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Vegetation Analysis:
A Graphical Analysis of Plant Succession in Desert Communities Affected by Fire

A thesis submitted in partial satisfaction
of the requirement for the degree of
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In

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by

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ABSTRACT

The Mojave Desert is affected by fire every year. With each fire comes the removal of old growth and, in its place, new growth – consisting primarily of those species which thrive in disturbed areas. The focus of my research is to look at plant communities that have been disturbed by fire, and examine the successional pathway of these disturbed environments. The seven environments I analyzed were burned within the last twenty years and are found in the *Coleogyne ramosissima* ecotone throughout the Spring Mountain range near Las Vegas, Nevada. The data was collected with randomly chosen circle plots in the burned environments, as well as the neighboring unburned environments. There was no correlation found between the length of time since the fire and the level of diversity of the environment. However, the degree of evenness is higher in the burned environments as compared to the unburned environments. It appears that there was not enough time between the fires to see a difference in the composition of the community.

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INTRODUCTION

The environment is constantly changing. This change is natural and usually subtle. However, the rate at which an environment changes may increase as a result of disturbances. Succession is defined as a directional temporal change in species composition or relative abundances following a disturbance (Holt 1995), and plays an important role in changing community composition. The mechanisms that drive succession have been debated throughout this century, and it seems that for every theory introduced, there are experiments to contradict it. The reason for this is that these theories only focus on a limited number of aspects, but in actuality succession is based on a complex web of interactions.

The focus of my research will be to look at desert plant communities that have been disturbed by fire. I will be examining the successional pathways of these communities following fire disturbance. The research will include fires of both high and low intensities, which were started by natural causes as well as human negligence.

The vegetation analysis will examine seven different plant communities of the Mojave Desert, near Las Vegas, Nevada, which have been affected by fire between the years 1979 and 1994. All seven occur in the Spring Mountain range to the West of Las Vegas and within the *Coleogyne ramosissima* (blackbrush) ecotone. The fires occurred at: First Creek, Cottonwood Valley, Zipper, Ice Box, Willow, Dear Pasture, and Newer Deer Pasture. The location and descriptions of each fire can be found in Table 1, and Figures 1and 2 are maps showing the fire locations.

Coleogyne communities appear to dominate at an elevation of 4000 to 5000 feet in the Mojave Desert (Beatley 1969), and form nearly monospecific stands in much of its range

(Lei and Walker 1997). These monospecific stands will provide a reference to which disturbed areas will be compared; fully recovered disturbed areas should closely resemble the monospecific blackbrush stands.

The aim of this study is to examine burned environments of different time intervals within the *Coleogyne* ecotone to determine if plant succession occurs along a specific time sequence. We expected to find: 1) higher diversity and evenness in burned areas than in areas that have never experienced burns; 2) greater cover but lower diversity in areas that fire occurred many years ago as compared to areas that were burned in recent years; and 3) no chronological time sequence in the recovery of a fire disturbed environment.

The forces which drive plant succession vary greatly and depend on many different factors that come together to influence the vegetation within particular environments. There are three different stages in which primary succession is influenced: initial biotic community, in which influential factors include the state of the vegetation prior to the disturbance; the abiotic world, which is influenced by the intensity or frequency of disturbance and the condition of the parent material following the disturbance; and the biotic realm, where colonization is an important factor.

The initial biotic community plays an important role in plant succession. It is the template by which all future communities will be measured. Initial plant communities display the species and relationships that inhabit an environment for extended periods of time with little to no disruption. These plants can also have a dramatic affect on the pathway of succession. The original floristic composition is often the first factor to influence succession. However, the extent of the influence original floristic composition has on succession ultimately depends on the type of disturbance (Glenn-Lewin et al. 1992).

Disturbance can have many different appearances, ranging from volcanic eruptions, deglaciation, fire, agricultural fields or toppled trees (as well as many more). Disturbance to the environment can be characterized by two different variables: frequency and intensity, each of which can have drastically different effects. Disturbance frequency is the number of times a particular environment is disturbed. As a result of repeated disturbances, species richness is reduced due to altering habitat structure and the elimination of intolerant species (Collins 1995). Disturbance intensity is a measure of magnitude of the disturbance, such as how hot or long a fire burns. In many cases, this one time disturbance is found to benefit the existing community as far as species richness is concerned, and in the case of fire, it is often required for the removal of ground litter and propagation of some species.

Disturbance plays a huge role in the state of parent material. Parent material is what is left in the soil following the disturbance. This often dictates what type of species returns to the disturbed environment first. If the parent material is left largely intact, then shrubs and woody plants may colonize quickly, as a result of some plants resprouting since they were not completely destroyed. Also, the soil is already suitable for sustaining these types of species. But if the parent material is severely altered, then it may take many years for succession to begin, and when it finally does it may be dominated by a trophic species such as lichens.

Colonization may occur through many different means. It may be the result of a plant that was not totally removed from the disturbed environment, in which case it may be able to reestablish a population relatively quickly with respect to succession time. Succession may also begin as the result of seed banks that have been in the soil. These seeds may begin to germinate and colonize the disturbed area. These seed banks may have remained dormant permanently, except that the disturbance provided them the opportunity to become established in a newly modified environment.

The size of the disturbance can also be important in colonization. Recovery is strongly affected by the degree of initial destruction and by the degree of isolation (Del Moral 1993). If the disturbance is of large scale, it may inhibit the colonization of the habitat based solely on the amount of distance that must be traveled by seeds to reestablish the area. However, if the disturbance is on a small scale, the surrounding vegetation can influence initial colonization relatively quickly. A pool source of plants that are near the disturbance will continue to disperse seeds, and with the newly available habitat, these seeds may be able to germinate and take root. In such a case, succession would occur relatively quickly, with old growth species getting a jump-start on colonization. However, when the pool source is relatively distant from the disturbed area, then seeds may not reach the new habitat and succession may occur quite slowly.

There is strong positive correlation between seed size and establishment success, and an inverse correlation between seed size and dispersal ability (Del Moral 1993). These results imply that isolated, highly disturbed sites recover slowly because well dispersed species are rarely successful, while those that could establish, rarely colonized (Del Moral 1993).

The role of seed dispersal in succession is one based on strategies of surrounding vegetation and the means by which they are able to disperse their seeds. Seeds that are capable of being dispersed over long distances may have an advantage in colonizing new habitat. These seeds tend to be wind dispersed and fairly small in size, with relatively low survival rates. Seeds that are capable of being transported over long distances are able to escape the influence of the parent plant, in which mature trees and shrubs may inhibit germination or growth of seedlings. For instance, mature vegetation shades the areas surrounding the base of the tree, thus preventing seedlings from reaching maturity. Mature trees also tend to attract a lot of seed predators, and therefore the farther away from the parent a seed gets, the better its chances of survival. But the seeds that have short dispersal distances tend to be heavier and better suited for survival. So ultimately each dispersal strategy has the potential to be successful, but the majority of seeds never germinate.

Just because a plant is successful in dispersing it seeds into the disturbed habitat, does not guaranteed a successful colonization. It is not just the dispersal of the seed that is important to colonization, but the location where the seed lands may be equally important. Each environment has space within it that is suitable for life, but much of these newly disturbed areas consist of inhospitable terrain. These disturbed lands contain microenvironments that are capable of sustaining growth. The size, distribution and frequency of these microenvironments ultimately determine where a species may grow. Some environments contain very small microenvironments, which may be just large enough for one small shrub or grass. This microenvironment may be on the down slope side of a rock, or in a depression on a hillside which prevents the seedling from being removed by winds or erosion. The result of this fragmented environment is a mosaic of microsites and early colonizers.

A microsite may also be created within a preexisting forest where a recently fallen tree provides a disturbance. This allows for a sufficient new environment in which germination may occur. This new environment may be based on a new opening in the canopy, which allows penetrating sunlight to reach the forest floor. Competition may then occur among many seedlings in order to fight for the available sunlight. These seedlings not only have to compete with each other for this sunlight, but also with established adults who may begin to branch in the direction of the new light.

As a result of this competition for new habitat, seedlings must compete with one another in order to capitalize on the limited resources available. It is here in the dynamics of succession that life histories can make the difference. Each species of plant has a life history that has evolved through time, and it is this strategy of life that can ultimately dictate whether the plant will survive primary succession. The plants which tend to do best as early colonizers are those with particular life history traits. The traits that tend to infer early colonization are things such as seed size, growth rate, age at first reproduction, maximum height and longevity (Chapin et al. 1994). Plants that have the ability to grow quickly may take advantage of the available sunlight. However, this is not enough, as is seen in Glacier Bay, Alaska, where *Picea sitchensis* (spruce) may have initially colonized a recently deglaciated habitat but could not withstand the competition from *Alnus sinuata* (alder) (Fastie 1995). *A. sinuata* is able to reproduce nearly 20-40 years sooner than *P. sitchensis* (Fastie 1995). In this way, *A. sinuata* is able to surround *P. sitchensis* in a dense thicket and not allow any new seedlings of *P. sitchensis* to reach maturity.

Even though primary succession will eventually occur, the length of time it takes and the vigor with which it occurs is unknown. Succession is based on a complex web of biotic and abiotic factors, of which it is difficult to say which will be the most influential at any particular site. Each microsite is established as the result of any number of successional factors combining to provide a survivable environment for new vegetation.

Succession needs to be examined across a wide array of disturbances, and at each of these sites information needs to be recorded detailing the specific environmental conditions unique to that site. Even with detailed studies of succession it will still remain impossible to fully determine the pathway of succession for any one environment. Each environment has a set of conditions which are unique, such as wind direction, soil content, seed pool source and level of disturbance (just a few of the many). The relative importance of mechanisms and processes differs among successional environments (Chapin et al. 1994), and thus makes predicting a pathway complex to say the least.

Fire is an important part of many environments and it plays a significant role in ecosystems (Crutzen 1993). A fire's greatest attribute to the environment is its effectiveness in removing ground litter, potential allelochemicals, and reducing competitors; it is the habitat changes following fires that can potentially provide successful conditions for reproduction (Crutzen 1993). Fire can be caused by a natural event such as lightning, or it may be a result of human negligence. Natural fires tend to be annual and occur during the arid times of year following a desert plants seasonal growth, such as *Coleogyne ramosissima* (Lei and Walker 1997). Fires started by people are perhaps the most harmful because of the time of year in which they may occur. Fires that are a result of human negligence can occur during peak reproductive periods of the year, having a much greater ecological impact than natural fires. Fires can also influence the dispersal of species in an environment. "High intensity fires tend to homogenize landscapes, whereas low intensity fires lead to mosaics of ecosystems of differing composition and structure" (Crutzen 1993).

MATERIALS AND METHODS

At each site a 50-meter transect was set, avoiding washes and slopes when possible. Then randomly chosen circle plots were used to collect the data. These circle plots were picked randomly with the use of a random number table. The number was used to determine the distance between each plot and how far from the line transect they would be centered. The sample plots alternated from right to left along the line transect to ensure they did not overlap. Each of these circle plots was created with the use of a rope, which was attached to a wooden stake that was placed at the center of each circle. There were a total of three plots taken at each site, with each circle having a radius of 5.642 meters, a circle with a radius of 5.642 meters yields a circle with an area of 100 meters square (Area of a Circle = πr^2). Data collection was repeated in an unburned region near each site so that it could be compared to the burned data. Data summaries are shown in Tables 2 and 3.

The number of individuals for each perennial species was counted in each plot, and then length, width and height measurements were taken for each individual plant. The calculated areas for the most abundant species are shown graphically for each study site (Figures 5 and 6). The distribution of all of the species at each site was analyzed graphically using proportional abundance, species richness, and diversity, the data can be seen in Figures 3-6, 9 and 10. The method used to calculate the diversity of each site is based on a formula known as the Shannon function (Krebs 1972). This formula takes into account both number of species, as well as equitability or evenness of allotment of individuals among the species. The higher the index value is a result of a higher level of diversity.

RESULTS

The results of the burned area show a higher species diversity when compared to the unburned environments in all but two of the locations, First Creek and Deer Pasture. This can be seen visually by comparing the diversity graphs for both the burned and unburned environments, Figures 3 and 4. The degree of evenness is also highest in the unburned areas as compared to the burned areas. This is determined based on a visual comparison of the slopes of the curves from the proportional abundance, Figures 5 and 6, the greater the slope the lower degree of evenness.

The analysis of vegetation cover for the burned environments resulted in a downward trend with respect to age of fire. The sites where fire occurred more recently resulted in a lower percentage of vegetative cover. However, this study of cover did provide one area of the burned environments that did not follow this trend. The fire at First Creek, which is the oldest, had the lowest percentage of cover than any of the other sites (Figure 7). The amount of diversity did not seem to be affected by the length of time since the fire (Figure 3).

There was not a time sequence evident in the recovery of an environment following a fire. However, the species richness at a site that has not been affected by fire is on average higher than an environment that has been disturbed by fire (Figures 9 and 10). At the same time there are no other time-related trends developing in the burned areas with regard to species richness.

DISCUSSION

The higher levels of evenness and diversity in the burned areas as compared to the unburned areas of the same sites were anticipated. The reason for this is that with higher levels of disturbance there would be a greater opportunity for more species and more individuals of a species to find an environment that is suitable for establishment. The unburned environments tend to have a higher percentage of cover, therefore providing less available habitat for new species, as a result of competition for resources.

The cover of these unburned environments is dominated by a single species, *Coleogyne ramosissima*, usually comprising of more than half of the total coverage (Figure 8). Although this domination by *Coleogyne ramosissima* does have a smothering effect it is interesting to note that the unburned environments did have a higher level of species richness. However, these other species that tend to be scattered amongst the *C. ramosissima* are rarely found in any significant numbers. This may be attributed to the lower percentage of available habitat, as well as an increase in competition for available resources.

The burned environments go through a change of species during the succession process. Through the course of succession different plants will dominate disturbed habitat, this was seen in the all of the different burned sites of this study (Figure 7). However, certain species specialize in colonizing disturbed environments. For instance, *Gutierrezia sarothrae*, which is known to thrive in areas disturbed by fire or grazing, (Bowers 1993), dominated the vegetation cover by more than 75 percent at the Ice Box fire (Figure 7). But each of the other sites was dominated by a different species, except for Cottonwood Valley and Deer Pasture which were both dominated by *Encelia Farinosa*. There was no particular order in which plant species returned. The reason for this is a result of the many different characteristics that are unique to each environment. These characteristics may range from water and nutrient availability in the soil to grazing pressure from wild horses and burros.

However, the most important characteristic may be the availability of near by seeds to be dispersed onto the newly disturbed habitat.

Several errors are inherent to the data collection process. For instance, the number of sites analyzed was limited due to the location of fires; most sites require a fair amount of hiking or the use of an off-road vehicle. One problem with the sites analyzed was the number of sample plots that were taken at each site, which in this case may have not been enough; this too was a function of location and time.

Another major factor that has a strong influence on the recovery of a plant community following a fire, is the intensity of the fire.

> “A fire characterized by high intensity results in extensive mortality of ground cover. Fire intensity is the rate at which heat is given off by the flame, and is more important than the flame temperature. Plant mortality depends on the amount of heat transferred to the plant and how much is absorbed, so as to raise the plant’s temperature to the lethal level.” (Johnson 1992).

Unfortunately, these measurements need to be taken at the time of the fire and there were no records found which provided this information, thus we were not able to analyze them with the rest of the data.

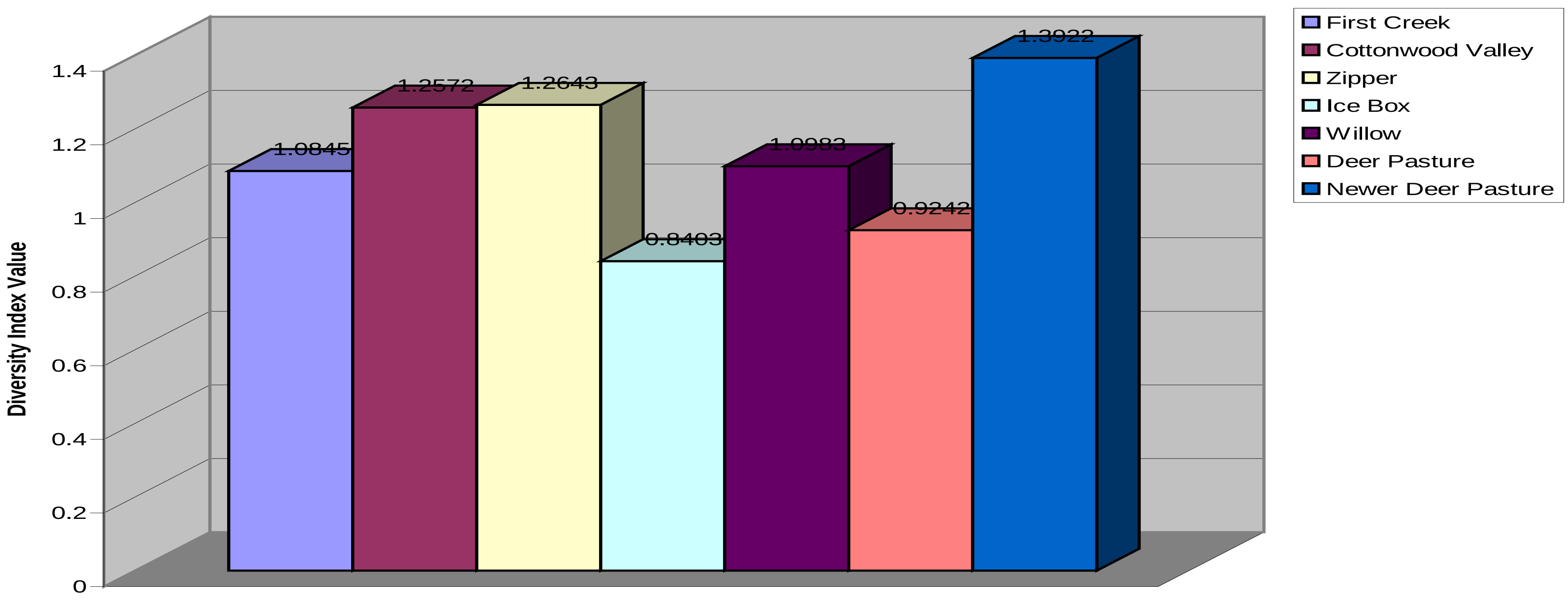
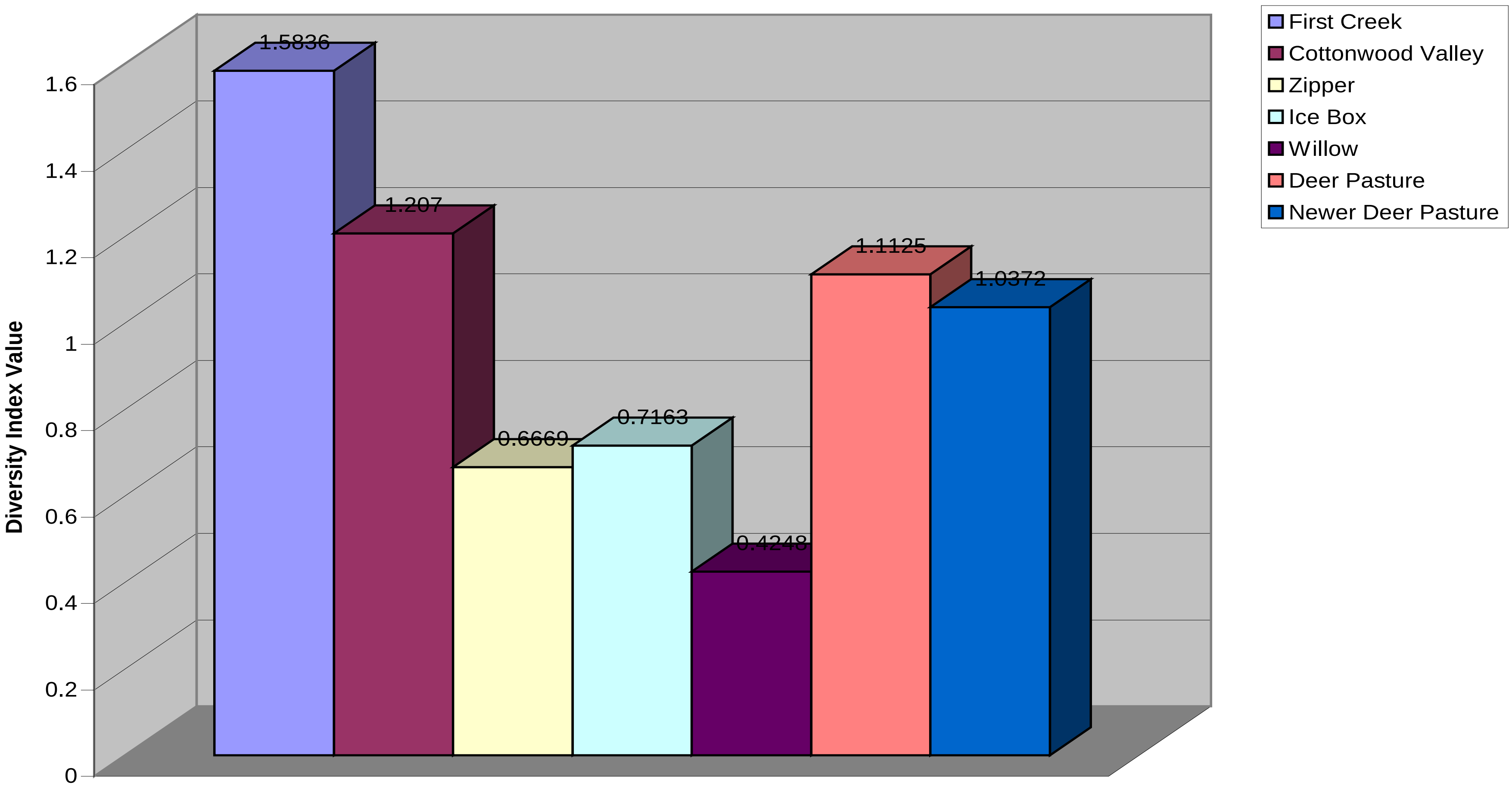


Figure 3: Shannon Index of Diversity for each Burned Site

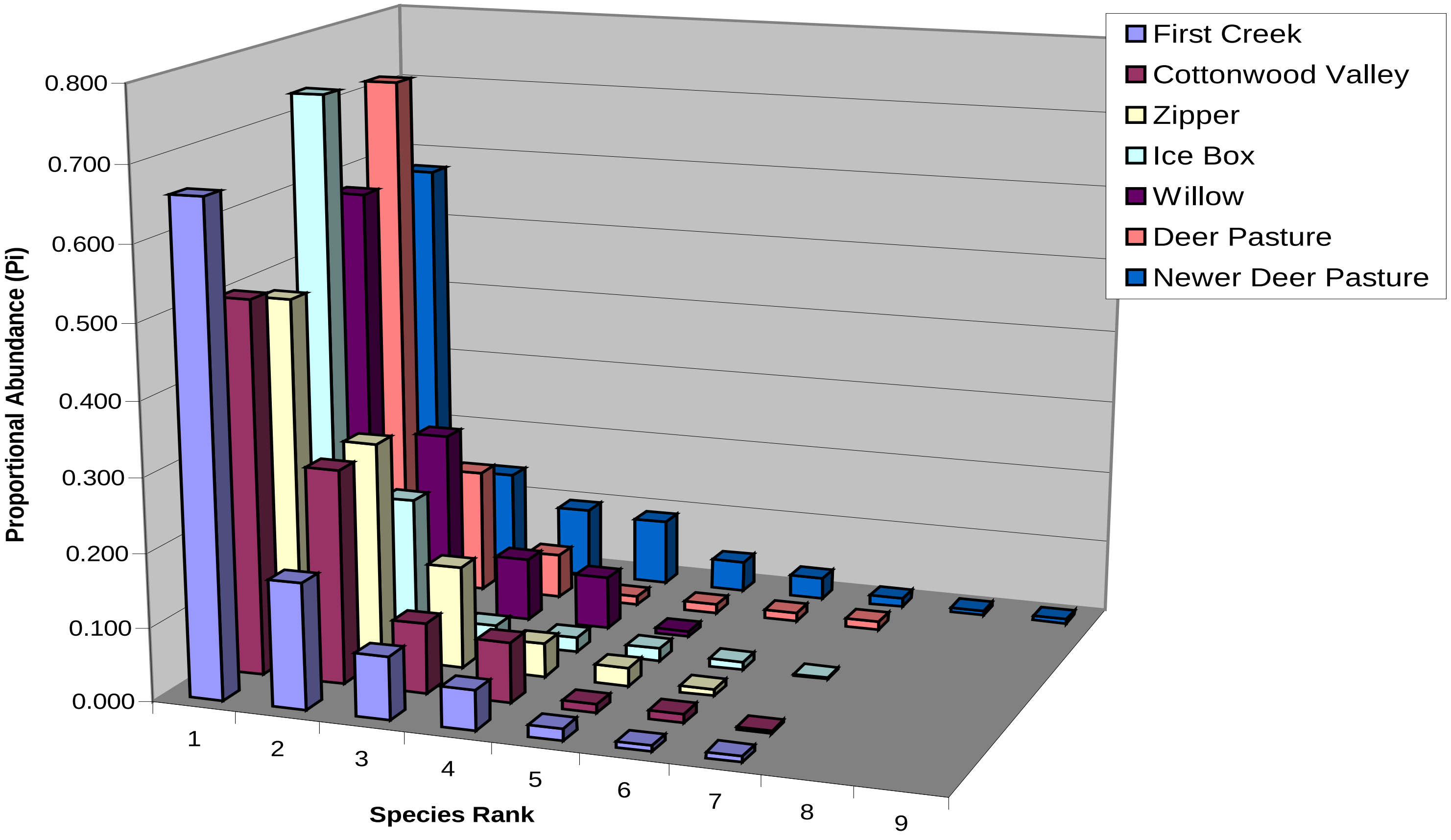
This figure is an indication of diversity at each of the burned sites. There are no definitive patterns of diversity that emerge in the burned sites.

Figure 4: Shannon Index of Diversity for each Unburned Site



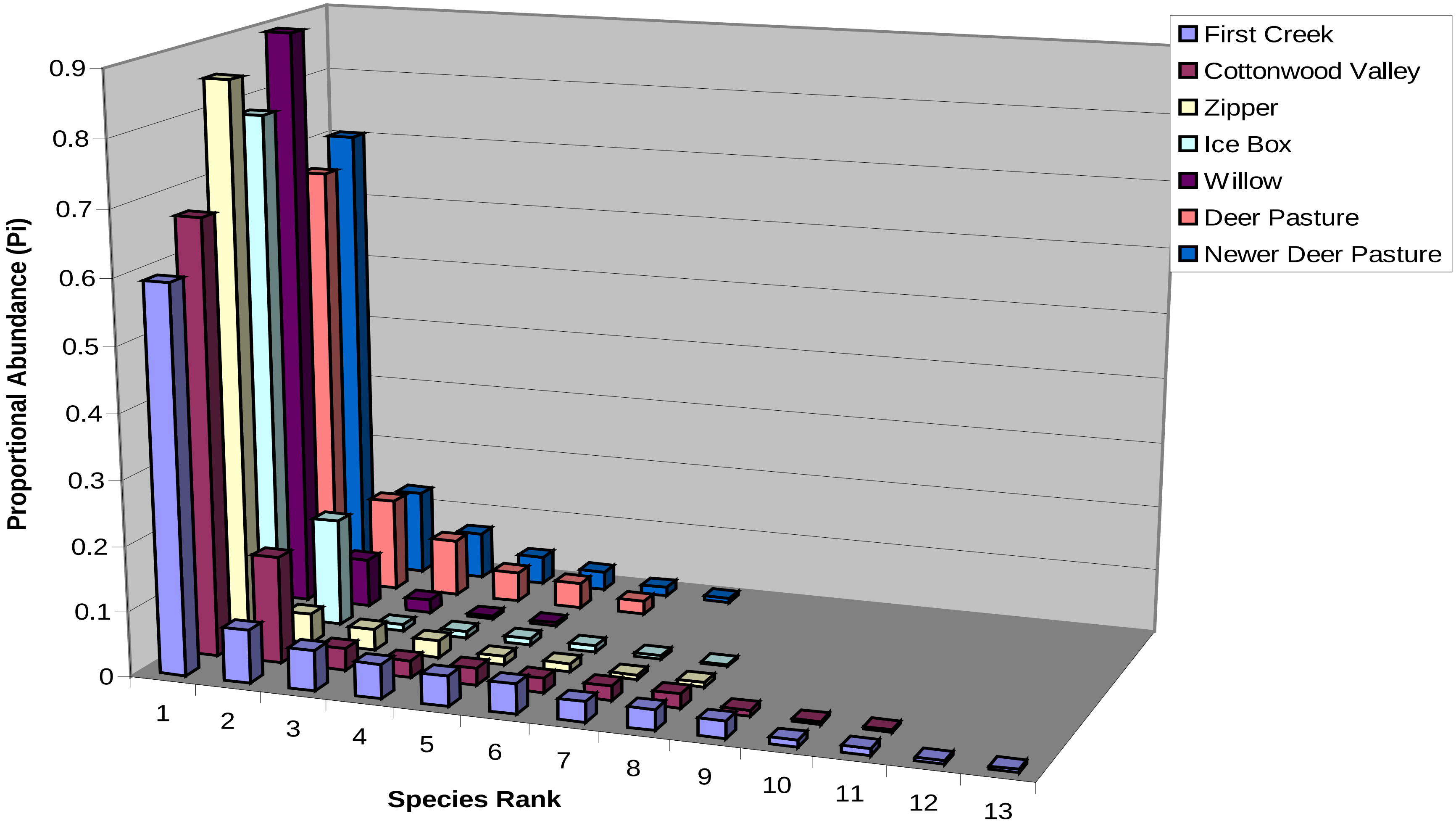
The species diversity has a wide range of values in the unburned sites, and this may be the result of a wide range of conditions that are unique to each site.

Figure 5: Proportional Abundance for all Species at each Burned Site



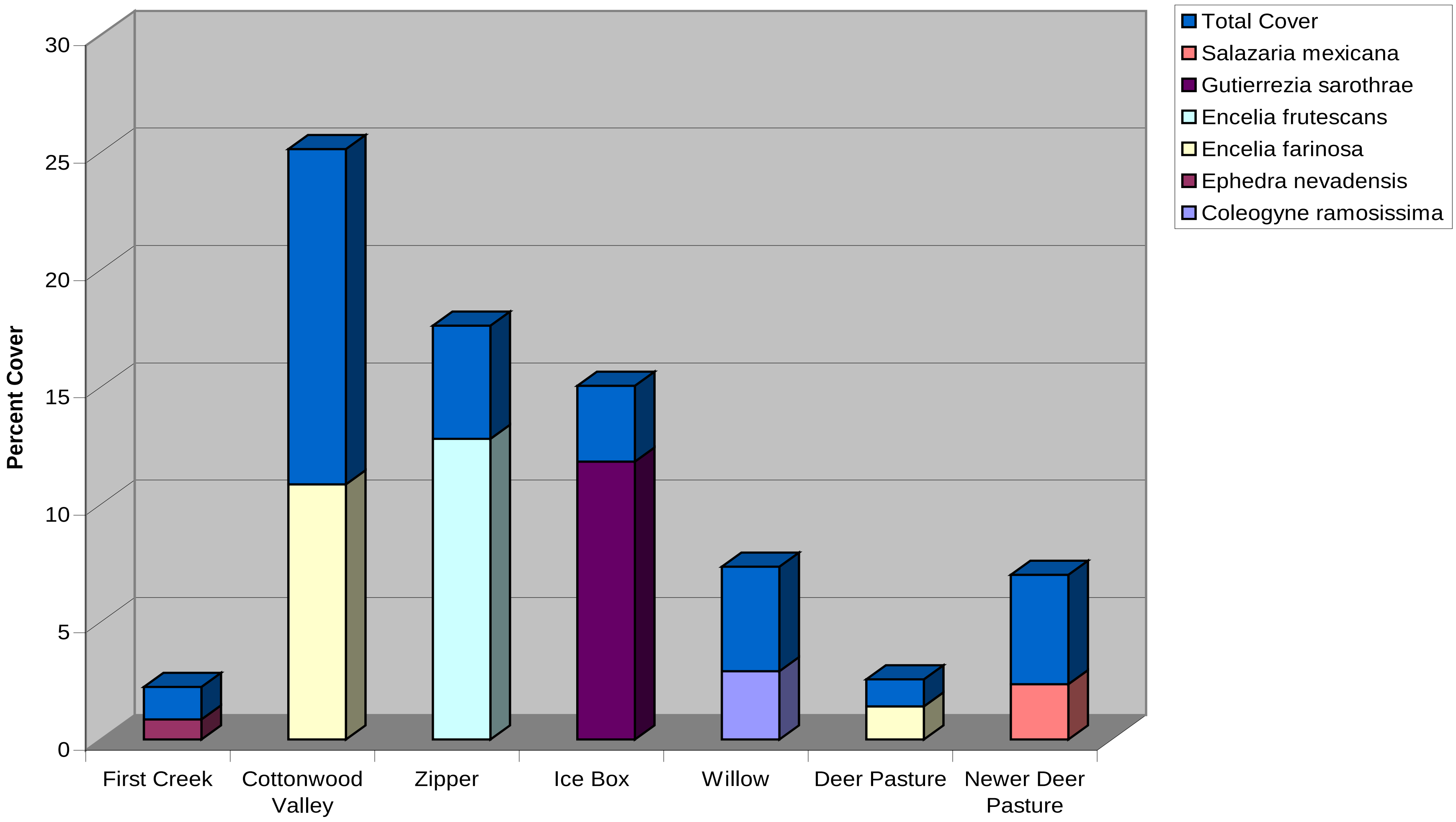
The species composition at the burned sites has a higher degree of evenness then the undisturbed sites. The degree of evenness is determined from a visual comparison of the slopes at each site. The proportional abundance is a ranking of each species in its relation to the other species at the site.

Figure 6: Proportional Abundance for all Species at each Unburned Site



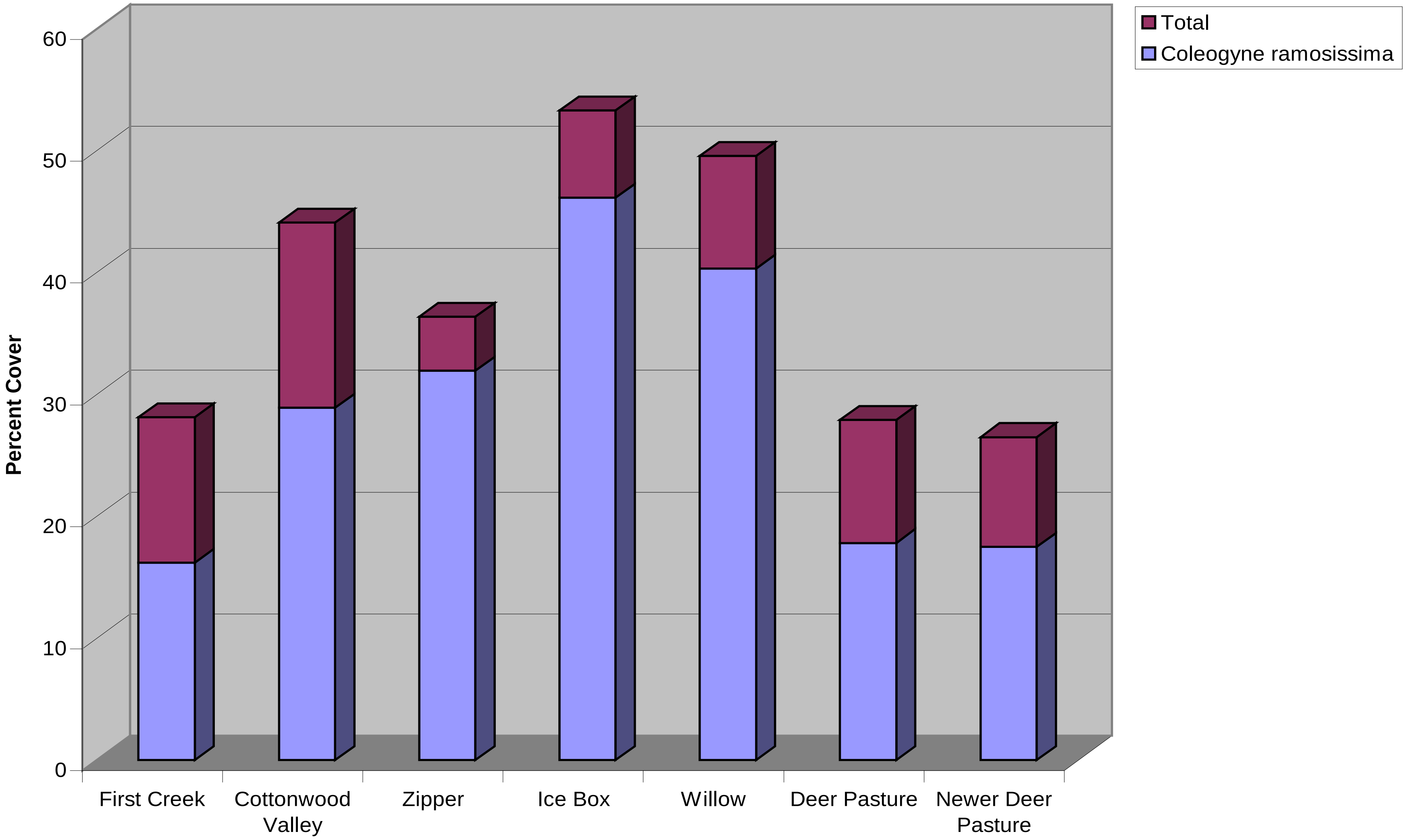
An abundant species as well as a low degree of evenness characterize the species composition at the unburned sites.

Figure 7: Vegetation Cover at Burned Sites
(Total Cover vs. Species with Greatest Cover)



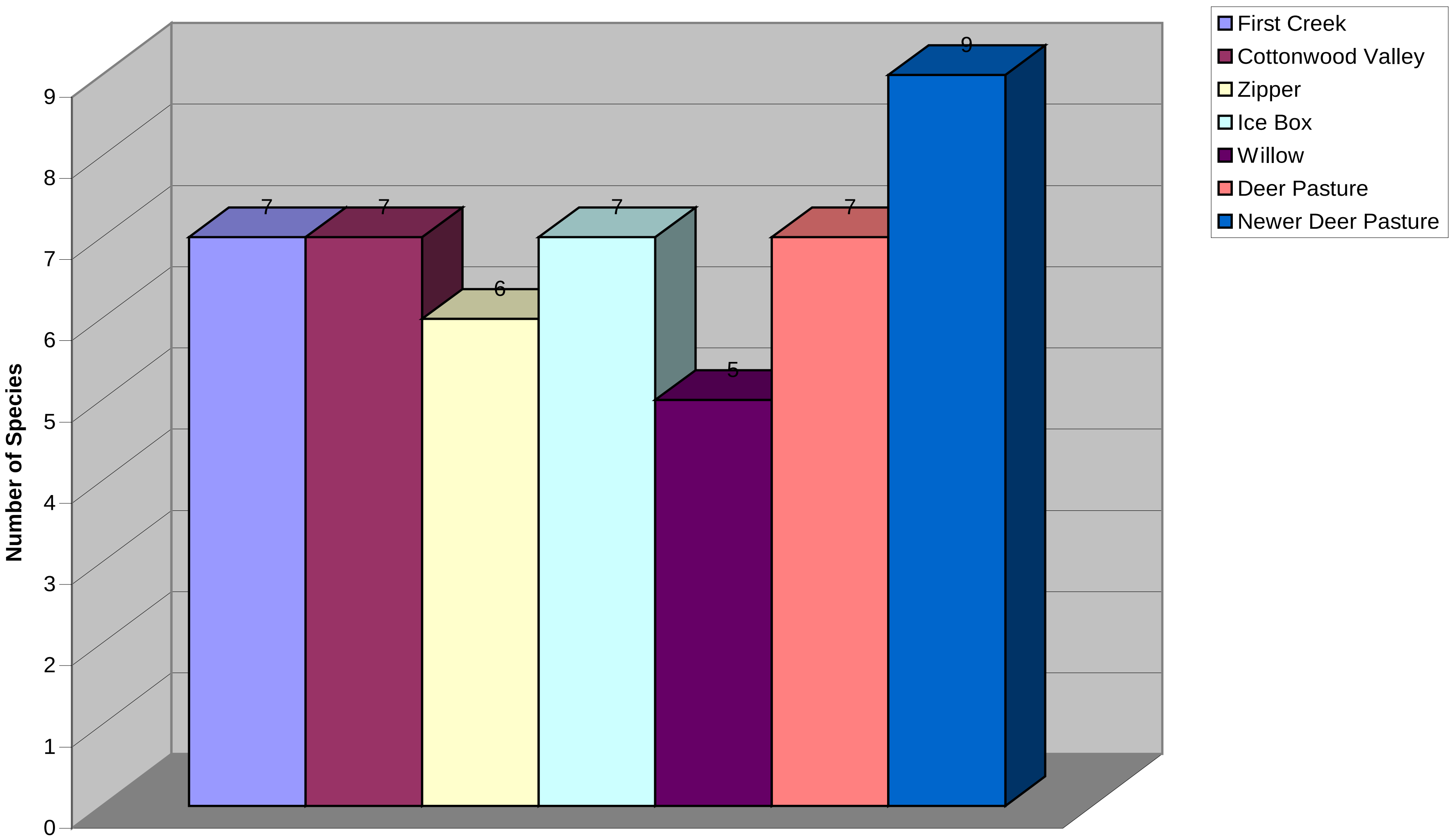
The dominant vegetation in burned environments varies greatly, with nearly each site having a different species dominate the vegetation cover. However, the dominant species does not imply the only species, the cover at most disturbed sites is comprised of many species.

Figure 8: Vegetation Cover at Unburned Sites (Total Cover vs. Species with Greatest Cover)



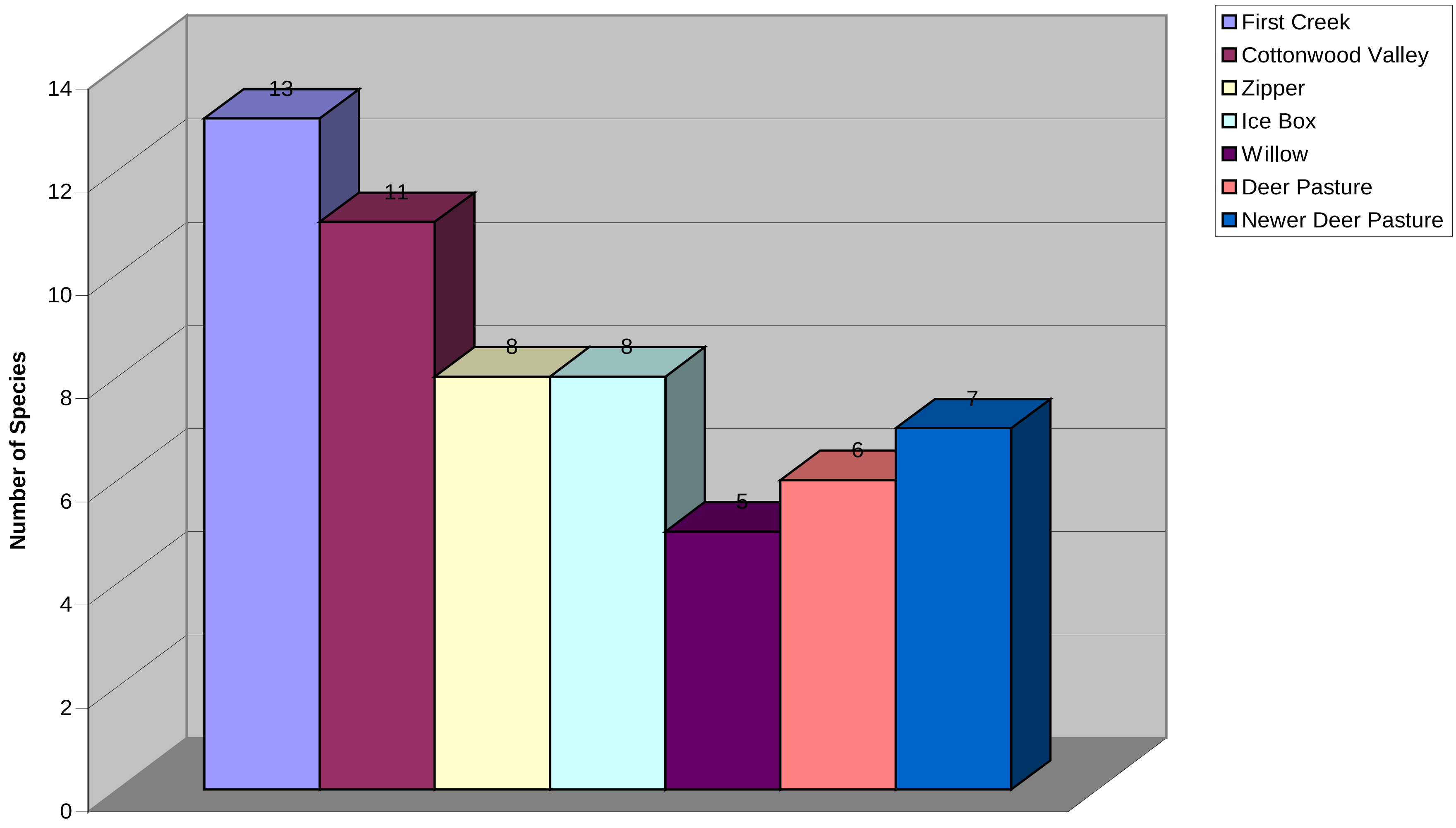
The unburned land is dominated by nearly monospecific stands of *Coleogyne ramosissima*. This leaves a minimal amount of resources for other species.

Figure 9: Species Richness in Burned Sites



Areas that have been burned recently show similar results in species richness. These burned sites also had many of the same species in common. The species at these sites are profiting from newly available habitat.

Figure 10: Species Richness in Unburned Sites



Areas that have remained relatively undisturbed can have varying characteristics, such as species richness. For instance, First Creek which has 13 different species, this is more than double both Willow and Deer Pasture.

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