RECREATION AND VEGETATION ASSESSMENTS IN PETRIFIED FOREST NATIONAL PARK, ARIZONA

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ABSTRACT

RECREATION AND VEGETATION ASSESSMENTS IN PETRIFIED FOREST NATIONAL PARK, ARIZONA

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This paper reviews the hypothesis that recreation, specifically hiking, is a major factor in regulating the growth patterns and distribution of trailside plant communities. Although the impacts of recreation have been well researched by other studies, it is important to gather site specific information for managerial decision-making by Petrified Forest National Park. Using data collected under the stewardship of the National Park Service and the Visitor Experience and Resource Protection (VERP) program at Petrified Forest National Park, it was gathered that recreation disturbance has a major role in vegetation alterations. Three common patterns emerged. 1. Vegetation nearest to trails are generally smaller in size. 2. Vegetation diversity increases as you move closer to the trail. 3. Environmental factors such as soil compaction can have a significant effect in more severe vegetation disturbances. The research concluded that increased recreational use will degrade and often alter the trail itself as well as neighboring vegetation communities. These adverse effects are reported in all types of ecosystems, and are therefore important for land managers as well as recreation students to understand and study further.

Keywords: *Recreation, Vegetation Assessment, Social Trails, Land Management, GIS*

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CHAPTER 1: INTRODUCTION

Assessing visitor impacts to vegetation within Petrified Forest National Park is the main focus of this study. The Visitor Experience and Resource Protection (VERP) program was utilized to collect data during the summer of 2017 in order to enhance the project in Petrified Forest National Park. Main considerations were given to native and invasive plant species found along social trails and disturbances found near paved trails, park road pull-offs, and “Off the Beaten Path” (OTBP) trails. The three types of sites were evaluated to determine the amount of recreation impacts and will be monitored to determine rate of change and carrying capacity in order to protect the surrounding natural resources. The intension is to enhance the experience of visitors, and create a natural environment for native wildlife.

Arizona is home to unique and diverse plant species (Kearney & Peebles 1960). For that reason, it is extremely important to study and protect native species of flora in Arizona. The following research is primarily focused on the plant species found within the boundaries of Petrified Forest National Park in northeastern Arizona. This diverse region includes many varieties of grasses, sedges, shrubs, succulents, and wildflowers.

This paper describes the process involved to carry out this project as well as the final results and recommendations. Procedures and analysis are very important in this study. The research introduces Petrified Forest National Park, the VERP program, vegetation located in northeast Arizona, and social trail recreation impacts. In addition, it is important to recognize the many monitoring techniques as well as management practices used to reduce recreation impacts around the world. This paper highlights methods that have proven effective in this arid region of northeastern Arizona known as Petrified Forest National Park. The results of this project will be included in the VERP yearly report and presented to the Petrified Forest National Park management team. Additionally, the results of the recreation and vegetation assessments will create a better understanding of recreation impact to local floral species of Petrified Forest National Park and will further develop the VERP program.

1.1 Petrified Forest National Park

Petrified Forest National Park is located in the northeast region of Arizona, approximately 18 miles east of Holbrook, Arizona. The region is known for its aridity, along with remarkable rainbow sediment strata, prehistoric fossil deposits, and ancient as well as historic cultural resources. According to the National Park Service (2017), Petrified Forest National Park was first established as a national monument by Theodore Roosevelt in 1906 after the Antiquities Act was passed by Congress. Roosevelt initially aimed to protect the petrified wood deposits and other resources in the area which were being abused. Petrified Forest National Monument was later declared a national park in 1962. In 1970, Congress designated a large portion of the park as one of the first National Wilderness Preservation Systems within a national park's boundaries. Then, in 2004, the boundaries of Petrified Forest National Park were nearly doubled (National Park Service 2017). The boundary expansion created an enormous increase in natural and cultural resources, as well as interest of the public. Today, the expansion lands are generally inaccessible to visitors, but may become more accessible in the future. The following recreation and vegetation assessments present a great opportunity to evaluate and improve management practices for the introduction of new infrastructure and rising visitor numbers.

In 2014, the park saw a significant increase in visitation, which prompted recreation monitoring to be implemented two years later. The National Park Service (2017) announced that Petrified Forest National Park hosted over 600,000 visitors in the year 2016. On average, the park experiences its highest rates of visitation in the months of June, July, and August. The peak of the summer season can bring in upwards of 110,000 visitors in a single month. Most, if not all of these visitors will participate in recreational activities during their visit (National Park Service 2017). With data gathered during this project, Petrified Forest National Park will be able to make educated decisions in order to accommodate the increased visitation in coming years.

According to National Park Service (2017), "the purpose of Petrified Forest National Park is to preserve and protect globally significant fossils, including petrified wood, nationally significant prehistoric and historic resources, as well as scenic values, in order to foster scientific research, public understanding, and enjoyment" (National Park Service 2017). As part of the Visitor Experience and Resource Protection (VERP) program, we hope to continue this focus in preserving the park's natural and cultural resources for visitors to enjoy.

1.2 Local Vegetation

Local vegetation to Petrified Forest National Park is affected by many physical and environmental factors. The region surrounding Petrified Forest National Park is located at an average elevation of 5,500 feet above sea level. Hanson (1924) suggests that the diverse landscape here is constantly changing to contain canyons, mesas, badlands, sand dunes, faults, etc. Northeastern Arizona is very arid; therefore, most vegetation is seen growing in weathered sand dunes or adobe soils found in washes. Hanson (1924) also points out that Petrified Forest National Park is geographically located in a region where sagebrush communities transition to grassland communities. Further, DataBasin.org defines three major vegetation classifications found within the park: Southern Colorado Plateau Sand Shrubland, Inter-Mountain Basins Semi-Desert Grassland, and Inter-Mountain Basins Semi-Desert Shrub-Steppe (Conservation Biology Institute, 2010).

In addition to physical features, the Southwest experiences annual monsoons in the summer months, which has establish a growing season for most local vegetation (J.L. Weiss et al., 2004). As a result of this primarily arid climate, shrubs and woody plants draw moisture from deeper in the ground while herbaceous perennials and annuals use monsoon moisture found in the top layers of soil (Lin et al., 1995). Plant communities in the region are locally adapted to the harsh geological and climatic conditions (Comstock 1992).

1.3 Visitor Experience and Resource Protection (VERP)

The Visitor Experience and Resource Protection (VERP) program was adopted and modified for the Petrified Forest National Park in 2016. The VERP program was originally designed to help large national parks assess carrying capacity in many different aspects. The U.S. Department of the Interior (1997) points out that with the increase of visitation to many of the U.S. National Parks, carrying capacity has become an important topic of study. The VERP program was designed in 1992, to help assess carrying capacity in order to balance enjoyment of visitors and the protection of natural and cultural resources. Arches National Park of Utah was the first park to adopt the VERP program, but was soon followed by a number of other national parks (U.S. Department of the Interior 1997).

According to the U.S. Department of the Interior (1997), in a general land management perspective, “carrying capacity” refers to the number of living things that can exist in an environment. The carrying capacity concept has been adapted specifically for management of the U.S. National Parks where carrying capacity can be defined as the number of visitors a particular park can handle without the deterioration of natural and cultural resources or the experience of those visitors (U.S. Department of the Interior 1997). Land managers must find the Limits of Acceptable Change (LAC) in order to maintain this delicate balance (McCool 2013). In addition to carrying capacity, the U.S. Department of the Interior (1997) states that the VERP program and other similar program frameworks have five common goals: desired future conditions, indicators of quality, acceptable standard, monitoring techniques, and management actions. These impacts are measured based on behavior of visitors, level of use, type of use, timing of use, and use location (U.S. Department of the Interior 1997).

During the first year of the VERP program at Petrified Forest National Park, baseline data was collected to assess: 1.) animal mortality, 2.) petrified wood theft, 3.) social trails movement and growth, 4.) cultural resources, and 5.) off the beaten path social trails and recommendations. During the second year of the project, the VERP research team continued collecting baseline data as well as a second year of additional data that has been added to the existing baseline data from 2016. The recreation and vegetation assessments have also been added to the baseline data collected for social trail monitoring and "Off the Beaten Path" (OTBP) trail management. In the first three years of the VERP program, the project will continue repeated monitoring of key sites to document the rate of change. Then, a threshold will be identified to determine a future carrying capacity that is acceptable for the park, its resources, and its visitors.

CHAPTER 2: PROBLEM STATEMENT

With increasing yearly count of visitors to our national parks, there will always be a need for recreation impact research (National Park Service 2017). The goal of this project is to improve the experience of future visitors and wildlife by better preserving frequently visited areas within Petrified Forest National Park. Retaining the quality of natural resources will help to make these spectacles available for the enjoyment of future generations.

This particular research project will show the location and degree of recreational disturbances on vegetation found along popular points of interest within the Petrified Forest National Park. The data recorded was useful in assessing local vegetation impacts and future management of these sites. The goal of this project is to immediately improve baseline data needed for the Visitor Experience and Resource Protection (VERP) program as well as improve stability of vegetation and social trails at frequently visited sites. These goals will enhance the ability to create restoration plans and heighten the understanding of native and invasive floral species. The following research will address three questions. 1. Is there significant damage to vegetation in Petrified Forest National Park because of recreational disturbances caused by hiking? 2. Is damage caused by hiking affecting vegetation abundance, diversity, or ground cover at Petrified Forest National Park? 3. How can we improve management practices for Petrified Forest National Park? How can we improve native vegetation diversity and prosperity in the future?

CHAPTER 3: LITERATURE REVIEW

If you have ever hiked on a public trail, you may have noticed some disturbances to the natural habitat. You may have noticed that the trail has been cleared of vegetation within the track, or that the trailside vegetation is short or is composed of different plants than elsewhere, or even that the path is fairly compacted. This section will review the concept that recreation, specifically hiking, is a major factor in regulating the growth patterns and distribution of trailside plant communities.

Considering the impacts of recreation on vegetation and other resources is very important in the land management field. Studying the formation of social trails and vegetation disturbance, we can better understand human recreation psychology and better prepare for the inevitable damage. Understanding the effects of recreation on vegetation and the appropriate monitoring techniques will allow land managers to make better decisions on how to preserve the local flora and other resources.

In order to understand and protect trailside vegetation, it is first necessary to understand what makes a social (informal) trail. From this definition, we can begin to analyze the effects of hiking on vegetation. Trailside vegetation can be very fragile and may be altered in many physical and developmental ways. Recreation can damage vegetation in many ways including, diversity, richness, ground cover, and physical characteristics. Recreational disturbances may also alter the environment to create unfavorable conditions for the native vegetation to grow.

3.1 What is a Social Trail?

Moskal & Halabisky (n.d.) suggest that social trails or informal trails are formed by repeated foot-traffic from humans or animals. The U.S. National Park Service defines a social trail as "an informal, non-designated trail between two locations" (Kriedeman & Markus 2013). Moskal &

Halabisky (n.d.) add that social trails create a complex structure of unnecessary trails that disturb and destroy resources such as vegetation. Disturbance of the ecological sense is best defined by the Encyclopaedia Britannica as “an event or force, of nonbiological or biological origin, that brings about mortality to organisms and changes in their spatial patterning in the ecosystems they inhabit.” In this case, social trails would be the force that destroys resources, as Moskal & Halabisky (n.d.) mention previously.

Social trails often represent the shortest path possible and do not fall inside typical regulations. These informal trails will generally part from the formal trails, often leading to points of interest or attractions such as fishing access or climbing routes. They can also be formed due to environmental factors. For example, soggy trails could lead to visitors choosing an alternative path on higher ground. These informal trails can also be created in futile areas and many times lead to nowhere. Much of this is simply caused by human psychology. For example, a single person may decide to travel off-trail, creating curiosity in bystanders. The curious bystanders will follow, flattening vegetation and compacting the earth, creating the beginnings of a social trail (Moskal & Halabisky n.d.).

Marion (2008) mentions that informal trails may also be poorly constructed because visitors often do not have adequate education or consideration for many environmental factors such as soil loss and vegetation destruction. These informal trails are frequently created to span the “shortest distance,” often running through steep slopes or dangerous sections of terrain (Marion 2008). While social trails are rarely constructed with such environmental and safety factors in mind, formal trails will have been evaluated by engineers and management teams to determine resource impacts before construction. Formal trails are designed with many diverse impacts in mind, such as vegetation loss, soil compaction, cultural resource destruction, safety, and erosion.

Additionally, they will often times be well maintained and accessible to a variety of visitors (Moskal & Halabisky n.d.).

According to Pickering, Hill, Newsome, & Leung (2010), impacts of recreational hiking could include soil compaction, soil moisture decline, organic matter loss, vegetation loss, native vegetation loss, increase in nonnative and invasive species, and a change in vegetation communities. For these reasons, it is very important to assess damage created by human recreation, especially hiking (Pickering et al. 2010).

Ballantyne & Pickering (2015) found that for some trails, the highest concentrations of impact is located only 1 meter away from the trail, but for other trails, high impacts can be seen up to 20 meters from the trail. This is all reliant upon habitat, vegetation communities, soil composition, and the use of each trail studied. Their research also shows that stress-tolerant weeds are more likely to grow near the path (in disturbed areas), while slower growing, woody plants are more commonly found further away from the trail. It is pointed out that trail disturbances can also affect vegetation structure. Therefore, vegetation closer to the trail can become stunted in growth or broken by foot traffic, yielding shorter vegetation (Ballantyne & Pickering 2015).

3.2 Monitoring Techniques

In a paper written on the dune vegetation of Isle of Palms, Purvis, Gramling, & Murren (2015) investigated vegetation growth and impacts along beach access paths. They considered path use (public or private), path construction materials (wood or sand) and frequency (distance to the next path). They compared data from three locations along each path: back-dunes, mid-dunes, and fore-dunes. Purvis et al. (2015) classified each path as public sand, private sand, or private wood. They used Google maps satellite imagery to locate and classify each of the beach access paths available. The analysis of the satellite imagery produced 433 paths. Next, they used a random number generator to select 20 paths of each category in order to generate a manageable study area. They then created survey blocks for each path. A transect was assigned, which would be perpendicular to the path but parallel to the beach and waterline. At each survey block, they recorded path type, distance to next path, width and height (height only recorded for wooden paths) of each path. They chose to make a series of three transects for each path (back-dune, mid-dune, and fore-dune). For each of these transects they created five survey plots. The plots were dispersed at 0, 1.5, 5, 10, and 20 meters away from the path. This created 720 survey plots for the 60 transects and 20 paths. A 0.66 square meter hoop was used to evaluate each survey plot. For each plot, they recorded all species present within the hoop, and then counted how many stems were present per species. They also recorded percent coverage in 5% increments, using 6 cover classes (sand, debris, grass, herb, shrub, and vine) (Purvis et al. 2015).

Another study by Nepal & Way (2007), took a similar approach to a backcountry trail in remote Mount Robson Provincial Park, British Columbia. They created transects along this 23 kilometer long backcountry trail at 450 meter intervals. They used a 1 square meter quadrat at each transect directly along the path, and another one at 5 meters from the path (control plot). The 5 meter distance to the control plot ensured similar topography, vegetation, and soil composition as the plot located along the path. They categorized each plot into vegetation cover types (forest, meadow/open, or rock/gravel). Then, they calculated ground cover type and frequency of plant species (woody, herbaceous, ferns, moss/lichen/fungi). To analyze their findings, they used a location diversity index (LDI) formula to calculate the abundance of a species and its frequency in the study. LDI=fi/F, where fi is the number of quadrats that a species is found in and F is the total number of quadrats that were surveyed. They also, calculated mean cover by using the following formula: Mean Cover (MC)= $(\sum xi)/f$, where xi is the percent cover of a species in a quadrat, and f is the number of quadrats in which a species is found (Nepal & Way 2007).

An alternative method for evaluating vegetation is one of many remote sensing techniques. Weiss, Gutzler, Coonrod, & Dahm (2004) used a NDVI (Normalized Difference Vegetation Index) method to examine green vegetation in New Mexico. NDVI can be used to observe changes in leaf area, canopy coverage, productivity, vegetation phenology, and chlorophyll density. He observed changes in ground cover over a large time period in order to construct a trend in vegetation growth or disturbance. Additionally, Lee (2009) used similar techniques for remote sensing in Joshua Tree National Park. He collected NAIP imagery of his study site to analyze social trail growth and vegetation movement. He used software such as ArcMap and Envi to locate the social trails and convert them into shapefiles. He eventually conducted NDVI and SAVI (soil adjusted vegetation index) to determine the level of vegetation in the imagery. These indices use the near-infrared and red bands in order to detect levels of green color. Lee (2009) used these techniques and calculations to monitor changes in vegetation over a multi-year timespan. He was able to detect the formation of new social trails and damage to vegetation caused by recreational visitation. (Lee 2009).

3.3 Effects of Recreation on Trailside Vegetation

According to Pickering & Hill (2007), recreational activities such as hiking can result in shorter vegetation, loss of biomass, loss of reproduction (fruits, flowers, etc.), and a decrease in land cover. These impacts can also cause an increase in organic litter, result in seedling damage, and can actually change species compositions completely. Additionally, recreation can introduce further indirect problems such as hydrological distress, soil compaction, increased nutrients, erosion, and invasive vegetation and pathogens. Vegetation will often respond to disturbances in one of three different ways: (1) high resistance, but low recovery after damage, (2) low resistance, but fast recovery, or (3) low resistance and low resilience. A low resistance and low resilience response will generate a species susceptible to trampling and visitor use damage. Pickering (2007) suggests that there are several environmental factors that could also affect the formation of a social trail and account for the considerable vegetation damage. These factors include vegetation characteristics, topography, soil characteristics, and climate and seasonality. Disturbance levels can also be affected by visitor group size, knowledge of Leave No Trace principles, and frequency/intensity of visitors. In addition, vegetation can be affected depending upon the life form of the plant. Shrubs, tall grass-like plants, and cushion plants seem to be more susceptible to trampling from visitors, while lower growing grass-like plants are generally less susceptible. Furthermore, walking on steeper slopes has shown to cause more damage than walking on flatter areas. Soil textures and composition could also play a role in ecosystem damage. It is important to consider porosity, gradients, and chemical properties of the soil layer in which visitors travel and plants grow. Likewise, the severity of recreation impacts can vary depending on factors such as trail construction type, amount of visitor use, type of recreation, the behavior of visitors, and the season of highest use (Pickering & Hill 2007).

Willard & Marr (1970) found that in the alpine tundra of Rocky Mountain National Park, there was no lasting effects when less than 20 hikers visited the tundra per year. They found that concentrated walking created much more of an impact than dispersed hiking. During their study, it took approximately two weeks to start seeing the beginnings of an actual social trail with damaged vegetation. After seven weeks, the plants near the path could no longer bloom. After 12 weeks, a trail had been formed with little to no vegetation left in the tracks. After three years of recreation impact, vegetation cover decreased as much as 33%, and much of the finer soil had been washed away from the area (Willard & Marr 1970). In addition, Dale & Weaver (1974) found that trail width will generally be greater in meadows than in forests. They suggest that vegetation in forests may corral hikers to walk in a single path, whereas meadow vegetation often encourages hikers to walk in different tracks, thereby disturbing more vegetation. They also found that in their study areas, there were no signs of trampling at a distance of 1 meter or more from the center point of the trails. In addition, trail widths in the forests increased with increased visitor traffic (Dale & Weaver 1974).

According to Price (1985), hiking will immediately cause damage to the parts of the plant that are present above ground. Furthermore, changes to physiology, species composition, and plant cover can occur after increased levels of disturbance. In a study conducted by Price (1985), it was found that plants growing near to the trail had lower carbohydrate levels than ones growing further away from the trail. These findings suggest that plants growing closer to the trail will be smaller in size and will often have lower reproductive potential, meaning a decrease in flowers on plants less than 1.7 meters away from the trail (Price 1985). . Still, Adkinson & Jackson (1996) disclose that they saw an increase in plant heights away from the trail. Additionally, Price (1985) supports the statement by suggesting that vegetation cover will generally increase the further away you move from the trails.

In a study conducted by Trottier & Scotter (1973), they reported that low to moderate recreational impacts lead to a decrease in low-growing shrub ground cover, but the number of plants remained the same showing that the shrubs just decreased in size. However, tall shrubs and herbaceous species decreased in both number of plants as well as plant cover with increased impacts. Locations with high recreational impacts were found to provoke grass-like plants and small herbaceous plants to increase in ground cover as well as number of individual plants.

These highly impacted areas also included trampling-tolerant species which were not found in other undisturbed areas (Trottier & Scotter 1973). Price (1985) states that vegetation next to trails is generally dominated by grass-like species and low-growing forbs, which will occur much less frequently in undisturbed areas. Undisturbed areas will not have tolerance to trampling. If there are a trampling-tolerant species present, they will most likely come to dominate trail sides. In addition, plant species vary in their long-term tolerance to trampling. Price (1985) suggests that impacts seem much grander to visitors because they are seeing the bulk of the disturbance while hiking, but the majority of the area will usually be undisturbed and will have normal plant communities and conditions.

While ground cover was found to increase distances from areas of higher impact, Bright (1986) found that species diversity decreased away from trailheads and areas of high disturbance. Diversity was also found to increase as the trail width became smaller (Bright 1986). In addition, Bhuju & Ohsawa (1998) was able to show that species richness was only slightly higher in trampled areas than untrampled areas. They found that some perennial and annual herbs were growing only in the trampled sites, while only a few shade-loving varieties were exclusively growing at untrampled sites. They also reported that woody plant sapling density was much less in trampled sites than in untrampled sites, suggesting successful establishment (Bhuju & Ohsawa 1998). Dale & Weaver (1974) theorize that smaller vegetation along trails received more sunlight, rainwater, and nutrients than those competing with trees and their roots deeper in the forest. Many plants commonly found in undisturbed areas of the forest are often not present near the trail at all, while others are only found trailside. In addition, they conclude that meadow vegetation is more commonly found growing near trails where they may receive more sunlight and water, and are therefore not commonly found further into the forest (Dale & Weaver 1974).

Adkinson & Jackson (1996) reinforce the above findings by reporting that within deciduous forests, smaller plants were found in higher concentrations along trailsides, while woody vegetation was found in higher numbers away from the trails. There was clearly higher species richness as well as ground cover along forested trails (Adkinson & Jackson 1996).

Another recreation impact was researched by Bhuju & Ohsawa (1998), where they found that trampling caused increased soil compaction and artificial deposition of sandy soils into the area. They also found that carbon and nitrogen levels were lower in the trampled soils than in the natural soils (~ C 6% and N 0.3% differences). Herbaceous species were found to be higher in cover in the untrampled sites than in the trampled sites. They found that plants growing in trampled areas often had a higher root to stem ratio than the untrampled sites. Bhuju & Ohsawa (1998) suggests this may be caused by reactions to soil compaction in the trampled areas. Roots were present deeper in untrampled sites, but expanded more laterally in trampled sites. Finally, Bhuju & Ohsawa (1998) concludes that growth rate is higher in untrampled areas than in trampled areas.

3.4 Management Practices

Although there are not many official protocols to managing social trails, a few methods have shown to improve natural resource conditions. Park, Manning, Marion, Lawson, & Jacobi (2008), were able to highlight some of the methods they found to be most successful in a national park setting. Their study was conducted in Acadia National Park on the popular Cadillac Mountain summit loop trail. They used strategies such as educational signs, verbal requests to stay on the paved trails, personal educational messages, prompter signs, and trailside fencing. As a result, it seems that the educational signage as well as trailside fencing was most effective in keeping visitors on the paved trail. The educational signage strategy consisted of signs being placed at the entrance and exit to the trail as well as several reminder signs at intervals along the trail. It also included some "prompter" signs at social trail locations to encourage visitors to remain on the trail. The trailside fencing strategy, however, included a series of trailside fences geared towards helping restrict visitors to the path (Park et al. 2008). While fencing may not be optimal in some locations, other management techniques have been proven to decrease social trail impacts as well.

Marion & Leung (2004) urge that education and monitoring are the best management practices to maintain safe and attractive trails. They argue that to minimize social trail impacts land managers should continue repeated monitoring. This can aid in defining a carrying capacity or a threshold for a healthy ecosystem, which is succeeded by implementation of appropriate management practices. Maintenance of formal trails can be very effective in preventing social trails. If the formal trail is easy to walk on, alternate routes will not arise. In addition, land managers should consider rerouting of formal and informal trails to create more sustainable routes. A planned formal trail to an attraction will create a socially and environmentally safe route for visitors (Marion & Leung 2004).

To conclude, removal or damage of vegetation along trails can cause many severe problems. Lack of vegetation can increase the amount of direct precipitation and light that trailsides receive. Erosional effects from over-drainage and the increase in nutrients from human and animal waste are also seen, as well as artificial plant dispersal along trails (Cole 1978). Through this data, we have learned that the best way to minimize impacts is to continue monitoring and educate the public about their actions in nature.

CHAPTER 4: RESEARCH METHODS

4.1 Research Questions

- Is there significant damage to vegetation in Petrified Forest National Park because of recreational disturbances caused by hiking?
- Is damage caused by hiking affecting vegetation abundance, diversity, or ground cover at Petrified Forest National Park?
- How can we improve management practices for Petrified Forest National Park? How can we improve native vegetation diversity and prosperity in the future?

4.2 Social Trail Mapping

During the initial data collection phase, the following mapping instruments were used to assess social trail networks: Garmin GPS, Trimble Handheld Data Collector, ArcMap, tape measures, compass, digital camera, and a topographical map. Social trail mapping procedures were applied from the *Petrified Forest National Park: VERP 2016 Report* in order to retain consistent results. Data collection began by assessing the trail condition of each site. This was initially accomplished using a Trimble Handheld Data Collector to record each social trail disturbance and the degree of degradation. Each disturbance was visually inspected and entered into the Trimble as one of the following shapefiles based on the shape of disturbance: barely discernible point (point), social trail (line), disturbed area (polygon). Barely discernible points (point) were defined by visually pinpointing a spot that visitors may have gotten off the path, but no trail or compacted area had been formed yet. Often times these locations were the beginnings of future trailheads or scenic photo opportunities. Consequently, social trails (line) were categorized as having a distinct, traditional, narrow trail shape. Lastly, a disturbed area (polygon) was recorded if an obvious area had been disturbed and could not be classified as a trail or barely discernable point. These disturbed areas were often found near lookouts and displayed a freeform shape. After the shapefile was created, a number of prompts were used to evaluate the condition of each type of disturbance. Social trails were classified by the severity of disturbance which was visually evaluated as light, medium, or heavy. Social trails and disturbed areas were also noted as being either braided or not braided. In addition, these two types of disturbance were evaluated for erosion levels, rutting, and compaction (lightly, moderately, or heavily) based on visual inspections. The barely discernable points did not receive further evaluations.

In order to record the location, length, and shape of the disturbances the Trimble GPS was taken down the length of the social trail, around the perimeter of the disturbed area, or to the barely discernable point. The information gathered in the Trimble GPS was later loaded onto ArcMap and analyzed for degradation, severity, and total area. For the purpose of this project, only locations of barely discernable points, condition classes of social trails, and compaction severity of disturbed areas were included (for additional trail data see *Petrified Forest National Park: VERP 2017 Report*.)

In addition to recording disturbance locations, lengths, and shapes, conditions at each social trail trailhead were recorded. This was carried out by first pairing the trailhead with the unique social trail identification number given to each trail on the Trimble GPS when a shapefile was created. Then, GPS coordinates were taken for the exact location of the trailhead. Next, a heading was recorded using the compass to show which direction the trail was headed as well as the direction of the subsequent photograph. Then, a photograph was taken to accurately record the actual condition of the trail head for future evaluations. In order to take a consistent photograph over many years, the camera was positioned so that the frame included the entire trailhead (approximately 3 meters from the start of the disturbed area), a whiteboard with the unique trailhead name, and a north arrow to confirm the compass heading taken previously. This photo will be used in later years in a repeat photography study to compare the progress of degradation at major attractions. After recording the location of the trailhead, the condition was, again, visually inspected and recorded as light, medium, or heavy. This information was recorded on a field worksheet on site and later converted to a spreadsheet. The information recorded may be used in future years to compare degrees of use, and to formulate the best management techniques in order to avoid further degradation.

4.3 Vegetation Survey

Vegetation survey procedures were designed around concepts and methods discussed by Purvis, Gramling, & Murren (2015), Purvis et al. (2015), and Nepal & Way (2007) found in the *Literature Review* as well as methods found suitable for this specific habitat. The survey conducted in Petrified Forest National Park required the following resources: plant identification field guides, assessment worksheets, tape measures, Garmin GPS, digital camera, compass, and trail condition data. Six total trail sites were selected from three different trail types in order to get a good representation of the entire park. Two pull-offs were chosen (Lacey Point and Route 66), as well as two paved trails (Crystal Forest and Puerco Pueblo), and two "Off the Beaten Path" (OTBP) trails (Billing's Gap and Martha's Butte). At each site, the following procedure was used.

To begin, a number of transects were selected for each trail. Each transect was chosen either randomly or systematically, depending on structure the of trail and vegetation communities present. Randomly chosen transects were located on trails and disturbed areas with many diverging paths and an inconsistent pattern, while the systematically chosen transects were located on trails that had a uniform structure (i.e. paved trails). If the given transects were chosen randomly, a compass was spun and randomly stopped on a heading number, the heading number represented the distance in meters to the next transect. If the transects were chosen systematically, the locations and distances were proportionately calculated according to the number of transects desired within the full trail length.

Once the transect locations were established, the local vegetation could be surveyed. This was done by using a transect of four quadrats. These quadrats were located in a line that crosses the trail in a perpendicular fashion along each previously selected transect (Purvis, Gramling, & Murren, 2015 and Purvis et al., 2015). Each quadrat measured one square meter in area (1m x 1m), and was taped off to create four equal squares. Quadrats 1 and 2 were located on either side of the trail, in order to get a good understanding of degradation along the disturbed area. Quadrats 3 and 4 were located to one side at 2 and 3 meters away from the trail. The quadrat located at 3 meters (quadrat 4) was considered a control plot for the study. According to Nepal & Way (2007), because vegetation varies so greatly at the study sites, it was necessary to create a control plot that would show accurate results for comparison. For those reasons established by Nepal & Way (2007), it was important to be flexible with control plot placement. Quadrats 3 and 4 were placed on the side of the trail that was most topographically consistent in order to gather good data.

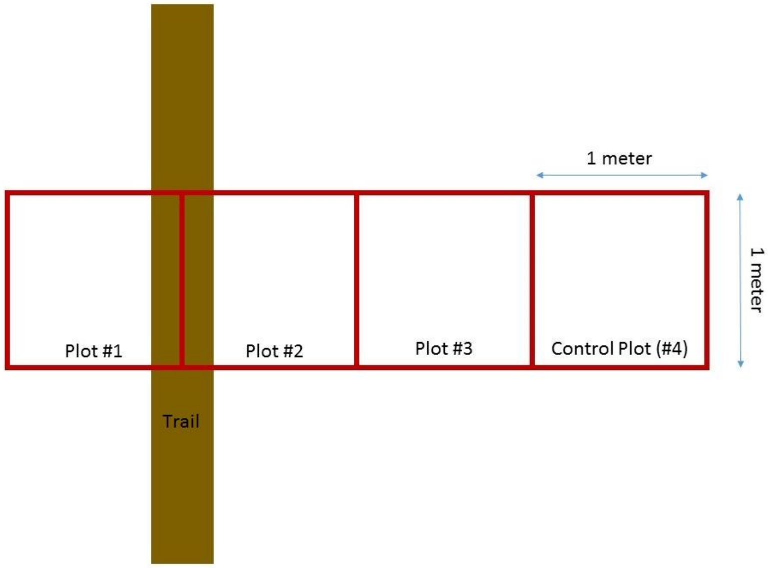

Figure 1: Vegetation survey plot diagram

The quadrats were physically created by using a tape measure and survey flags. A tape measure was stretched in a straight line from quadrat 1 to quadrat 4. Then, survey flags were placed at each meter. This process was repeated one meter away, parallel to the first line, creating 4 identical boxes that reflect *Figure 1*.

Next, at each transect, a compass heading, GPS point, and a photograph was taken to document the location of the transect. The compass heading was taken in the direction that the photograph was taken. The camera was positioned at the quadrat 1 end, and pointed towards the quadrat 4 end along the transect line, perpendicular to the trail (see *Appendix III*). A GPS coordinate was also taken by standing in the center of the trail, at the transect, in order to record the exact location of the transect sites and to assign a unique name for each site. In the field worksheet, the transect number, trail name (location), and date were recorded, as well as the GPS coordinates compass heading, and photograph number.

Transect #:	Location:		Date:	
	Plot #1	Plot #2	Plot #3	Plot #4
# of Varieties				
Variety Name				
total				
Variety Name				
total				
Variety Name				
total				
Variety Name				
total				
Variety Name				
total				
Succulent				
Biotic soil				
Sand				
Debris				
Herb				
Shrub				
Grass				
Trampled				
Photo #:				
Transect Heading:				

Figure 2: Vegetation survey field worksheet

In addition to location, using Nepal & Way (2007) as a reference, the vegetation within each quadrat at each transect was individually measured for diversity, abundance, and ground cover and recorded on the vegetation survey field worksheet (*Figure 2*). In order to record vegetation diversity, each floral variation was recorded individually for each quadrat in the transect site as the "variety name". After all varieties within the quadrat, or plot, had been documented, the sum was placed in the "# of varieties" box near the top. Then, to show vegetation abundance for each quadrat (plot), the number of stems were counted for each variety of plant recorded previously, and recorded at the "total" box for each variety. Furthermore, in order to calculate ground cover, the percent coverage was estimated visually by inspecting the cover of vegetation within each quadrat (plot). Each type of cover was given a percentage of ground covered inside the quadrat (plot). Ground cover was classified into eight categories (biotic soils, succulents/cactus, herbaceous, grass, shrub, trampled vegetation, debris, and sand) using 5% intervals.

Finally, using ArcMap, and the GPS mapping field data, a map was constructed to reflect the locations and conditions of each trail, highlighted in the research results. In addition, locations of vegetation transects were plotted and correlated to the condition of each trail. Then, diversity, abundance, ground cover, and trail type were analyzed in order to uncover significant results and make educated recommendations for future management plans.

CHAPTER 5: RESEARCH RESULTS

Survey sites were chosen to best reflect the structure of the park, while also gathering useful information for highly visited attractions. To represent longer, backcountry locations, two of the most popular and vulnerable "Off the Beaten Path" (OTBP) trails were chosen. In addition, two prominent vehicle pull-off sites were selected, as well as two popular established (paved and maintained) trails. Each survey site varied in number of transect locations due to the varying lengths of trail. Billing's Gap OTBP trail received 11 transects while Martha's Butte OTBP trail possessed 9 transects, the Route 66 pull-off and Lacey Point pull-off had 5 and 6 transects, and Crystal Forest trail and Puerco Pueblo trail included 15 and 8 transects. At each survey site, data about trail condition, vegetation abundance, vegetation diversity, and biotic ground cover was collected. This data has been displayed in maps and figures in the following sections.

5.1 Trail Condition

The following maps have been created to display the data collected about disturbance levels of each survey site. Each location was visually inspected for disturbances such as barely discernable points (point), social trails (line), and disturbed areas (polygon). Social trails were catalogued based on condition class, disturbed areas were classified by compaction severity, and barely discernable points were carefully recorded by location.

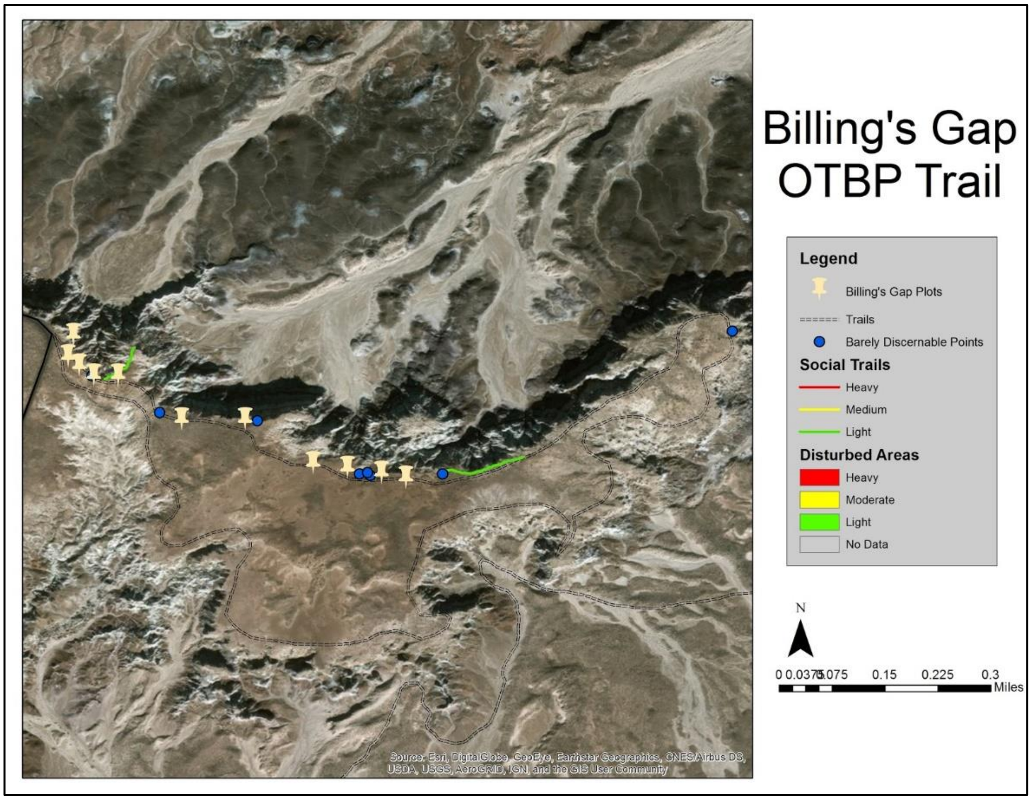

Figure 3: Billing's Gap OTBP Trail map

5.1.1 Billing's Gap OTBP

This trail is a loop that measures approximately 3 miles in length. However, all of the disturbances were located on the north side of the loop. There were eight barely discernable points recorded as well as two light social trails, and no disturbed areas. Eleven vegetation transect sites were distributed along the north section of trail.

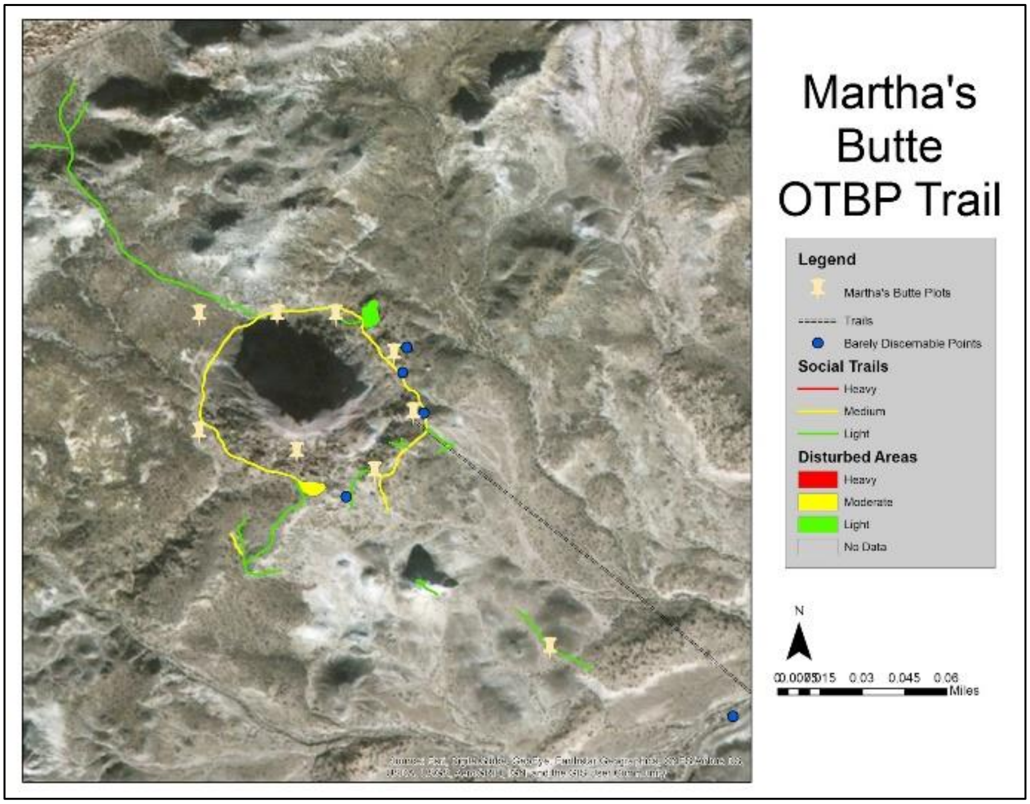

Figure 4: Martha's Butte OTBP Trail map

5.1.2 Martha's Butte OTBP

This trail is approximately 1 mile one-way. The majority of disturbances were located around the base of the butte, where the main archaeological attraction exists. Ten barely discernible points were recorded at this location. Additionally, 22 social trails were mapped in total, two of them being heavy trails, three medium trails, and 17 light trails. Aside from the discernible points and social trails, one lightly compacted and one moderately compacted disturbed area was recorded. Martha's Butte OTBP trail possessed nine vegetation transect sites.

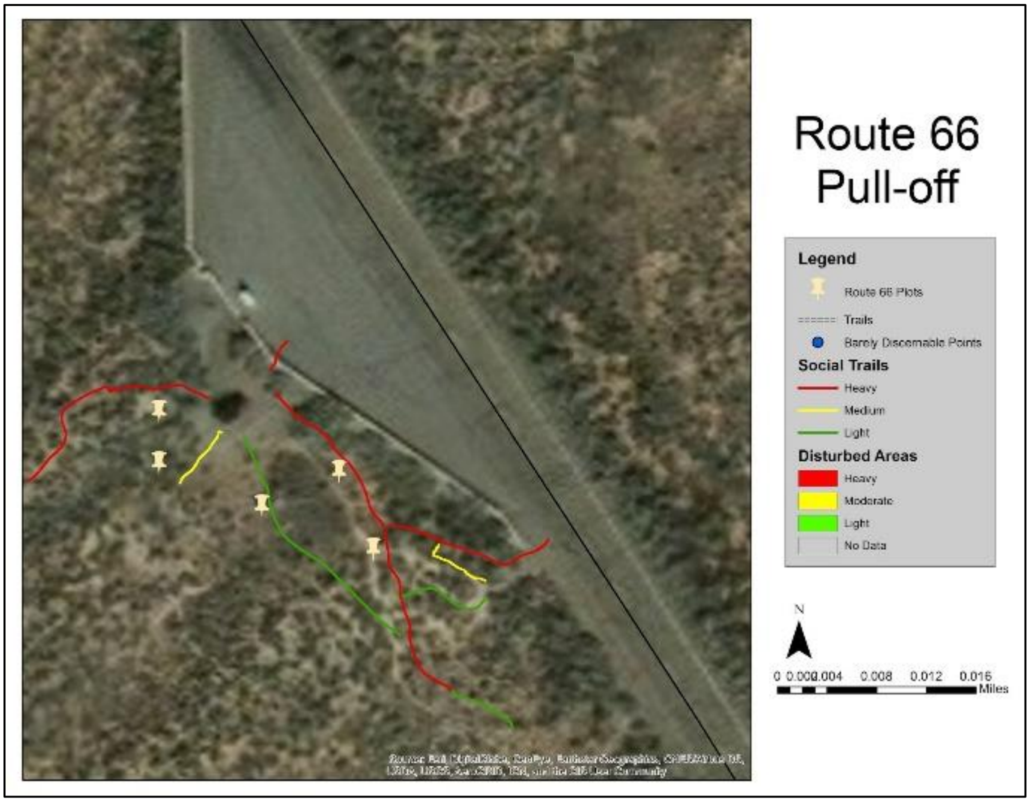

Figure 5: Route 66 Pull-off map

5.1.3 Route 66 Pull-off

This site is located directly adjacent to the main park road and allows visitors to walk around an old automobile resting on Historic Route 66. At this site, no barely discernible points or disturbed areas were recorded. Additionally, nine social trails were located; four of the social trails were heavy trails, two were recorded as medium trails, and three trails were light trails. A total of five vegetation transect sites were placed at this location.

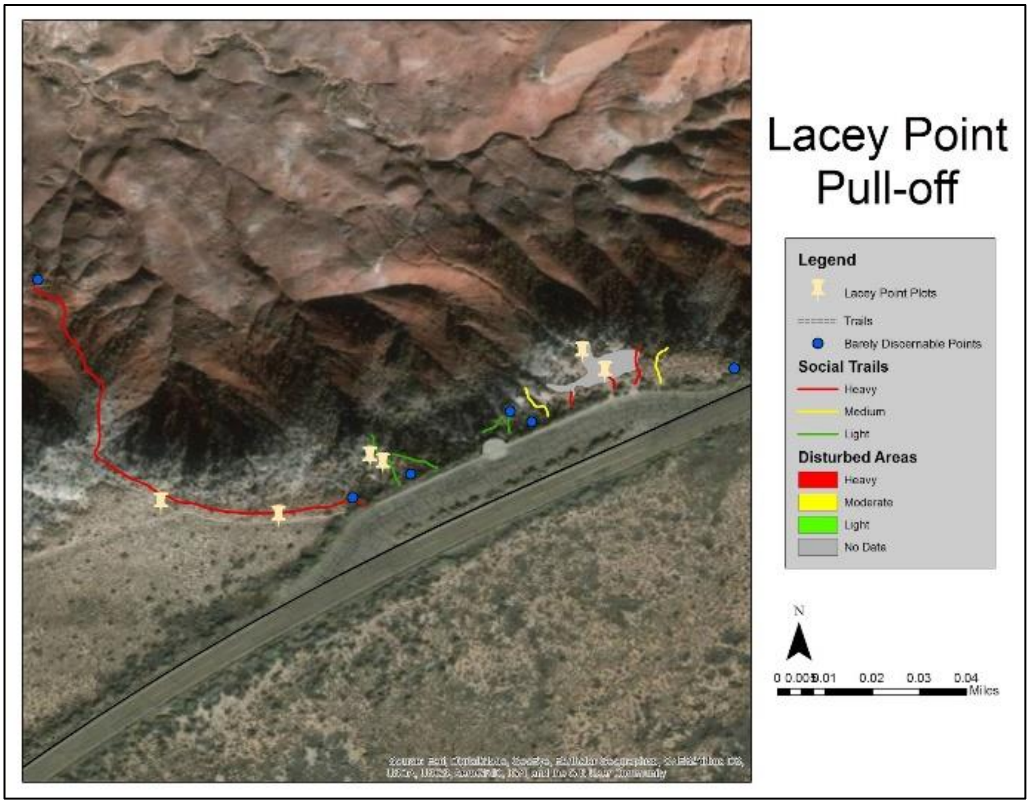

Figure 6: Lacey Point Pull-off map

5.1.4 Lacey Point Pull-off

This site is another pull-off located directly off the main park road where visitors can stand at the rim of the Painted Desert and view the badlands below. Six barely discernible points were located. In addition, ten social trails were recorded off the pavement at this site; four of these were considered heavy trails, two were medium trails, and another four were light trails. There was also one disturbed area present, but compaction severity data was not available. Six vegetation transect sites were situated along these disturbances.

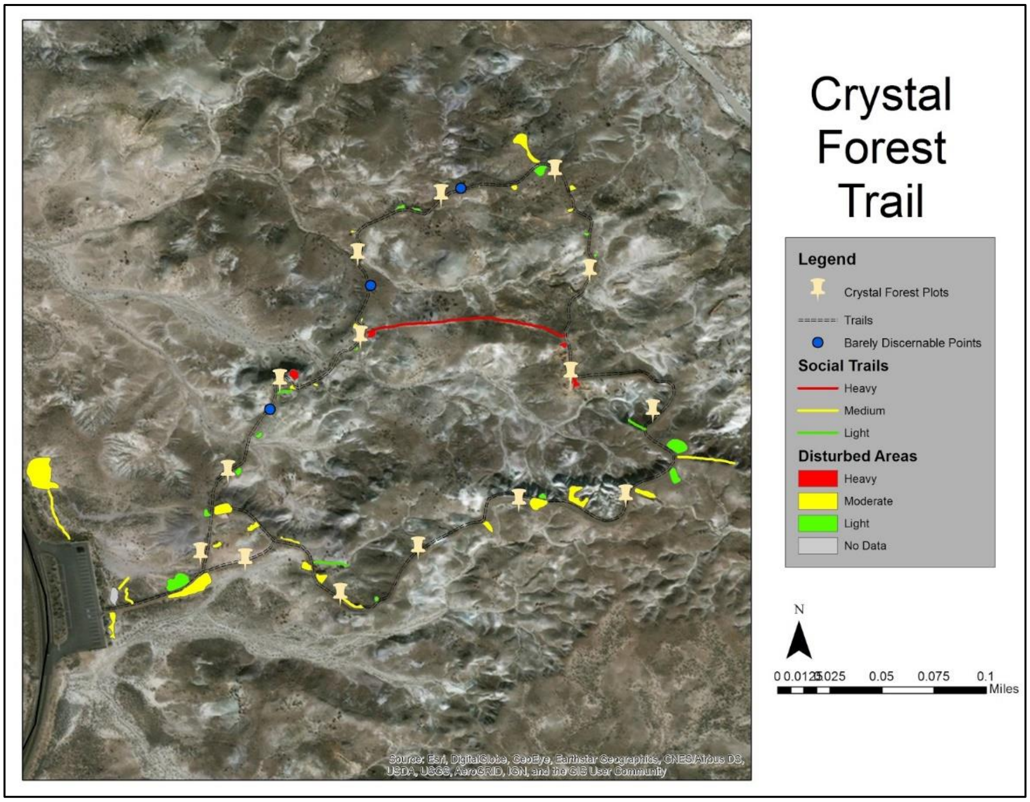

Figure 7: Crystal Forest Trail map

5.1.5 Crystal Forest Trail

This is a formal, paved trail that extends into a 0.75 mile loop. The trail leads visitors through a rich deposit of petrified logs. Located along the pavement, three barely discernible points were recorded. Further, extending from the paved trail, eight social trails were mapped, with one being a heavy trail, four were medium trails, and three were considered light trails. Additionally, there were 44 disturbed areas recorded along the paved trail, where four were considered heavily compacted, 25 were moderately compacted, and 14 were lightly compacted. Fifteen total vegetation transect sites were marked at this site.

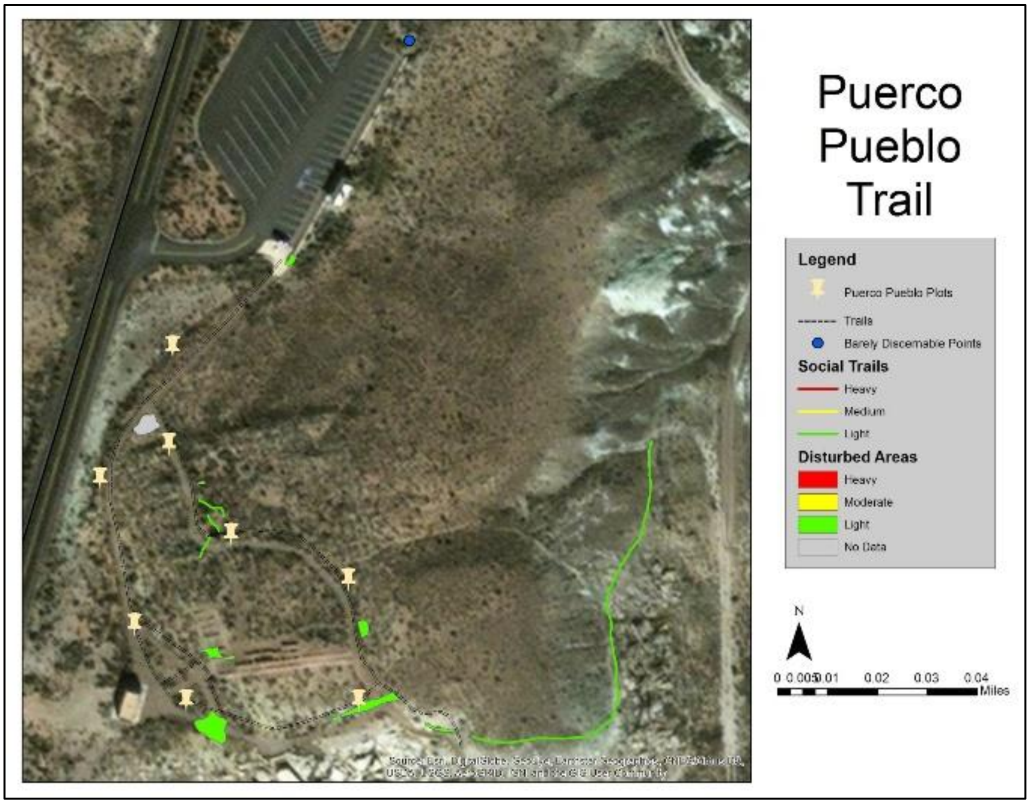

Figure 8: Puerco Pueblo Trail map

5.1.6 Puerco Pueblo Trail

This trail is also a formal, paved trail that circles a major archeological site in a 0.3 mile loop. This site has many fences to prevent visitors from disturbing the prehistoric structures. One barely discernible point was recorded in addition to four light social trails that were diverging from the paved trail. Furthermore, eight disturbed areas were recorded, seven of them being lightly compacted, and one of them having no data. This trail hosted eight vegetation transect sites.

5.2 Vegetation Abundance

For each survey location, a graph was created to summarize the vegetative abundance for each quadrat (plot). Abundance was calculated by recording the total number of individual stems found in each plot. The graphs were designed to represent the set of transects and quadrats (plots) used in the field, where "Plot #1" and "Plot #2" are located on either side of the trail, "Plot #3" is located at two meters from the trail, and "Plot #4" is located at 3 meters from the trail. The bars represent the abundance of each vegetation type, and the line is the result of the total summed abundance of all vegetation types found in each plot.

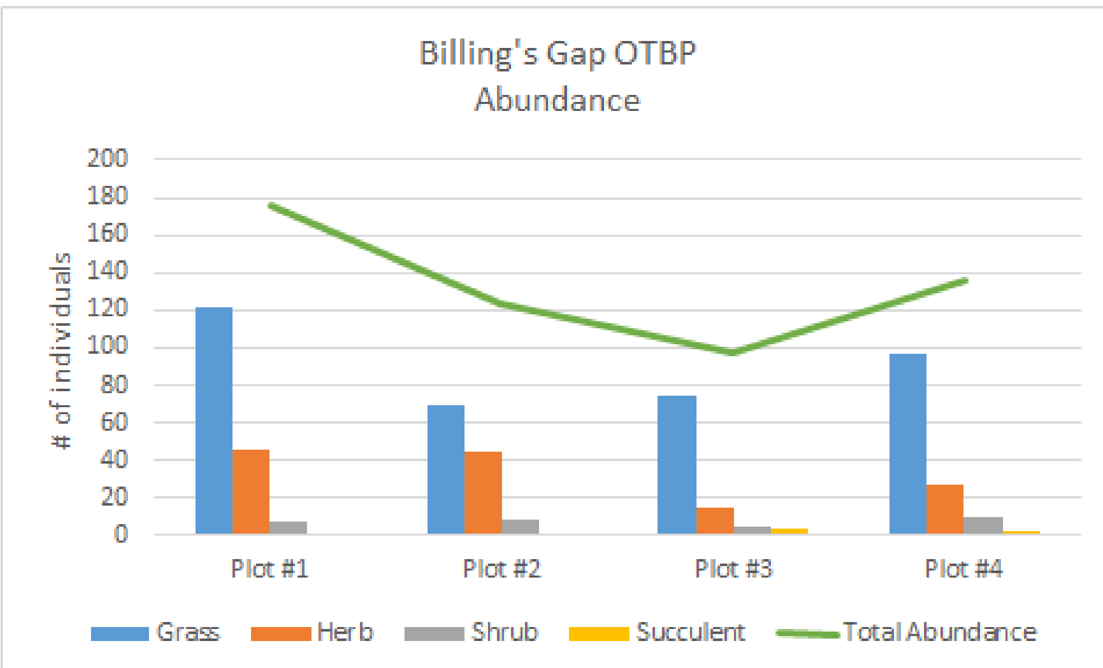

Figure 9: Billing's Gap OTBP vegetation abundance

5.2.1 Billing's Gap OTBP

This trail is located in a dry grassland area of the park. Eleven different vegetation transects were established by random selection, and recorded through field worksheets. Analysis found that grasses and herbaceous varieties are dominant closest to the disturbed area, but persist further from the trails as well. Shrub varieties are present in all areas, but were never able to become dominating figures in abundance. Furthermore, succulents are only present in areas further from the trail. Total vegetative abundance peaks in plot #1 and decreases into plot #3, while plot #4 increases in abundance once again.

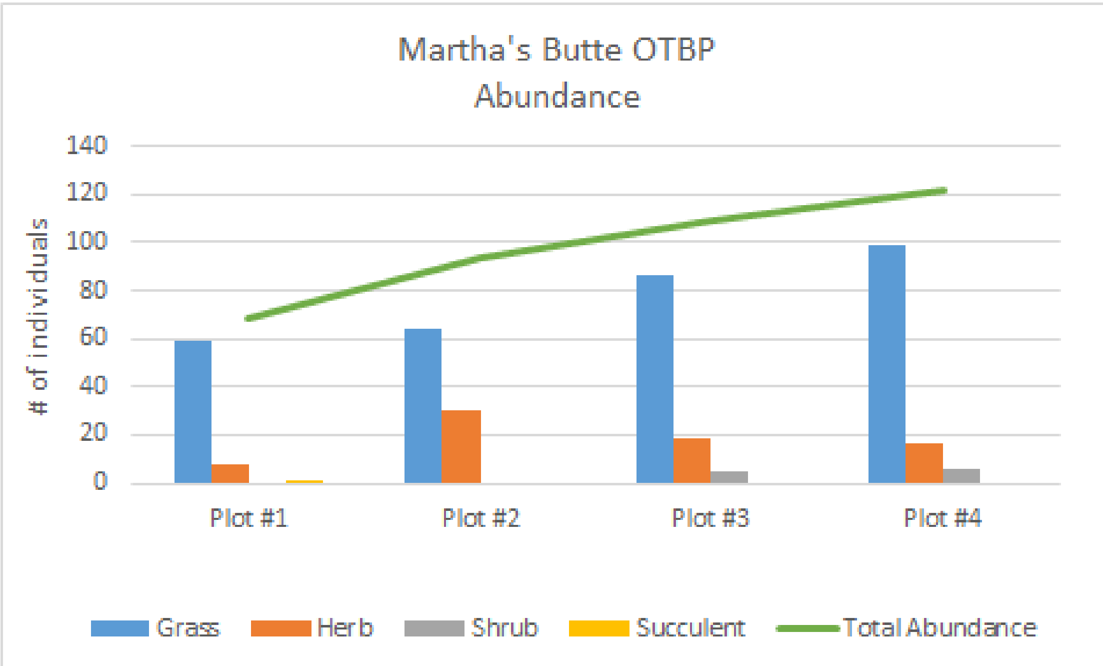

Figure 10: Martha's Butte OTBP vegetation abundance

5.2.2 Martha's Butte OTBP

This trail is also a trail with no official infrastructure. It is considered a backcountry trail as Billing's Gap is, with intermittent social trails present. The majority of the randomly selected vegetation survey plots were located around the base of the butte of interest, where the majority of the definite social trails are located. A total of nine transects were taken from this trail. Once again, grasses are the dominant vegetation along the trails, but even more so further from the disturbed areas. Herbaceous varieties show a presence in all plots, while shrub varieties only appear further from the social trail disturbances, in plot #3 and #4. Succulents were only recorded in plot #1. Overall abundance strongly increases the further from the trail through plot #3 and #4.

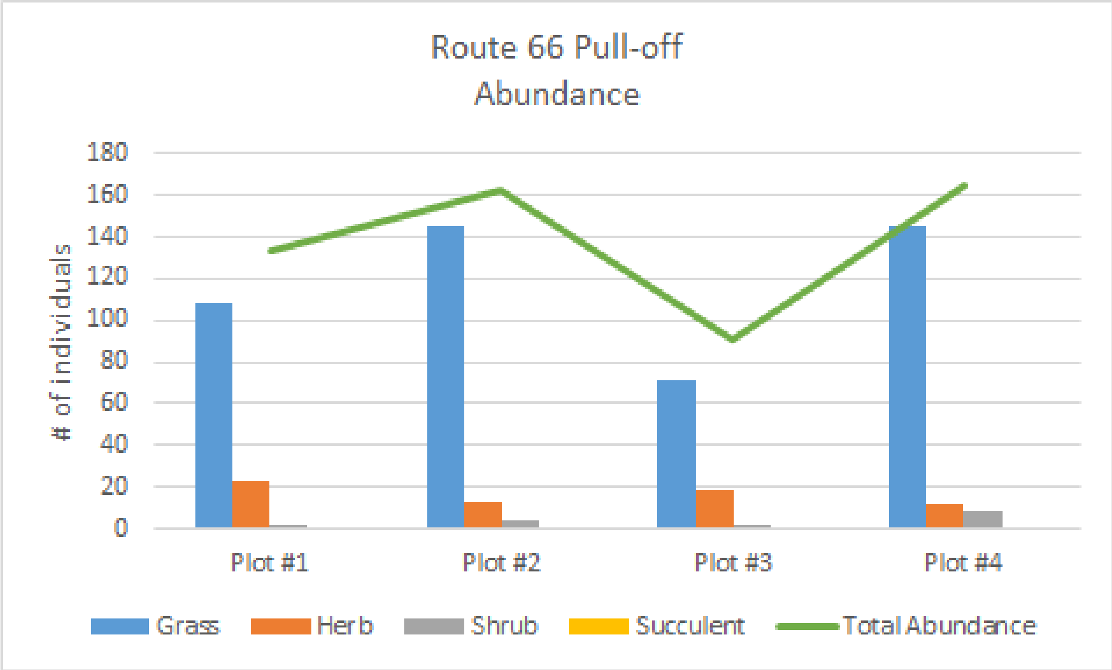

Figure 11: Route 66 Pull-off vegetation abundance

5.2.3 Route 66 Pull-off

This pull-off is located in the northern portion of the park. It is quite a small site with only an old automotive skeleton remaining. Most of the disturbances are concentrated in the area surrounding the automobile skeleton. Only five transects were randomly selected in this confined area. However, it is evident that grasses are dominant in this area, and shrubs only become present further away from the disturbances. Herbaceous varieties are, again, present throughout the plots. No succulents were recorded at this location. Total abundance spikes both along the trail, in plot #2, and furthest from the trail, in plot #4.

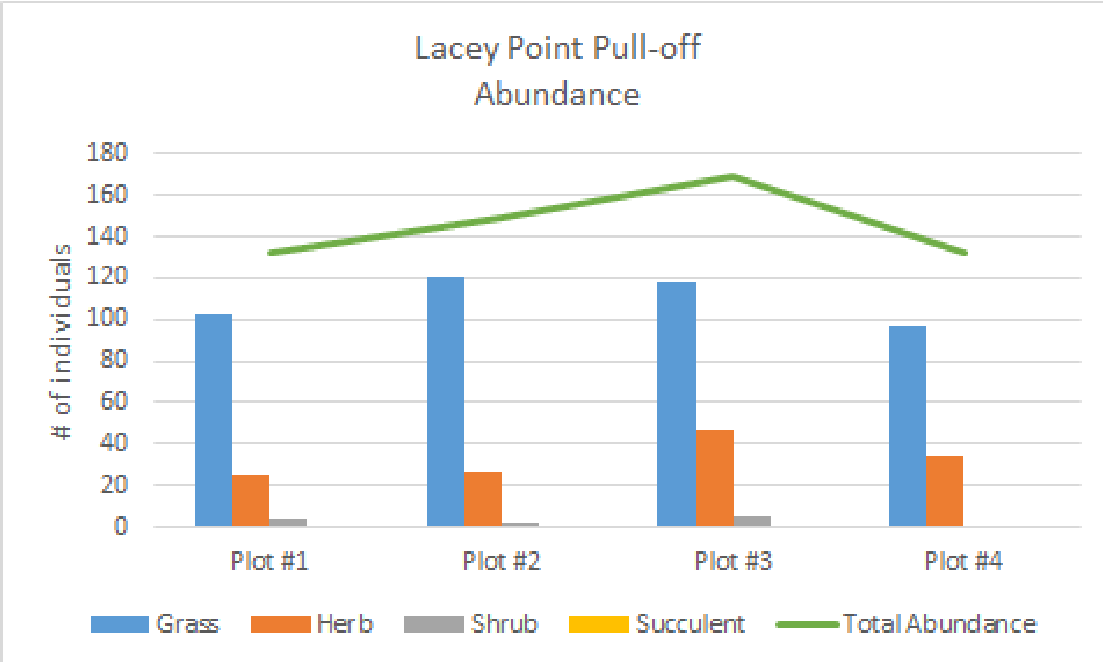

Figure 12: Lacey Point Pull-off vegetation abundance

5.2.4 Lacey Point Pull-off

This site is also located on the north end of the park. It is situated along the rim of the Painted Desert with a paved parking area. Six transects were randomly selected for this location. This area is dominated by grasses and herbaceous flora. Shrubs are present throughout the transect, but are not very abundant. The herbaceous varieties become slightly more abundant further from the disturbed areas, in plot #3 and #4. Succulents made a single appearance in plot #2. Total abundance peaks in plot #3.

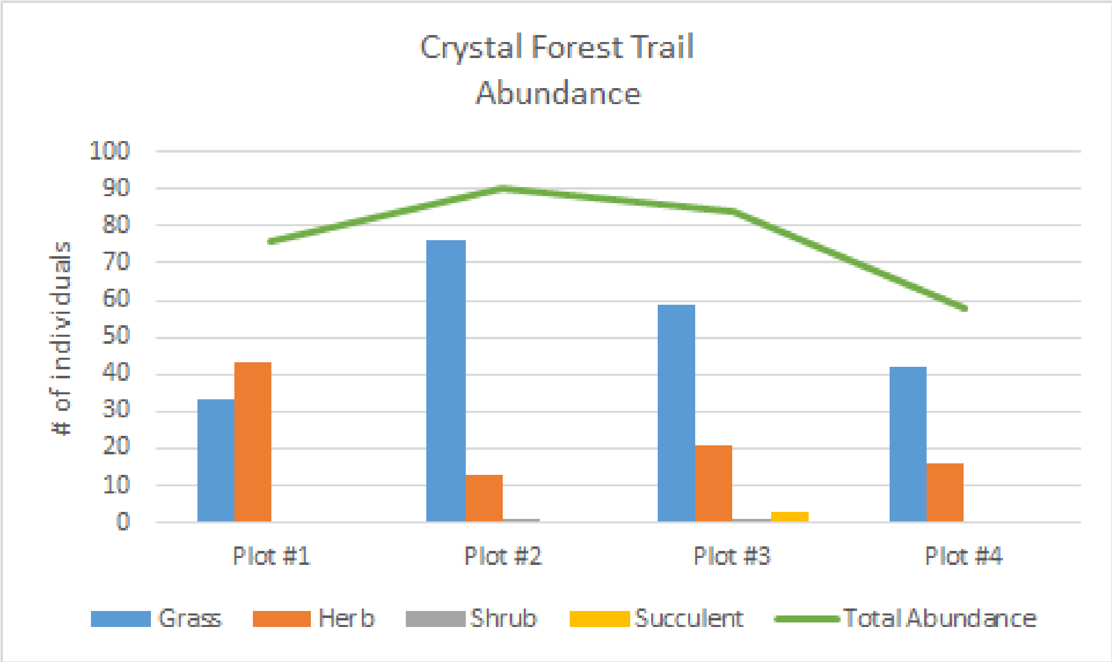

Figure 13: Crystal Forest Trail vegetation abundance

5.2.5 Crystal Forest Trail

This location is a paved loop trail which circles a dense deposit of petrified wood. Grasses are once again dominant in the 15 transects systematically surveyed at this location. Herbaceous vegetation abundance was fairly consistent across the plots. Shrub individuals are only seen in plot #2 and plot #3, while succulents were only recorded in plot #3. Grasses and herbaceous vegetation show a decrease in growth into plot #3 and #4. Total abundance shows a downward trend extending away from the trail in plot #3 and #4.

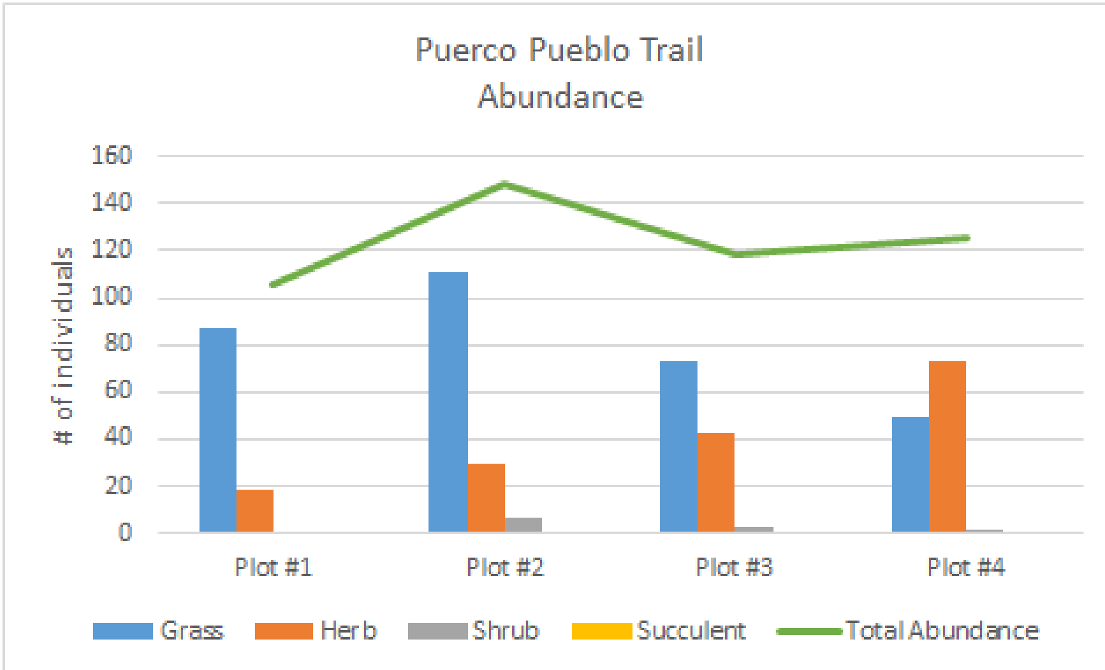

Figure 14: Puerco Pueblo Trail vegetation abundance

5.2.6 Puerco Pueblo Trail

This trail consisted of eight transects located along a paved loop trail that circles a significant archeological site. Grass abundance was highest closest to the trail in plot #1 and #2, while herbaceous varieties increased in abundance with increasing distance from the trail. Shrubs were recorded consistently across the plots with low numbers. Overall abundance shows the highest and lowest numbers in the plot #1 and #2, located on either side of the trail.

5.3 Vegetation Diversity

Another set of graphs were created to summarize the vegetative diversity seen at each study site. The diversity of these sites was based on the number of different vegetative varieties found in each quadrat (plot) of each transect.

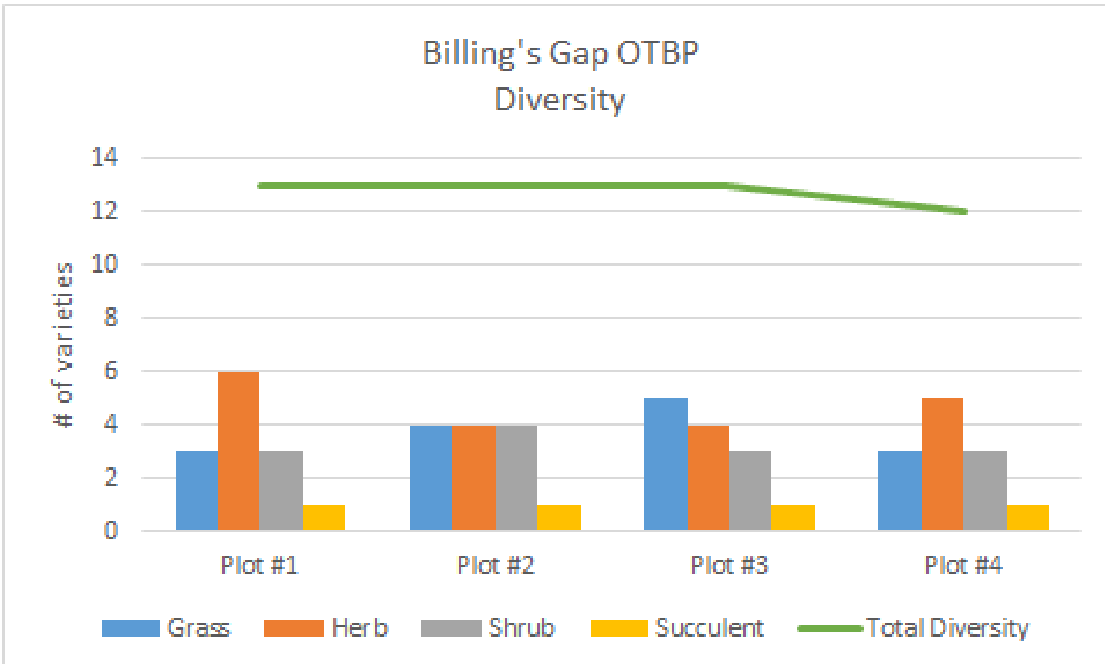

Figure 15: Billing's Gap OTBP vegetation diversity

5.3.1 Billing's Gap OTBP

This trail showed consistent diversity results. Grasses are most diverse in plot #3, and herbaceous vegetation peaks in both plot #1 and #4. Shrubs and succulents reflect a very consistent amount of diversity. Overall diversity for this location is fairly constant across the plots.

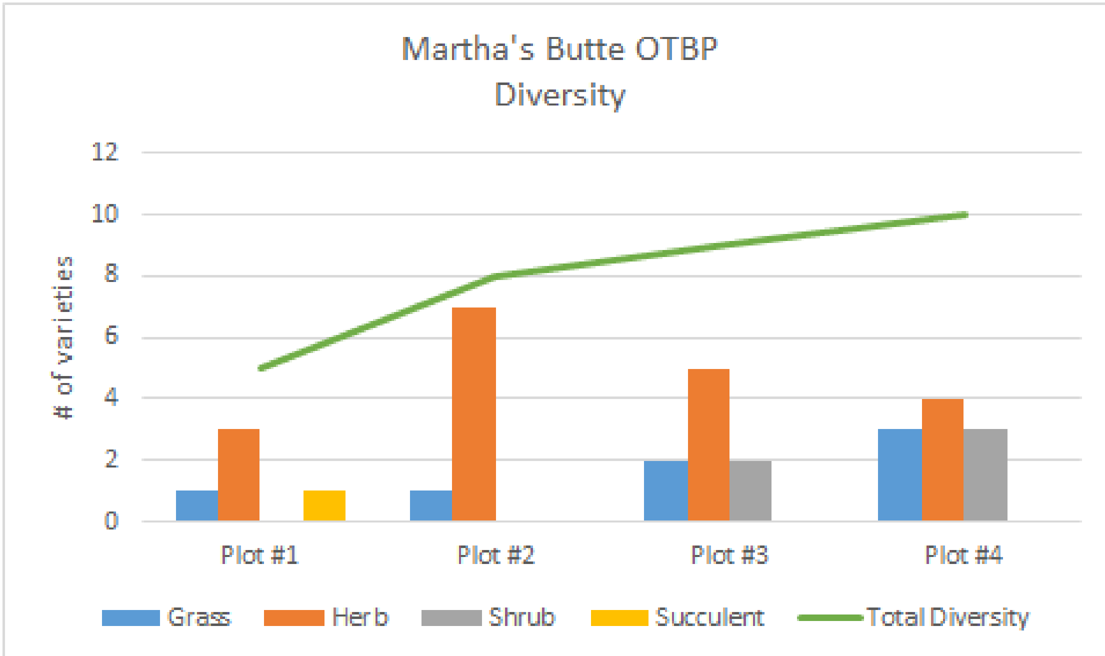

Figure 16: Martha's Butte OTBP vegetation diversity

5.3.2 Martha's Butte OTBP

This trail survey clearly shows a total diversity increase as you move further away from the trail in plot #3 and #4. This is the result of an increase in grass diversity further from the trail, as well as a sharp shrub diversity increase in plot #3 and #4. Herbaceous vegetation shows a peak in number of varieties in plot #2, but remains relatively high in plots #3 and #4. Succulent varieties were only observed in plot #1. Overall, herbaceous vegetation shows the greatest diversity at this location.

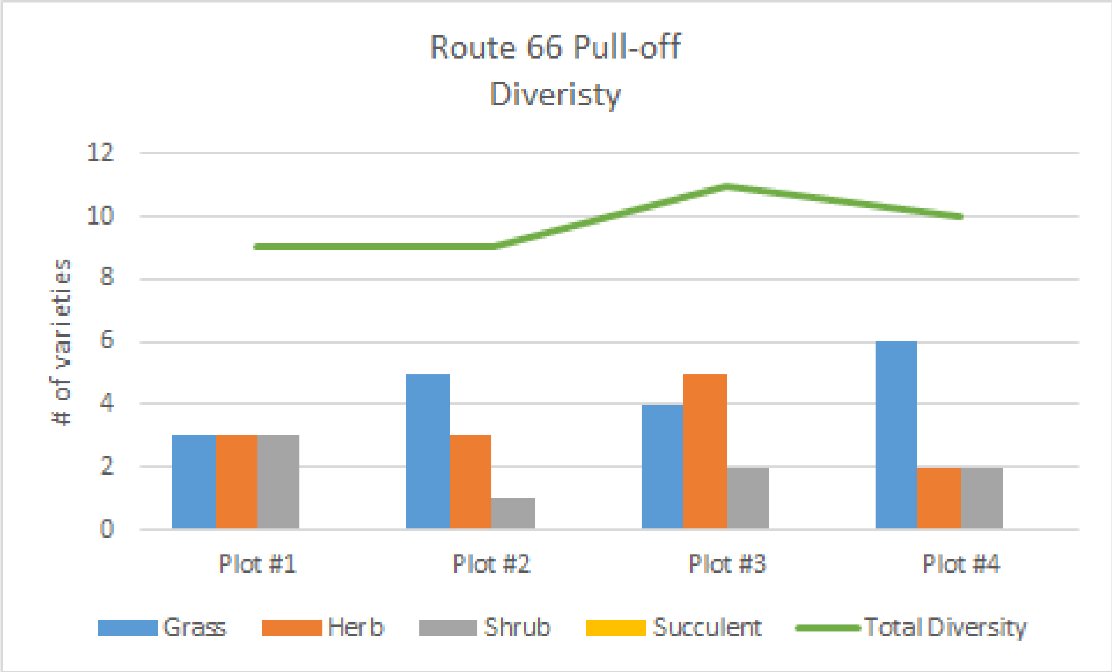

Figure 17: Route 66 Pull-off vegetation diversity

5.3.3 Route 66 Pull-off

This site shows an increase in diversity in plot #3 and #4, or the further from the disturbed areas you move. Grasses are predominantly responsible for this trend as they increase in variety in plot #4. Herbaceous plants dominate in diversity in plot #3, and shrub variations decrease slightly further from the disturbed area. There were no succulent varieties recorded at this location.

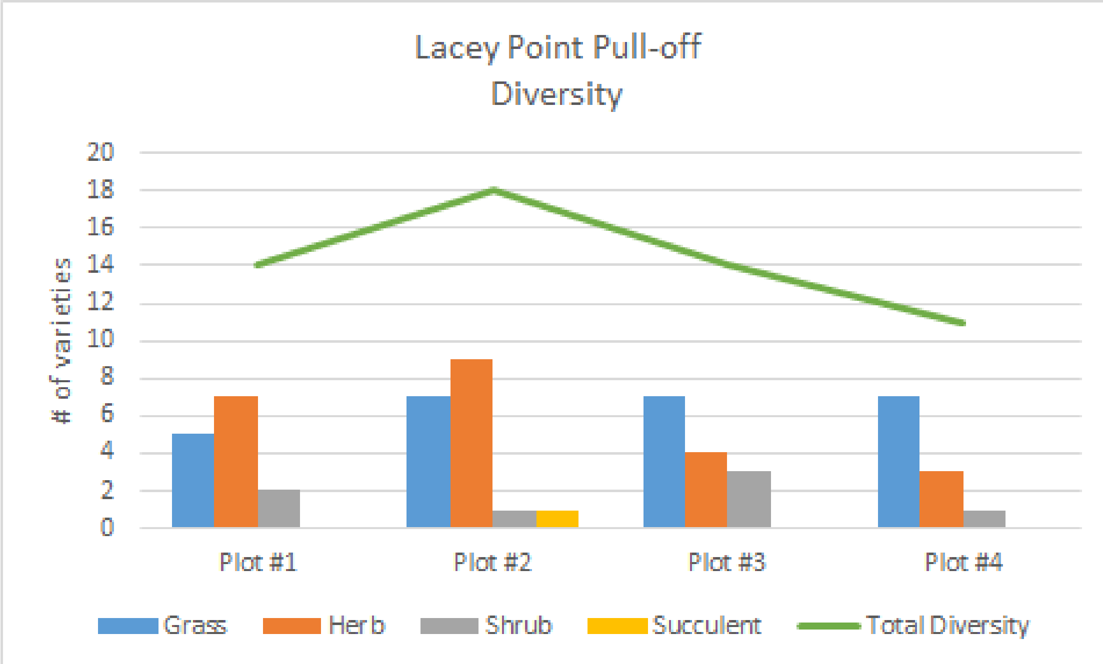

Figure 18: Lacey Point Pull-off vegetation diversity

5.3.4 Lacey Point Pull-off

This site resulted in a decrease in diversity surrounding the disturbed area, to plot #4. Grass variations do not show a significant change in diversity throughout the surveyed plots, but herbaceous vegetation is predominantly diverse adjacent to the disturbed areas, plot #1 and #2, and decreases in count away from the disturbances, in plot #3 and #4. Shrubs are fairly consistent across the plots. Succulents are only seen in plot #2.

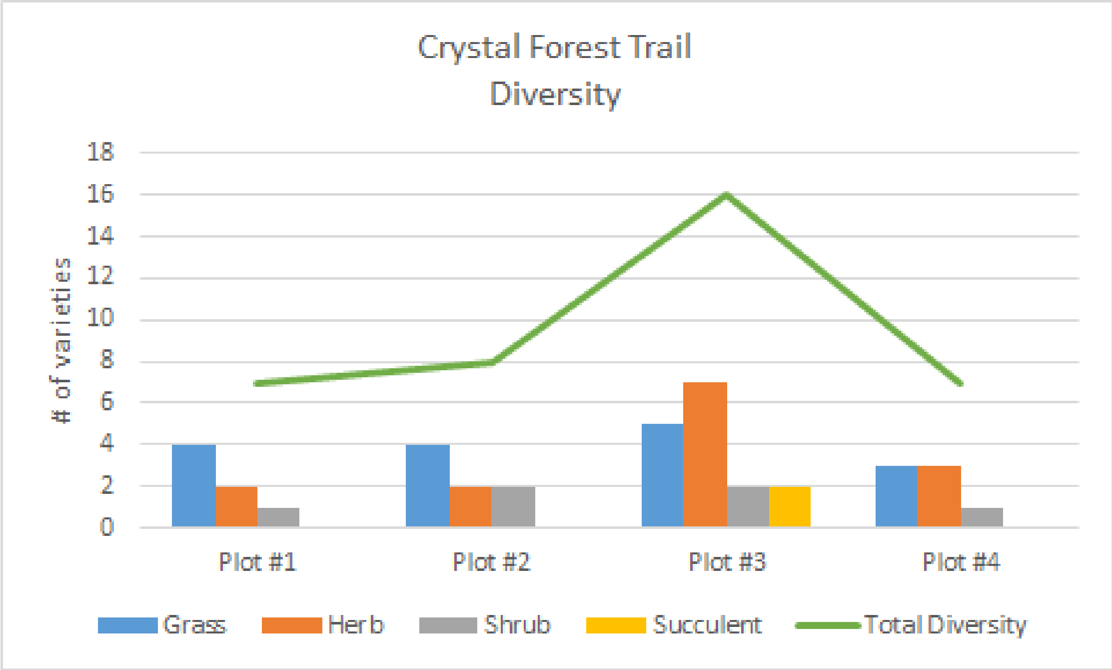

Figure 19: Crystal Forest Trail vegetation diversity

5.3.5 Crystal Forest Trail

This trail presents a unique diversity trend. Total diversity actually peaks at about 2-3 meters away from the trail, in plot #3. Grass and herbaceous varieties show high diversity in plot #3, but taper off in all other plots. Plots #1 and #2 are dominated by high grass diversity. Shrub varieties show a very consistent trend in diversity, while succulents are only recorded in plot #3.

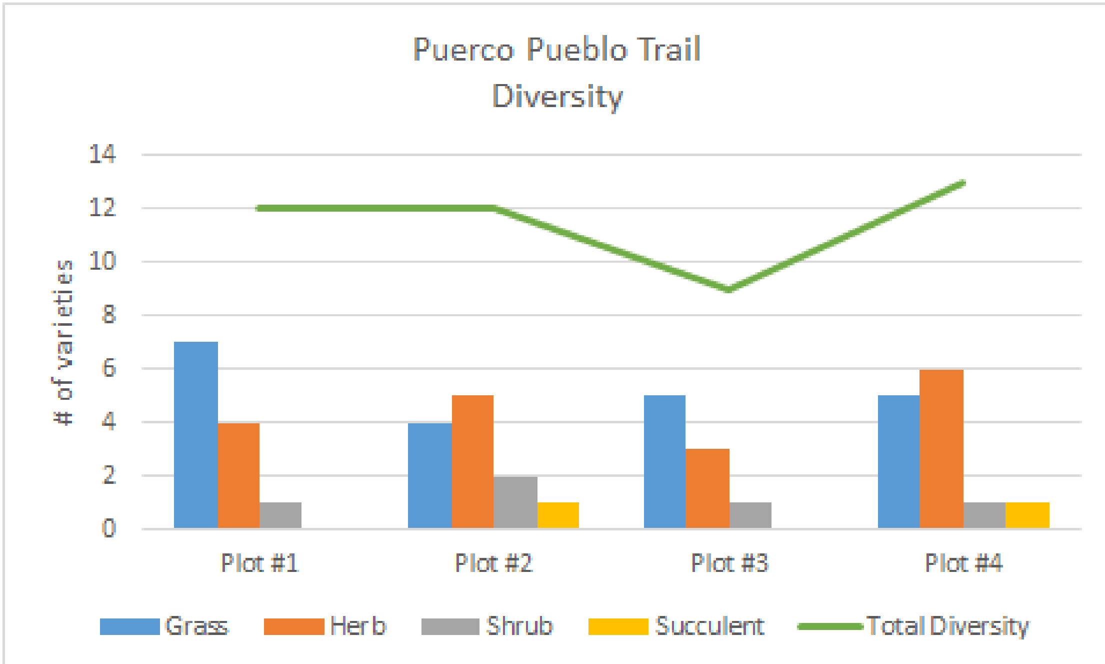

Figure 20: Puerco Pueblo Trail vegetation diversity

5.3.6 Puerco Pueblo Trail

This trail also shows a unique trend in total diversity. Total diversity is at its lowest in plot #3, approximately 2-3 meters from the trail. Grass and herbaceous varieties reflect the majority of the diversity seen in this location. Shrub diversity peaks in plot #2, and succulents are only seen at low diversity in plots #2 and #4.

5.4 Ground Cover

The ground cover data was recorded by visually examining each plot from above. Percentages were estimated to reflect the occupied space for each plot. Ground cover was recorded in eight different categories: biotic soil, sand, debris, herbaceous, shrub, grass, succulent, and trampled vegetation. These eight categories were then summarized into two classes: abiotic and biotic material. Abiotic material constitutes sand and debris in this study while biotic material includes the remaining biotic soil, herbaceous, shrub, grass, succulent, and trampled vegetation. The following figures reflect the environment in which this vegetation was observed.

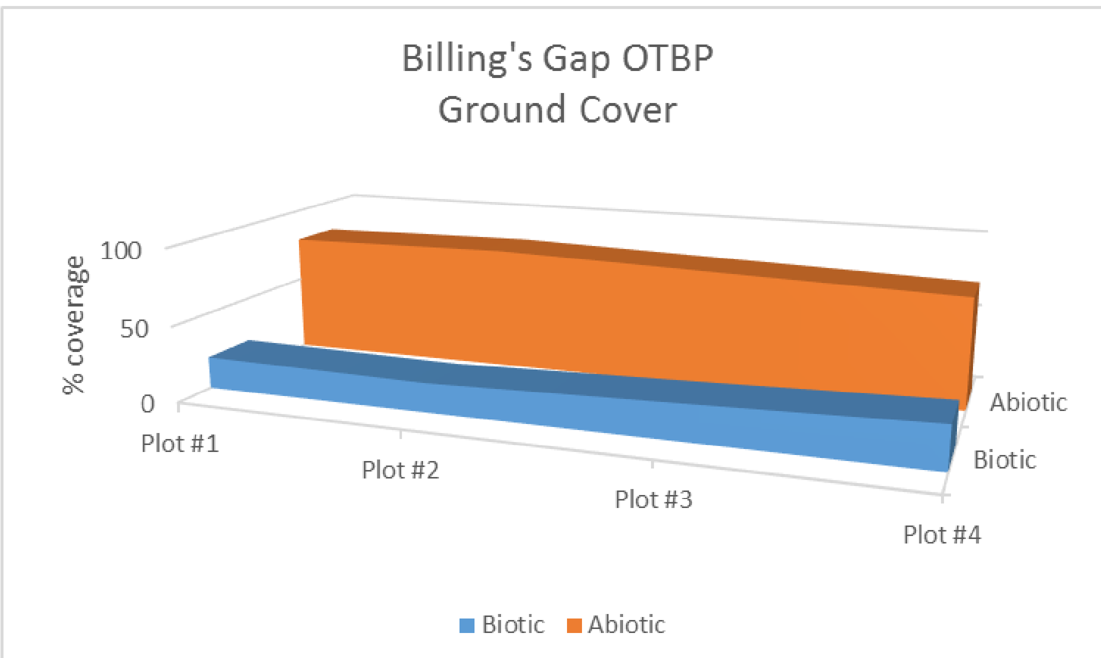

Figure 21: Billing's Gap OTBP biotic and abiotic ground cover

5.4.1 Billing's Gap OTBP

This trail shows a slight increase from 20% biotic coverage next to the trail, in plot #1 and #2, to an increased 28% biotic material further from the trail, in plot #4.

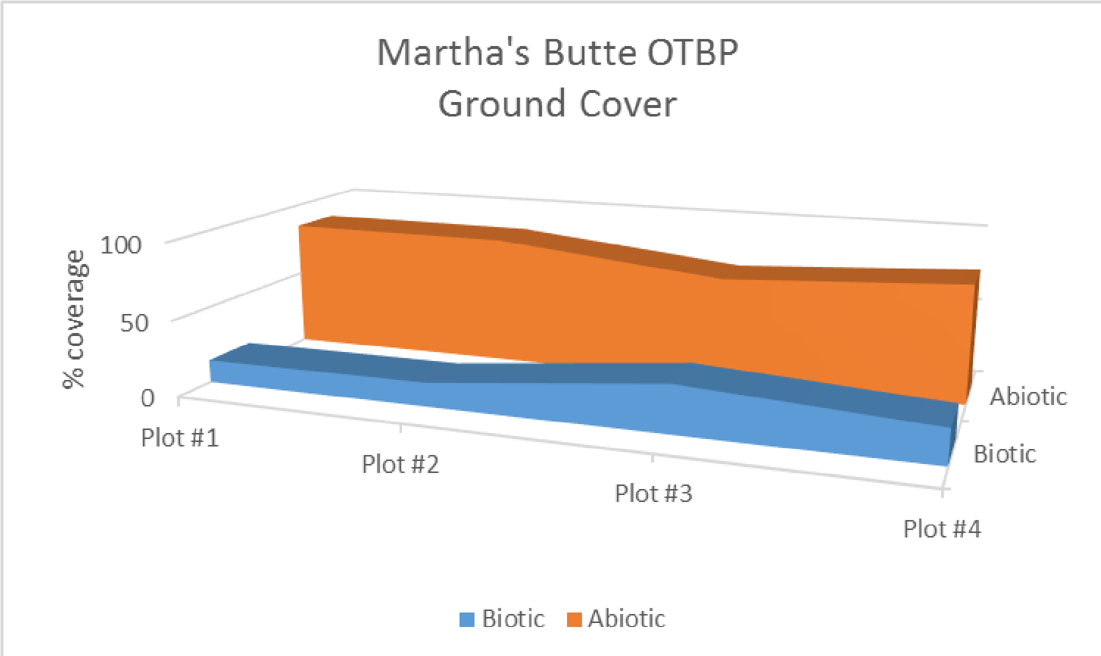

Figure 22: Martha's Butte OTBP biotic and abiotic ground cover

5.4.2 Martha's Butte OTBP

This trail saw an increase in biotic material as you move further from the disturbed areas. Plot #1 and #2 show 15% biotic material 85% abiotic material. Biotic material doubles in coverage in plot #3 and #4.

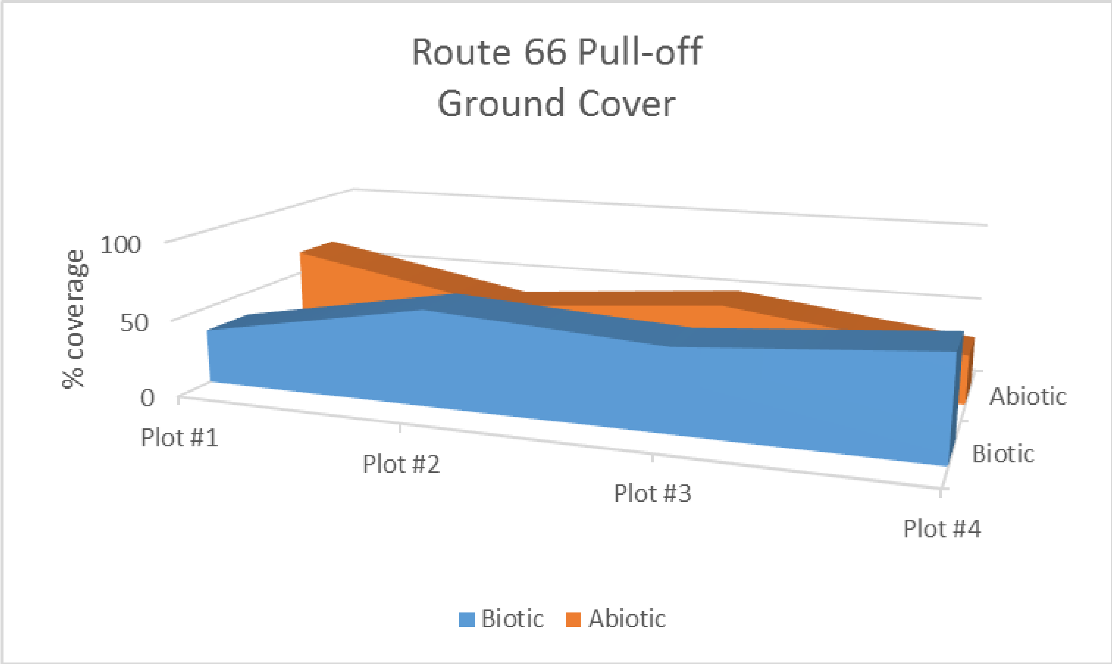

Figure 23: Route 66 Pull-off biotic and abiotic ground cover

5.4.3 Route 66 Pull-off

This site shows an overall upward trend of biotic material as you move further from disturbed areas. Biotic ground cover fluctuates from 35% cover in plot #1 to 65% cover in plot #4.

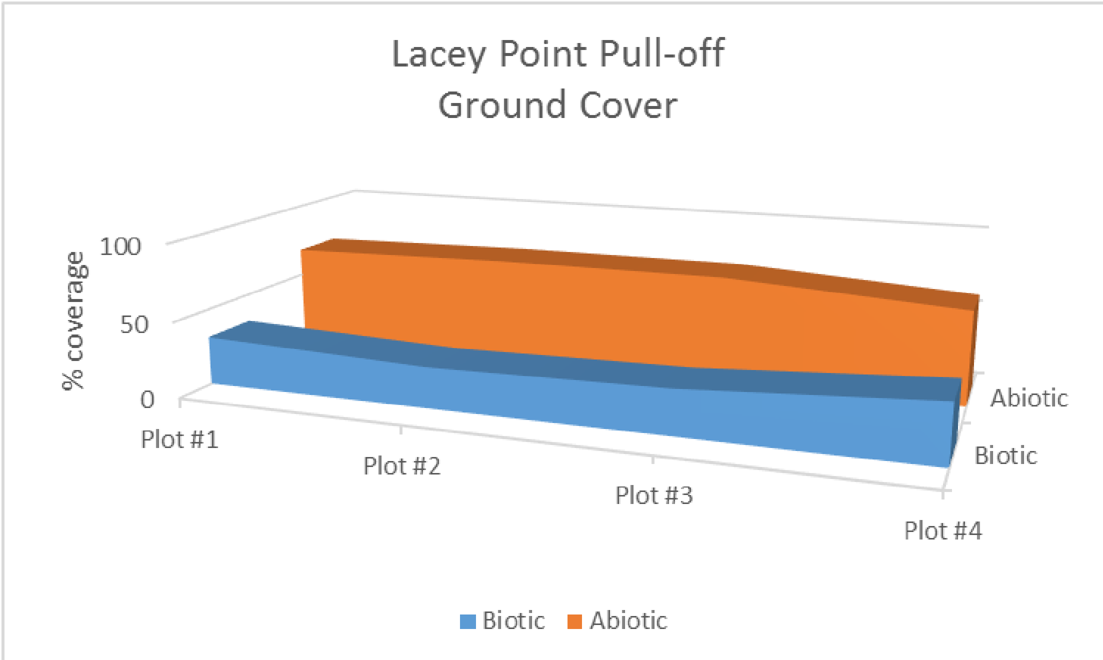

Figure 24: Lacey Point Pull-off biotic and abiotic ground cover

5.4.4 Lacey Point Pull-off

This pull-off also shows a slight upward trend in biotic material starting at 26% cover in plot #2, and increasing to 38% cover as you move further from the disturbed areas in plot #4.

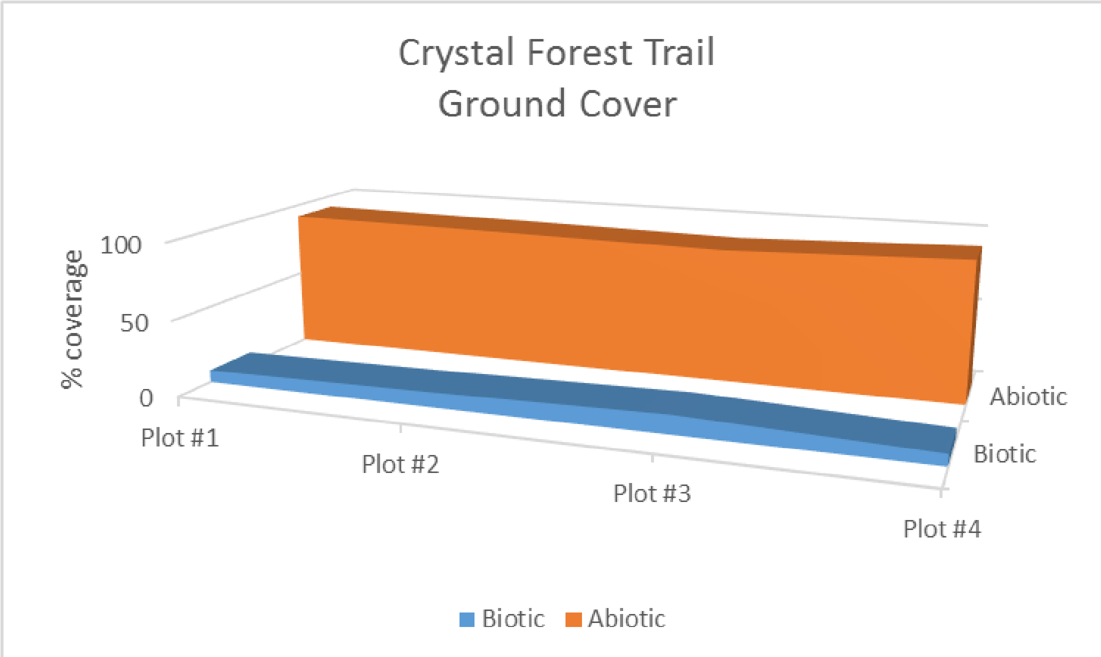

Figure 25: Crystal Forest Trail biotic and abiotic ground cover

5.4.5 Crystal Forest Trail

This trail shows biotic material peaking in plot #3 with 12% ground cover, but has little change in biotic ground cover, and little biotic cover to begin with.

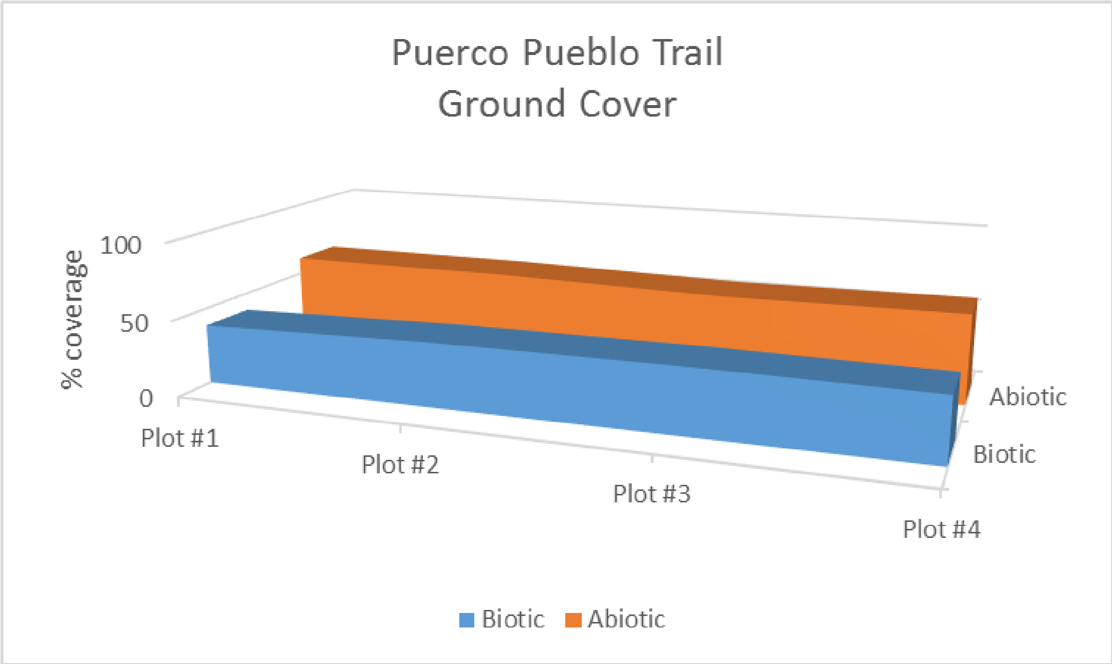

Figure 26: Puerco Pueblo Trail biotic and abiotic ground cover

5.4.6 Puerco Pueblo Trail

This trail shows little to no change in biotic ground cover as you increase distance from the paved trail. Biotic ground cover varies between 39%, in plot #1, to 41% in plot #4.

5.5 Discussion

Although, some clear correlations can be made between impact measurements and trail types, it is important recognize the limiting factors that may have had an effect on the data collected. The recreation and survey assesssments suggests that trail construction may play an important role in the distribution and composition of surrounding plant communities. Additionally, many of the survey sites were lengthy trails that crossed many habitats, ecosystems, and communities. Summarizing trails and plots separately may display different results. Furthermore, monsoon season established another limitation. The additional moisture to the area made the survey of diversity and abundance simpler, while likely increasing ground cover. Lastly, comparisons and further analysis can be made with additional data collection beyond this baseline data.

5.5.1 OTBP Trails: At these sites, grasses are the most abundant, however, every vegetation type was present. Herbaceous varieties, though, decreased in abundance further from the trail. At Billing's Gap, herbaceous individuals decreased in abundance with distance, but diversity remained consistent throughout the plots. Succulents, however, increase with distance from the disturbed areas, which is likely a direct result of trampling (Cavendish 2001). Furthermore, at Martha's Butte, grass individuals increase along-side grass varieties, as do herbaceous selections. For both "Off the Beaten Path" (OTBP) trails, ground cover increases as you move further from the trail. Further, at Billing's Gap, it appears that the increased ground cover is due to shrub appearance. The shrub individuals further from the trail tend to be larger and more mature than individuals closer to the disturbance. However, increases in ground cover at Martha's Butte was more likely due to the increase in grass individuals in addition to shrubs. Shrubs were only present further from the trails. Additionally, Martha's Butte seems to show a direct correlation between abundance, diversity, and ground cover. As abundance increases, so too does diversity and ground cover.

5.5.2 Pull-offs: The pull-off locations most noticeably displayed an increase in ground cover in plot #4, which is about 2-3 meters from the trail. Additionally, grasses were far more abundant than any other vegetation type, with only a single succulent recorded in either location. At the Route 66 pull-off, it is apparent that abundance, diversity, and ground cover increase with distance from the trail. However, abundance displays an odd trend line, which could be due to larger vegetation originating in plots #2 and #4, leaving minimal space for vegetation to establish in plot #3. Biotic ground cover reflects a similarly odd pattern at Route 66 sites, however, plot #3 shows the highest diversity. Larger vegetation in plot #2 and #4 will result in lower diversity because of the reduced available space. Therefore, plot #3 had many smaller individuals, which left more space for diversity. On the contrary, at the Lacey Point pull-off, abundance peaks in plot #3. This is a result of an increase in herbaceous vegetation and shrub individuals. In addition, diversity decreases with distance from the trail, which is due to the decrease in herbaceous varieties. Lacey Point also displays similar numbers of plant individuals further from the trail as it does closer to the trail, but it includes few varieties further from the trail. In addition, at this location, as diversity decreases, ground cover increases. Again, this is due to the increased presence of mature shrub individuals. Additionally, both pull-off locations were the only sites with multiple high traffic social trails, explaining the lack of succulents and the increase in ground cover further from the disturbed ground.

5.5.3 Paved Trails: At these locations, total abundance is at its highest closest to the trail. Both locations are dominated by grass and herbaceous individuals. However, at Puerco Pueblo, grass individuals decrease in abundance with distance from the trail, and herbaceous individuals increase with distance from the trail. Likewise, Crystal Forest sites result in a decreased grass abundance with distance from the trail. Additionally, both locations resulted in very consistent ground cover across the plots, and have very little biotic ground cover to begin with. Puerco Pueblo displays a slight increase in biotic ground cover in plot #4. However, Crystal Forest showed very little ground cover across the plots. This is legitimized by the lack of shrub individuals at this site. In addition, succulents are only present further from the disturbed areas, which has been described before as a symptom of disturbance.

5.5.4 Cheatgrass: This research introduced an interesting and surprising issue, cheatgrass. Cheatgrass, or *Bromus tectorum,* is an annual grass that is not native to the United States' Southwest region. According to Knapp (1996), this pest species is thought to have been introduced by means of agriculture. It is likely that the seeds would have been stuck in livestock hair or hidden in agricultural grains before being introduced to the west. Cheatgrass has invaded much of the west and has dominated much of the arid Great Basin because of its specialized root system. These advanced roots essentially absorb water from deep in the ground that other native annuals and perennials cannot access with their more shallow root systems. Additionally, cheatgrass is specially adapted to thrive in locations that have had high amounts of disturbance. It is common in areas that have had high grazing impacts or fires. This invasive species has a very high germination success rate at 99.5%, while also being able to quickly generate a complex root system. It will often beat out many native species because of its great resilience. Furthermore, cheatgrass seed can be quickly dispersed on the fur of animals where it will get caught with special hooks. These characteristics make cheatgrass a highly invasive species and of great interest to land managers (Knapp 1996).

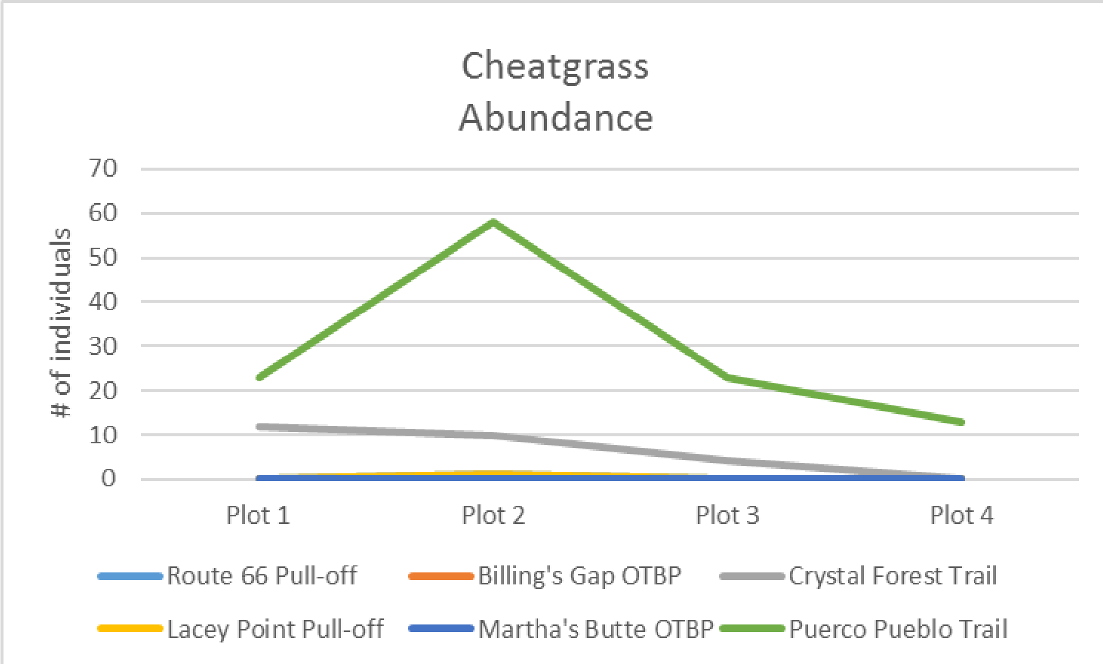

Figure 27: Cheatgrass abundance

The graph displays the number of cheatgrass individuals found in each plot on each trail. It is clear that cheatgrass is virtually only found on paved trails, and that it is predominantly located closest to the trail. This is likely caused by the high disturbance levels found at these sites. The paved trails have had machinery on site in order to construct and maintain the paved path. Additionally, the areas directly adjacent to the paved trails are very compacted and it is evident that visitors step off the path often. Furthermore, the hooked seeds could potentially get stuck on socks and shoes of visitors the same way they would to the legs of cattle, creating a means of dispersal and expansion. Ultimately, human activity beyond the formal trails will only increase the occurrence of invasive species like cheatgrass. With this critical information, future ecology crews will be able to locate and eradicate invasive species through improved conservation practices.

CHAPTER 6: CONCLUSION

After close analysis, it was concluded that increased recreational use will degrade and often alter the trail itself as well as neighboring vegetation communities. Trailside environments are very fragile and therefore susceptible to recreational disturbances. These disturbances cause substantial damage to both the physical vegetation communities as well as the environment in which they are growing. Three major patterns emerged from this conclusion. Firstly, vegetation located nearest to the trails is generally smaller in size. Trampling, soil compaction, and frequent disruption causes trailside plants to be smaller in composition. In addition, biotic ground cover decreases as you get closer to the trail, due largely to the dominance of small vegetation types such as grass and herbaceous varieties. As you move further from the trail, however, there is space for larger vegetation such as shrubs, therefore increasing biotic ground cover. Secondly, vegetation diversity decreases as you move away from the trail. Higher numbers of grass varieties and individuals are found directly adjacent to the trails accounting for the increase in diversity. However, shrubs found further from the trail will have low population count, but will generally cover more ground, creating a higher percentage of biotic ground cover and a decrease in diversity. Finally, environmental factors such as soil compaction can have a hand in more severe vegetation disturbances. Bhuju & Ohsawa (1998) suggested that trampling and compaction is directly related to root growth and shape. Plant varieties such as shrubs have robust roots that require much more space than those of shallow-rooted grass varieties. Pickering & Hill (2007) also conclude that shrubs and fragile plant varieties are more susceptible to trampling, while lower growing grasses are generally more resilient to disturbance.

Increasing damage and visitation to many public lands have made way for research and documentation on how to monitor and manage these fragile trailside environments. These recreation and vegetation assessments allowed the chance to assess the effects of recreation on native and invasive vegetation found in Petrified Forest National Park through the Visitor Experience and Resource Protection (VERP) program. The results of this research will become very important to land managers of Petrified Forest National Park and other public lands to preserve natural resources and the visitor experience. This study will also prove helpful to future students studying recreation or ecology.

6.1 Recommendations

This section contains a list of recommendations for improving recreation and vegetation patterns within Petrified Forest National Park. The recommendations support data gathered about disturbances recorded at the six survey locations. Additionally, these suggestions have been adapted from methods used by scientists and land managers reviewed in the *Literature Review* section of this paper. Optimistically, these recommendations will be considered with the supporting evidence covered in this project, and soon be implemented in order to improve future visitor experiences and natural/cultural resource protection.

- "Off the Beaten Path" (OTBP) trails should be monitored for social trail movement as well as natural and cultural resource prosperity regularly, but currently have few urgent impacts.
- Place signage and educational material about natural resources and invasive species at the entrances of paved trail locations.
- Create more opportunities for the public to get educated on recreation impacts through Leave No Trace principles.
    - Add information to existing educational signage at trails and OTBP brochures.
    - Train interpretive rangers to present LNT principles.

- Consider creating an official trail at the high impact, lengthy social trail found at the west end of Lacey Point pull-off to accommodate visitor interest and safety.
- Eradicate cheatgrass at Puerco Pueblo trail and Crystal forest trail in order to reduce the spread of this invasive species.
- Continue repeat monitoring yearly or biyearly at the same vegetation survey transect sites to pinpoint areas of significant impact in the future.

6.2 Future Studies

This section suggests several ideas that should be considered in future studies and during repeat monitoring of Petrified Forest National Park. Firstly, future data could be compared to the baseline data collected this year (2017), and new data could be collected at other trail locations to improve our understanding of accompanying factors such as: weather, climate, visitation, and animal disturbances. New data could also provide information on types of vegetation and unique vegetation communities present at different trail conditions. In addition, evaluating each individual transect site could yield different results. Because the trails are lengthy, and consist of many different vegetation communities and levels of impact, the results of this project and future studies could yield varied results. Another future consideration would be to conduct the vegetation surveys during monsoon season in order to more easily identify the vegetation available. Monsoon season brings the majority of yearly moisture to the area, and therefore, aids in the growth of important identification characteristics for many of the vegetation types reported in this project. In addition, future studies could include data driven by vegetation genetic or visitation numbers. Lastly, repeat monitoring is extremely important for sustainable management of the important natural and cultural resources as well as the visitor experiences made in Petrified Forest National Park.

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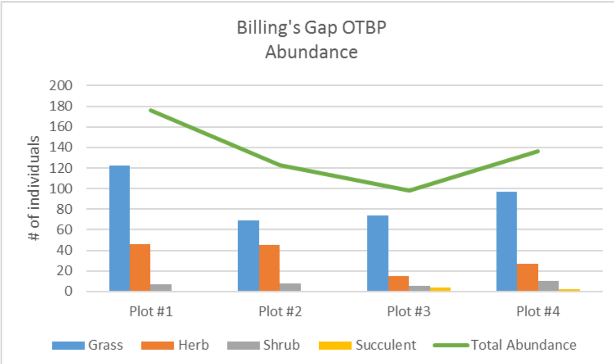
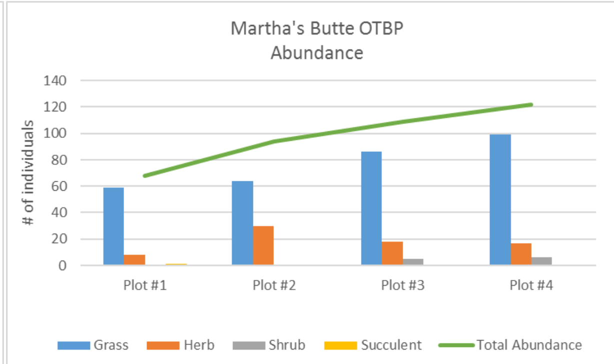
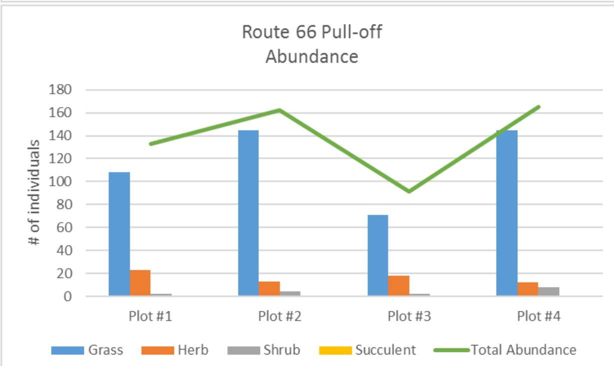
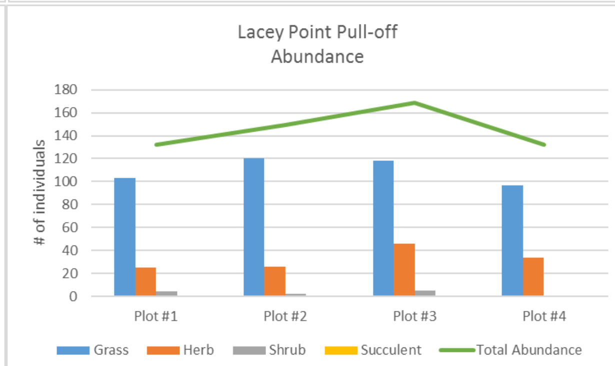
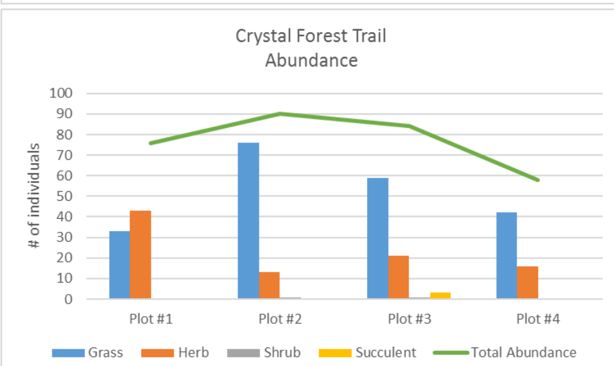
APPENDIX I: VEGETATION GRAPHS

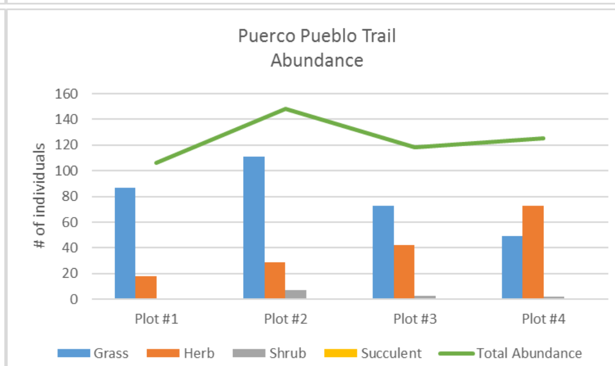


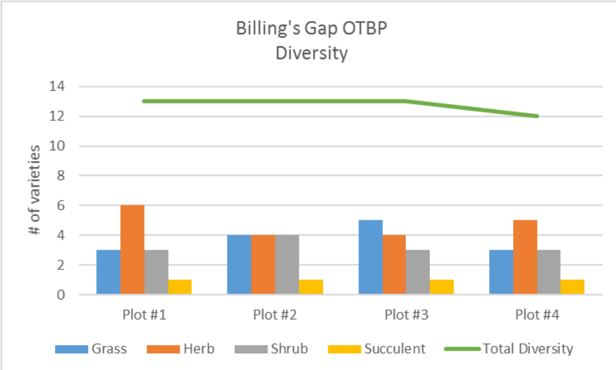


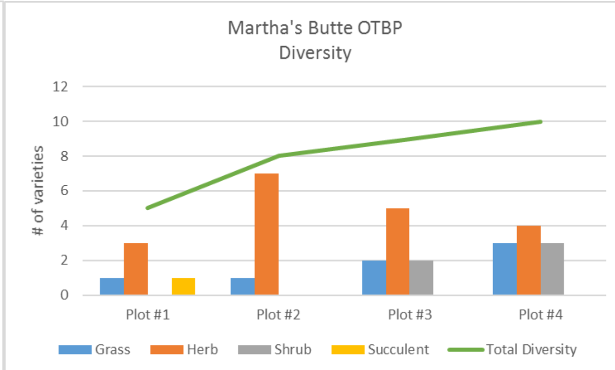


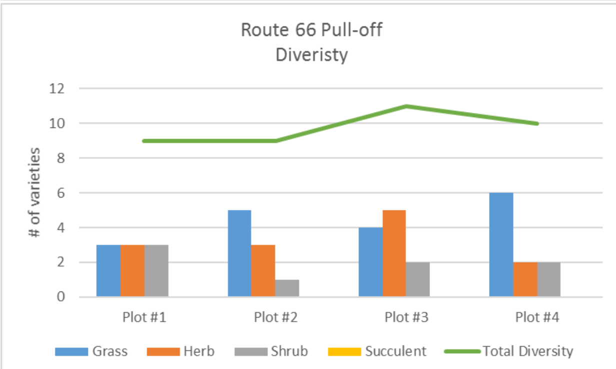


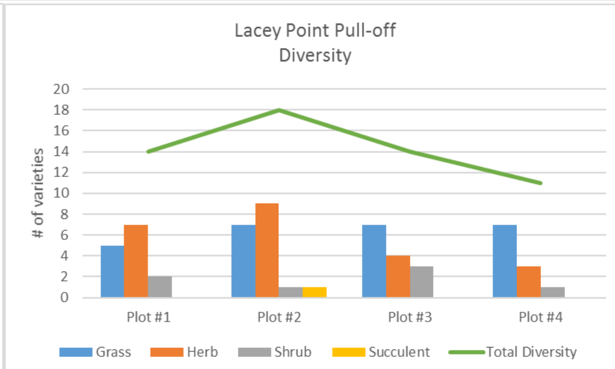


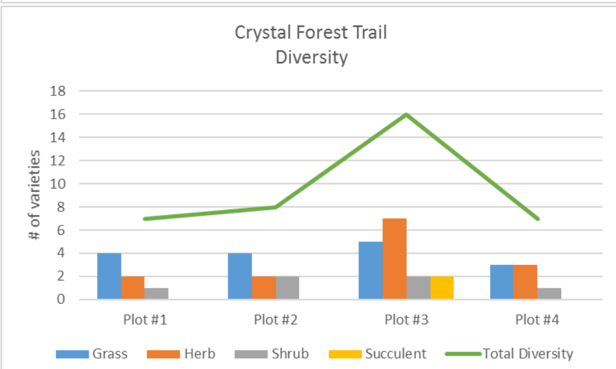


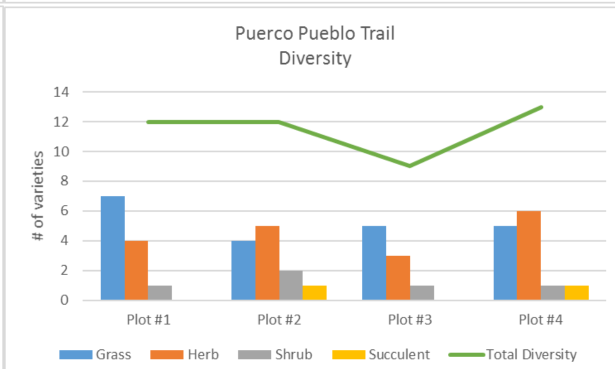

Billing's Gap OTBP
Diversity
# of varieties
14
12
10
8
6
4
2
0
Plot #1
Plot #2
Plot #3
Plot #4
Grass
Herb
Shrub
Succulent
Total Diversity

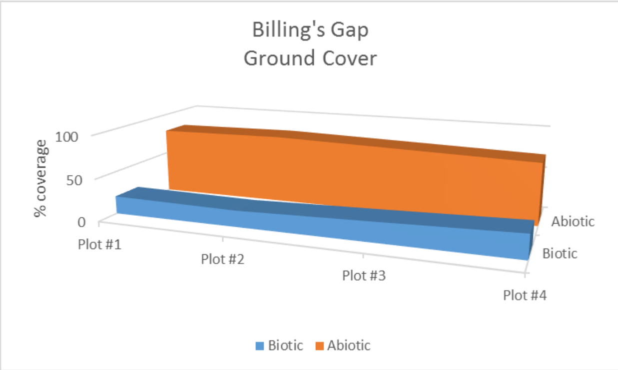

Martha's Butte OTBP
Diversity
# of varieties
12
10
8
6
4
2
0
Plot #1
Plot #2
Plot #3
Plot #4
Grass
Herb
Shrub
Succulent
Total Diversity

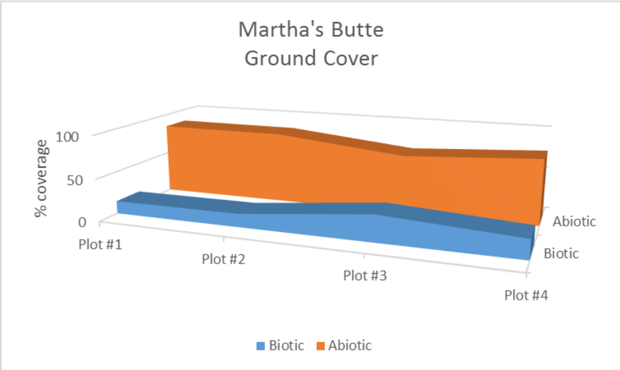

Route 66 Pull-off
Diveristy
# of varieties
12
10
8
6
4
2
0
Plot #1
Plot #2
Plot #3
Plot #4
Grass
Herb
Shrub
Succulent
Total Diversity

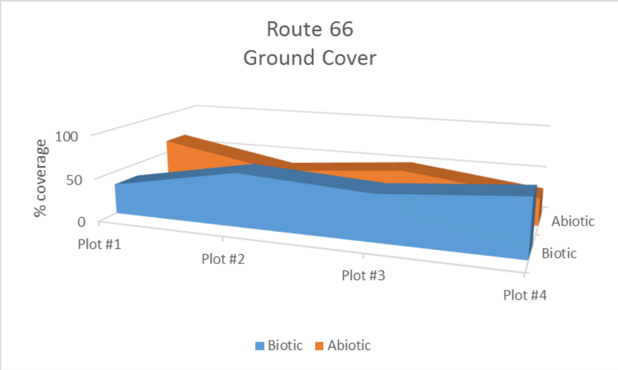

Lacey Point Pull-off
Diversity
# of varieties
20
18
16
14
12
10
8
6
4
2
0
Plot #1
Plot #2
Plot #3
Plot #4
Grass
Herb
Shrub
Succulent
Total Diversity

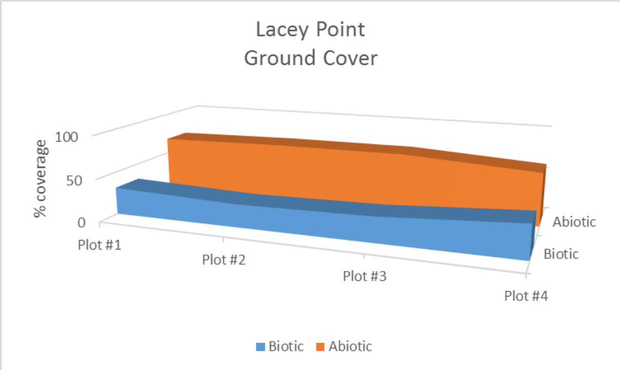

Crystal Forest Trail
Diversity
# of varieties
18
16
14
12
10
8
6
4
2
0
Plot #1
Plot #2
Plot #3
Plot #4
Grass
Herb
Shrub
Succulent
Total Diversity

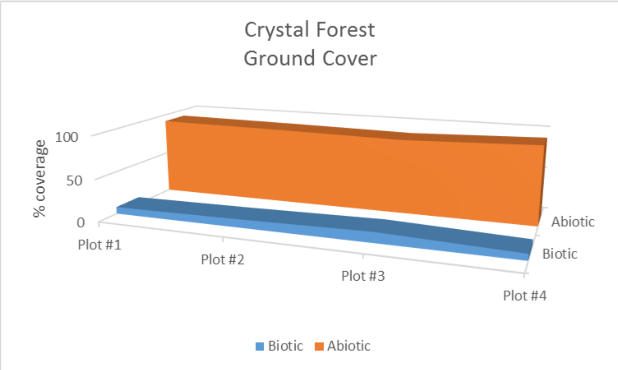

Puerco Pueblo Trail
Diversity
# of varieties
14
12
10
8
6
4
2
0
Plot #1
Plot #2
Plot #3
Plot #4
Grass
Herb
Shrub
Succulent
Total Diversity

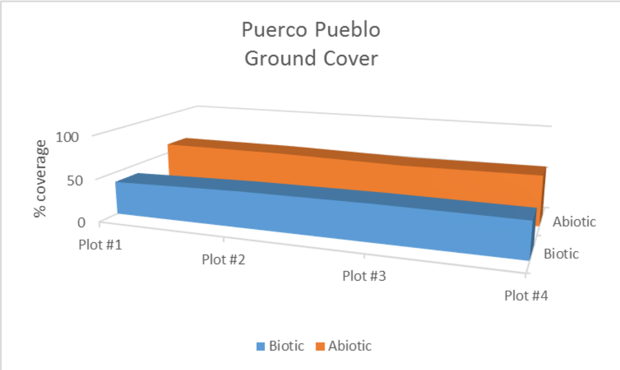

Billing's Gap
Ground Cover
% coverage
100
50
0
Plot #1
Plot #2
Plot #3
Plot #4
Abiotic
Biotic
Biotic Abiotic


Martha's Butte
Ground Cover
% coverage
100
50
0
Plot #1
Plot #2
Plot #3
Plot #4
Abiotic
Biotic
Biotic Abiotic


Route 66
Ground Cover
% coverage
100
50
0
Plot #1
Plot #2
Plot #3
Plot #4
Abiotic
Biotic
Biotic Abiotic


Lacey Point
Ground Cover
% coverage
100
50
0
Plot #1
Plot #2
Plot #3
Plot #4
Abiotic
Biotic
Biotic Abiotic


Crystal Forest
Ground Cover
% coverage
100
50
0
Plot #1
Plot #2
Plot #3
Plot #4
Abiotic
Biotic
Biotic Abiotic


Puerco Pueblo
Ground Cover
% coverage
100
50
0
Plot #1
Plot #2
Plot #3
Plot #4
Abiotic
Biotic
Biotic Abiotic

APPENDIX II: FIELD TABLES

Transect #: 1	Location: Billings Gap		Date:	7/25/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	6	4	8	4
Sp. Name	plantain	plantain	narrow leaf yucca	nevada jointfir
total	34	22	1	2
Sp. Name	galleta	indian rice grass	nevada jointfir	indian rice grass
total	11	1	3	3
Sp. Name	grass (unknown)	yellow flower	grass (unknown)	grass (unknown)
total	23	18	8	11
Sp. Name	pepper grass	grass (unknown)	galleta	plantain
total	1	21	1	15
Sp. Name	snakeweed		brome 1	
total	1		1	
	velvet herb		plantain	
	1		8	
			yellow flower	
			2	
			saltbush	
			1	
Biotic Soil	0	0	0	0
Succulent	0	0	15	0
Sand	70	70	45	55
Debris	0	0	0	0
Herb	5	10	5	5
Shrub	0	0	25	20
Grass	20	20	10	20
Trampled	5	0	0	0
Photo #:	1		N 34.93933	
Transect Heading:	N		W 109.75282	
Bag 1: velvet herb				

Transect #: 2	Location: Billings Gap		Date:	7/25/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	1	1	3
Sp. Name	grass (unknown)	grass (unknown)	grass (unknown)	nevada jointfir
total	11	15	25	1
Sp. Name				narrowleaf yucca
total				2
Sp. Name				grass (unknown)
total				27
Sp. Name				
total				
Sp. Name				
total				
Total Indv.	11	15	25	30
Biotic Soil	0	0	0	0
Succulent	0	0	0	5
Sand	70	75	80	70
Debris	0	10	0	0
Herb	0	0	0	0
Shrub	10	0	0	10
Grass	15	15	20	15
Trampled	5	0	0	0
Photo #:	2		N 34.93889	
Transect Heading:	SW		W 109.75293	
all unkonwn grass is most likely the same species				

Transect #: 3	Location: Billings Gap		Date:	7/25/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	3	2	4
Sp. Name	grass (unknown)	yellow flower	yellow flower	big sage
total	14	9	6	1
Sp. Name		grass (unknown)	grass (unknown)	nevada jointfir
total		8	10	1
Sp. Name		new herb		narrowleaf yucca
total		1		1
Sp. Name				grass (unknown)
total				8
Sp. Name				
total				
Succulent				10
Sand	80	80	75	55
Debris	5	5	10	15
Herb		10	5	
Shrub				20
Grass	15	5	10	5
Trampled				
Photo #:	3		N 34.9387	
Transect Heading:	SW		W 109.7527	
transect 3 on slope on both sides				
Bag 1: new herb				

Transect #: 4	Location: Billings Gap		Date:	7/25/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	3	1	2	3
Sp. Name	new herb	grass (unknown)	pic 5	velvet herb
total	18	10	1	3
Sp. Name	snakeweed		snakeweed	red flower
total	1		1	5
Sp. Name	grass (unknown)			grass (unknown)
total	1			6
Sp. Name				
total				
Sp. Name				
total				
Sand	65	70	70	70
Debris	20	15	20	20
Herb	10		10	5
Shrub			0	
Grass	5	15		5
Trampled				
Photo #:	4		N 34.9385	
Transect Heading:	SSW		W 109.7524	
Bag 1: red flower				
Bag 2: pic 5				

Transect #: 5	Location: Billings Gap		Date:	7/25/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	5	3	1	2
Sp. Name	branchy shrub	snakeweed	grass (unknown)	snakeweed
total	1	2	5	3
Sp. Name	rabbit brush	grass (unknown)		grass (unknown)
total	5	4		6
Sp. Name	snakeweed	rabbit brush		
total	1	2		
Sp. Name	grass (unknown)			
total	1			
Sp. Name	big sage			
total	1			
Sand	55	75	80	75
Debris	25			
Herb	5	15		10
Shrub	5			
Grass	10	10	20	15
Trampled				
Photo #:	6		N 34.9385	
Transect Heading:	SE		W 109.7519	
Bag 1: branchy shrub				

Transect #: 6	Location: Billings Gap		Date:	7/25/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	4	4	3	2
Sp. Name	indian rice grass	big sage	indian rice grass	indian rice grass
total	1	2	5	1
Sp. Name	snakeweed	grass (unknown)	snakeweed	grass (unknown)
total	2	5	2	11
Sp. Name	narrowleaf yucca	snakeweed	grass (unknown)	
total	1	2	2	
Sp. Name	grass (unknown)	foxtail barley		
total	11	1		
Sp. Name				
total				
Succulent	10			
Sand	60	70	70	85
Debris				
Herb	20	15	15	
Shrub		10		
Grass	10	5	15	15
Trampled				
Photo #:	7		N 34.9376	
Transect Heading:	SE		W 109.7506	
Bag 1: ID ed grass	foxtail barley			

Transect #: 7	Location: Billings Gap		Date:	7/25/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	3	2	3	6
Sp. Name	mimosa leaf	nevada jointfir	ID ed grass	big sage
total	2	1	3	1
Sp. Name	snakeweed	big sage	grass (unknown)	nevada jointfir
total	1	1	2	1
Sp. Name	grass (unknown)		big sage	mimosa leaf
total	2		1	5
Sp. Name				indian rice grass
total				2
Sp. Name				blue grama
total				5
				grass (unknown)
				6
Sand	60	50	55	20
Debris	15	15	10	
Herb	15			10
Shrub	5	25	20	50
Grass	5	5	15	20
Trampled		5		
Photo #:	8		N 34.9376	
Transect Heading:	N		W 109.7493	

Transect #: 8	Location: Billings Gap		Date:	7/25/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	2	2	1	3
Sp. Name	gelleta	galleta	galleta	snakeweed
total	19	1	6	1
Sp. Name	grass (unknown)	branchy shrub		grass (unknown)
total	5	1		2
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Sand	70	75	80	75
Debris	10	15	10	10
Herb				10
Shrub	10	5		
Grass	10	5	10	5
Trampled				
Photo #:	9		N 34.9367	
Transect Heading:	SSW		W 109.7479	

Transect #: 9	Location: Billings Gap		Date:	7/25/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	2	1	2
Sp. Name	grass (unknown)	branchy shrub	grass (unknown)	saltbush
total	7	1	3	4
Sp. Name		grass (unknown)		grass (unknown)
total		1		4
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Sand	80	75	85	60
Debris	10	15	10	15
Herb				
Shrub		5		15
Grass	10	5	5	10
Trampled				
Photo #:	10		N 34.9366	
Transect Heading:	S		W 109.7472	
Plot 1 has drainage through it				

Transect #: 10	Location: Billings Gap		Date:	7/25/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	2	3	2
Sp. Name	new herb	grass (unknown)	narrowleaf yucca	snakeweed
total	3	1	3	1
Sp. Name		narrowleaf yucca	grass (unknown)	grass (unknown)
total		1	4	5
Sp. Name			snakeweed	
total			1	
Sp. Name				
total				
Sp. Name				
total				
Succulent		10	15	
Sand	45	80	60	75
Debris	50	10	10	10
Herb	5		10	10
Shrub				
Grass			5	5
Trampled				
Photo #:	11		N 34.9365	
Transect Heading:	S		W 109.7465	

Transect #: 11	Location: Billings Gap		Date:	7/25/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	2	2	2	1
Sp. Name	galleta	snakeweed	snakeweed	grass (unknown)
total	2	1	2	6
Sp. Name	grass (unknown)	grass (unknown)	grass (unknown)	
total	10	9	1	
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Sand	75	70	65	75
Debris	5	15	10	15
Herb		5	10	
Shrub			10	
Grass	15	10	5	10
Trampled	5			
Photo #:	12		N 34.9364	
Transect Heading:	S		W 109.7460	

Transect #: 1	Location: Martha's Butte		Date:	7/10/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	2	3	4
Sp. Name	sandpaper bush	Houstonia	Houstonia	snakeweed
total	1	4	1	7
Sp. Name		grass (unknown)	blue grama	blue grama
total		18	6	3
Sp. Name			grass (unknown)	grass (unknown)
total			12	22
Sp. Name				fringed sagebrush
total				2
Sp. Name				
total				
	Plot #1	Plot #2	Plot #3	Plot #4
Biotic Soil	0	0	15	10
Sand	95	85	30	10
Debris	0	0	0	5
Herb	5	5	5	25
Shrub	0	0	0	0
Grass	0	10	50	50
Trampled	0	0	0	0
Photo #:	2		N 34.8497	
Transect Heading:	NE		W 109.8174	
Notes: trail goes in to drainage				

Transect #: 2	Location: Martha's Butte		Date:	7/10/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	1	2	0
Sp. Name	grass (unknown)	grass (unknown)	snakeweed	
total	23	6	5	
Sp. Name			grass (unknown)	
total			4	
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
	Plot #1	Plot #2	Plot #3	Plot #4
Sand	85	85	70	100
Debris	0	0	0	0
Herb	0	0	20	0
Shrub	0	0	0	0
Grass	15	5	10	0
Trampled	0	10	0	0
Photo #:	3		N 34.8503	
Transect Heading:	E		W 109.8174	
Notes: drainage runs next to transect				

Transect #: 3	Location: Marth's Butte		Date:	7/10/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	1	2	3
Sp. Name	snakeweed	snakeweed	grass (unknown)	snakeweed
total	1	1	7	2
Sp. Name			snakeweed	grass (unknown)
total			3	14
Sp. Name				plantain
total				1
Sp. Name				
total				
Sp. Name				
total				
	Plot #1	Plot #2	Plot #3	Plot #4
Sand	80	90	60	30
Debris	0	5	15	50
Herb	20	5	10	5
Shrub	0	0	0	0
Grass	0	0	15	15
Trampled	0	0	0	0
Photo #:	4		N 34.8503	
Transect Heading:	S		W 109.8170	
Notes: transect near drainage				

Transect #: 4	Location: Martha's Butte		Date:	7/10/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	3	4	7	6
Sp. Name	stinking milkvetc	stinking milkvetch	pepper grass	indian rice grass
total	1	7	2	3
Sp. Name	grass (unknown)	snakeweed	nevada jointfir	big sagebrush
total	2	1	1	1
Sp. Name	snakeweed	pepper grass	stinking milkvetch	nevada jointfir
total	2	1	2	3
Sp. Name		little red leaf	snakeweed	snakeweed
total		2	2	2
Sp. Name			sandpaper bush	grass (unknown)
total			1	3
			big sagebrush	little red leaf
			1	1
			grass (unknown)	
			2	
	Plot #1	Plot #2	Plot #3	Plot #4
Biotic Soil	0	0	10	0
Sand	75	70	25	70
Debris	5		0	0
Herb	20	25	15	5
Shrub	0	0	45	15
Grass	0	0	5	10
Trampled	0	5	0	0
Photo #:	5		N34.8503	
Transect Heading:	NNE		W 109.8167	
Photo #6: mimosa leaf				
Photo #7: little red leaf				

Transect #: 5	Location: Martha's Butte		Date:	7/10/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	3	2	1	1
Sp. Name	snakeweed	grass (unknown)	big sagebrush	grass (unknown)
total	2	5	1	2
Sp. Name	grass (unknown)	stinking milkvetch		
total	7	1		
Sp. Name	narrowleaf yucca			
total	1			
Sp. Name				
total				
Sp. Name				
total				
	Plot #1	Plot #2	Plot #3	Plot #4
Succulent	5	0	0	0
Sand	85	60	15	20
Debris	0	30	80	75
Herb	5	5	0	0
Shrub	0	0	5	0
Grass	0	0	0	5
Trampled	5	5	0	0
Photo #:	8		N 34.8501	
Transect Heading:	E		W 109.8164	

Transect #: 6	Location: Martha's Butte		Date:	7/1017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	3	2	1
Sp. Name	grass (unknown)	grass (unknown)	Houstonia	grass (unknown)
total	8	3	2	17
Sp. Name		Wright's bluets	grass (unknown)	
total		3	12	
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
	Plot #1	Plot #2	Plot #3	Plot #4
Sand	90	80	80	70
Debris	0	0	0	15
Herb	0	5	5	0
Shrub	0	10	0	0
Grass	10	5	15	15
Trampled	0	0	0	0
Photo #:	9		N 34.8498	
Transect Heading:	E		W 109.8163	

Transect #: 7	Location: Martha's Butte		Date:	7/10/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	3	1	1
Sp. Name	grass (unknown)	snakeweed	grass (unknown)	grass (unknown)
total	10	4	20	22
Sp. Name		Houstonia		
total		1		
Sp. Name		grass (unknown)		
total		15		
Sp. Name				
total				
Sp. Name				
total				
	Plot #1	Plot #2	Plot #3	Plot #4
Sand	75	75	75	75
Debris	10	5	10	10
Herb	0	10	0	0
Shrub	0	0	0	0
Grass	10	0	15	15
Trampled	5	10	0	0
Photo #:	10		N 34.8495	
Transect Heading:	SE		W 109.8165	

Transect #: 8	Location: Martha's Butte		Date:	7/10/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	0	3	2	3
Sp. Name		sandpaper bush	big sagebrush	snakeweed
total		1	2	3
Sp. Name		snakeweed	grass (unknown)	pepper grass
total		4	6	1
Sp. Name		grass (unknown)		grass (unknown)
total		3		2
Sp. Name				
total				
Sp. Name				
total				
	Plot #1	Plot #2	Plot #3	Plot #4
Sand	75	60	85	80
Debris	25	25	0	0
Herb	0	5	0	10
Shrub	0	0	0	0
Grass	0	5	5	5
Trampled	0	5	10	0
Photo #:	11		N 34.8496	
Transect Heading:	S		W 109.8169	

Transect #: 9	Location: Martha's Butte		Date:	7/10/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	2	1	2	2
Sp. Name	sandpaper bush	grass (unknown)	grass (unkonwn)	grass (unknown)
total	1	14	15	10
Sp. Name	grass (unknown)		blue grama	blue grama
total	9		2	1
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
	Plot #1	Plot #2	Plot #3	Plot #4
Sand	65	90	75	85
Debris	0	0	0	0
Herb	0	0	0	0
Shrub	20	0	0	0
Grass	15	5	10	15
Trampled	0	5	15	0
Photo #:	12		N 34.8486	
Transect Heading:	S		W 109.8156	

Transect #: 1	Location: RT66		Date:	7/6/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	2	2	2	3
Sp. Name	Sand Sagebrush	Sand Sagebrush	Sand Sagebrush	Sand Sagebrush
total	1	3	0	1
Sp. Name	Grass (unknown)	Grass (unknown)	Grass (unknown)	Grass (unknown)
total	1	4	8	34
Sp. Name			Wright's birdbeak	yellow flower
total			1	2
Sp. Name				
total				
Sp. Name				
total				
Total Individuals	2	7	9	37
Sand	45	10	5	10
Debris	0	0	5	0
Herb	0	0	0	0
Shrub	50	85	75	50
Grass	5	5	15	30
Trampled	0	0	0	10
Photo #:	1			
Transect Heading:	ESE			
		N 35.05111		
control plot may touch a disturbed ar		W 109.80540		

Transect #: 2	Location: RT66		Date:	7/6/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	5	3	3	5
Sp. Name	oatgrass	Yellow flower	Grass (unknown)	rabbit bush
total	2	4	6	5
Sp. Name	galleta	galleta	yellow flower	indian rice grass
total	3	9	1	2
Sp. Name	grass (unknown)	grass (unknown)	rabbit bush	oatgrass
total	30	29	2	1
Sp. Name	flower			yellow flower
total	2			1
Sp. Name	yellow flower			sand sagebrush
total	4			1
Total Individuals	41	42	9	10
Sand	60	45	45	30
Debris	0	0	25	0
Herb	5	5	5	15
Shrub	0	0	15	45
Grass	25	25	10	10
Trampled	10	25	0	0
Photo #:	2			
Transect Heading:	WNW			
		N 35.05105		
Sampled: grass (tall) and flower		W 109.80540		
Phot # 3: rosemary thing				

Transect #: 3	Location: RT66		Date:	7/6/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	4	5	5	4
Sp. Name	yellow flower	yellow flower	snake weed	galleta
total	11	4	2	8
Sp. Name	galleta	yellow spiny daisy	yellow flower	grama grass
total	2	2	3	2
Sp. Name	grass (unknown)	sand sagebrush	grama grass	grass (unknown)
total	27	1	2	23
Sp. Name	plantain	galleta	galleta	snakeweed
total	1	4	2	1
Sp. Name		wild oats	grass (unknown)	
total		1	22	
Sp. Name		grass (unknown)		
total		55		
Total Individuals	41	12	31	34
Sand	55	25	45	40
Debris	10	5	30	5
Herb	10	10	15	5
Shrub	0	0	0	0
Grass	25	45	20	50
Trampled	0	15	0	0
Photo #:	4			
Transect Heading:	NE			
		N 35.05100		
		W 109.80528		

Transect #: 4	Location: RT66		Date:	7/6/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	3	4	4	2
Sp. Name	galleta	yellow spiny daisy	snake weed	snake weed
total	3	1	1	1
Sp. Name	grass (unknown)	snake weed	herb with flower	galleta
total	29	1	2	45
Sp. Name	branchy	galleta	galleta	
total	5	32	15	
Sp. Name		grass (unknown)	grass (unknown)	
total		5	5	
Sp. Name				
total				
Total Individuals	37	39	23	46
Biotic Soil	0	0	0	10
Sand	75	15	10	15
Debris	5	0	5	0
Herb	5	10	15	5
Shrub	0	0	0	0
Grass	15	70	70	70
Trampled	0	5	0	0
Photo #:	5			
Transect Heading:	SW			
		N 35.05104		
		W 109.80519		

Transect #: 5	Location: RT66		Date:	7/6/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	2	4	5	4
Sp. Name	sand sagebrush	yellow flower	snake weed	sand sagebrush
total	1	1	1	1
Sp. Name	grass (unknown)	photo 7 (grass)	grass (tall)	grass (tall)
total	11	2	1	1
Sp. Name		indian rice grass	sunflower plant	yellow flower
total		1	1	7
Sp. Name		grass (unknown)	yellow flower	grass (unknown)
total		3	6	11
Sp. Name			grass (unknown)	
total			10	
Total Individuals	12	7	19	20
Sand	70	85	75	50
Debris	5	5	10	10
Herb	0	5	10	10
Shrub	15	0	0	0
Grass	10	5	15	15
Trampled	0	0	0	0
Photo #:	6			
Transect Heading:	SW			
		N 35.05095		
Photo #8: sunflower plant		W 109.80515		

Transect #: 1	Location: Lacey Point		Date:	7/7/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	4	8	5	6
Sp. Name	galleta	peppergrass	black grama	black grama
total	10	1	2	15
Sp. Name	peppergrass	galleta	peppergrass	foxtail barley
total	2	4	1	1
Sp. Name	black grama	grass 2	grass 2	yellow tube
total	12	5	6	1
Sp. Name	grass (unknown)	black grama	grass (unknown)	grass (unknown)
total	17	4	11	3
Sp. Name		grass (unknown)	sunflower/daisy	grass 2
total		25	1	1
Sp. Name		mountain pussy toes		peppergrass
total		1		1
Sp. Name		yellow tube		
total		3		
Sp. Name		dandelion thing		
total		1		
	Plot #1	Plot #2	Plot #3	Plot #4
Sand	35	50	75	55
Debris	10	0	0	5
Herb	0	5	0	25
Shrub	0	0	0	0
Grass	50	330	25	15
Trampled	5	15	0	0
Photo #:	2		N 35. 06562	
Transect Heading:	NW		W 109.78128	
Photo # 1: sunflower/daisy annual				
Notes: plots 2,3,4 have small barely discernable social trail running through them				

Transect #: 2	Location: Lacey Point		Date:	7/7/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	8	4	4	2
Sp. Name	snakeweed	snakeweed	indian rice grass	indian rice grass
total	1	2	1	2
Sp. Name	galleta	galleta	grass (unknown)	grass (unknown)
total	8	4	33	28
Sp. Name	black grama	big sage	big sage	
total	6	1	1	
Sp. Name	indian rice grass	grass (unknown)		
total	2	24		
Sp. Name	grass (unknown)			
total	27			
	big sage			
	3			
	Plot #1	Plot #2	Plot #3	Plot #4
Sand	60	75	75	80
Debris	0	0	0	0
Herb	10	10	5	0
Shrub	10	0	0	0
Grass	20	10	20	20
Trampled	0	5	0	0
Photo #:	3		N 35.06282	
Transect Heading:	NNW		W 109.80328	

Transect #: 3	Location: Lacey Point		Date:	7/7/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	4	5	5	3
Sp. Name	indian rice grass	narrow leaf yucca	indian rice grass	snakeweed
total	1	1	5	3
Sp. Name	yellow flower	snakeweed	snakeweed	indian rice grass
total	14	1	1	3
Sp. Name	snakeweed	yellow flower	yellow flower	grass (unknown)
total	2	10	10	11
Sp. Name	grass (unknown)	indian rice grass	grass (unknown)	
total	4	4	11	
Sp. Name		grass (unknown)	big sage	
total		13	1	
	Plot #1	Plot #2	Plot #3	Plot #4
Succulents	0	15	0	0
Sand	65	50	70	40
Debris	0	0	0	0
Herb	10	15	10	15
Shrub	5	0	5	0
Grass	15	20	15	45
Trampled	5	0	0	0
Photo #:	4		N 35.06286	
Transect Heading:	SSW		W 109.80364	

Transect #: 4 **Location:** Lacey Point **Date:** 7/7/2017

	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	0	2	5	5
Sp. Name		indian rice grass	shrub 2	snakeweed
total		2	2	2
Sp. Name		wild oats	wild oats	shrub 2
total		4	2	2
Sp. Name			peppergrass	foxtail barley
total			2	2
Sp. Name			grass (unknown)	indian rice grass
total			1	1
Sp. Name				peppergrass
total				4

	Plot #1	Plot #2	Plot #3	Plot #4
Sand	100	75	70	45
Debris	0	15	0	0
Herb	0	0	2.5	35
Shrub	0	0	25	15
Grass	0	10	2.5	5
Trampled	0	0	0	0

Photo #: 5 N 35.06332
Transect Heading: NE W 109.80235

Notes: Distrubed Area

Transect #: 5 **Location:** Lacey Point **Date:** 7/7/2017

	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	4	6	4	2
Sp. Name	globemallow	dark green sprig	peppergrass	peppergrass
total	1	1	25	20
Sp. Name	dark green sprig	galleta	galleta	fishtail grass
total	1	3	25	2
Sp. Name	light green sprig	light green sprig	fishtail grass	
total	1	1	4	
Sp. Name	grass (unknown)	foxtail barley	shrub 3	
total	1	1	1	
Sp. Name		wild oats		
total		1		
		photo 8		
		4		

	Plot #1	Plot #2	Plot #3	Plot #4
Sand	90	70	45	60
Debris	0	10	20	15
Herb	5	5	15	25
Shrub	0	0	5	0
Grass	5	10	15	0
Trampled	0	5	0	0

Photo #: 6 N 35.06326
Transect Heading: ENE W 109.80228

Photo #7: spring parsley or baby globemallow
Photo #8: one from book
Notes: Disturbed Area

Transect #: 6	Location: Lacey Point		Date:	7/7/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	6	4	2	5
Sp. Name	snakeweed	wild oats	wild oats	indian rice grass
total	1	25	17	2
Sp. Name	wild oats	indian rice grass	snakeweed	wild oats
total	9	1	6	19
Sp. Name	indian rice grass	shrub 3		grass (unknown)
total	1	1		5
Sp. Name	grass (unknown)	yellow flower		foxtail barley
total	5	1		2
Sp. Name	shrub 3			snakeweed
total	1			3
	photo 9			
	2			
	Plot #1	Plot #2	Plot #3	Plot #4
Sand	50	60	55	65
Debris	0	20	15	5
Herb	30	0	10	10
Shrub	5	5	0	0
Grass	15	15	20	20
Trampled	0	0	0	0
Photo #:	10		N 35.06298	
Transect Heading:	N		W 109.80296	
Photo #9: herb				
Notes: Disturbed Area/Braided Trail				

Transect #: 1	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	3	2	1
Sp. Name	sandpaper bush	brome 1	brome 1	sandpaper bush
total	4	9	3	1
Sp. Name		brome 2	brome 2	
total		6	4	
Sp. Name		grass (unknown)		
total		12		
Sp. Name				
total				
Sp. Name				
total				
Sand	90	70	80	85
Debris	5	5	5	10
Herb	5	0	0	5
Shrub	0	0	0	0
Grass	0	25	15	0
Trampled	0	0	0	0
Photo #:	1		N 34.86415	
Transect Heading:	W		W 109.79118	

Transect #: 2	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	0	0	0
Sp. Name	sandpaper bush			
total	2			
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Biotic soil				
Sand	85	90	95	95
Debris	10	10	5	5
Herb	5	0	0	0
Shrub	0	0	0	0
Grass	0	0	0	0
Trampled	0	0	0	0
Photo #:	2		N 34.86472	
Transect Heading:	SE		W 109.79099	

Transect #: 3	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	3	0	3	3
Sp. Name	galleta		galleta	galleta
total	7		5	4
Sp. Name	grass (unknown)		grass (unknown)	grass (unknown)
total	3		10	8
Sp. Name	rabbit bush		yellow flower	yellow flower
total	1		4	7
Sp. Name				
total				
Sp. Name				
total				
Biotic soil				
Sand	65	90	75	70
Debris	5	5	5	5
Herb	5	0	5	5
Shrub	0	0	0	0
Grass	25	0	10	20
Trampled	0	5	5	0
Photo #:	3		N 34.86535	
Transect Heading:	SW		W 109.79063	

Transect #: 6	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	3	3	1	1
Sp. Name	brome 2	galleta	sandpaper bush	brome 1
total	12	14	1	1
Sp. Name	brome 1	brome 1		
total	6	7		
Sp. Name	sandpaper bush	brome 2		
total	1	4		
Sp. Name				
total				
Sp. Name				
total				
Biotic soil				
Sand	60	70	80	80
Debris	10	5	10	15
Herb	10	0	10	0
Shrub	0	0	0	0
Grass	20	25	0	5
Trampled	0	0	0	0
Photo #:	6		N 34.86663	
Transect Heading:	NW		W 109.78951	

Transect #: 4	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	0	2	1	1
Sp. Name		rabbit brush	brome 1	brome 1
total		1	8	14
Sp. Name		brome 1		
total		15		
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Biotic soil				
Sand	85	60	80	75
Debris	10	10	5	10
Herb	0	15	0	0
Shrub	0	0	0	0
Grass	0	15	10	15
Trampled	5	0	5	0
Photo #:	4		N 34.86565	
Transect Heading:	E		W 109.79007	

Transect #: 5	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	0	2	1	0
Sp. Name		salt bush	brome 1	
total		1	5	
Sp. Name		grass (unknown)		
total		1		
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Biotic soil				
Sand	90	85	65	90
Debris	10	5	25	10
Herb	0	5	0	0
Shrub	0	0	0	0
Grass	0	0	10	0
Trampled	0	5	0	0
Photo #:	5		N 34.86622	
Transect Heading:	E		W 109.79009	

Transect #: 7	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	0	2	1	2
Sp. Name		rabbit brush	grass (unknown)	snakeweed
total		1	4	2
Sp. Name		grass (unknown)		brome 1
total		3		2
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Biotic soil				
Sand	90	75	80	80
Debris	10	10	10	10
Herb	0	5	0	5
Shrub	0	0	0	0
Grass	0	10	10	5
Trampled	0	0	0	0
Photo #:	7		N 34.86680	
Transect Heading:	NE		W 109.78872	

Transect #: 8	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	0	0	3	1
Sp. Name			rabbit brush	sandpaper bush
total			2	1
Sp. Name			dark green sprig	
total			1	
Sp. Name			galleta	
total			13	
Sp. Name				
total				
Sp. Name				
total				
Biotic soil				
Sand	70	90	50	90
Debris	30	10	5	5
Herb	0	0	20	5
Shrub	0	0	0	0
Grass	0	0	20	0
Trampled	0	0	5	0
Photo #:	8		N 34.86611	
Transect Heading:	ESE		W 109.78848	

Transect #: 9	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	0	0	6	2
Sp. Name			Nevada jointfir	snakeweed
total			1	2
Sp. Name			cholla	galleta
total			1	3
Sp. Name			narrowleaf yucca	
total			2	
Sp. Name			snakeweed	
total			1	
Sp. Name			mountain muhley	
total			3	
			brome 1	
			3	
succulent/cactus	0	0	15	0
Sand	95	90	30	70
Debris	5	10	30	10
Herb	0	0	5	10
Shrub	0	0	5	5
Grass	0	0	15	5
Trampled	0	0	0	
Photo #:	9		N 34.86540	
Transect Heading:	N		W 109.78861	

Transect #: 10	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	1	0	1
Sp. Name	sandpaper bush	galleta		grass (unknown)
total	5	2		1
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Biotic soil				
Sand	85	85	85	85
Debris	10	10	15	10
Herb	5	0	0	0
Shrub	0	0	0	0
Grass	0	5	0	5
Trampled	0	0	0	0
Photo #:	10		N 34.86514	
Transect Heading:	SE		W 109.78804	

Transect #: 11	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	0	0	0
Sp. Name	sandpaper bush			
total	3			
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Biotic soil				
Sand	80	90	90	85
Debris	10	10	10	15
Herb	10	0	0	0
Shrub	0	0	0	0
Grass	0	0	0	0
Trampled	0	0	0	0
Photo #:	11		N 34.86455	
Transect Heading:	W		W 109.78823	

Transect #: 12	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	1	1	0
Sp. Name	sandpaper bush	sandpaper bush	sandpaper bush	
total	1	1	1	
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Biotic soil				
Sand	90	85	85	80
Debris	5	10	15	20
Herb	5	5	5	0
Shrub	0	0	0	0
Grass	0	0	0	0
Trampled	0	0	0	0
Photo #:	12		N 34.86452	
Transect Heading:	S		W 109.78897	

Transect #: 13	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	2	2	2	0
Sp. Name	sandpaper bush	sandpaper bush	aster/cosmo	
total	13	2	4	
Sp. Name	brome 1	brome 1	globemallow	
total	4	1	1	
Sp. Name				
total				
Sp. Name				
total				
Sp. Name				
total				
Biotic soil				
Sand	80	80	85	90
Debris	10	10	10	10
Herb	5	5	5	0
Shrub	0	0	0	0
Grass	5	5	0	0
Trampled	0	0	0	0
Photo #:	13		N 34.86419	
Transect Heading:	SE		W 109.78967	

Transect #: 14	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	1	3	2	2
Sp. Name	dark green sprig	purple flower	sandpaper bush	brome 1
total	1	7	3	9
Sp. Name		sandpaper bush	purple flower	rabbit brush
total		1	1	1
Sp. Name		brome 1		
total		2		
Sp. Name				
total				
Sp. Name				
total				
Biotic soil				
Sand	80	70	85	75
Debris	15	15	10	10
Herb	5	10	5	5
Shrub	0	0	0	0
Grass	0	5	0	10
Trampled	0	0	0	0
Photo #:	14		N 34.86387	
Transect Heading:	NE		W 109.79021	

Transect #: 15	Location: Crystal Forest		Date:	7/26/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	3	0	1	1
Sp. Name	rabbit brush		sandpaper bush	sandpaper bush
total	5		3	2
Sp. Name	brrome 1			
total	1			
Sp. Name	sandpaper bush			
total	7			
Sp. Name				
total				
Sp. Name				
total				
Biotic soil				
Sand	70	85	80	85
Debris	20	15	15	10
Herb	5	0	5	5
Shrub	0	0	0	0
Grass	5	0	0	0
Trampled	0	0	0	0
Photo #:	15		N 34.86411	
Transect Heading:	SE		W 109.79087	

Transect #: 1	Location: Puerco Pueblo		Date:	7/20/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	5	3	1	4
Sp. Name	brome 2	saltbush	brome 2	brome 2
total	5	1	10	4
Sp. Name	blue grama	brome 2		brome
total	3	28		1
Sp. Name	snakeweed	pepper grass		pepper grass
total	1	1		1
Sp. Name	grass (unknown)			plantain
total	3			12
Sp. Name	yellow flower			
total	3			
Sand	65	60	85	75
Debris				
Herb	20			5
Shrub		15		10
Grass	5	25	15	10
Trampled	10			
Photo #:	1		N 34.97566	
Transect Heading:	SE		W 109.79426	
saltbush plot 2- dying				

Transect #: 2	Location: Puerco Pueblo		Date:	7/20/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	6	3	8	5
Sp. Name	globemallow	prickly pear	indian rice grass	saltbush
total	6	1	1	1
Sp. Name	snakeweed	brome 2	brome 2	prickly pear
total	1	7	12	1
Sp. Name	blue grama	plantain	plantain	brome 2
total	3	6	21	7
Sp. Name	brome 2		blue grama	grass (unknown)
total	23		2	3
Sp. Name	prairie oatgrass		grass (unknown)	plantain
total	1		2	16
Sp. Name	brome		snakeweed	
total	11		1	
Sp. Name			saltbush	
total			1	
Sp. Name			galleta	
total			1	
succulent/cactus		5		
Sand	65	65	65	10
Debris				
Herb	15		5	5
Shrub			10	60
Grass	15	15	20	25
Trampled	5	15		
Photo #:	2		N 34.97528	
Transect Heading:	ENE		W 109.79447	
bag 1=new grass				

Transect #: 3	Location: Puerco Pueblo		Date:	7/20/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	3	3	5	3
Sp. Name	snakeweed	snakeweed	blue grama	grass (unknown)
total	2	3	2	2
Sp. Name	grass (unknown)	gelleta	galleta	snakeweed
total	1	7	9	2
Sp. Name	indian rice grass	grass (unknown)	grass (unknown)	plantain
total	1	5	1	3
Sp. Name			snakeweed	
total			4	
Sp. Name			plantain	
total			11	
Biotic soil		5	10	80
Sand	70	45	55	
Debris				15
Herb	20	25	20	
Shrub				5
Grass	5	15	15	
Trampled	5	10		
Photo #:	3		N 34.97486	
Transect Heading:	SW		W 109.79437	

Transect #: 4	Location: Puerco Pueblo		Date:	7/20/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	3	5	2	4
Sp. Name	globemallow	blue grama	snakeweed	snakeweed
total	1	5	2	2
Sp. Name	prairie oatgrass	brome 2	grass (unknown)	prairie oatgrass
total	1	1	7	3
Sp. Name	grass (unknown)	grass (unknown)		blue grama
total	6	11		3
Sp. Name		plantain		grass (unknown)
total		17		7
Sp. Name		snakeweed		
total		2		
Biotic soil		5		5
Sand	5	55	65	65
Debris	70	5		5
Herb	5	10	20	10
Shrub				
Grass	20	25	15	15
Trampled				
Photo #:	4		N 34.97464	
Transect Heading:	S		W 109.79422	

Transect #: 5	Location: Puerco Pueblo		Date:	7/20/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	2	4	1	3
Sp. Name	grass (unknown)	big sage	grass (unknown)	saltbush
total	4	4	9	1
Sp. Name	snakeweed	globemallow		buckwheat
total	1	1		1
Sp. Name		buckwheat		grass (unknown)
total		1		6
Sp. Name		grass (unknown)		
total		4		
Sp. Name				
total				
Sand	60	55	65	65
Debris	5	15	10	10
Herb	5	5	10	5
Shrub	10	15		10
Grass	5	10	15	10
Trampled	15			
Photo #:	5		N 34.97464	
Transect Heading:	NW		W 109.79372	

Transect #: 6	Location: Puerco Pueblo		Date:	7/20/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	2	3	4	2
Sp. Name	grass (unknown)	blue grama	plantain	grass (unknown)
total	7	7	1	6
Sp. Name	saltbush	grass (unknown)	saltbush	plantain
total	1	8	1	2
Sp. Name		snakeweed	brome 2	
total		1	1	
Sp. Name			grass (unknown)	
total			5	
Sp. Name				
total				
Sand	50	45	50	70
Debris	5		15	
Herb		10	5	5
Shrub	10		10	
Grass	5	20	20	25
Trampled	30	25		
Photo #:	6		N 34.97499	
Transect Heading:	SW		W 109.79375	

Transect #: 7	Location: Puerco Pueblo		Date:	7/20/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	2	3	2	4
Sp. Name	globemallow	brome 2	saltbush	brome 2
total	1	20	1	2
Sp. Name	grass (unknown)	saltbush	grass (unknown)	peppergrass
total	10	1	6	1
Sp. Name		peppergrass		bluets
total		2		1
Sp. Name				flame flower
total				1
Sp. Name				
total				
Sand	45	65	5	85
Debris				5
Herb	5			5
Shrub		25	85	
Grass	25	20	10	5
Trampled	25	10		
Photo #:	7		N 34.97512	
Transect Heading:	SE		W 109.79409	

Transect #: 8	Location: Puerco Pueblo		Date:	7/20/2017
	Plot #1	Plot #2	Plot #3	Plot #4
# of Species	4	4	2	3
Sp. Name	peppergrass	grass (unknown)	grass (unknown)	peppergrass
total	2	2	5	5
Sp. Name	grass (unknown)	galleta	peppergrass	grass (unknown)
total	6	4	2	5
Sp. Name	prairie oatgrass	brome 2		plantain
total	1	2		26
Sp. Name	mountain muhly	saltbush		
total	1	1		
Sp. Name				
total				
Sand	50	75	45	55
Debris				10
Herb	5		5	10
Shrub	25	5		
Grass	20	20	50	25
Trampled				
Photo #:	8		N 34.97538	
Transect Heading:	NE		W 109.79427	

plot 1 has fence

bag 1: grass 3

APPENDIX II: TRANSECT PHOTOS

Billing's Gap OTBP:







Martha’s Butte OTBP:




Route 66 Pull-off:

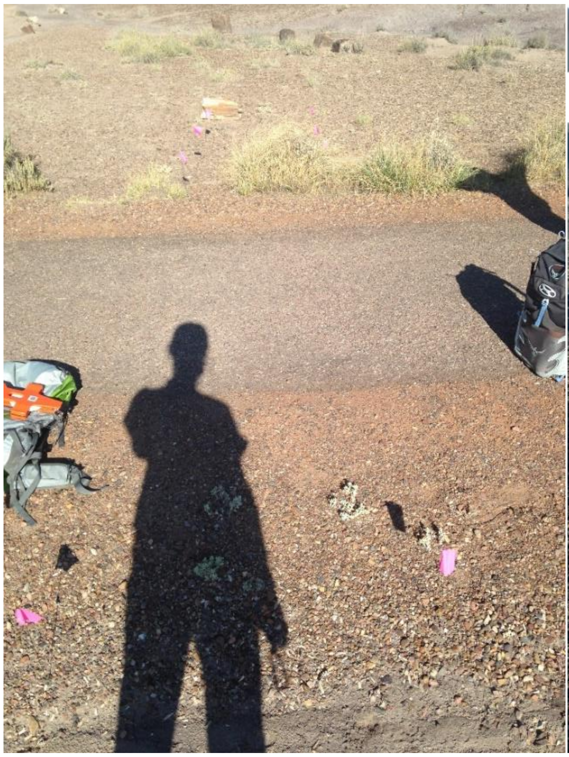


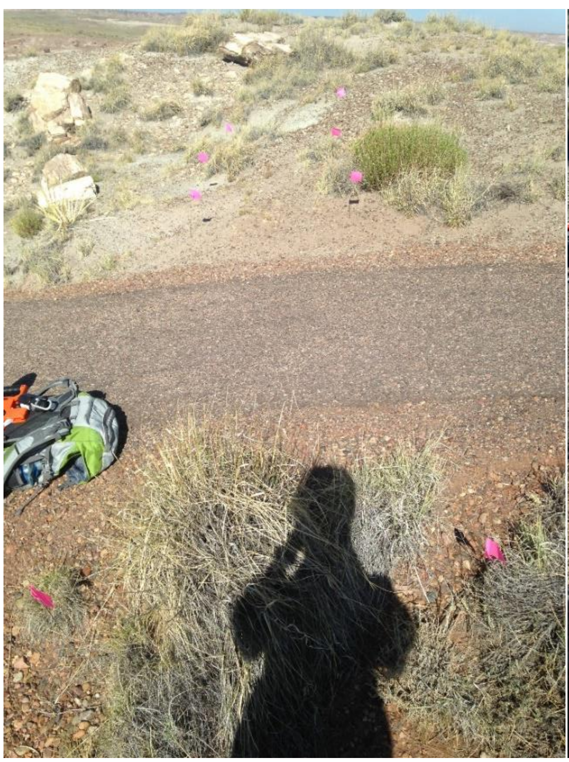

Lacey Point Pull-off:



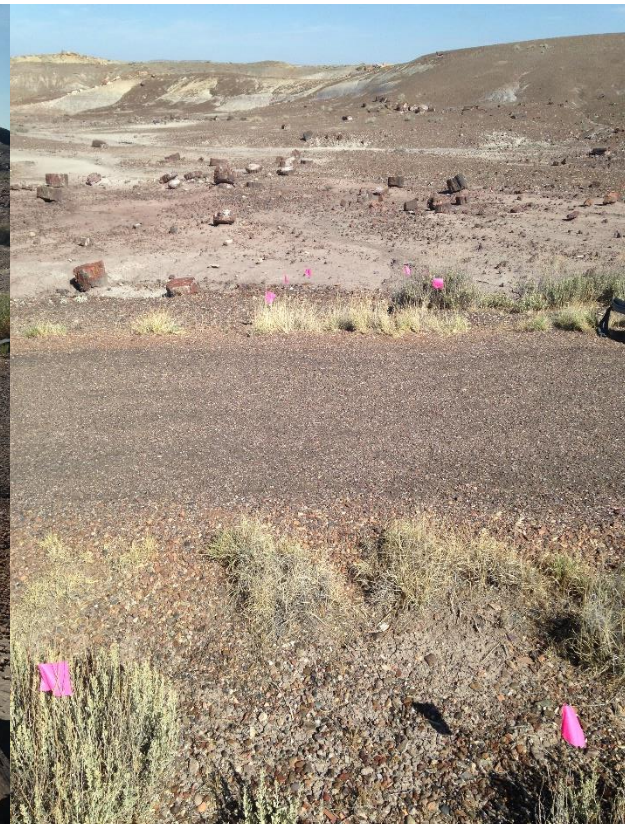


Crystal Forest Trail:














Puerco Pueblo Trail: