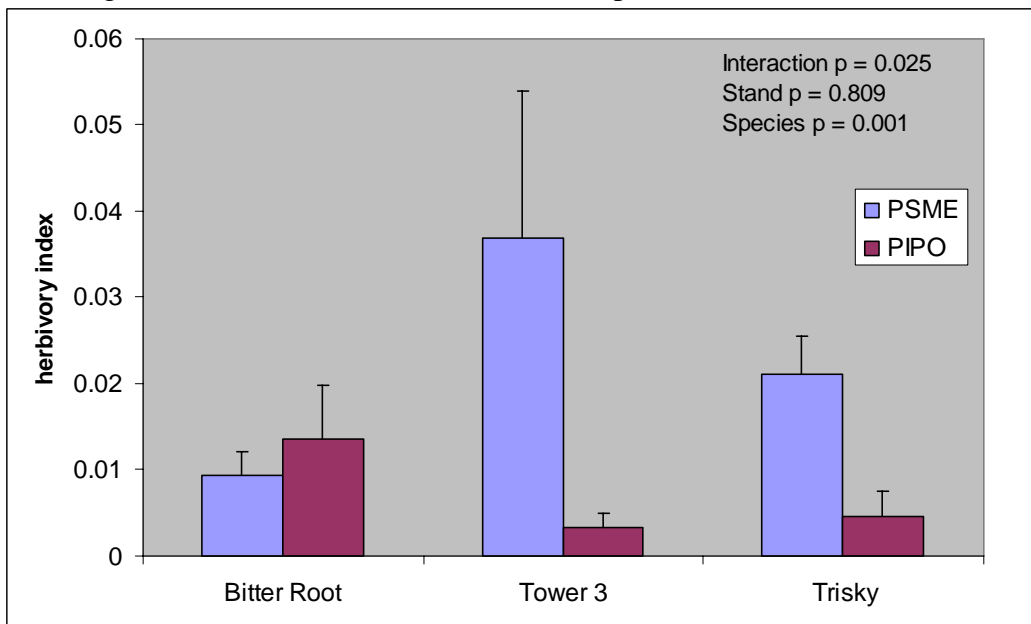


Figure 3. Density Function of the distance between saplings: Shows that over 80% of the saplings sampled were within 5m of another sapling.

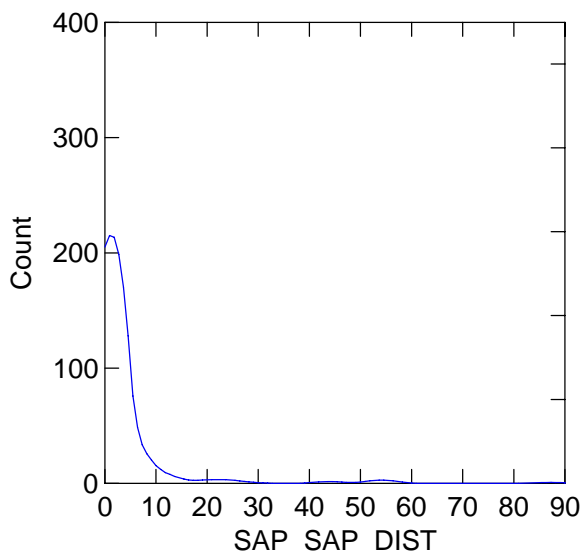


Table 1. Percent herbivory on each plant for both species combined (the number of branches clipped out of total number branches on each plant for an individual plant) variables. No significant variables were found when each species were run separately. Closest to significance were percent canopy and height of plant ($p=0.152$, $p=0.156$).

| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
|--------------|-------------|-----------|----------|-----------|--------|-----------|
| CONSTANT | 0.032 | 0.009 | 0.000 | . | 3.718 | 0.000 |
| TRANSLOPE | 0.130 | 0.126 | 0.090 | 0.735 | 1.029 | 0.305 |
| HEIGHT | -0.000 | 0.000 | -0.110 | 0.944 | -1.425 | 0.156 |
| TRAN_SKY | 0.106 | 0.074 | 0.114 | 0.903 | 1.437 | 0.152 |
| SAP_TO_SAP | 0.000 | 0.000 | 0.087 | 0.979 | 1.142 | 0.255 |
| SAP_TO_EDGE | -0.000 | 0.000 | -0.027 | 0.875 | -0.331 | 0.741 |
| SAP_TO_PROAD | 0.000 | 0.000 | 0.009 | 0.702 | 0.100 | 0.921 |

| Analysis of Variance | | | | | |
|----------------------|----------------|-----|-------------|---------|-------|
| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
| Regression | 0.001 | 6 | 0.000 | 1.062 | 0.387 |
| Residual | 0.038 | 171 | 0.000 | | |

Table 2a. Stepwise regression of overall sapling abundance against elevation, canopy, slope, aspect, herbivory sign, transect to edge. The significant values found was the aspect ($p=0.051$) and the distance from transect to edge of the stand ($p=0.033$).

| Dep Var: TOTAL_ABUND N: 23 Multiple R: 0.535 Squared multiple R: 0.286 | | | | | | |
|--|----------------|-----------|-------------|-----------|--------|-----------|
| Adjusted squared multiple R: 0.215 Standard error of estimate: 9.039 | | | | | | |
| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
| CONSTANT | 26.309 | 4.332 | 0.000 | . | 6.073 | 0.000 |
| ASPECTRAT | -1.667 | 0.802 | -0.400 | 0.962 | -2.079 | 0.051 |
| TRANSECT_EDG | -0.038 | 0.016 | -0.442 | 0.962 | -2.293 | 0.033 |
| Analysis of Variance | | | | | | |
| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P | |
| Regression | 655.883 | 2 | 327.941 | 4.014 | 0.034 | |
| Residual | 1634.031 | 20 | 81.702 | | | |

Table 2b. Stepwise regression of Ponderosa Pine abundance against elevation, canopy, slope, aspect, herbivory sign, transect to edge. The only significant value found was the aspect of the stands ($p=0.057$).

| Dep Var: PP_ABUND N: 15 Multiple R: 0.501 Squared multiple R: 0.251 | | | | | | |
|--|----------------|-----------|-------------|-----------|--------|-----------|
| Adjusted squared multiple R: 0.193 Standard error of estimate: 3.182 | | | | | | |
| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
| CONSTANT | 6.959 | 1.398 | 0.000 | . | 4.977 | 0.000 |
| ASPECTRAT | -0.679 | 0.326 | -0.501 | 1.000 | -2.085 | 0.057 |
| Analysis of Variance | | | | | | |
| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P | |
| Regression | 43.999 | 1 | 43.999 | 4.346 | 0.057 | |
| Residual | 131.601 | 13 | 10.123 | | | |

Table 2c. Stepwise regression of Douglas fir abundance against elevation, canopy, slope, aspect, herbivory sign, transect to edge. No significant values were found; herbivore sign was approaching significance with a p-value of 0.093.

| Dep Var: FIR_ABUND N: 23 Multiple R: 0.527 Squared multiple R: 0.277 | | | | | | |
|--|----------------|-----------|-------------|-----------|--------|-----------|
| Adjusted squared multiple R: 0.163 Standard error of estimate: 7.308 | | | | | | |
| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
| CONSTANT | 16.163 | 3.725 | 0.000 | . | 4.339 | 0.000 |
| ASPECTRAT | -0.996 | 0.660 | -0.305 | 0.929 | -1.509 | 0.148 |
| HERBIVORY_SI | 0.276 | 0.156 | 0.359 | 0.926 | 1.771 | 0.093 |
| TRANSECT_EDG | -0.021 | 0.013 | -0.309 | 0.936 | -1.532 | 0.142 |
| Analysis of Variance | | | | | | |
| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P | |
| Regression | 389.267 | 3 | 129.756 | 2.430 | 0.097 | |
| Residual | 1014.646 | 19 | 53.402 | | | |

Table 3a. Total herbivory index stepwise regression vs. elevation, canopy, slope, aspect, herbivory sign, transect to edge. The only significant value found in this regression was herbivores sign at each transect ($p=0.001$).

| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
|--------------|-------------|-----------|----------|-----------|-------|-----------|
| CONSTANT | 0.025 | 0.004 | 0.000 | . | 5.706 | 0.000 |
| HERBIVORY_SI | 0.001 | 0.000 | 0.634 | 1.000 | 3.760 | 0.001 |

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|------------|----------------|----|-------------|---------|-------|
| Regression | 0.003 | 1 | 0.003 | 14.138 | 0.001 |
| Residual | 0.005 | 21 | 0.000 | | |

Figure 3a. Total herbivory index by the number of herbivory signs. The extremely high point is an outlier where very high herbivory occurred and many scat were present. Without this outlier, the trend is still strongly positive.

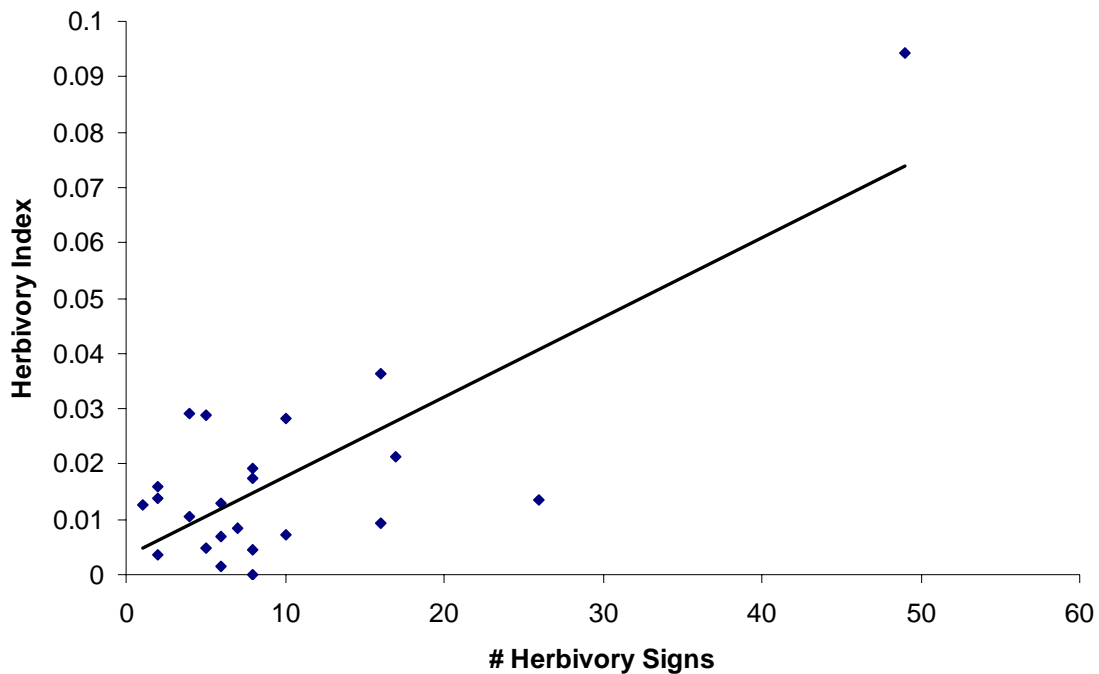


Table 4. Herbivory index for Douglas fir stepwise regression vs. elevation, canopy, slope, aspect, herbivory sign, transect to edge. The only significant value found in this regression was herbivores sign at each transect ($p=0.001$) and the slopes at each transects were approaching a level of significance ($p=0.089$).

| Dep Var: TRAN_FIR_HER N: 23 Multiple R: 0.703 Squared multiple R: 0.494 | | | | | | |
|---|----------------|-----------|-------------|-----------|--------|-----------|
| Adjusted squared multiple R: 0.443 Standard error of estimate: 0.017 | | | | | | |
| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
| CONSTANT | -0.017 | 0.025 | 0.000 | . | -0.671 | 0.510 |
| HERBIVORY_SI | 0.001 | 0.000 | 0.656 | 0.998 | 4.120 | 0.001 |
| TRANS_SLOPE | 0.893 | 0.499 | 0.285 | 0.998 | 1.789 | 0.089 |
| Analysis of Variance | | | | | | |
| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P | |
| Regression | 0.005 | 2 | 0.003 | 9.763 | 0.001 | |
| Residual | 0.006 | 20 | 0.00 | | | |

Figure 4a. The Douglas fir herbivory index by the number of herbivory signs. The extremely high point is an outlier where very high herbivory occurred and many scat were present. Without this outlier, the trend is still strongly positive.

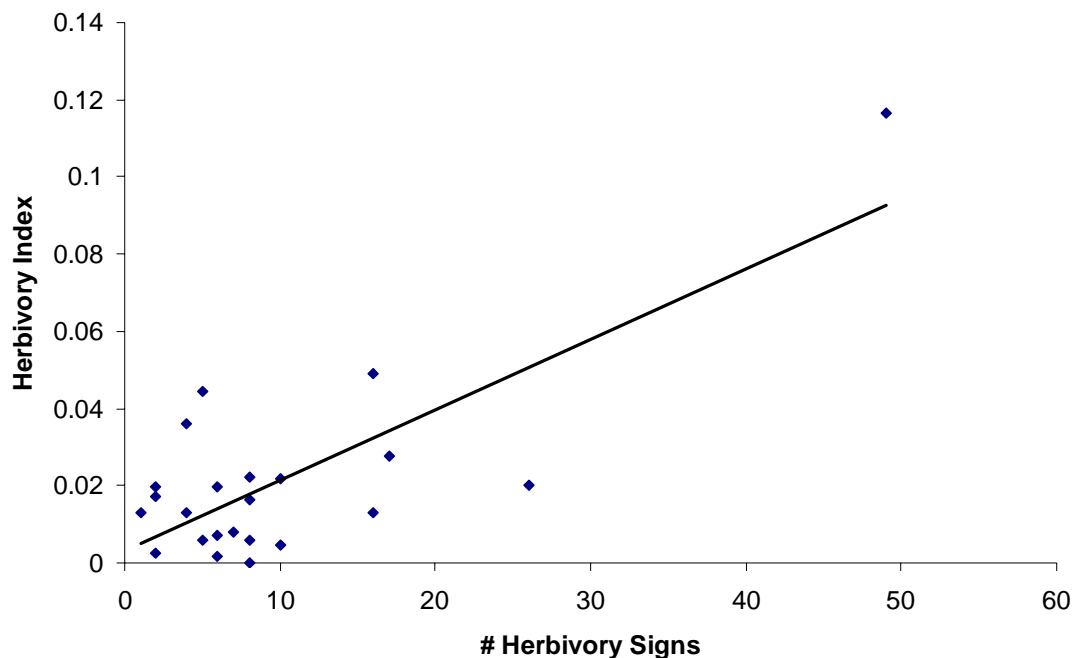


Figure 4b. . The Douglas fir herbivory indexes by the percent slopes for each transect. The extremely high point is an outlier where very high herbivory occurred. Without this outlier, the trend shows a slight positive increase.

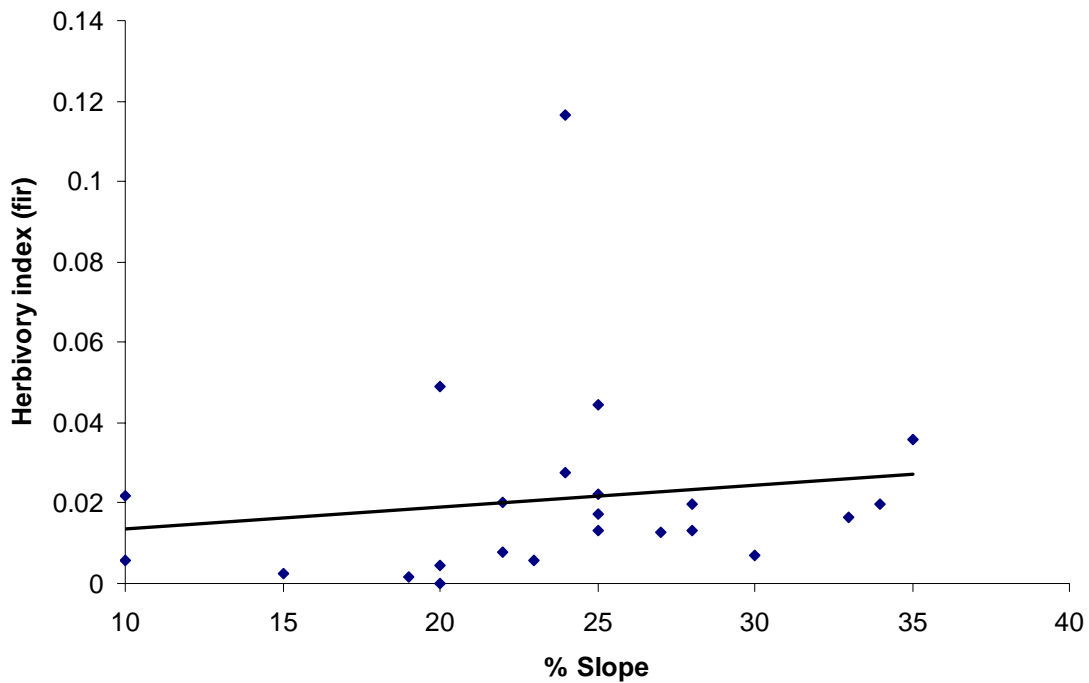


Table 5. Herbivory index for Ponderosa pine stepwise regression vs. elevation, canopy, slope, aspect, herbivory sign, transect to edge. The significant value found in this regression was elevation at each transect ($p=0.002$) and the canopy at each transects were approaching a level of significance ($p=0.145$).

| Dep Var: TRANS_PP_HER N: 15 Multiple R: 0.745 Squared multiple R: 0.555 | | | | | | |
|--|----------------|-----------|-------------|-----------|--------|-----------|
| Adjusted squared multiple R: 0.481 Standard error of estimate: 0.014 | | | | | | |
| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
| CONSTANT | -0.224 | 0.066 | 0.000 | . | -3.421 | 0.005 |
| ELEVATION | 0.000 | 0.000 | 0.783 | 0.899 | 3.854 | 0.002 |
| TRAN_TOT_CAN | 0.315 | 0.202 | 0.317 | 0.899 | 1.559 | 0.145 |
| Analysis of Variance | | | | | | |
| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P | |
| Regression | 0.003 | 2 | 0.001 | 7.489 | 0.008 | |
| Residual | 0.002 | 12 | 0.000 | | | |

Figure 5a. The Ponderosa pine herbivory index by the number of herbivory signs. This regression has an extremely high point is an outlier where very high herbivory occurred at a high elevation. Without this outlier, the trend is still strongly positive

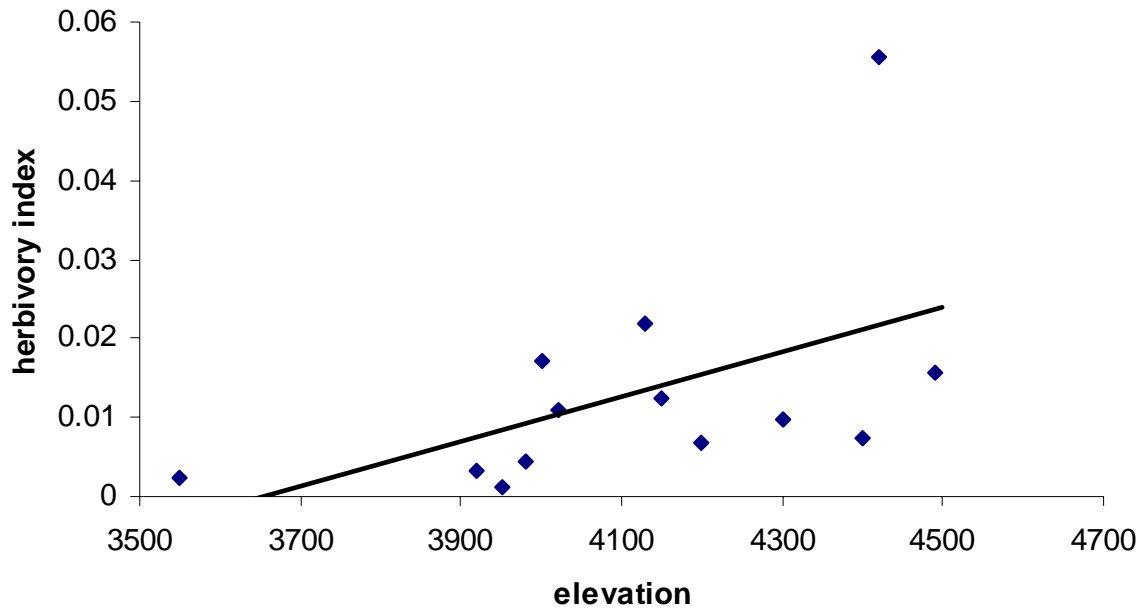


Figure 5b. The Ponderosa pine herbivory index by the number of herbivory signs. The regression has a slight negative trend.

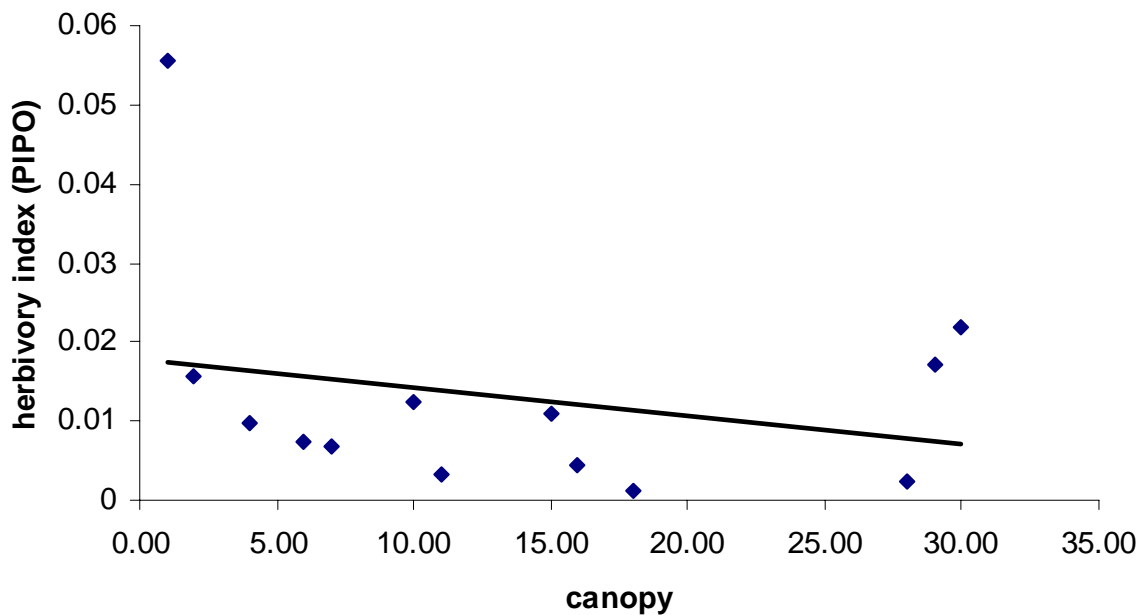


Table 6a. Linear regression of total herbivory index by distance to road, regression is approaching significance ($p=0.091$).

| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
|-------------|-------------|-----------|----------|-----------|-------|-----------|
| CONSTANT | 0.027 | 0.005 | 0.000 | . | 4.963 | 0.000 |
| TRANSECT_RD | 0.000 | 0.000 | 0.369 | 1.000 | 1.778 | 0.091 |

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|------------|----------------|----|-------------|---------|-------|
| Regression | 0.001 | 1 | 0.001 | 3.160 | 0.091 |
| Residual | 0.004 | 20 | 0.000 | | |

Table 6b. Linear regression of herbivory index for Douglas fir by distance to road, regression is significant ($p=0.049$).

| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
|-------------|-------------|-----------|----------|-----------|-------|-----------|
| CONSTANT | 0.027 | 0.006 | 0.000 | . | 4.340 | 0.000 |
| TRANSECT_RD | 0.000 | 0.000 | 0.426 | 1.000 | 2.104 | 0.048 |

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|------------|----------------|----|-------------|---------|-------|
| Regression | 0.001 | 1 | 0.001 | 4.425 | 0.048 |
| Residual | 0.005 | 20 | 0.000 | | |

Figure 7. The Douglas fir herbivory index by the distance to road. This regression has an extremely high point is an outlier where very high herbivory occurred; however, the trend is still positive.

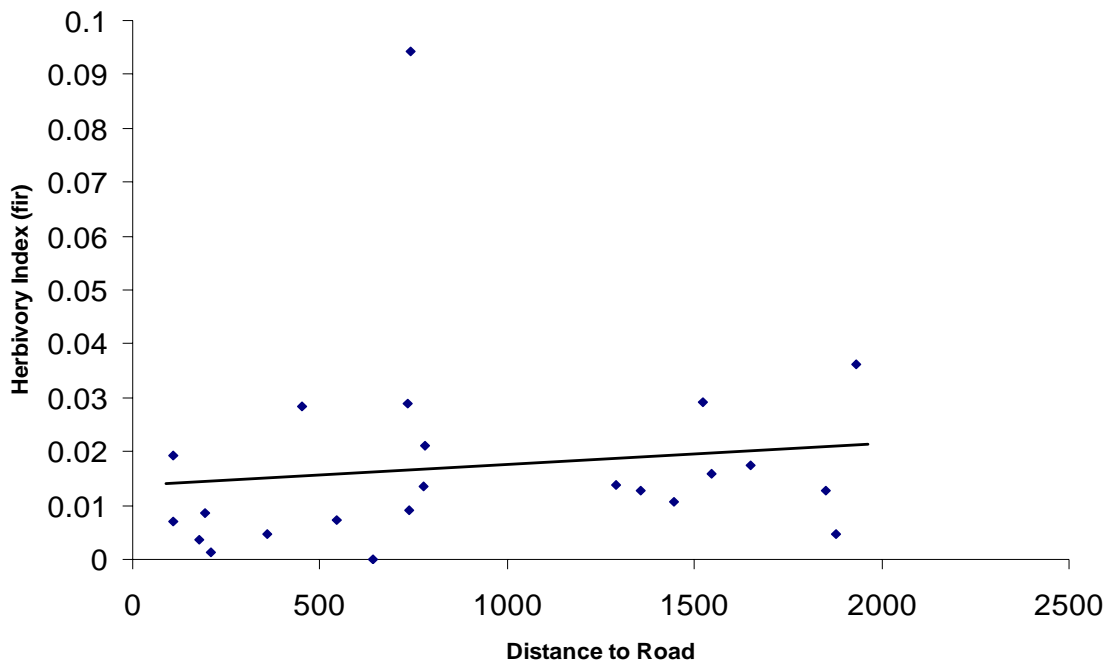


Figure 8. Experimental Transect Layout located at each stand.

