Using Biodiversity and Evenness Comparisons Among Plant Communities as a Plant Conservation Management Tool in the Pryor Mountains, Montana

The south side of the Pryor Mountains looking north toward the *Eriogonum brevicaule, Juniperus osteosperma* and *Artemisia nova* sites with East Pryor in the east and Big Pryor and Red Pryor in the west.

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Please cite this report as:
Durney, Simone, K. Flathers, and J. Lyman. 2013. Using Biodiversity and Evenness Comparisons Among Plant Communities as a Plant Conservation Management Tool in the Pryor Mountains, Montana. Report YRRC 2013-02. Submitted to the Pryors Coalition and Cinnabar Foundation. Yellowstone River Research Center, Billings, MT. 41 pp. plus appendix

Introduction

For many years, ecologists classified and described plant communities by focusing on methods to determine species composition. They developed methodology to assess the association of plant species on a landscape. Daubenmire plots, quadrat size, random or even placement of quadrats and the number of quadrats sufficient to capture most species were used to assess plant communities by ecologists for years (Clements 1963; Daubenmire 1968; Barbour et al. 1999). However, description alone could not provide the basis for understanding variation in plant communities. In the late twentieth century, changes in land use, damaging effects of pollution and climate change began to alter vegetation communities. These changes were occurring in the absence of any baseline information about plant community composition in many areas of the world so it was difficult to assess the impacts to plant community structure and function in order to develop conservation strategies. After years of focusing on the methods for measuring diversity, ecologists realized the need to understand the environmental factors that influence plant community dynamics. Plant community ecology during the past few decades has focused on conducting baseline surveys using traditional measuring methods in our remaining natural areas and using this information to develop management strategies, to study the ecology of plant community dynamics, and establish monitoring programs to track ecological changes (Grime 2012).

For example, Grime (1977) looked for causes of plant community distribution by asking questions about factors that drive species competition, stress tolerance and disturbance. He developed a model that focused on the evolution of plant community structure by focusing on the levels of influence of three primary strategies: (1) morphological features; (2) resource allocation; (3) phenology; (4) response to stress. Ecological theory suggests that in many cases, high diversity in an ecosystem supports stability or approaches equilibrium. In other words, an increase in species diversity increases the structural complexity of the ecosystem with increased competition and the availability of niche space (Kormondy 1969; South 1980, Ricklefs & Miller 2000). The intermediate disturbance hypothesis was developed when ecologists began to address the effects of disturbance on plant communities. This hypothesis suggests that plant species richness is promoted by recurring disturbances at intermediate frequencies through time (Roxburgh et al. 2004).

Plant ecologists also found that natural selection processes are intensified at population margins of communities. Gene flow at the periphery of populations is reduced because of isolation from the core or center of the plant community where individuals of a species are more abundant and where there are fewer neighbors of the same species. In other words, at population margins, individuals of a species experience different regimes of natural selection from those in the center. Plant species at margins may become genetically distinct because of divergent natural selection (Lesica and Allendorf 1995). Lesica (1994) recognized that the south side of the Pryors is the northern-most extent of the Great Basin flora and therefore plant communities there are peripheral to the center of distribution to the south. He argues that monitoring and conserving peripheral populations will protect the evolutionary and environmental processes that are likely to generate future evolutionary diversity (Lesica and Allendorf 1995).

Another way of interpreting plant community diversity is to focus on endemic species within a community. Lesica (2007) describes the Pryor Mountains as a botanical hot spot or area of exceptional botanical diversity because of the high rate of plant endemism as well as high plant community diversity (Crawley 1997). Many areas of high endemism support local species that have evolved recently (Lesica 2006). For example, eight species of plants in the Pryors and adjacent Northern Bighorn Basin occur in this region and nowhere else on Earth. Bighorn fleabane (*Erigeron allocotus*), Cary's penstemon (*Penstemon caryi*), Pryor bladderpod (*Physaria lesicii*), and Sullivantia (*Sullivantia hapemanii*) occur only in the Pryor Mountains and the adjacent northern Bighorn Mountains. Beartooth goldenweed (*Pyrrocoma carthamoides* var. *subsquarrosa*) and Shoshone carrot (*Shoshonea pulvinata*) also occur in the foothills of the Pryors and the eastern Beartooth-Absaroka uplift while Rabbit buckwheat (*Eriogonum brevicaule canum*) and Wooly prince's-plume (*Stanleya tomentosa*) are found in the Bighorn Basin desert (Lesica 2007).

It wasn't until 1978 that botanists published articles about the uniqueness of the Pryor Mountain flora (Lesica et al. 1992). The United States Forest Service (USFS), Bureau of Land Management (BLM) and Montana Natural Heritage Program (MNHP) recognized the need to study the basic plant community distributions, presence of rare plant species, and identification of research natural areas (Pryors Coalition 2007).

Since 1978, nearly 1,000 plant species have been recorded in the Pryor Mountains. Dorn initially observed in 1978 that desert plant species characteristic of the Great Basin reach their northern range limits in the Pryor Mountain Desert (Lesica et al. 1992). A flurry of botanical activity occurred in the 1990s when the BLM and MNHP completed plant community surveys throughout the Pryors. During this period, the MNHP surveyed *Shoshonea pulvinata* populations, and USFS identified Lost Water Canyon as a Research Natural Area (RNA). The Montana Native Plant Society and MNHP designated the South Pryor Mountain's Important Plant Area (IPA), which supports five plant species considered to be Species of Concern (SOC) in Montana and over 29 distinct plant communities (Lesica 2012). DeVelice and Lesica (1993) identified and mapped 33 vegetation communities on BLM public lands, nine of which had not been reported elsewhere in the United States and 14, which are considered to be globally rare. McCarthy (1996) reviewed herbarium literature and completed a floristic survey of the Pryor Mountains in 1994 and 1995. In a comparative study with eleven other regions she calculated that the Pryors species richness is 948 species per 1000 km^2. However, this species richness number was determined for the Pryors as a whole and not by plant community. In July 2012, a two-day bioblitz effort identified 336 plants and over 122 pollinators (Ostovar 2012). Conserving high-quality examples of plant communities helps to protect more than the usual or unusual species. Less conspicuous organisms benefit as well (Lesica 1994). Unfortunately none of these previous studies go beyond cataloguing the presence and distribution of vascular plant species. Heidel's (2001) work with the MNHP, which included periodically monitoring *Shoshonea pulvinata* populations, has been the only work that involves baseline surveys for the diversity of particular plant communities in the Pryor Mountains. Therefore ecologists have no way to track changes in plant community structure or function over time.

Recent developments that affect the Pryor Mountains highlight the need to go beyond describing plant species distributions. There is a dire need for baseline surveys that provide ecologists with detailed information about species abundance, dominance, and rarity in particular plant communities so that conservation managers have the tools to make conservation decisions. For example, climate change is a potential threat to vegetation communities in the Pryor Mountains. Rising temperatures, changes in seasonality, and acceleration of the hydrologic cycle will shift ecosystem types and connections with other ecosystems irreversibly. Plant communities are vulnerable to changes in climate factors such as precipitation quantity and timing along with temperature regimes (South 1980). Climate change velocity is the rate of change in the climate and may result in plant species migration. Velocities of up to 20 kilometers per year have been observed in the US from 1960 to 2009, as compared to velocities of 0.002 kilometers per year since the last glaciation to present day (Grimm et al. 2013). In addition to shifting vegetation, climate change may increase species vulnerability to population loss and extinction across the globe, threatening global biodiversity (Klausmeyer et al. 2011).

Continual monitoring of temperature and precipitation levels in various climates has found long-term trends toward lower precipitation and extended warm periods (Running 2013). Changes in plant community diversity may occur over time as a result of changes in temperature levels (Spellerberg 2005). In order to develop conservation strategies that facilitate adaptation to change, managers must understand the vulnerability of the habitats and their species they are managing. Our study provides important plant community data for a subset of the Pryor Mountains at a critical time where anthropogenic influences have the potential to affect the vegetation.

Motorized vehicle use, such as off highway vehicles (OHV), also threatens the stability of plant communities. Busby et al. (2008) found that out of all of the factors analyzed the intensity of motorized disturbance appeared to play the greatest role in vegetation change. Anthropogenic disturbances can accelerate the rate of change in an ecosystem, and set them back to an earlier stage of succession (South 1980). In addition to changing the vegetation composition, OHV use increases soil erosion and decreases vegetation development (Anderson et al. 2007). The Beartooth Ranger District Travel Management Plan in Custer National Forest, released in 2008, designated motorized and non-motorized trails. Most trails were designated motorized since the Pryor Mountains are open and highly accessible (United States Forest Service 2008). The plan, which favors off highway vehicle use over hiking trails, leaves open the possibility for introduction of non-native species from motorized use and off highway vehicles. An increase in motorized use may decrease vegetation cover and density, lowering diversity and leaving the community susceptible to non-native species invasion. Monitoring studies like the one described below will provide data on plant community species composition dynamics that can help managers identify the most vulnerable species and the reason for vulnerability to climate change (Klausmeyer et al. 2011).

The significance of our study is to provide baseline biodiversity indices for native and non-native species in nine plant communities in the Pryors. This data can be used to:

1. Monitor plant community changes over time
2. Monitor weed dynamics
3. Study the ecological factors that regulate plant community structure and function

Our study is the first to quantify levels of biodiversity in the Pryor Mountains. It provides baseline surveys as a starting point for periodic monitoring to guide conservation managers in their development of management plans that will conserve the unique biodiversity of the Pryor Mountain region.

Methods

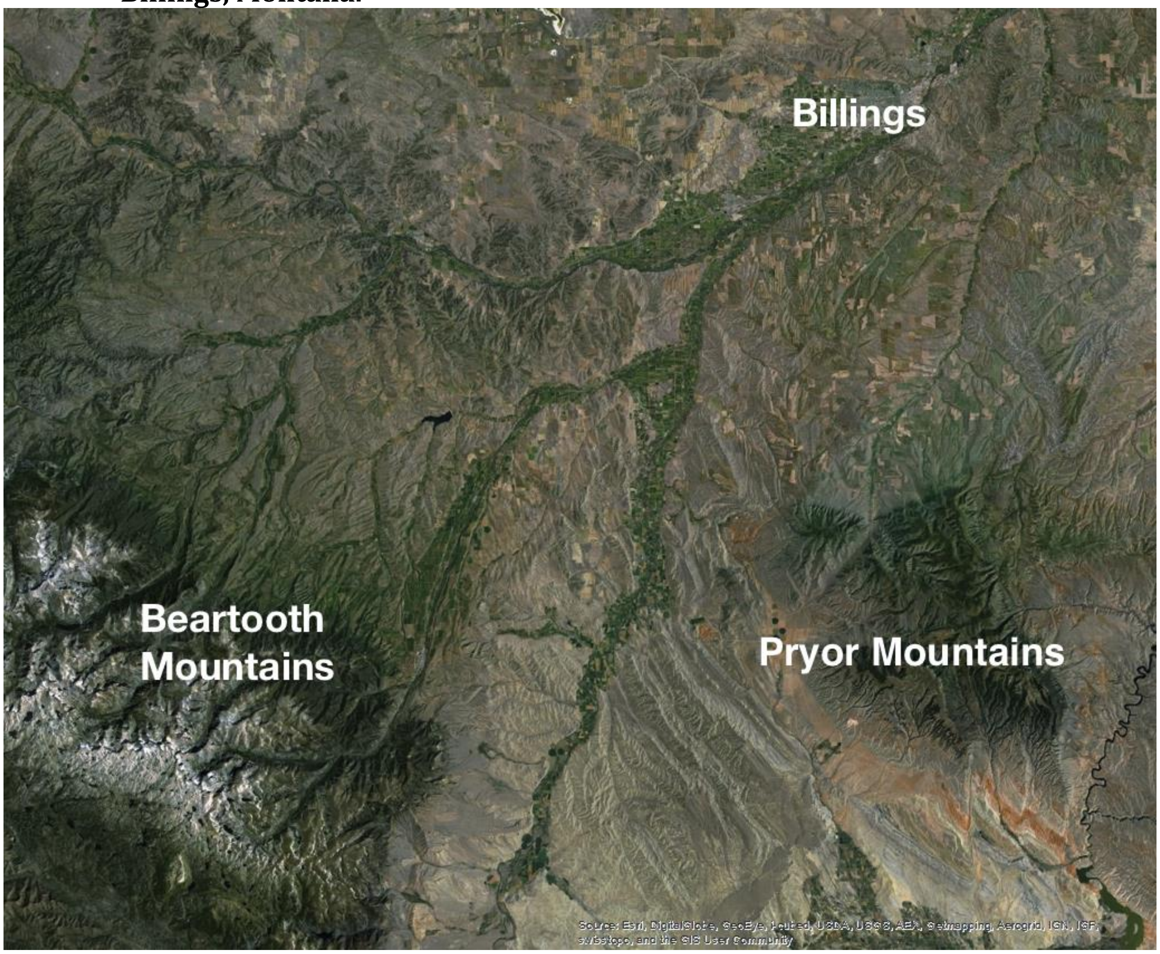
Study Area – Abiotic & Edaphic Factors

The Pryor Mountains are located in south central Montana about 40 miles south of Billings, MT. They differ from the adjacent glacially carved granitic Beartooth Mountains because they are composed of limestone. Their canyons and uplifts contribute to unusual and diverse vegetation communities. The two ranges also differ in geological age with the Beartooths dating back 3.3 billion years, while the Pryors are between 359 and 326 million years old (Alt & Hyndman 1991). The Bighorn Basin falls between the Beartooths and the

Pryors. It is an oval depression in the landscape that covers 10,000 miles^2. It contains exposed anticlines and other features as a result of the Laramide orogeny. The Beartooths on the west and Pryors on the east were thrust over the Laramide orogeny 60 to 55 million years ago to create the basin margins seen today (Lageson & Spearing 2000). The Pryor Mountains are uplifted basement rock with younger sedimentary rocks that were shoved east about 50 million years ago. The exposed rocks in the Pryors are Paleozoic sedimentary formations, primarily Madison limestone. The south side of the range in Wyoming is composed of Precambrian basement rock (Alt & Hyndman 1991). The limestone substrate comprising the Pryor Mountains supports unusual plant communities and species.

The geographical orientation of the Pryor Mountains, the variety of precipitation, wind patterns and the soil types combine to foster the growth of many vegetation communities, some of which are associated with the plants of the Great Basin. The Pryors are oriented east-west with Crooked Creek between the two tallest peaks (Big Pryor on the west side and East Pryor on the east side). The slope, aspect and angle of the mountains all contribute to and influence the microclimates. For example, the south side of the Pryors is hotter and drier (7-8 in or 18-20 cm) while the north side is remarkably cooler and wetter (18-20 in or 46-51 cm). In comparison, the Beartooth Mountains receive 26 to 34 inches (66-86 cm) annually (Montana Average Annual Precipitation, 1971-2000)(Figure 1). On average, during May and June, winds blow from the north through the Pryor Mountains (Western Regional Climate Center 2002). The soil types found in the Pryors include mollisols, aridisols and entisols. Sandy or silty well-drained loams occur on the northeast side. The south and west areas are higher in clay content, often saline, and plant productivity is often low due to the natural aridity of the environment (McCarthy 1996).

Figure 1: Map of the Pryor Mountains in Relation to the Beartooth Mountains and Billings, Montana.



Monitoring Sites

We selected nine vegetation communities for long-term monitoring (personal communication Lyman, McCracken, and Walton 2013). Lesica's (1994) vegetation survey maps were used to identify communities for this work. Access to the sites was a factor in site selection. The sampling area, where data collection occurs, is located within the monitoring site. Sampling areas were chosen using ocular estimates to achieve maximum diversity and represent the vegetation community (Figure 2 and Table 1).

Figure 2: Map of Monitoring Sites

Nine plant communities in the Pryor Mountains identified by dominant species or habitat. USFS and BLM land ownership boundaries

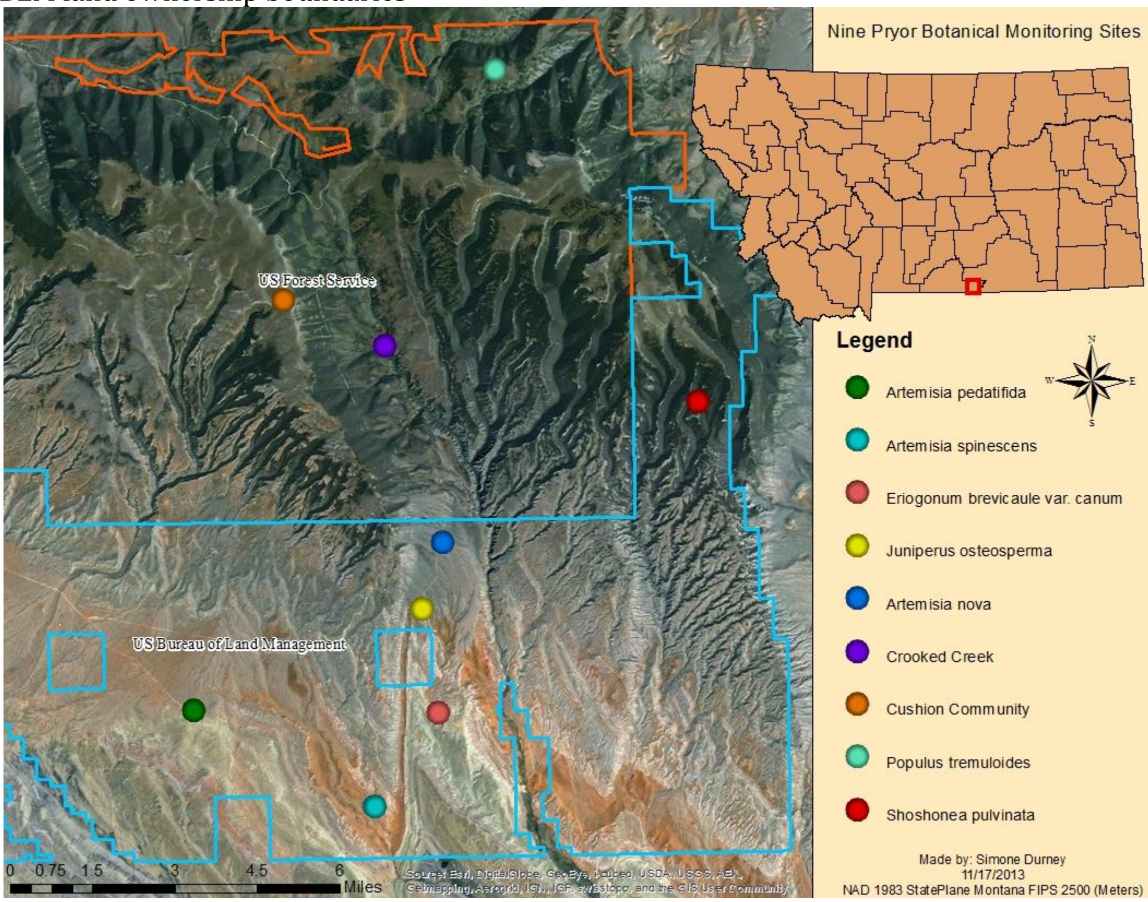


Table 1: Monitoring Sites with GPS Coordinates and Elevation Values

Site	GPS	Elevation (feet)
Artemisia pedatifida	N 45.039608° W 108.501801°	5031 - 5056
Artemisia spinescens	N 45.013500° W 108.434680°	4735 - 4738
Eriogonum brevicuale	N 45.038090° W 108.410800°	4744 – 4815
Juniperus osteosperma	N 45.065540° W 108.416210°	5356 - 5394
Artemisia nova	N 45.082870°	5453 - 5784

	W 108.408110°	
Crooked Creek Riparian Area	N 45.134640° W 108.428950°	6039 – 6312
Cushion Plant Community Subalpine Meadow	N 45.147460° W 108.466560°	8491 - 8632
Populus tremuloides Punchbowl	N 45.207400° W 108.386280°	6798 – 6828
Shoshonea pulvinata	N 45.119140° W 108.312180°	7552 - 7615

Sampling Method

We used line intercepts and Daubenmire plots to describe plant communities quantitatively. In each of the nine community types the following data were recorded: percent plant cover, frequency and density by species (personal communication Lyman and Velman 2013). Plant surveys took place from 22 May 2013 to 29 June 2013. Lesica's (2012) *Manual of Montana Vascular Plants*, Hitchcock et al. (1990) *Vascular Plants of the Pacific Northwest* and Schiemann (2005) *Wildflowers of Montana* and the internet site Consortium of Pacific Northwest Herbaria (www.pnwherbaria.org 2007-2013) were used for species identification.

At each of the nine monitoring sites, two 100-meter line intercepts were laid out at right angles (Bonham 1989; Barbour et al.1999; Stohlgren 2007; personal communication Lyman 2013). The first line was set in an east-west direction and the second north-south. We took a GPS point at the beginning of lines one and two and at the intersection of the two lines. All sites had three GPS points, except Crooked Creek with four points with two lines running along either side of the creek. Each point was marked using rebar buried lengthwise three to four inches into the ground. Along each line, Daubenmire plots were placed every 10 meters alternating sides always placing the first frame on the right side of the transect (personal communication Lyman 2013)(Figure 3). Daubenmire frames are 20 cm by 50 cm and were used to estimate percent cover, density and frequency of living herbaceous plant species (Daubenmire 1968; Bonham 1989). The edges of the frame were marked in five percent, 25 percent, 50 percent, and 75 percent increments to estimate percent cover (Figure 4). Minor adjustments were made to the sampling methodology if necessary.

Figure 3: Sampling Methodology within Plant Community

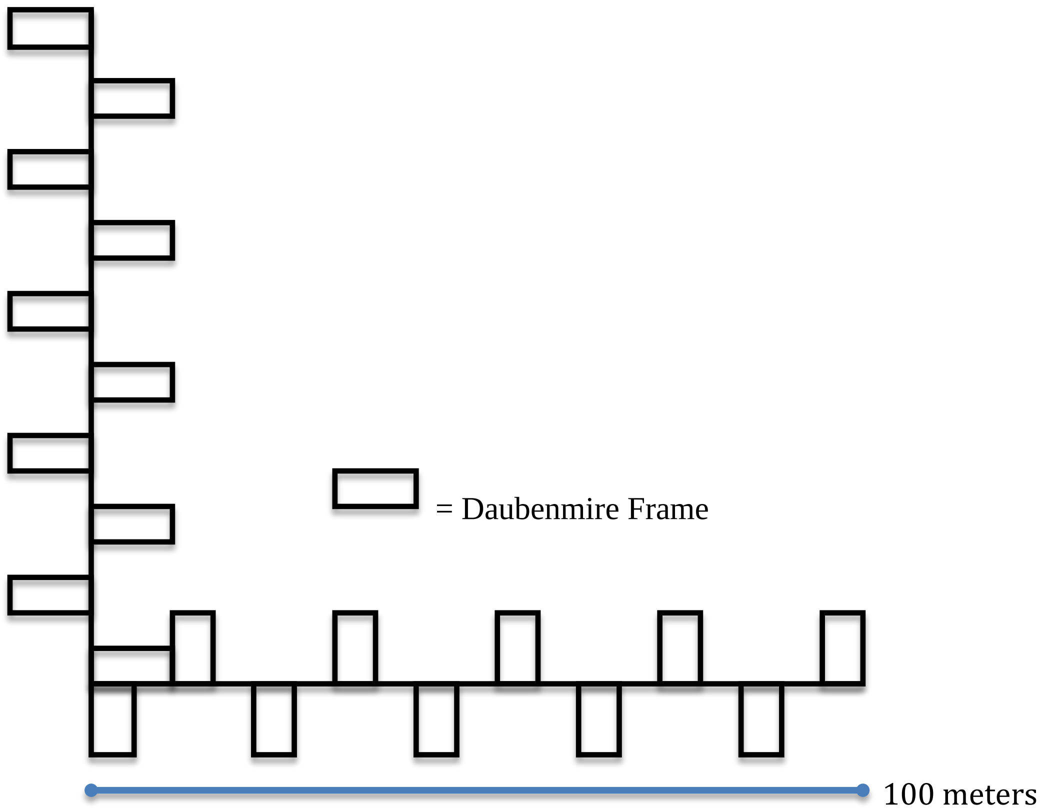
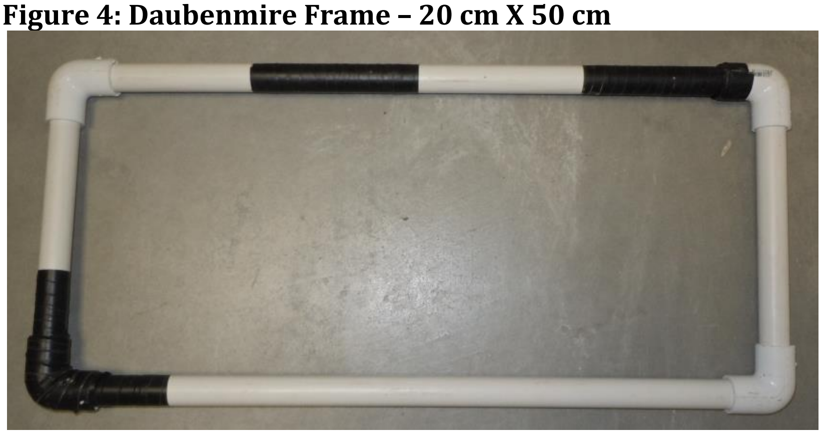


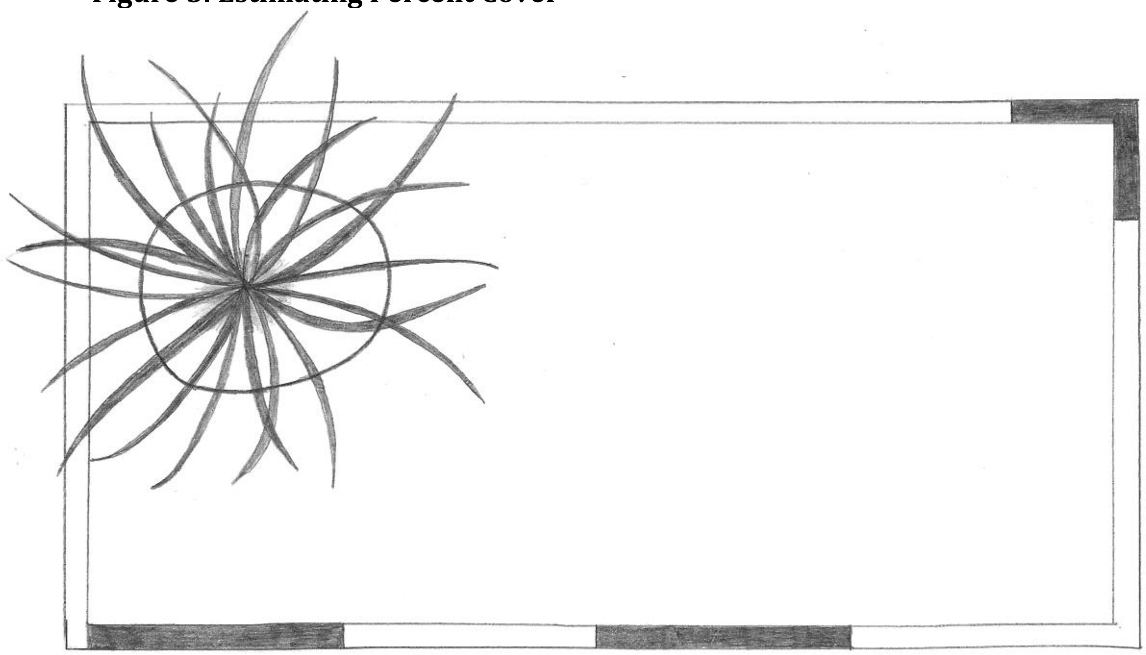
Figure 4: Daubenmire Frame – 20 cm X 50 cm



Daubenmire Frame Data Collection

For each frame, the percent cover was estimated for each individual plant rooted within the frame as well as bare ground. The circle (Figure 5) outlines the area estimated for percent cover. Counting and recording the individual plants of each species within each frame determined density. The frequency of a species was assessed by its occurrence in 20 frames at each monitoring site. For example, if a species occurred in seven out of 20 frames the species had 35 percent frequency. Overall, the data collected with the Daubenmire frames were: (1) percent cover; (2) density; and (3) frequency.

Figure 5: Estimating Percent Cover



Line Intercept Data Collection

Species that fell underneath the 100-meter line were identified and their distance along the line recorded. Bare ground distance along the line was also recorded in this study. This sampling method provides additional data on percent cover and density of species within the nine sampling areas.

Complete Vascular Plant List

In order to record all species among each vegetation community, researchers walked around each monitoring site for about 10 to 20 minutes and recorded new species that were not previously recorded in the sampling area. This completed the vascular plant list of each of the monitoring sites.

Data Analysis

The Shannon-Weaver diversity index and evenness values were calculated to evaluate the diversity of each monitoring site. The values were calculated once with all species including non-natives and once excluding the non-native species. These values help determine the dominance or rarity of species in order to understand the dynamics at work.

Shannon-Weaver Diversity Index

The Shannon-Weaver diversity index (SWDI) is calculated with the following formula.

$$H' = -\sum_{i=1}^{R} pi(\ln(pi))$$

This formula is used to characterize species diversity in a community. The SWDI accounts for the abundance of individuals (density) and evenness of species present. The proportion of species (i) relative to the total number of species (pi) is multiplied by the natural logarithm of the proportion. The product is then summed and multiplied by -1 (Heip et al. 1998; Beals et al. 2000). Microsoft Excel (2008) formulas were used in this study to calculate the density of each species present in the Daubenmire frames of each monitoring site.

Evenness Value

Evenness tells how evenly the numbers of individuals are divided amongst the species. The evenness value assumes a value is between zero and one, with one being complete evenness. It is calculated by dividing the diversity index (H') by the natural logarithm of the total species count (Heip et al. 1998; Beals et al. 2000). Microsoft Excel (2008) formulas were used to calculate this value.

$$E = H' / \ln(s)$$

Distribution Classification

Distribution over the sampling area was calculated using the frequency data collected with the Daubenmire frames. Frequency tells us the percent occurrence of a species on the landscape, which relates to distribution of a species. In this study a species was considered regularly distributed if it occurred greater than or equal to 50 percent. A species was considered to have random distribution if it occurred less than 50 percent. According to this study a community is considered regularly distributed if five or more species have regular distribution (personal communication Lyman 2013).

Native vs. Non-Native

Our study took into account the ratio of native and non-native species. A chi-square test was used to examine the ratio of native versus non-native species. This test determines if there is a significant relationship between native and non-native species. If the test returns a value greater than 0.05 the data is deemed significantly different or unlikely to occur by chance alone (personal communication Ulrich Hoensch 2013).

Elevation Relative to Species Count

Using Microsoft Excel (2008) we conducted a regression analysis to see if there was a relationship between species count and the rise in elevation (personal communication Ulrich Hoensch 2013). In this study a set of data is significant if it has a p-value of 0.05 or less.

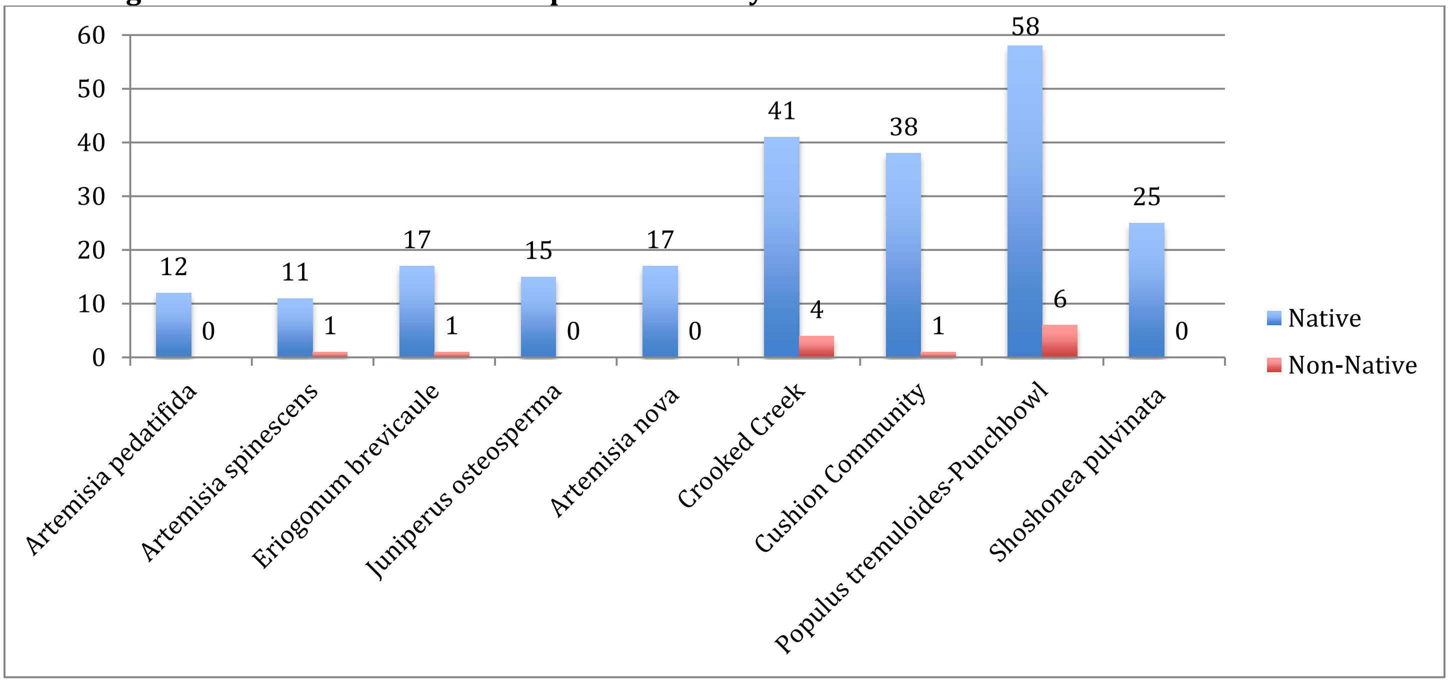
Results

During our study we documented 247 plants species. Fifteen species are considered non-native, while the remaining 232 are native to Montana. A complete vascular plant list of each vegetation community is found in appendix 1.

Native Species vs. Non-Native Species Results

We wanted to know the extent of non-native species invasion in the plant communities in order to be able to track any changes between monitoring events. Five out of the nine sites had non-native species, while the four remaining were free of non-natives (Figure 6). The chi-square test comparing the number of native and non-native species at each site was not significant with a p-value value of 7.990.

Figure 6: Native and Non-Native Species Diversity at Each Site



Distribution Classification Results

As the number of regularly distributed species increases at the site the more regularly distributed the community becomes. The same applies to random distribution, as the number of randomly distributed species increases the more random the communities' distribution. The most regularly distributed site was the cushion plant community/subalpine meadow with eight species evenly distributed. *Artemisia spinescens, Shoshonea pulvinata, Eriogonum brevicaule* sites were the most random with no species regularly distributed (Table 2).

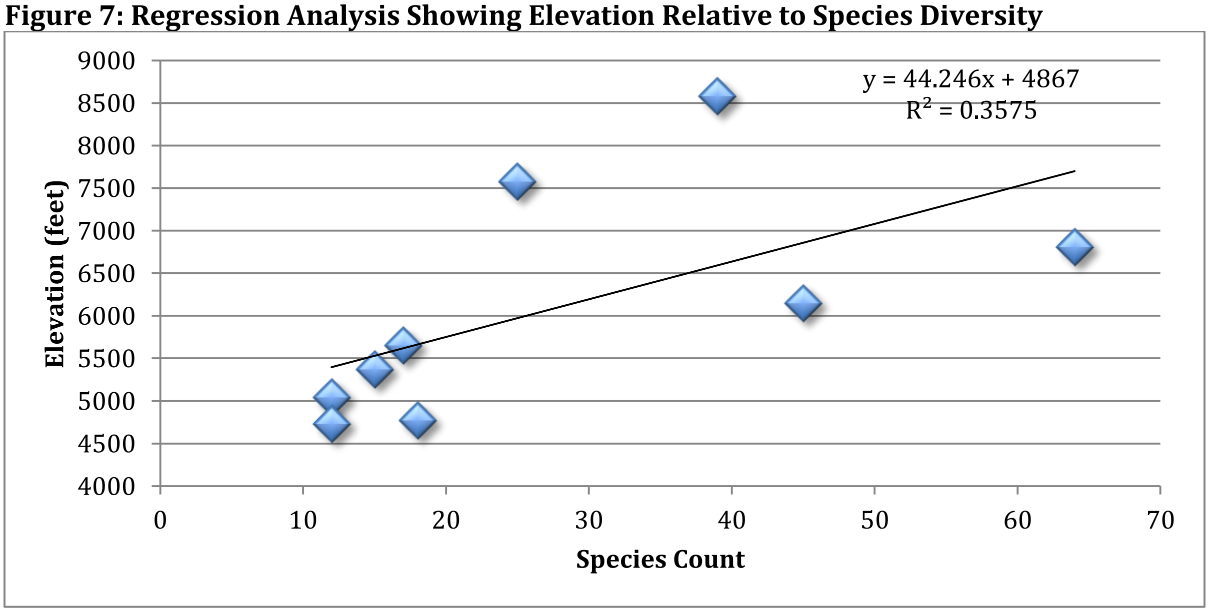
Table 2: Distribution Classification of Each Monitoring Site

Site	Regular Distribution	Random Distribution
Artemisia pedatifida		X
Artemisia spinescens (most random)		X
Eriogonum brevicuale (most random)		X
Juniperus osteosperma		X
Artemisia nova	X	
Crooked Creek Riparian Area	X	
Cushion Plant Community Subalpine Meadow (most regular)	X	
Populus tremuloides Punchbowl	X	
Shoshonea pulvinata (most random)		X

Elevation Relative to Species Diversity Results

We found a relationship between the number of species as elevation increased. A regression analysis showed no significance between the two factors with a p-value of 0.089 (Figure 7).

Figure 7: Regression Analysis Showing Elevation Relative to Species Diversity



Diversity Index and Evenness Results

We used the Shannon-Weaver diversity index and evenness values to analyze the condition of each vegetation community. The values calculated below exclude non-native species data (Figure 8). Figure 9 includes non-native species in calculations. Figures 10 and 11 are a comparison of the diversity index and evenness value including and excluding non-native species. *Populus tremuloides*-Punchbowl had the highest diversity index and the second highest evenness value. *Artemisia pedatifida* had the lowest diversity index and evenness values.

Figure 8: Diversity Indices and Evenness Values of Nine Plant Communities in the Pryor Mountains excluding non-native species.

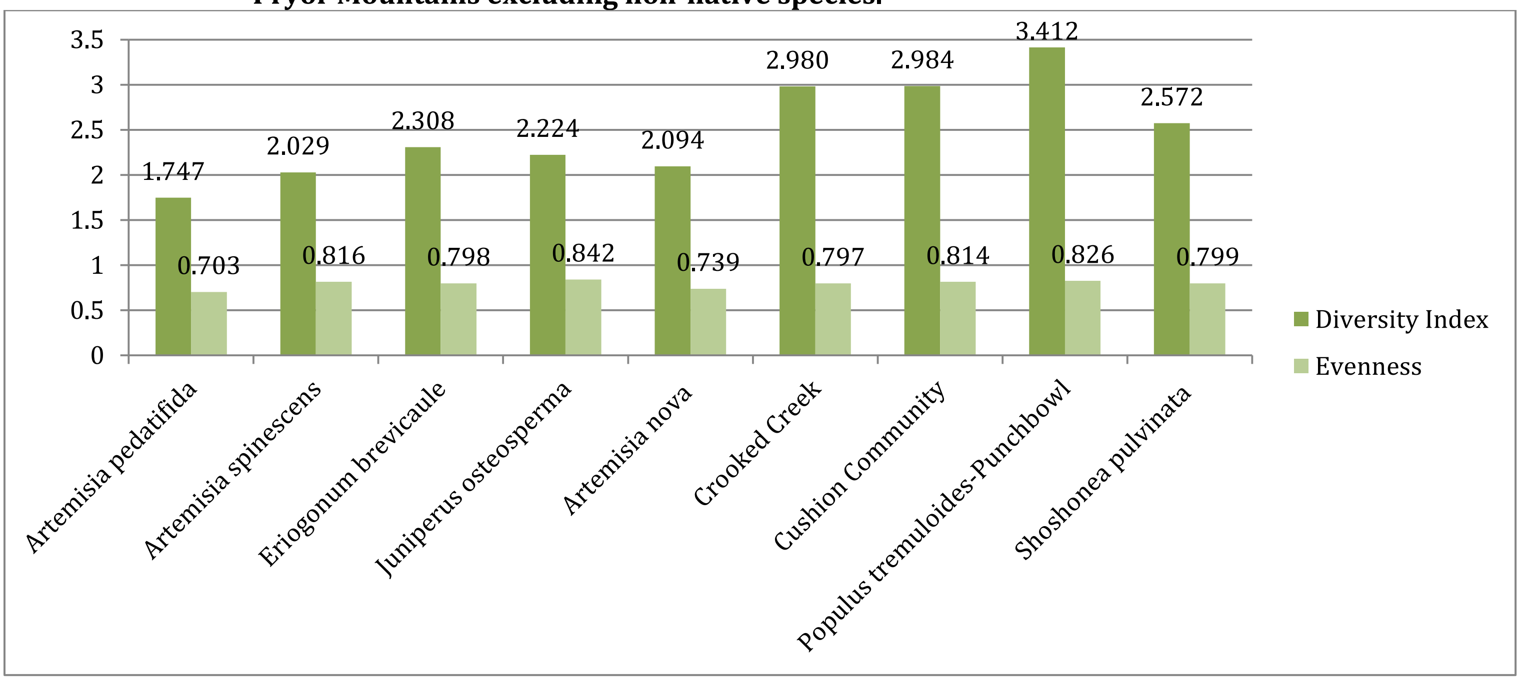


Figure 9: Diversity Indices and Evenness Values of Nine Plant Communities in the Pryor Mountains including non-native species.

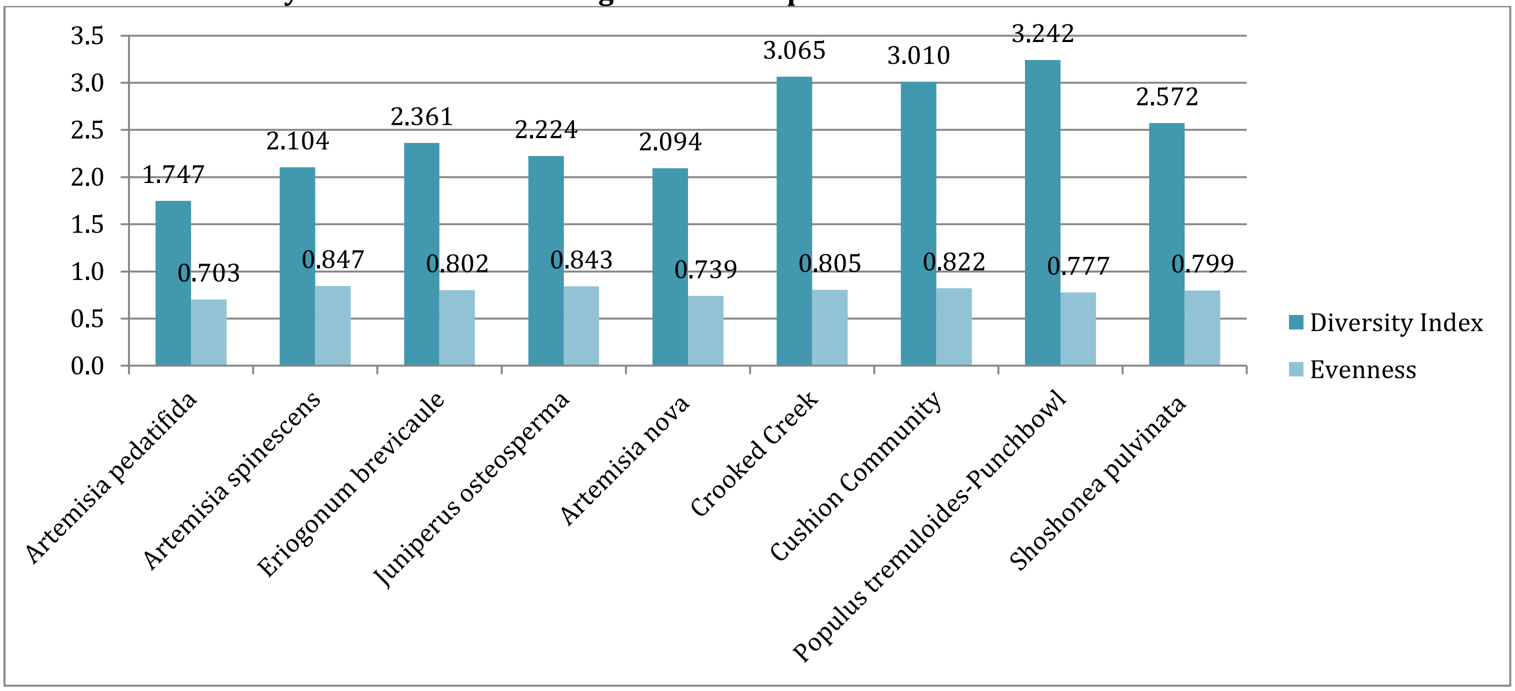


Figure 10: Diversity Indices of Nine Plant Communities in the Pryor Mountains
Calculations excluding and including non-native species

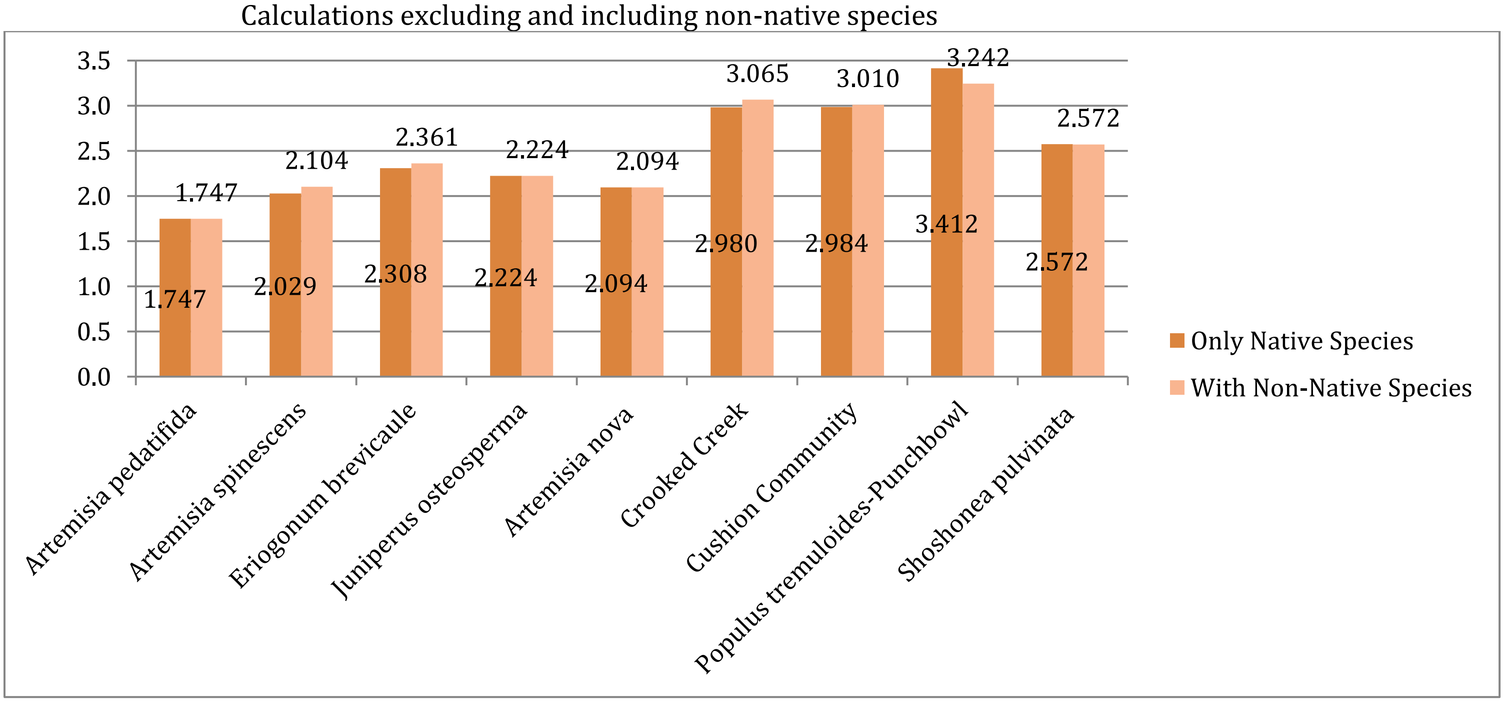
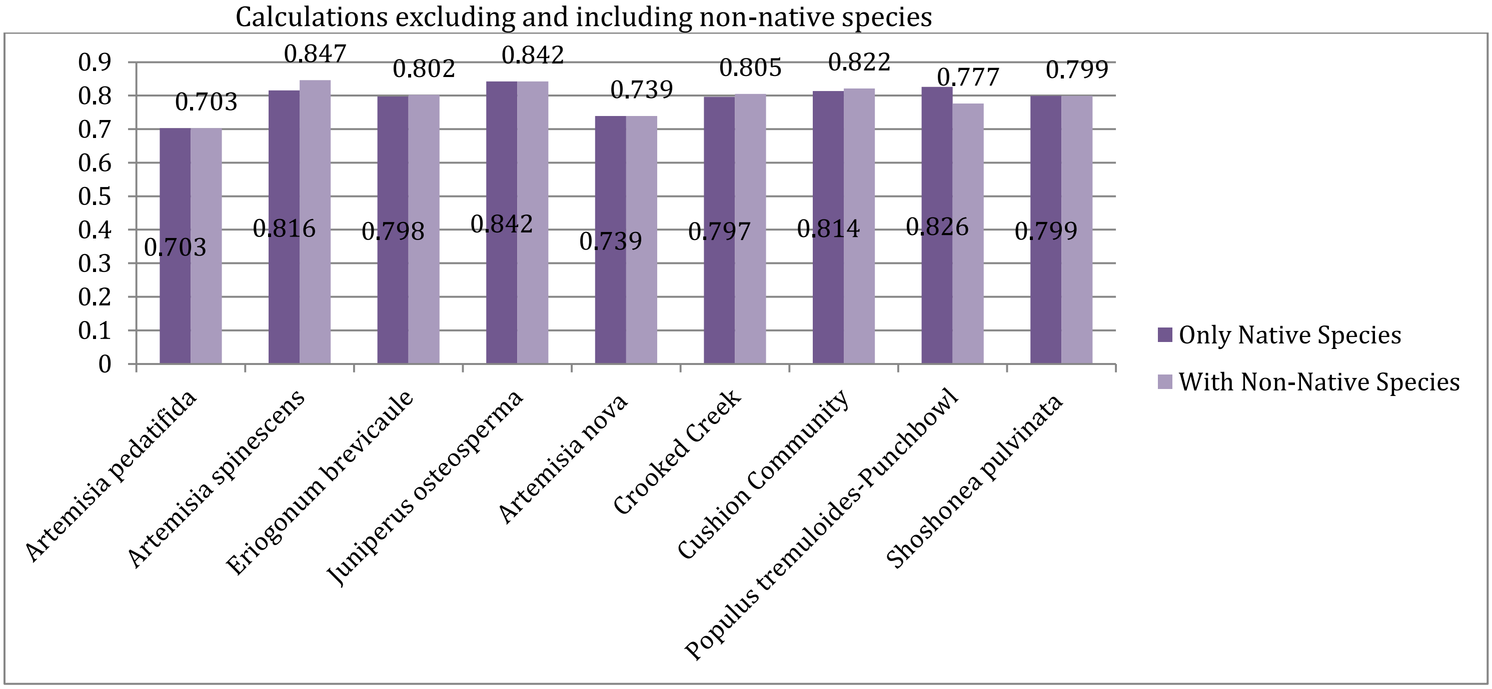


Figure 11: Evenness Values of Nine Plant Communities in the Pryor Mountains



Vegetation Community Observations

Artemisia pedatifida

This site is located in the southwest portion of the Pryors among the low-elevation foothills. The soils have a high clay content observed by the pedestal effect around the plants, the cracking soil and its sticky texture when wet (Figure 12). *Artemisia pedatifida* and *Agropyron spicatum* dominate the vegetation community. Gyps Springs Road is near the sampling area and signs of livestock were observed. There were no non-native species recorded. Currently, the vegetation community is composed of species native to Montana.

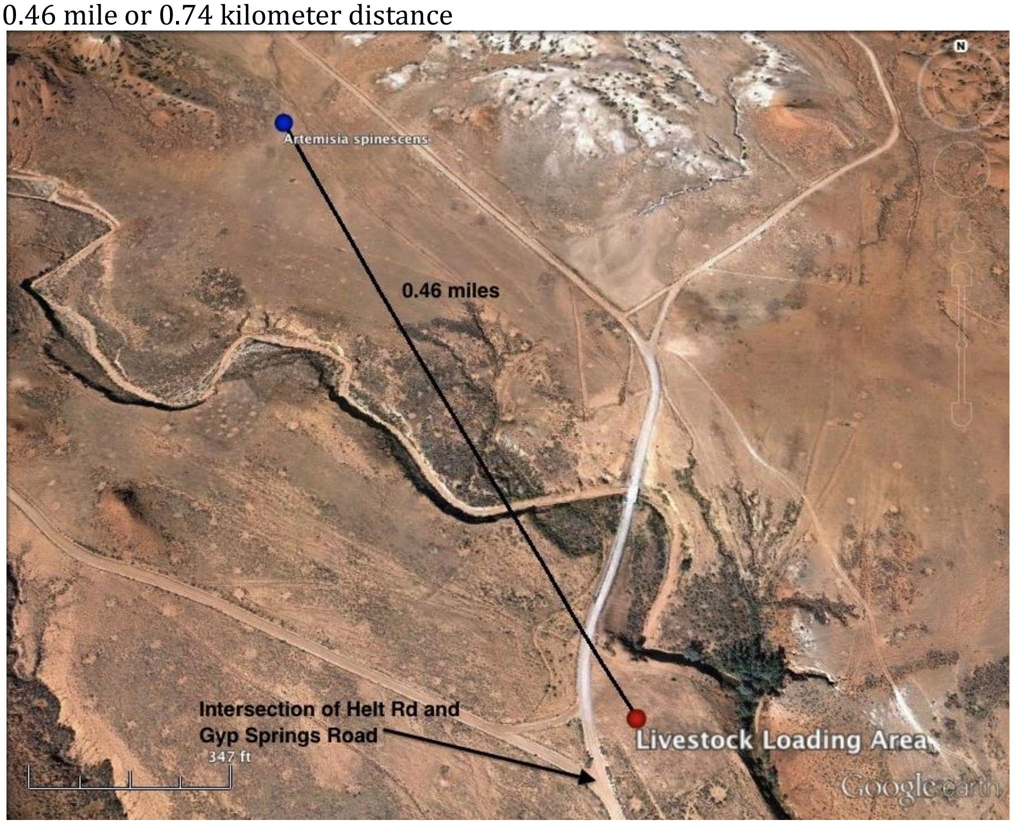
Figure 12: Visual characteristics of *Artemisia pedatifida* Soil
Dry cracked soil can be seen in the lower left hand corner. Wind and water erosion produce a pedestal effect as seen here with *Agropyron spicatum* and *Artemisia pedatifida.*

Artemisia spinescens

Artemisia spinescens (bud sage or spiny sage) occurs in the southern area of the Pryors and falls in-between Gyp Springs Road and Helt Road. The vegetation community is found on the flat lands among the foothills. The soil is a highly weathered red silty loam, which is characteristic of southern Utah's deserts (Moorhead 2013). Parallel trenches carved 12 inches (30 cm) into the ground were observed. There are two possible reasons for the trenches: (1) the area was plowed in the past or (2) they are old irrigation ditches. Dead Russian thistle (*Salsola sp.)* lined the sides of the trenches (Figure 13). The intersection of Gyps Spring Road and Helt Road is half a mile from the vegetation community. A large livestock unloading and loading area is located at the intersection (Figure 14). Since the community is located on the flats, livestock are likely to graze there when released. *Poa compressa* was the only non-native species documented. *Salsola sp.* was observed but not considered in data collection and analysis because it was dead.

Figure 13: Trench at *Artemisia spinescens* community
Looking toward Gyp Springs

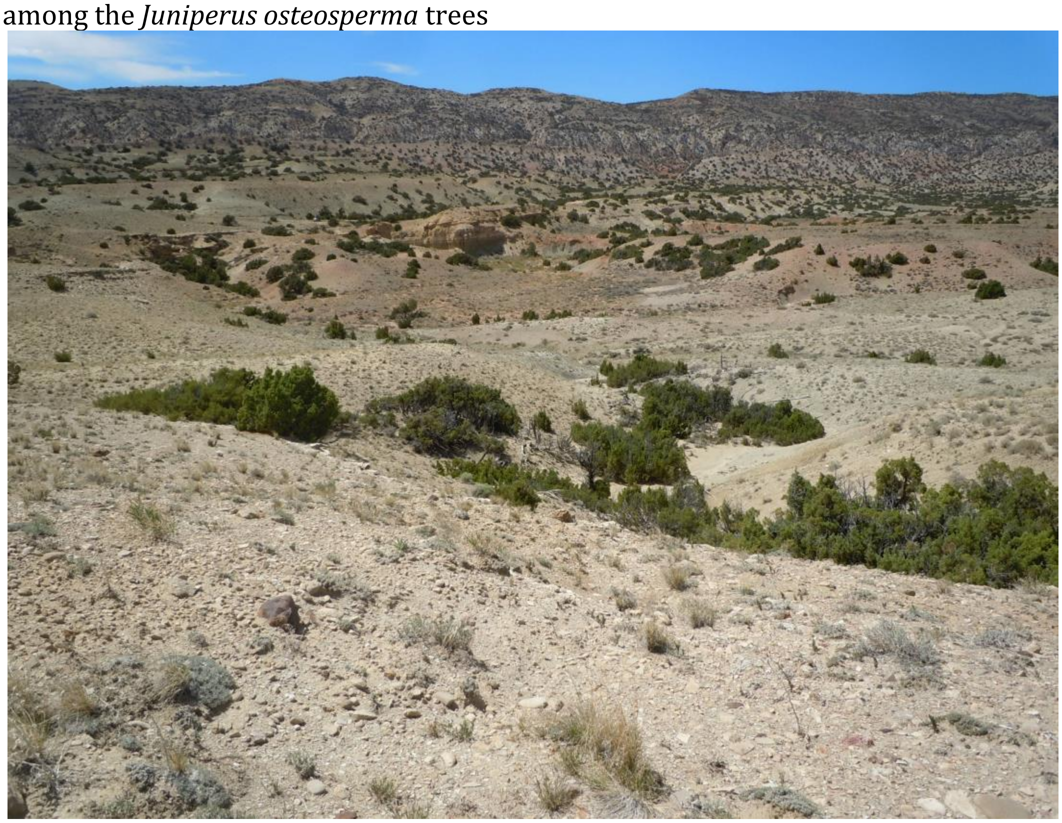
Figure 14: Livestock loading area in relation to the *Artemisia spinescens*
0.46 mile or 0.74 kilometer distance



Eriogonum brevicaule

The *Eriogonum brevicaule* community is located on the south side of the Pryors in-between Crooked Creek Road on the west and Penny Peak on the east. The monitoring area is among seasonal drainages (Figure 15). Of all sites, this community is the hardest for motorized vehicles to access. No OHV trails were observed. The only apparent disturbance in the area is in the spring when the snow melts. It runs off into the drainages and wipes out the vegetation changing the community periodically. There were visible signs of flash flooding. *Halogeton glomeratus* was the only non-native species found among the community.

Figure 15: *Eriogonum brevicaule* community
The site is among multiple seasonal drainages where *Halogeton glomeratus* grows among the *Juniperus osteosperma* trees



Juniperus osteosperma

The sampling area is west of Crooked Creek Road. The vegetation community extends up the surrounding hills and out towards Demijohn Flats to the northeast (Figure 16). There was no apparent sign of livestock or OHV use. The only disturbance at the site is from motorized use on Crooked Creek Road and natural events like water erosion. Out of the 15 species recorded all are native to Montana.

Figure 16: *Juniperus osteosperma* vegetation community
View of the *Juniperus osteosperma* vegetation community look west from Crooked Creek Road

Artemisia nova

The *Artemisia nova* community occurs north of the *Juniperus osteosperma* vegetation community. The community extends from the base of the foothills east of Crooked Creek Road down onto Demijohn Flats. The sampling area is located near two roads: (1) Crooked Creek Road and (2) leads down the canyon to access Crooked Creek. Cattle were observed grazing the area during sampling. The soil features sub-angular rocks embedded in light tan sediment. *Juniperus osteosperma* trees are scattered throughout the low shrub community (Figure 17). All 17 species recorded are native to Montana.

Figure 17: ***Artemisia nova*** **vegetation community**

Crooked Creek – Riparian Area

The sampling area is along Crooked Creek at Gooseberry Hollow adjacent to Crooked Creek Road. Transect lines were laid parallel on either side of the creek. The first line 100 meters and the second line 50 meters with Daubenmire frames placed every five meters alternating sides. Changes were made to the sampling methodology for safety and ease of sampling. The second transect fell along the trail entrance to the creek where vegetation was sparse and the non-native weed, *Taraxacum officinale,* was prevalent (Figure 18). The four non-native species recorded included: *Cirsium arvense, Cynoglossum officinale, Schedonorus pratensis* and *Taraxacum officinale*. Cattle were observed grazing along the Gooseberry Hollow trail near Crooked Creek Road.

Figure 18: Crooked Creek vegetation community with the Trail Entrance Identified

Cushion Community – Subalpine Meadow

The vegetation community is a cushion plant meadow in between Red Pryor and Big Pryor (Figure 19). The upper four inches of the soil are composed of organic matter with interspersed with rocks and gravel. Out of the 39 species recorded *Draba nemorosa* was the only non-native species recorded. We observed rabbit droppings, cow pies, signs of minimal grazing and small mammals burrowing.

Figure 19: Cushion Community – Subalpine Meadow vegetation community

Populus tremuloides – Punchbowl

The vegetation community is on the north side of the Pryor Mountains in an area called Punchbowl (Figure 20). The monitoring area had two *Populus tremuloides* stands, but the first and biggest one was infected with an unidentified rust. The second stand was smaller but didn't seem to be infected. Fifty meter transect lines were used due to the small stand size. The five non-native species recorded included: *Phleum pratense, Poa pratensis, Rumex acetosella, Taraxacum officinale* and *Trifolium pratense*. The sampling area is near a forest service road. There were signs of livestock or light grazing with a stock tank nearby, cattle feces and ranches on the way up to Punchbowl.

Figure 20: *Populus tremuloides* vegetation community & Punchbowl overlook

Shoshonea pulvinata

The *Shoshonea pulvinata* population is south of Dry Head Vista heading toward Mystery Cave. A cliff and nearby road restricted the size of the monitoring area. In addition, the vegetation's small population size changed the sampling methodology to 50 meter transect lines. All 25 species recorded are native to Montana. The community inhabits a gradual cliff so vegetation is sparse on the rocky face (Figure 21). Nearby motorized use and natural erosion were the two disturbances observed.

Figure 21: ***Shoshonea pulvinata*** **vegetation community &** ***Shoshonea pulvinata***

Discussion

It is important to analyze multiple factors in order to achieve an understanding of the quality of a vegetation community. This study specifically looked at diversity, evenness, distribution and observations to assess the structure and quality of each of the nine vegetation communities selected. Below is a brief discussion of the terminology and how it is used to analyze the sites.

Diversity

The Shannon-Weaver diversity index is designed so that maximum plant community diversity exists if each individual within the community is a different species. Minimum plant community diversity exists if all individuals belong to one species. The diversity index varies from zero, for a community with only one species, to values seven or more for species rich areas like tropical rainforests. Areas of intermediate diversity fall between values two and three (Barbour et al. 1999). The specific plant communities located in the Pryors have their own subset of diversity indices and in order to be thorough we chose to evaluate the communities on a local subset rather than global. When interpreting diversity indices, a low diversity index suggests a site with few species and a few dominant species. A high diversity index value suggests considerably more species (Stohlgren 2007). Our study found diversity indices ranging from 1.747 to 3.412 (Figure 8). A standard assumption is that the more species in a community the more stable the community, but this is not always the case. Species diversity does play a part in the overall stability of a community, but there are other factors involved (Barbour et al. 1999). Diversity has been considered a trait that makes a community more complex and therefore more resistant to change. For example, Barbour (1999) identified diversity as a reflection of the many interactions that characterize complex communities. Ecologists have considered homogenous communities to be more susceptible to change and invasion than heterogeneous communities (Stohlgren 2007). New studies, however, suggest that in many situations high species diversity is not necessarily better in quality than lower species diversity (Ricklefs and Miller 2000). Some communities naturally have low species diversity; so determining the quality of the habitat requires further analysis of other factors (Barbour 1999). It is the combination of all abiotic and biotic factors working for or against each other that help determine a community's status.

Maintenance of high diversity may require a level of periodic, random disturbance (Barbour 1999). Disturbance allows species to migrate and resets the rate of succession. Very stable homogenous communities exhibit lower diversity than communities composed of patches disrupted at various times by wind, fire and disease (Ricklefs and Miller 2000). Barbour (1999) found that after disturbance events, diversity increased with time until dominance by a few species reversed the trend and diversity began to decline. Worm and Duffy (2003) observed that the highest species richness often occurred at intermediate disturbance intensity or frequency. For example, the *Artemisia pedatifida* community experiences continual disturbance from wind and water erosion in addition to motorized disturbance. This community is dominated by two native species, the bunch grass *Agropyron spicatum* and the mat-forming subshrub *Artemisia pedatifida*.

The intermediate disturbance hypothesis is a nonequilibrium explanation for the maintenance of species diversity in ecological communities (Roxburgh et al. 2004). This hypothesis looks at levels of disturbance and their effects on vegetation community diversity. In this study disturbance is defined as the destruction of biomass that creates an opening for new individuals to utilize available resources. Intermediate disturbance implies coexistence promoted by recurring disturbances at intermediate frequencies, or the generation times of organisms present, over time. The hypothesis suggests that under high frequencies disturbance regimes the better competitor and poorer disperser cannot persist so all species begin to decline. At low disturbance frequencies the better competitor outcompetes the proficient disperser and the community eventually becomes a homogenous with the better competitor (Roxburgh et al. 2004). According to Roxburgh et al. (2004) coexistence is generated by a trade-off between competitive and dispersal ability. In order for an inferior competitor to coexist with a superior one, ecological differences must exist between the species to differentiate their responses to disturbance (Roxburgh et al. 2004).

These ideas apply to places where non-native species invasions are an issue. There is concern about the potential negative impacts of non-native plant species on native plant diversity, wildlife habitat, native pollinators, fire regimes, and nutrient cycling. Case (1990) uses mathematical modeling to suggest that areas of high species diversity should be resistant to invasion on non-native species. Highly competitive communities form a barrier that repels invaders when they invade in low numbers. The models generally claim that colonization by non-native species should decline when species are strongly interacting and maximizing resource use. Chambers et al. (2007) studied the susceptibility of Great Basin *Artemisia tridentata* communities to the invasion of the exotic species *Bromus tectorum*. They found that *Bromus tectorum* invasibility varies across elevation gradients and related to temperatures at higher elevations (2,300 m) and soil water availability at lower elevations (1,600 m). Highly variable soil water levels and clumped or random distribution of native plant species may increase invasion potential at lower elevations. Invasibility is lowest at sites with a relatively high percentage cover of perennial herbaceous species (Chambers et al. 2007). However, other studies have shown that species-rich vegetation communities in the north-central United States appear to be highly vulnerable to invasion by non-native species (Stohlgren 2007).

Thus, a simple analysis of species diversity should not be the only indicator of habitat quality or resistance to invasion in a community. Diversity indices are just one aspect contributing to the overall assessment of condition in a vegetation community.

Evenness

The distribution of individuals in a species' population is evenness. A community's evenness is considered maximized when all species have the same number of individuals. Evenness is minimized when one or two species dominate the number of individuals in a community (Barbour 1999). Evenness values are evaluated on a zero to one scale. Zero consists of one species dominating the community, while the value one means all species in a community have the number of individuals (Heip et al. 1998; Beals et al. 2000). This value helps in understanding the complex relationship between species and the environment where they reside. A low evenness value has two possible outcomes of stability and instability. The first situation is the result of all plant individuals in a community belonging to one or two dominant species. Even though a community with dominant species may have a low evenness value, those species are flourishing and can help maintain a stable community. The second situation is when there are very few individuals. If there are many species but only one or two individuals of each species the likelihood of that community stabilizing is very low. On the opposite end of the spectrum, a high evenness value is the result of many species with many individuals of each of those species. Since there are a high number of species and high number of individuals of each competing with one another, a high evenness value contributes to a stable community. Like the diversity index, the evenness value is one component among many that help to evaluate just a component in evaluating the condition and quality of a vegetation community (Barbour 1999, personal communication Lyman 2013).

Distribution Classification

Distribution relates to the arrangement of individuals of plant species on the landscape. Clements developed the idea of a closed community where species are clustered together along gradients of environmental conditions and form a regular distribution pattern. Gleason developed the idea of an open community where species have no natural boundaries and are distributed randomly with respect to one another (Ricklefs and Miller 2000). For our study regular distribution is classified as a species covering at least 50 percent of the community's ground reducing the amount of bare ground available to invading species (Figure 22). Species with random distribution cover less than 50 percent of the ground (Figure 23). Theoretically, the less area within a community that a species covers, the more bare ground is available to new species colonization. As the number of regularly distributed plant species increases, so might the stability of the community. The same is true for random distribution, as the number of species with random distribution increases the stability of the community begins to decline. The combination of the diversity index, evenness value, species distribution and on site observations help evaluate the baseline data to determine community quality (personal communication Lyman 2013).

Figure 22: Regular Distribution Classification
Regular distribution of the cushion plant – subalpine meadow community

Figure 23: Random Distribution Classification
Random distribution of the *Shoshonea pulvinata* community

Discussion of Each Plant Community

Artemisia pedatifida

From a species distribution perspective the *Artemisia pedatifida* community is susceptible to non-native species invasion. The diversity index (1.747) and evenness value (0.703) are the lowest out of all nine sites sampled. In other words there is a low number of species present and all the individual plants within the vegetation community are concentrated to a few species rather than many. The community had an overall random distribution. However, there are two dominant species classified as regularly distributed. Pressures of nearby motorized use and livestock use have the potential of negatively affecting the soil and infiltrating the vegetation community with non-native species. Thus, this site is considered to be at risk. Continual monitoring is important to alert changes within this vegetation community.

Artemisia spinescens

Figure 8 shows that the *Artemisia spinescens* vegetation community has relatively low diversity index (2.029) and intermediate evenness value (0.816) with random distribution (Table 2). All species had a random distribution, which suggests that bare ground is available between individual plants. Proximity to two roads, major intersection for livestock loading and past plowing events make this a disturbed site. The result of a low diversity index, intermediate evenness value, complete random distribution and a higher rate of disturbance suggest that this community may be unstable. We conclude that the *Artemisia spinescens* community is at risk and periodic monitoring will reveal whether or not the availability of open ground invites non-native species or may be the result of ecological factors such as competition (above or underground), stress, or some other factor.

Eriogonum brevicaule

The *Eriogonum brevicaule* community's diversity index (2.308) and evenness value (0.798) are in this low intermediate range compared to other communities in the study. The community is distant from motorized use (about 0.25 miles from Crooked Creek Road). Disturbance is from natural events. The primary threat to the *Eriogonum brevicaule* community comes from impacts from surrounding higher elevation vegetation communities. Vegetation is sparse and may not be resistant to non-native species invasions that may be washed down the drainages. Lesica (1994) expressed concern that *Halogeton glomeratus* is spreading within this community. Our study found *Halogeton glomeratus* had a frequency of two frames out of 20 Daubenmire frames sampled.
It will be important to monitor this site closely to see if the abundance of *Halogeton glomeratus* continues to increase.

Juniperus osteosperma

The *Juniperus osteosperma* community's diversity index (2.224) falls within the intermediate range between high and low. The evenness value (0.842) is the highest value in our study. The number of individuals in the community are distributed evenly among all species present. *Agropyron spicatum* was the only species to have a regular distribution so the site is randomly distributed. There is little influence from motorized use and the community is composed of native species. Currently, the *Juniperus osteosperma* vegetation community is considered to be in good condition with regard to weed invasion, but periodic sampling of the area is important in order to monitor changes that may occur.

Artemisia nova

The *Artemisia nova* community's diversity index (2.094) and evenness value (0.739) are low when compared to the other sites (Figure 8). Five species have regular distribution while 12 species are randomly distributed. Even though the diversity index and evenness value are low, the community is regularly distributed with little bare ground available to invading species. Influences from observed disturbances are minimal, so non-native species are less likely to invade the area. Currently, the *Artemisia nova* community is in good condition, because it is free of non-natives with little available space to invade. Periodic sampling of the area will be useful to monitor any changes that may develop in the future.

Crooked Creek – Riparian Area

The Crooked Creek vegetation community's diversity index (2.980) is high for our nine sites. The evenness value (0.797) falls within this intermediate range. While, the vegetation distribution was regular with seven species regularly distributed. According to the values the site appears to be doing well. However, this community had the second highest count of non-native species. Two of the seven regularly distributed species were the non-natives *Cynoglossum officinale* and *Taraxacum officinale*. Observations conclude that the site was disturbed by grazing and flooding. Naturally the creek is flooded every spring due to runoff so the condition of vegetation communities higher in elevation may influence the Crooked Creek community. This community's diversity, evenness and distribution are stable, but disturbances may influence change. It is vital to monitor this site since it is an upstream corridor that influences many other downstream vegetation communities in the area and contributes to the Yellowstone River watershed.

Cushion Community – Subalpine Meadow

The cushion community's diversity index (2.984) and evenness value (0.814) are high, with regular distribution. This community had the most regularly distributed plants out of all of the communities with eight species populations regularly distributed. Observations indicate that there is minimal influence from animal disturbance. Out of all nine communities sampled, the cushion plant community is apparently the most stable.

Populus tremuloides – Punchbowl

The *Populus tremuloides* vegetation community's diversity index (3.412) and evenness value (0.826) are high, with regular distribution. This community has the highest diversity index and second highest evenness value out of all of the communities sampled. Punchbowl's diversity index (3.242) and evenness value (0.777) decreased when non-native species were factored in. All of the other communities' diversity index and evenness value increased when non-native species were included. The diversity index and evenness value account for the distribution and the number of individuals present in a population. We assume that the non-native species present occur in low-density and are clumped randomly among the community.

According to observations, there is minimal influence from disturbance. The values calculated in this study suggest that this community is stable, however the highest amounts of non-native species (5) were recorded. One of the five regularly distributed species was the non-native *Poa pratensis*. Since the north side of the Pryor Mountains receives18-20 inches of annual precipitation it is a possibility that non-native species are thriving in this community from the available moisture. Punchbowl is a bowl, which captures and contains the precipitation received. Grime's C-S-R model (1977) helps hypothesize the reason for non-native species in this community. Non-native species are typically ruderal and flourish in favorable conditions like increased precipitation combined with open ground. In comparison, vegetation communities on the south side are more stress tolerant and the ruderal species cannot thrive in the low precipitation levels. Currently this community is comprised of a diverse collection of native species, but there is a higher rate of non-native invasion here compared to other vegetation communities in the Pryors. Further periodic monitoring will help determine the dynamics of the *Populus tremuloides* vegetation community.

Shoshonea pulvinata

The *Shoshonea pulvinata* vegetation community's diversity index (2.572) and evenness value (0.799) fall in the high end of the intermediate range. The community had a random distribution with none of the 25 species recorded having regular distribution. There is minimal influence from disturbances. Overall, the values indicate a stable community, but the vegetation is very sparse. *Shoshonea pulvinata* is an endemic species that naturally occurs in small populations. It is very important to monitor this site for the survival of the species *Shoshonea pulvinata*.

Table 3: The Current Condition of the Nine Vegetation Communities
This table summarizes the above findings to indicate the condition of the sampled communities. Communities classified as at risk show evidence that their condition is currently compromised or possibly in the future. Communities classified as "possibly stable" seem to be in good condition. However, future monitoring will be needed to determine if the community is in fact stable.

Site	At Risk	Possibly Stable
Artemisia pedatifida	X	
Artemisia spinescens	X	
Eriogonum brevicuale		X
Juniperus osteosperma		X
Artemisia nova		X
Crooked Creek Riparian Area		X
Cushion Plant Community Subalpine Meadow		X
Populus tremuloides Punchbowl		X
Shoshonea pulvinata		X

Ecological Implications of the Study

J.P. Grime's (1977) C-S-R Model provides a framework for focusing ecological research. Grime suggested that environmental factors that limit plant biomass may be classified as either stress, competition, or disturbance related. Grime (1974) defines competition as "the tendency of neighboring plants to utilize the same quantum of light, ion of a mineral nutrient, molecule of water, or volume of space." Stress, in Grime's usage, encompasses "the external constraints which limit the rate of dry matter production of all or part of the vegetation" (Bryophyte Ecology 2006). Following this concept, stressors are those conditions that restrict production while disturbance is the partial or total destruction of the plant biomass arising from herbivores, pathogens, humans, wind damage, frost, desiccation, erosion, or fire. Competition results from intraspecific or interspecific interactions that will inhibit biomass accumulation of individuals or species. Plants respond to these limiting factors with three types of life strategies: stress-tolerant, ruderal, and competitive. Individual plant species compromise with the conflicting selection pressures of competition, stress, and disturbance. These relationships can be arranged in a triangle known as the C-S-R model (Bryophyte Ecology 2006).

Grime's C-S-R triangular theory models plant life histories between the extremes of stress tolerators, ruderals, and competitors. Stress tolerators often grow slowly in extreme environmental conditions and exhibit low seedling establishment. Ruderals and competitors often grow in more favorable conditions. Competitors are often found in stable favorable conditions suitable to a life history strategy of large stature, maturation at a large size, and long life spans while ruderals colonize and occupy disturbed habitat, exhibit rapid growth, high reproductive rates, and high-speed dispersal (Ricklefs and Miller 2000). For example, the *Juniperus osteosperma* vegetation community has the highest evenness value so species populations are distributed evenly among the community. This community experiences high amounts of competition among stress tolerant species. In contrast, the *Artemisia pedatifida* vegetation community has the lowest evenness value with two dominating species populations that out compete many other species in the community. The C-S-R model provides a framework for future ecological studies that focus on community structure and function in the Pryor Mountains. Our baseline surveys provide a starting point for ecological studies that focus on ecosystem function in the unusual environmental setting of the Pryor Mountains. Experiments that focus on identifying how plant species respond to competition, stress, and non-native plant species invasions will help us to design careful and targeted management strategies to conserve the Pryor plant communities.

Our community analyses provide missing baseline information that is essential for a basic understanding of plant community dynamics in the Pryor Mountains. We quantitatively evaluated nine different vegetation communities with the Shannon-Weaver diversity index, evenness value and the distribution of plant individuals on the landscape. We evaluated the extent of non-native invasions, identified current and potential disturbances to plant communities, provided photographic evidence of communities and developed a rapid method of sampling plant communities that can be repeated every three to five years by conservation managers. Periodic monitoring of these communities will provide ecologists and land managers with tools to focus their management efforts in order to repel non-native invasion and future loss of species. Evaluating these plant communities highlights the array of diversity found nearby, while providing ecological exploration for researchers and pertinent information for land managers.

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Appendix 1:
Vascular plant list of each vegetation community

Artemisia pedatifida

Agropyron spicatum
Arenaria hookeri
Artemisia pedatifida
Artemisia tridentata
Astragalus missouriensis
Atriplex confertifolia
Atriplex gardneri
Bouteloua gracilis
Castilleja angustifolia
Cryptantha celosioides
Cymopterus glaucus
Gutierrezia sarothrae
Krascheninnikovia lanata
Lappula redowskii
Lomatium cous
Oenothera sp.
Opuntia polyacantha
Oryzopsis hymenoides
Penstemon eriantherus
Phlox hoodii
Poa secunda
Sphaeralcea coccinea
Townsendia spathulata
Xanthisma grindelioides
Xylorhiza glabriuscula

Artemisia spinescens

Agropyron cristatum
Arenaria hookeri
Aristida purpurea
Artemisia spinescens
Artemisia tridentata
Astragalus adsurgens
Astragalus gilviflorus
Atriplex canescens
Atriplex confertifolia
Atriplex gardneri
Bouteloua gracilis
Chaenactis douglasii
Cryptantha celosioides

Cymopterus glaucus
Elymus elymoides
Gutierrezia sarothrae
Krascheninnikovia lanata
Lappula redowskii
Malcolmia africana
Opuntia polyacantha
Oryzopsis hymenoides
Phlox hoodii
Poa compressa
Poa secunda
Salsola sp.
Schoenocrambe linifolia
Sphaeralcea coccinea
Stipa comata
Tetraneuris acaulis

Eriogonum brevicaule

Agropyron spicatum
Arenaria hookeri
Aristida purpurea
Artemisia tridentata
Astragalus hyalinus
Astragalus sp.
Comandra umbellate
Cryptantha celosioides
Elymus elymoides
Ericameria nauseosa
Eriogonum brevicaule
Eriogonum mancum
Eriogonum ovalifolium
Eriophyllum lanatum
Gutierrezia sarothrae
Halogeton glomeratus
Hedysarum boreale
Ipomopsis spicata
Juniperus osteosperma
Krascheninnikovia lanata
Mentzelia albicaulis
Opuntia polyacantha
Oryzopsis hymenoides
Paronychia sessiliflora
Phlox hoodii
Phlox muscoides

Physaria didymocarpa
Platyschkuhuria integrifolia
Rhus aromatica
Sphaeralcea coccinea
Stanleya pinnata var. pinnata
Stephanomeria runcinata
Tetraneuris acaulis
Townsendia hookeri
Townsendia incana
Townsendia spathulata
Wyethia scabra
Xanthisma grindeloides

Juniperus osteoperma

Agropyron spicatum
Arenaria congesta
Arenaria hookeri
Aristida purpurea
Artemisia nova
Artemisia tridentata
Astragalus spatulatus
Carex scirpoidea
Castilleja angustifolia
Erigeron ochroleucus
Eriogonum ovalifolium
Eriogonum pauciflorum
Gutierrezia sarothrae
Ipomopsis spicata var. spicata
Juniperus osteosperma
Koeleria macrantha
Lomatium acaulis
Opuntia polyacantha
Penstemon aridus
Phlox hoodii
Poa secunda
Stenotus acaulis
Stipa comata
Zigadenus venenosus

Artemisia nova

Agropyron spicatum
Alyssum sp.
Arenaria hookeri

Artemisia nova
Artemisia tridentata
Astragalus lotiflorus
Astragalus purshii
Astragalus spatulatus
Calochortus nuttallii
Castilleja angustifolia
Comandra umbellate
Crepis modocensis
Erigeron ochroleucus
Eriogonum ovalifolium
Gutierrezia sarothrae
Juniperus osteosperma
Koeleria macrantha
Krascheninnikovia lanata
Lewisia rediviva
Linum lewisii
Lomatium foeniculaceum
Lomatium orientale
Mertensia lanceolata
Opuntia polyacantha
Phlox hoodii
Poa secunda
Senecio eremophilus
Stenotus acaulis
Tetraneuris acaulis
Townsendia spathulata
Tragopogon dubius
Zigadenus venenosus

Crooked Creek – Riparian Area
Acer negundo
Achillea millefolium
Actaea rubra
Allium brevistylum
Amelanchier alnifolia
Anaphalis margaritacea
Anemone patens
Apocynum androsaemifolium
Arnica cordifolia
Artemisia ludoviciana ssp. Canadicans
Berberis repens
Calamagrostis canadensis
Calamagrostis sp.

Carex sp.
Cerastium arvense
Cirsium arvense
Clematis occidentalis
Conimitella williamsii
Cornus stolonifera
Cynoglossum officinale
Epilobium angustifolium
Equisetum arvense
Eurybia conspicua
Fragaria vesca
Fragaria virginiana
Galium boreale
Galium triflorum
Geranium richardsonii
Geranium viscosissimum
Geum rivale
Heracleum lanatum
Juniperus communis
Koeleria macrantha
Lamiaceae (unknown genus species)
Lithospermum incisum
Lomatium dissectum
Lomatium triternatum var. triternatum
Mertentsia oblongifolia
Monarda fistulosa var. menthifolia
Osmorhiza depauperata
Poa pratensis
Potentilla gracilis var. flabelliformis
Prosartes trachycarpa
Prunus virginiana
Pseudotsuga menziesii
Ribes montigenum
Schedonorus pratensis
Shepherdia canadensis
Smilacina racemosa
Smilacina stellata
Spirea betulifolia
Symphoricarpos albus var. loevigatus
Taraxacum officinale
Tetraneuris acaulis
Thalictrum occidentale
Trifolium pratense
Valeriana acutiloba
Veronica americana
Viola adunca

Viola canadensis
Viola nuttallii
Viola purpurea
Valeriana acutiloba

Cushion Plant Community – Subalpine Meadow

Achillea millefolium
Agropyron scribneri
Agropyron spicatum
Allium cernuum
Anemone patens
Antennaria dimorpha
Artemisia frigida
Astragalus sp.
Bessya wyomingensis
Bromus carinatus
Bupleurum americanum
Carex filifolia
Carex rupestris
Cerastium arvense
Crepis runcinata
Cymopterus glaucus
Cymopterus nivalis
Dodecatheon conjugens
Draba nemorosa
Draba oligosperma
Erigeron divergens
Eriogonum caespitosum
Eriogonum flavum
Eritrichium howardii
Festuca idahoensis
Frasera speciosa
Gentiana calycosa
Geum triflorum
Ipomosis spicata
Koeleria macrantha
Lomatium cous
Mertensia lanceolata
Micranthes rhomboidea
Minuartia austromontana
Minuartia nuttalii
Minuartia obtusiloba
Oxytropis sericea
Pedicularis cystopteridifolia

Phlox hoodii
Physaria pycnantha
Poa secunda
Polygonum bistortoides
Potentilla ovina
Selaginella densa
Tetraneuris acaulis
Townsendia spathulata
Valerianna edulis

***Populus tremuloides* – Punchbowl**

Achillea millefolium
Amelanchier alnifolia
Anaphalis margaritacea
Anemone patens
Antennaria microphylla
Antennaria neglecta
Arabis nuttallii
Arctostaphylos uva-ursi
Arenaria congesta var. cepahaloidea
Arnica cordifolia
Arnica folgens
Artemisia tridentata ssp. vaseyana
Balsamorhiza incana
Berberis repens
Bessya wyomingensis
Carex geyeri
Carex sp.
Cerastium arvense
Collinsia parviflora
Crepis atribarba
Crepis runcinata
Delphinium bicolor
Dodecatheon conjugens
Erythronium grandiflorum
Festuca idahoensis
Fragaria vesca
Fragaria virginiana
Frasera speciosa
Galium boreale
Galium sp.
Galium triflorum
Geranium richardsonii
Geum triflorum

Hedysarum sp.
Hedysarum sulphurescens
Heterosperma sp.
Juncus confusus
Juncus parryi
Juniperus communis
Lathyrus sp.
Leucopoa kingii
Lithophragma parviflorum
Lithospermum ruderale
Lomatium cous
Lomatium triternatum
Lupinus argenteus
Mertensia oblongifolia
Micranthes hieraciifolia
Monarda fistulosa
Osmorhiza depauperata
Oxytropis sp.
Phleum pratense
Phlox kelseyi var. missoulensis
Pinus contorta
Pinus flexilis
Poa pratensis
Polygonum bistortoides
Populus tremuloides
Potentilla concinna
Potentilla fruticosa
Potentilla gracilis
Potentilla ovina
Pseudotsuga menziesii
Ranunculus glaberrimus
Ranunculus uncinatus
Ribes montigenum
Rosa woodsii
Rumex acetosella
Sedum lanceolatum
Smilacina racemosa
Spirea betulifolia
Stellaria nitens
Symphoricarpos albus
Taraxacum officinale
Thalictrum occidentale
Trifolium pratense
Valeriana acutiloba
Veronica sp.
Viola adunca

Viola canadensis
Viola nuttallii
Zigadenus elegans
Zigadenus venenosus

Shoshonea pulvinata
Allium cernuum
Anemone patens
Antennaria microphylla
Astragalus miser
Boechera sp. or *Arabis sp.*
Carex rupestris
Clematis columbiana
Draba oligosperma
Erigeron ochroleucus
Eritrichium howardii
Heuchera parvifolia
Ipomopsis spicata
Juniperus scopulorum
Leucopoa kingii
Lomatium triternatum
Minuartia nuttallii
Musineon vaginatum
Phlox hoodii
Physaria alpina
Pinus flexilis
Potentilla ovina
Pseudotsuga menziesii
Ribes cereum
Ribes viscosissmum
Sedum lanceolatum
Senecio canus
Shepherdia canadensis
Shoshonea pulvinata
Symphoricarpos albus
Tetraneuris acaulis
Zigadenus venenosus