Effect of Hydromulch and Fire Intensity on Post-Fire Chaparral:

A Griffith Park Case Study

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Question: Does hydromulch as a post-fire erosion mitigation treatment affect vegetation recovery in a chaparral ecosystem?

Location: Griffith Park, Los Angeles, California.

Methods: Vegetation sample transect plots were marked at two separate locations within the park, one to which hydromulch was applied, and one to which it was not. At the two locations, we selected one transect plot each of high and low burn severity, and species and number of individuals were sampled. The heights and widths of several indicator species were also sampled. Paired t-tests were used to test our hypothesis.

Results: Species diversity was found to statistically insignificant when comparing hydromulched to non-hydromulched areas. Plant density was found to be statistically significant with greater plant density found in non-hydromulched area. Plant growth, in terms of height and width, was found to have no conclusive trends or differences between hydromulched and non-hydromulched areas.

Conclusions: While species diversity was not statistically significant, the p-value was very close to being significant, signifying that a larger sample might have yielded a statistically significant result. The species diversity seemed to converge over time, as the number of herbaceous annuals reduced in the low fire intensity/non-hydromulched transect. The statistically significant higher plant density in non-hydromulched area signifies that hydromulch acts as a physical barrier, impeding vegetation recovery. Therefore, policymakers should be aware that hydromulch will reduce initial plant density. The plant growth data was inconclusive, because a random sampling of individuals does not account for individual growing conditions and varying germination times.

Nomenclature: Jepson Manual, Hickman (1993)

Keywords: species diversity, succession, disturbance

Introduction:

Wildfires are common in the chaparral communities of Mediterranean ecosystems. Seven of nine brush-dominated counties in southern California have experienced a significant increase in fires per decade according to U.S. Forest Service data (Keeley 1999). As development continues to encroach on wildlands, effective mitigation techniques to protect values at risk downstream are critical. Much research has been done on fire ecology in general, but there is a need for more information on the impact erosion mitigation strategies have on vegetation recovery. This study will explore the relationship between these factors utilizing the case study of the May 8th, 2007 fire at Griffith Park in Los Angeles, California.

California chaparral vegetation is characterized by herbs, shrubs, and grasses in elevations ranging from 300-1500 meters and occurs in each of the five Mediterranean climates zones of the world (Barro and Conard 1991). Typically comprised of steep terrain and shallow soils incapable of holding water, a wet, winter growing season is followed by summer drought. Since wildfires are common in several of these regions, fire features significantly in the evolution and ecology of the flora (Montenegro 2004). Frequency of fire coupled with soil type, exposure and altitude determine species diversity. Mature chaparral is even-aged, and consists of few seedlings or herbs beneath the canopy level (Keeley and Keeley 1981). Shrubs are evergreen and sclerophyllous and reach heights of 2-4 m in mature chaparral (Hanes 1977 in Keeley 1987).

For the purposes of this study, species are categorized according to their response to fire. Woody species range from those that germinate only from seed (obligate seeders), to those that regenerate only by resprouting (obligate resprouters), with some being capable of both (facultative seeders). The life cycle of obligate seeders is highly fire-dependent (Keeley 1986 in Montenegro 2004). Seeding plant species can persist after complete burn due to extensive seed banks that accumulate in the soil between fire intervals (Gill 1981), and are characterized by shallow fibrous root systems (Bell 2001). Obligate resprouters, however, can only persist if the below ground portion of the plant survives, so deeply penetrating root systems and thick bark are common (Gill 1981). The proportion of resprouters in California chaparral is typically 44-50% and 50-55% for seeders (Bell 2001). Keeley and Keeley identify four classifications of herbaceous flora: generalized herbaceous perennials, generalized annuals**—**both present before and after fire, specialized “fire annuals” and specialized “fire perennials”**—**present only after fire (1981)**.** Germination of fire-dependent species can be triggered by chemicals form charred wood or smoke (de Lange & Boucher 1990, Brown 1993, Keeley 1994, Dixon et al. 1995 in Montenegro 2004). Herbaceous annuals and perennials germinate from seeds as opposed to resprouting.

Ecological succession after fire takes a particular course; following disturbance diversity tends to peak early, usually in the first year (Guo 2003, Keeley 1981, Tyler 1995). This is the only time that all four temporary-cover groups described above exist concurrently (Keeley and Keeley 1981). Substantial seedling establishment occurs during the first several years following fire, highlighted by an abundance of herbaceous annuals and perennials (Keeley and Keeley 1981). Many studies have found that decades can pass before some species return (Sampson 1944; Sweeney 1956; Keeley *et al.* 1981; Keeley and Keeley 1988 in Tyler 1995). Guo postulates that, “human impacts may have led to a dramatic increase in the diversity and biomass of short-lived plants, especially annuals (including many exotics) and herbaceous perennials” (2003).

Fire intensity can significantly impact landscape and vegetation response. The Department of the Interior's Burned Area Emergency Rehabilitation (BAER) process handbook categorizes fire intensity into low, moderate, and high, determined by the diameter of branches completely burned (Davis & Holbeck 2001). A 1991 study found that intensity can "profoundly modify seedling production" after fire (Moreno & Oechel). Seeding plants can thrive in moderate intensity fires, while resprouting plant recovery has been shown to have an inverse relationship to intensity (Keeley 1978). Another study reports that maximum seedling abundance occurs at low fire intensity (Tyler 1995). This study includes sites of high and low fire intensity.

A subsurface hydrophobic soil layer can be formed during a wildfire, which can reduce water storage capacity by 20 times or more (Rice 1974; Wells 1981 in Barro and Conard 1991). This layer reduces infiltration, promotes overland flow (Wohlgemuth 2006) and makes slopes highly susceptible to erosion (Barro and Conard 1991). A 1985 study found that "water yield doubled from unburned to moderately burned watersheds and was nine times greater on intensely burned watersheds. Sediment production nearly tripled from moderately burned to intensely burned watersheds" (Riggan in Barro 1991). Robichaud reports threefold erosion increases after fire compared to undisturbed ecosystems (2000). The first year following fire is the most dangerous time for erosion, so a prompt management response before the first rain of the season is essential.

Hydromulch describes a range of products that are applied to hillslopes in order to prevent the loss of sediment and to increase the infiltration of precipitation, reducing the amount of overland flow that occurs during a rain event. It was originally used to stabilize slopes disturbed by road building, fill slopes, and other construction (Moglen 2005). The composition of hydromulch has evolved from simply mulch to a high-tech compound produced in "numerous combinations of tackifier, polymers, bonded fiber, seeds, etc" (Moglen 2005). The primary constituents of hydromulch are paper, wood chips, wheat and rice straw, jute, and natural and synthetic fabrics (Robichaud 2006). Typically it is only used to protect "high value resources, such as municipal water sources, water quality, habitat, roads, structures, and sensitive cultural sites" (Moglen, 2005). Limited research exists on how hydromulch affects vegetation recovery.

Methods

Study Area:

Griffith Park in Los Angeles, California is the second largest urban park in the United States. It is comprised of primarily chaparral vegetation. On May 8, 2007, a fire burned 800 acres of the park. The Griffith Park Fire Management Team utilized aerial hydromulch to 479 of the burned acres to reduce sediment flow off of the slopes. A hydromulch compound that consisted of wood and other vegetative fibers, organic guar gum tackifier, and water was used. It did not include seeds of any kind.

Setting Up the Transects:

Five transects were chosen to compare re-growth in hydromulch:

1. hydromulch low fire intensity
2. hydromulch high fire intensity
3. non-hydromulch low fire intensity
4. non-hydromulch high fire intensity
5. control unburned, non-hydromulch

The location of transects were determined using ArcGIS software. Data from the Griffith Park Project eRoom that had been gathered from previous studies was downloaded into the program, and maps were created using ArcMap.

Map 1 shows the locations of high and low fire intensity from the May 2007 fire in Griffith Park. It was created by importing the Griffith Park map shapefile into ArcMap, importing the fire intensity shapefile into ArcMap, and transposing the fire intensity shapefile on top of the map shapefile. The red areas show high fire intensity and the green areas show low fire intensity.

To control for aspect, Map 2 was created by transposing the aspect shapefile over the map shapefile. All non-south facing slopes were then colored blue and all south facing slopes were colored yellow. To determine site locations, Map 2 was transposed over Map 1 to create Map 3. All the light red areas are south facing high fire intensity slopes and all the light green areas are south facing, low fire intensity slopes. Six south facing points were then chosen as potential sites for transects 1 through 4, three in the high fire intensity areas and three in the low fire intensity areas. Another point was chosen where no burning had occurred to set up the control transect. The GPS coordinates of these points were then recorded in degrees minutes seconds. (See Table 1 for these point locations)

Because there was no available hydromulch mapping data, the first four transect sites had to be decided upon in the field. Each of the six potential sites was visited to determine whether or not it was hydromulched. The exact point locations were found using a GPS unit. Points 1 and 2 turned out to be hydromulched, while points 3 through 6 were not hydromulched. Points 1 through 4 were chosen as the final locations for the transects because their slope was more similar to each other than points 5 and 6.

Each transect was 1 m by 30 m, and was marked off using 2 wooden dowels. For each transect, 1 wooden dowel was placed at the GPS location recorded off of the map. This way, bias in choosing the location of the transect was eliminated because the exact location was chosen before the site was visited. The second wooden dowel was placed 30 m downslope of the first wooden dowel, and the GPS coordinates were recorded. Photographs were then taken at the both ends and at the midpoint of each transect.

Sampling:

To measure vegetation growth, Griffith Park was visited four times over a two-month period. During each visit, the number of individual plants was counted, and plant height and width was measured for the first four transects. Because transect five was the control plot, the plants in it were not counted or measured. Instead, the species names of the plants were recorded to compare the species diversity of the chaparral in the control plot to the four experimental plots.

At each transect, a tape measure was strung taught between the two dowels and tied at each end. Eight square meters, in 1 square meter intervals, were chosen at random along the tape measure. The intervals were outlined by a 1m by 1m quadrat made out of PVC pipe. Each 1m by 1m quadrat was divided into four, equal .5m by .5m grids. The measurements were taken within these quadrats.

To ensure that the locations are random, a statistically random number generator was used before the visit. Numbers 1 through 30 were inputted into the generator. The generator put these numbers in a random order. The first eight numbers that appeared in the randomly generated list were chosen as the eight locations along the tape that the quadrats will be placed. For example, if the first eight numbers that are listed are 4, 15, 8, 27, 22, 11, 3, 21; the midpoint of one edge of the quadrat was be placed at 4m, 15m, 8m, 27m, 22m, 11m, 3m, and 21m respectively.

Within each quadrat, the number of plants were counted and recorded by species. Dead plants were not included in this count. In addition, the height and diameter of indicator plant species were measured. Indicator species were chosen on the basis that they were prevalent in more than one transect. The height was measured from the base of the plant to the tip of the highest branch. To measure the width, the diameter of the emerging or resprouting branches was determined.

Once all the plants in the first 1 m by 1 m quadrat were counted, the quadrat was shifted along the string to the next location, and the counting, measuring, and recording was repeated. This continued until all eight quadrats have been measured. Once data was collected in 1 whole transect, the steps were repeated for the remaining transects.

Data Analyses:

Data was analyzed in three different categories: species diversity, plant density, and growth of indicator species over time.

A paired t-test was used to find the p-value to determine the statistical significance of the species diversity and plant density results. A p-value of less than 0.05 was considered significant. Results were compared in hydromulch versus non-hydromulch transects, controlling for high and low fire intensity. Each t-test had an n value of 4, representing the four separate days that data was collected.

Indicator species were chosen for growth analysis if they were found in more than one of the four transects. For each species, the height and width values for in transect were averaged for each sampling date. The standard deviations of these values were also calculated. The averages were then plotted on a line graph to analyze growth patterns over time.

Results

Species Diversity:

Figure 1 shows the differences in total number of species between hydromulched and non-hydromulched areas. The species diversity is greater in the non-hydromulched transect in both high and low fire intensity areas. In the high fire intensity area, the non-hydromulched transect has 2 more species than the hydromulched transect. In the low fire intensity area, the non-hydromulched transect had 11 more species than the hydromulched transect.

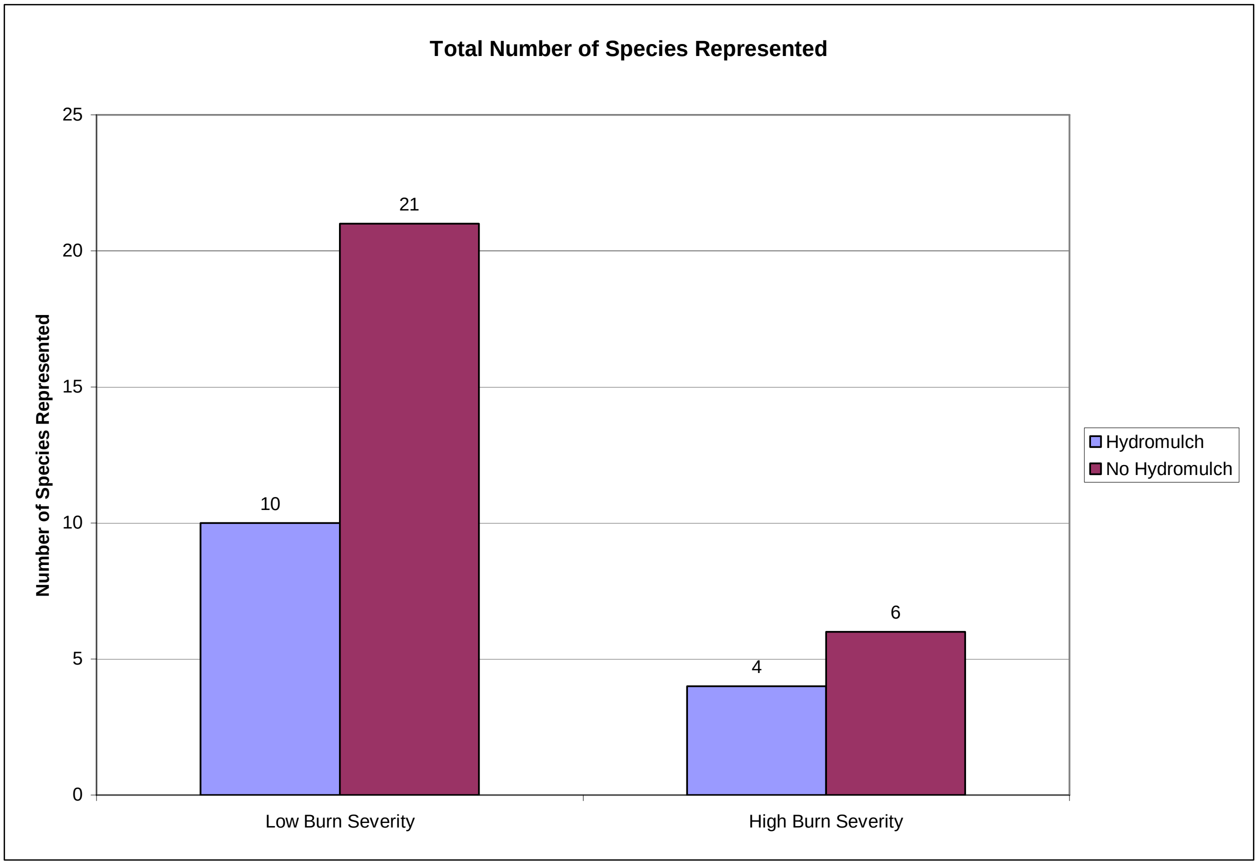


Figure 1

Figure 2 shows the number of species in each transect represented over time. The low fire intensity/ non-hydromulched transect hosts the greatest number of species throughout the two-month time period, with a peak during the first sampling date. It decreases from 17 species to 6 species during this time. The high fire intensity/non-hydromulched transect hosts the second greatest number of species throughout the entire time period. It decreases from 6 to 5 species during this time. The species diversity in the low fire intensity/ hydromulched transect had a constant species count of 6 over the two-month time period, aside from a minor dip to 5 species on May 4th. The high fire intensity/hydromulched transect had the least number of species over the entire sampling period. Over the two months, the species count increased from 2 to 3, with a dip to 1 species on May 4th. Over time, the species diversity in all four transects seem to be converging.

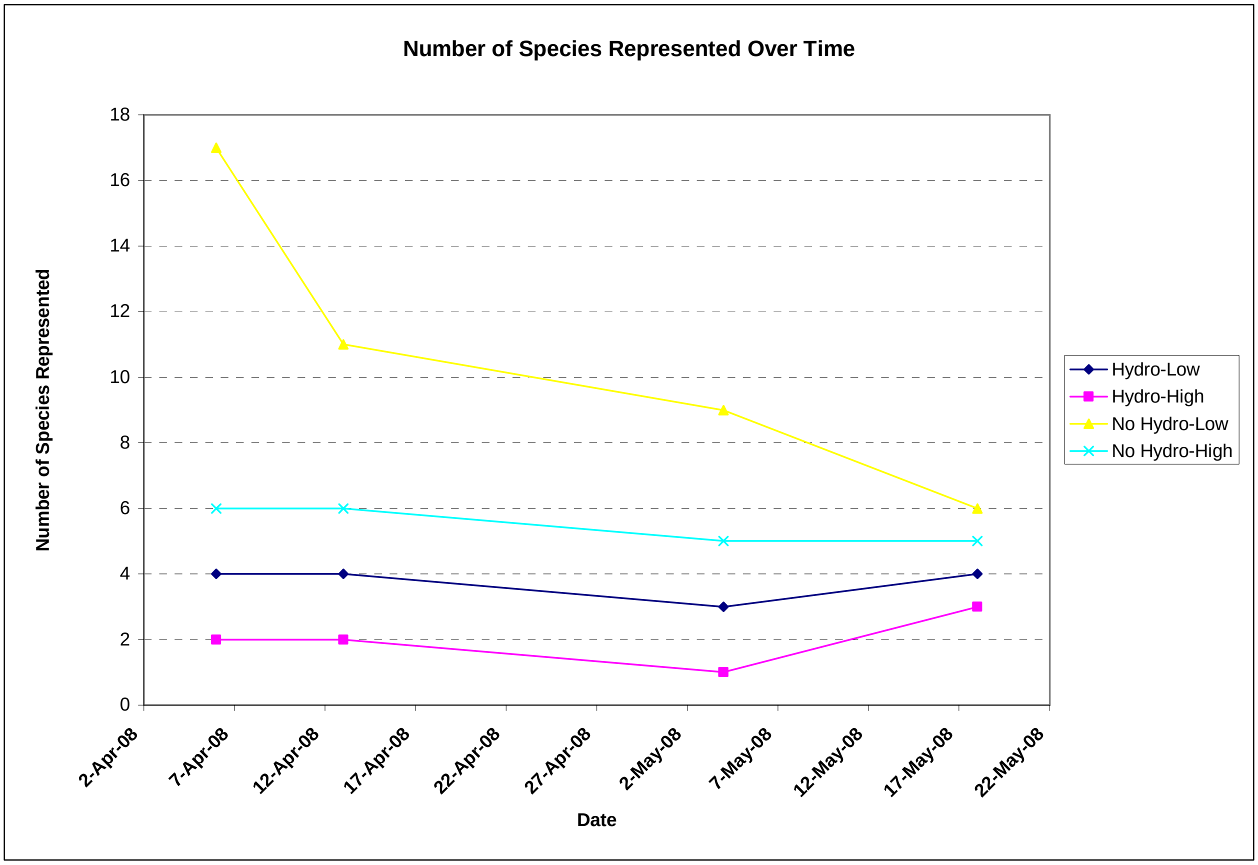


Figure 2

It was found that there was no statistical difference in the species diversity between the hydromulched and non-hydromulched transects in high fire intensity areas (p=0.4361). Although it came close, there was also no statistical difference in species diversity between the hydromulched and non-hydromulched transects in low fire intensity areas (p=0.0536). Therefore, the null hypothesis, that hydromulch does not have an impact on species diversity, cannot be rejected.

Plant Density:

Figure 3 shows the difference in total number of plants between hydromulched and non-hydromulched areas. The plant density is much greater in the non-hydromulched transect in both high and low fire intensity areas. In the high fire intensity area/the non-hydromulched transect has 162 more individual plants than the hydromulched transect. In the low fire intensity area, the non-hydromulched transect had 310 more individual plants than the hydromulched transect.

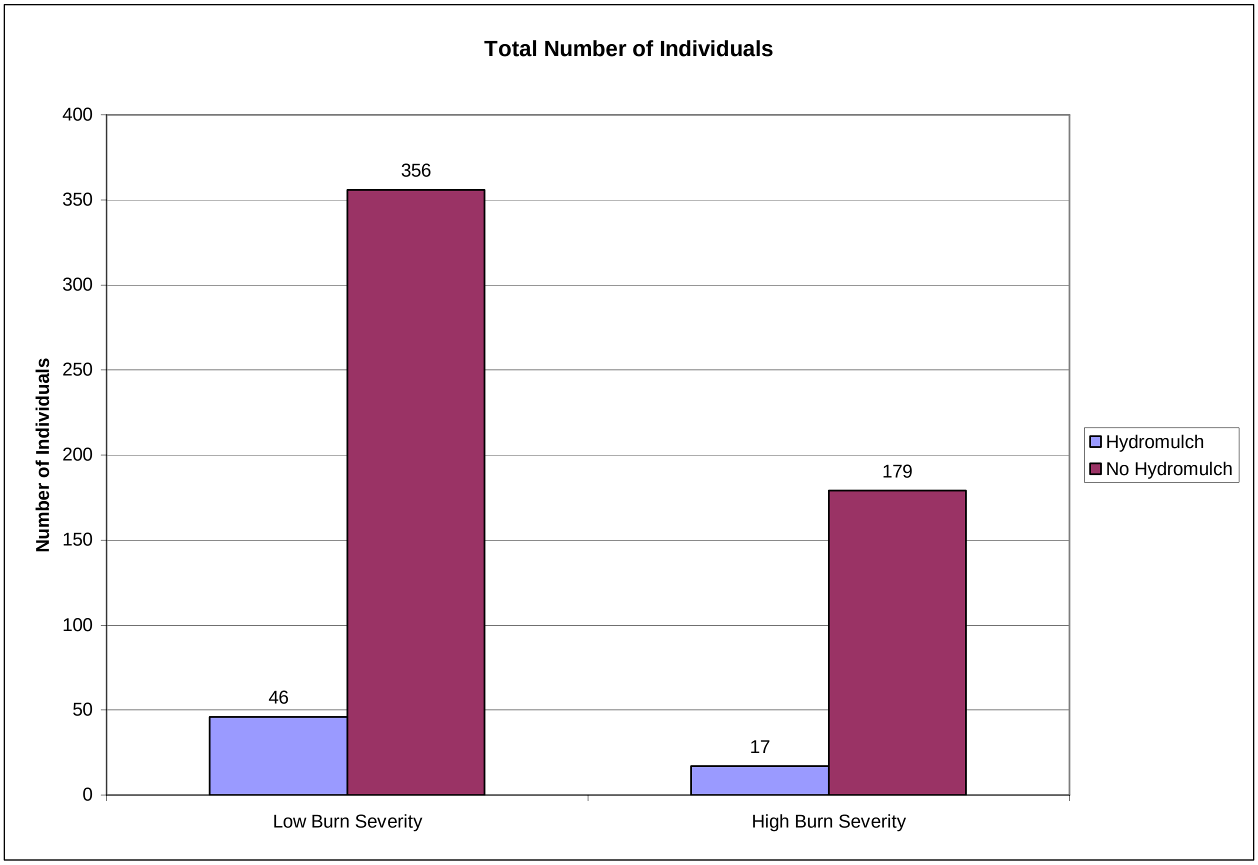


Figure 3

Figure 4 shows the number of individual plants in each transect represented over time. The low fire intensity/non-hydromulched transect hosts the greatest number of individual plants throughout the two-month time period, with a peak of 132 plants on April 13. It then decreases to 31 plants by May 18. The high fire intensity/non-hydromulched transect hosts the second greatest number of individual plants throughout the two-month time period. It decreases from 70 to 31 plants during this time. The plant density in the low fire intensity/hydromulched transect had a constant plant count of 11 over the two-month time period, aside from a minor peak to 17 plants on April 13. The high fire intensity/hydromulched transect had the least number of individual plants over the entire sampling period. Over the two months, the plant count increased from 6 to 8, with a dip to 1 individual plant on May 4th. Over time, the plant density in the two non-hydromulched transects seem to converge, and the plant density in the hydromulched transects seem to converge.

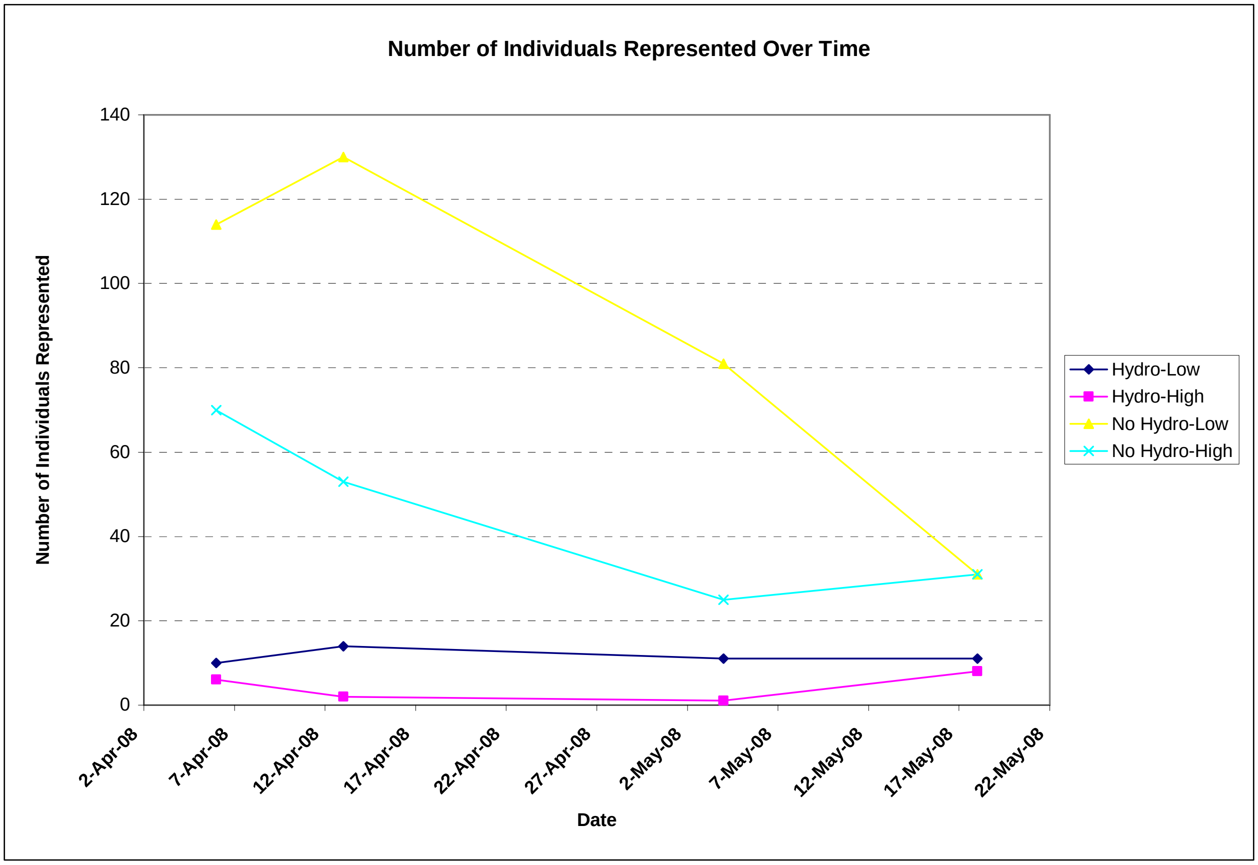


Figure 4

It was found that there was a statistical difference between in plant density between the hydromulched and non-hydromulched transects in low fire intensity areas (p=0.0366). The plant density difference between the hydromulched and non-hydromulched transects in high fire intensity areas were found to be very statistically significant (p=0.0282). Therefore, the null hypothesis, that hydromulch does not have an impact on the plant density, can be rejected.

Plant Growth:

Lotus strigosus

Lotus strigosus was only found in the non-hydromulched transects. The average height (Figure 5) and width (Figure 6) growth was greater in the high fire intensity transect than in the low fire intensity transect for the entire study period. The standard deviation of this average was also greater in the high fire intensity transect than in the low fire intensity transect for the entire study period. The high and low fire intensity transects follow a similar growth pattern, with both height and width peaking on April 13 and reaching a low on May 4.

Encelia californica

Encelia californica was only found in the non-hydromulched transects. The average width (Figure 8) was greater in the high fire intensity transect than in the low fire intensity transect for the entire study period. The standard deviation of this average was also greater in the high fire intensity transect than in the low fire intensity transect for the entire study period. The high and low fire intensity transects follow a similar average width growth pattern, peaking on May 18 and reaching a low on April 9. The average width is greater in the high fire intensity transect than in the low fire intensity transect for the entire study period, except on May 18. The standard deviation of this average was also greater in the high fire intensity transect than in the low fire intensity transect for the entire study period.

The average height (Figure 7) in the high and low fire intensity transects do not follow the same height growth pattern. The high fire intensity transect peaks on April 6 and reaches a low on April 13 before it increases again, while the height growth in the low fire intensity transect increases over time.

Hazardia squarrosa

Hazardia squarrosa was only found in the non-hydromulched transects, except on May 4, when it was found in the low fire intensity/hydromulched transect. The average width (Figure 10) was greater in the high fire intensity/non-hydromulched transect than in the low fire intensity/ non-hydromulched transect for the entire study period. The standard deviation of this average was also greater in the high fire intensity transect than in the low fire intensity transect for the entire study period, except for May 4. The high and low fire intensity transects follow a similar average width growth pattern, decreasing slightly over time. The average width of the *Hazardia squarrosa* in the hydromulched transect on May 4 is greater than the average widths of the *Hazardia squarrosa* in the two non-hydromulched transects.

The average height (Figure 9) in the high and low fire intensity/non-hydromulched transects do not follow the same average height growth pattern. There is also no pattern in the standard deviation between the two transects. The high fire intensity transect height increases until May 4 an then begins decreasing, while the low fire intensity height decreases throughout the entire study period. The average height of the *Hazardia squarrosa* in the hydromulched transect on May 4 is greater than the average height of the *Hazardia squarrosa* in the two non-hydromulched transects.

Brassica nigra

Brassica nigra was found in all transects except for high fire intensity/non-hydromulched. The average width (Figure 12) was greatest in the high fire intensity/ hydromulched transect and lowest in the low fire intensity/hydromulched transect for the entire study period, except on April 13, when *Brassica nigra* was not found in the high fire intensity/ non-hydromulched transect. There was no pattern in the standard deviation among the three transects. The two low fire intensity transects follow a similar average width growth pattern, starting with a low on April 6 and peeking on May 18.

The average height (Figure 11) was greatest in the low fire intensity/non-hydromulched transect and lowest in the low fire intensity/hydromulched transect for the entire study period. There was no pattern in the standard deviation among the three transects. All three transects follow a similar height growth pattern, with a low on April 6 and a high on May 18.

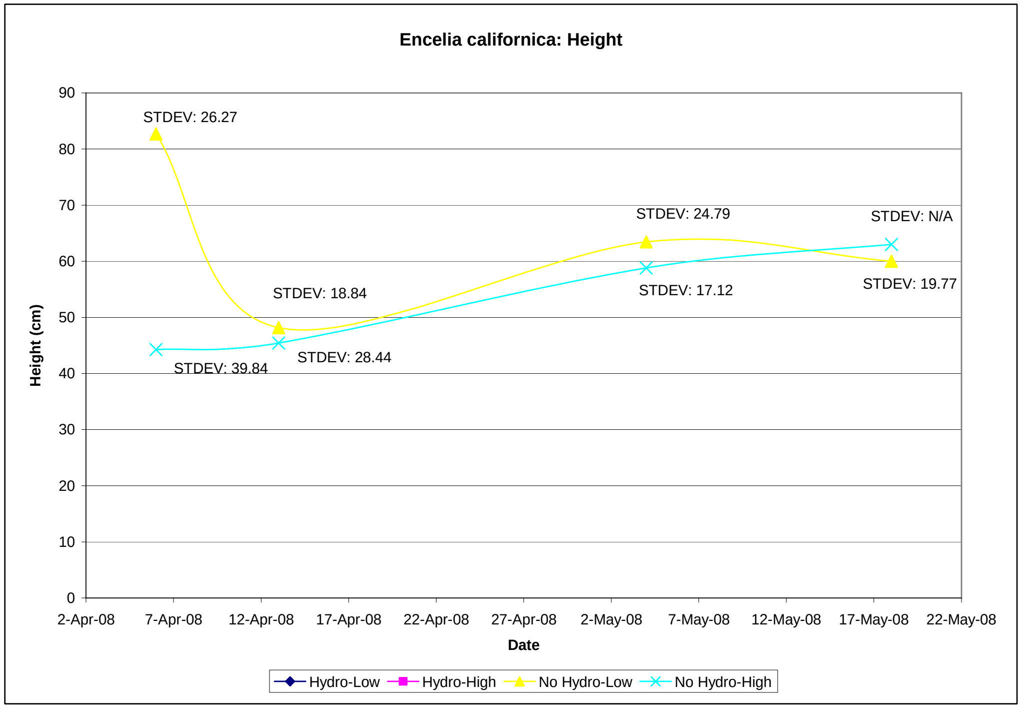


Figure 5

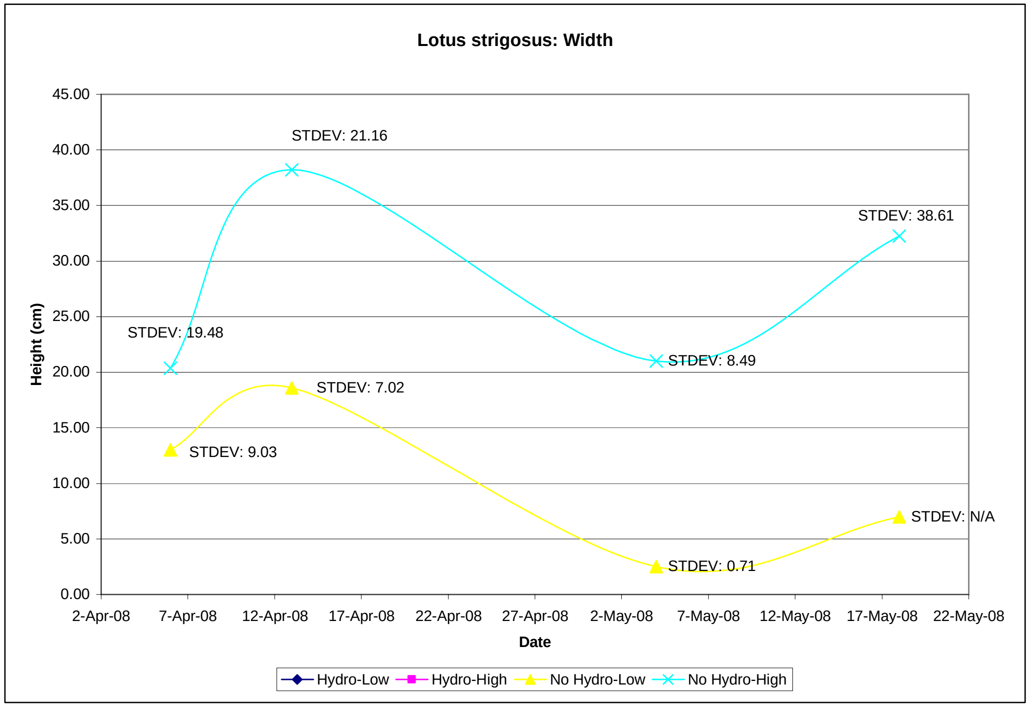
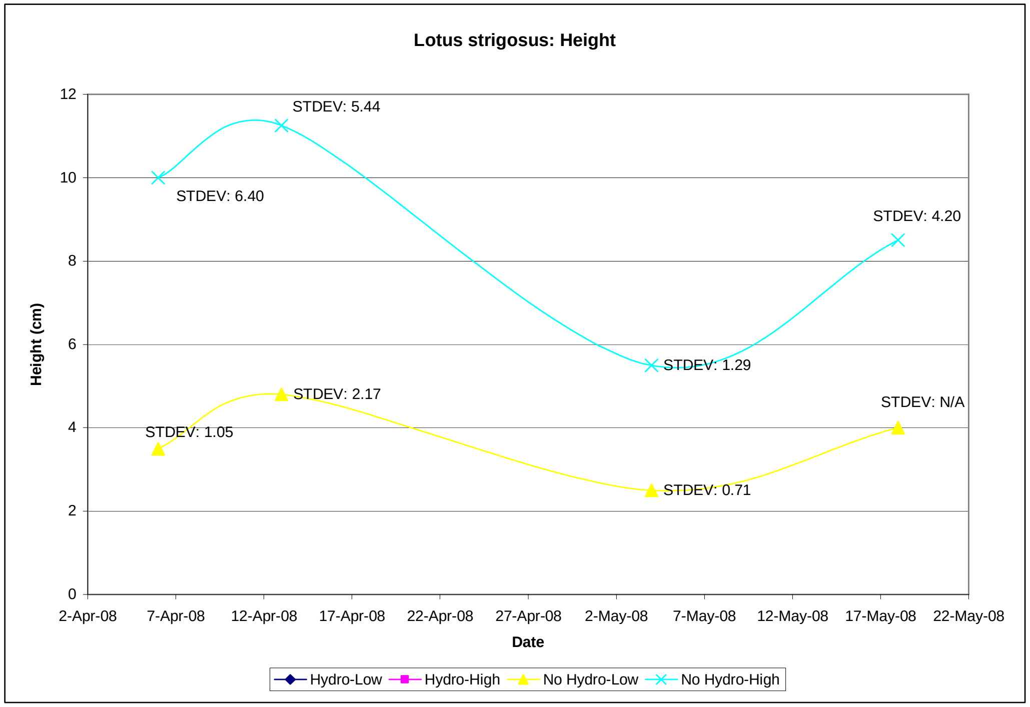


Figure 6

Figure 7



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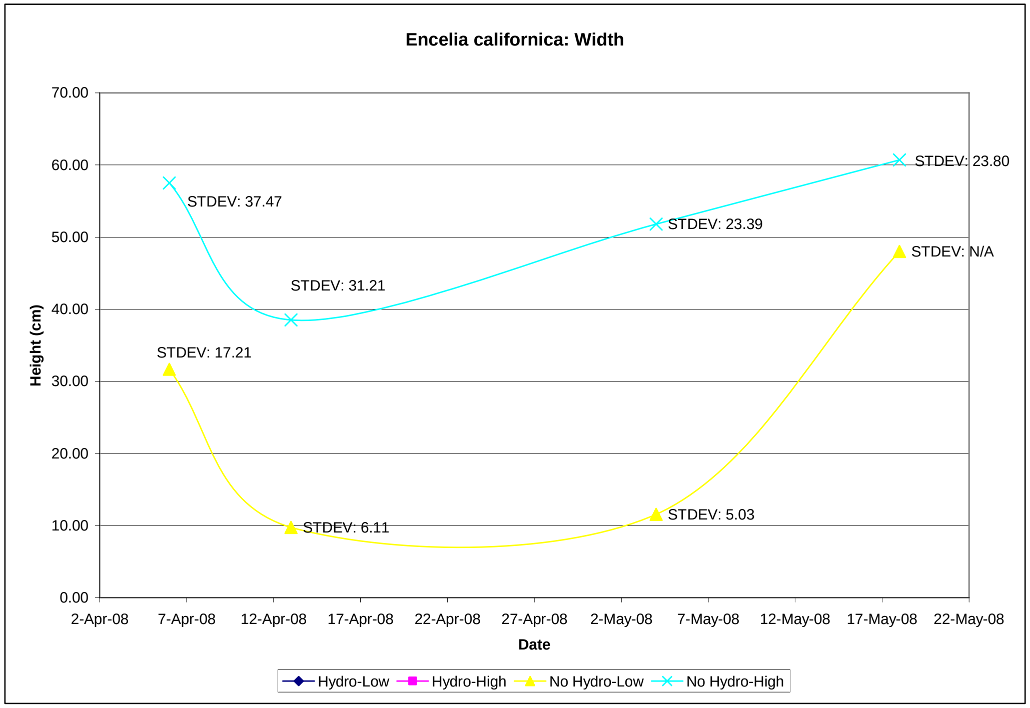


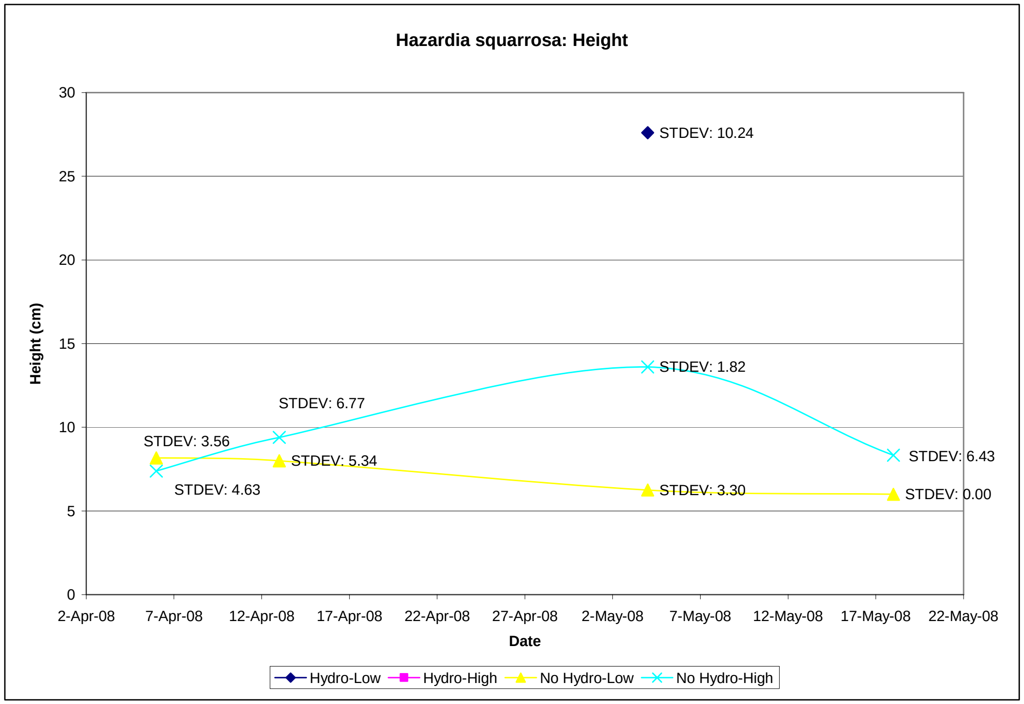


Figure 9

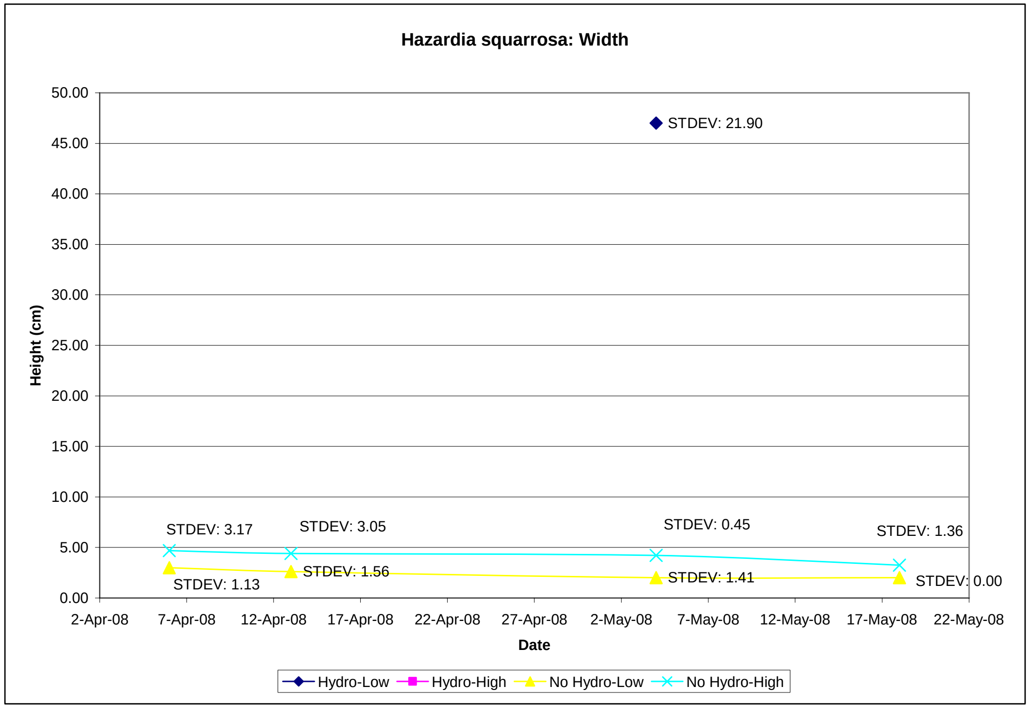


Figure 10

Figure 11

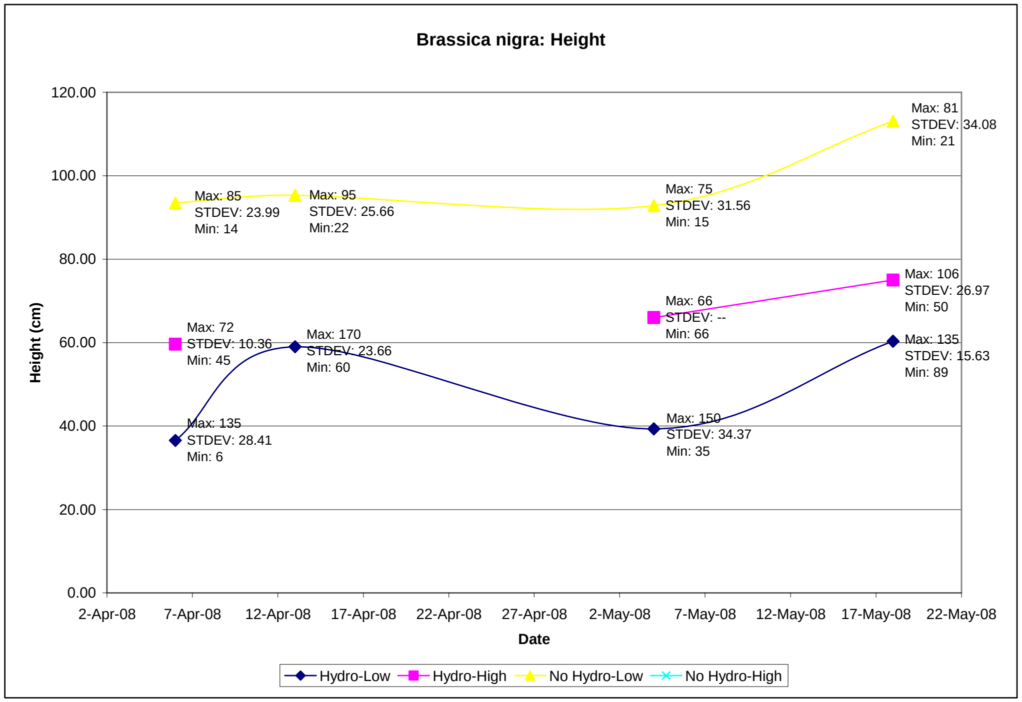
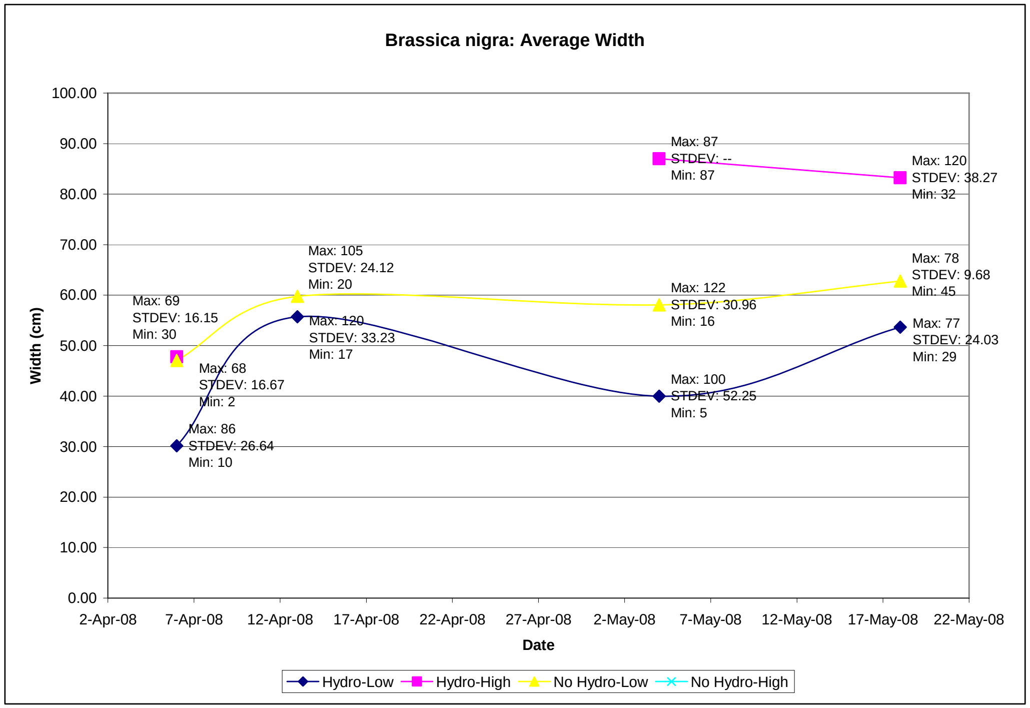


Figure 12



Discussion

As seen in Figure 1, a greater number of species were found in the non-hydromulched transects compared to the hydromulched transects of the same fire intensity. While this seems to point to hydromulch dampening species diversity, a statistical analysis shows that there is no significant difference between the species diversity of hydromulched and non-hydromulched transects of the same fire intensity. It is important to point out, however, that in low fire intensity, the p-value was only 0.0036 away from being statistically significant. Our data collection was based on 8 square meters randomly chosen out of the 30 square meter transect for each visit. Therefore, it is possible that the difference in species diversity of hydromulched and non-hydromulched transects in low fire intensity might have been statistically significant if the sample had been larger.

As seen in Figure 2, the species diversity of the transects converged over time. The low fire intensity/non-hydromulched transect began with a much higher number of species than the other three transects, yet over time decreased rapidly to converge with the other transects. This convergence may be related to the number of herbaceous annuals that existed in the low fire intensity/non-hydromulched transect. In all four transects, the number of species according to type was comparable, except for herbaceous annuals. The low fire intensity/non-hydromulched transect had a much higher number of herbaceous annuals to begin with than any other transect. Over time, the herbaceous annuals in this transect decreased the most, contributing to the apparent convergence. This observation is supported by the idea that diversity tends to peak in the first year (Guo 2003, Keeley 1981, Tyler 1995).

The fact that the herbaceous annuals are the most abundant in the low intensity/non-hydromulched transect may be explained by the following two reasons. First, herbaceous annuals are seeders and would, therefore, be better able to thrive in low fire intensity areas due to less damage to the seed bank. Second, a non-hydromulched area does not present a physical barrier to plant growth, giving these plants an advantage. The rapid decrease of the herbaceous annuals over the course of the two-month study period can be attributed to the seasonal cycle of the chaparral ecosystem. Chaparral ecosystems are characterized by lush greenery during the spring. As summer approaches, the heat and lack of water force many plants to go dormant. This is especially true for non-woody plants, such as herbaceous species, which are less hardy and drought tolerant. The data shows that number of woody plant species stayed relatively constant in all transects, as the herbaceous annuals rapidly decreased over time.

While there are many fears about the effects of hydromulch on natural ecosystems, the data suggests that hydromulch does not adversely affect species diversity. According to this study, species diversity need not be a primary concern for policymakers in deciding whether or not to use hydromulch.

Figure 3 shows that the number of individuals in the non-hydromulched transects were much higher than those in the hydromulched transects. Statistical analysis showed this data to be significant. Therefore, it is possible to conclude that hydromulch reduced the capacity for vegetation to recover. Since species diversity was not statistically significant, we conclude that hydromulch inhibits vegetation recovery but cannot determine that it affects particular species. This significant finding can be explained by the fact that hydromulch poses a physical barrier, which increases resistance against a plant trying to break through the surface.

Figure 4 shows that abundance of individual plants spanned a very large range between the four transects on the first day of data collection. Abundance in non-hydromulched transects appeared to converge, and abundance in the hydromulched transects appeared to converge through the remainder of the study period. However, there is not a strong convergence between the hydromulched and non-hydromulched transects. These trends could be due to the fact that much of the abundance in the non-hydromulched areas was made up of annuals, which follow a seasonal pattern. Therefore, they may have already gone dormant and would therefore not be included in the count. The annuals in the hydromulched transects may not yet have reached dormancy, as there was much less competition for resources with so few plants.

When policymakers are exploring erosion mitigation strategies, they should take into account that hydromulch will decrease the initial plant density treated areas for the first year. Since one of the primary concerns of policymakers is slope stability and the safety of nearby man-made structures, more research needs to be conducted to determine which provides more stability: the presence of hydromulch or the initial profusion of plant growth in non-hydromulched areas.

The data of the growth (height and width) of several indicator species is inconclusive. There does not seem to be any discernable pattern across the species that indicates whether or not hydromulch affected individual plant growth. Moreover, the standard deviations of data points are very great, signifying that there are too many variables to simply average the data to obtain data points. These variables include varying germination times for individuals and individual growing conditions. From the data, it seems that individuals of a particular species cannot be treated as a group to track growth over time. For future research, it would be beneficial to tag individuals and monitor their growth over time.

Although not addressed directly in this study, it is important to note that make-up and application of hydromulch can be considerably variable, and can therefore significantly impact post-fire re-vegetation. Primary constituents of hydromulch range from paper and wood chips to straw or even synthetic fabrics. The matrix formed is dependent upon the combination of these constituents (ie. long, coarse straw fragments cannot interlock as tightly as paper and allow for a less continuous surface matrix) in conjunction with the amount and makeup of tackifier used. A porous surface is easier for fragile seedlings to penetrate than a densely packed matrix. Wood, vegetative fibers, and organic guar gum tackifier were used at our study site. Utilizing larger fibers of any type would likely have impacted the ability of vegetation to recover. Additionally, simple observation of the study site revealed a thick carpet of hydromulch. Decreasing the thickness, while still creating a continuous surface layer creates less of a barrier to impede vegetation recovery and may allow more light to pass through. Aerial hydromulching from helicopters fitted with slurry tanks is the most practical application technique for mountainous burn areas, but slope variation will cause uneven application in a helicopter flying at a constant speed. A further study comparing vegetation recovery among different compositions and thicknesses is needed to find the optimal application for chaparral ecosystems. Hillslope grade, climate, and vegetation makeup must all be considered in the process of selecting the appropriate technique and constituents for hydromulch.

A study conducted on a 2003 wildfire in San Diego County, California by Hubbert et al. examined the impact of hydromulch on vegetation recovery. Aerial hydromulch consisting of a wood and paper matrix and non-water soluble binder was used to prevent erosion. Similar management strategies, climate, and vegetation provide an opportunity for comparison to our study. This site is not subjected to as much disturbance as our study site, however. After the first growing season, Hubbert et al. found no apparent vegetation suppression due to hydromulch. This result conflicts with our analysis. One reason for the disagreement may be due to the prevalence of resprouters (which create interruptions in the hydromulch) in the San Diego study plots, while our plots had more seeder plants. Another difference may be the result of incomplete coverage in San Diego. Although 100% application was intended, actual mean value of coverage was 51%. The Griffith Park plots had 100% hydromulch coverage in all plots. This reinforces our view that once an optimal hydromulch application level for sediment erosion prevention is found, care should be taken to not to exceed this level for purposes of encouraging vegetation growth.

It is important to note that the length and timing of this study provides a definite disadvantage. The study was only conducted over a two month period, ending at the one-year anniversary of the fire. The brief length of the study made it difficult to find patterns or draw any conclusions on the growth of the individual indicator species. More time is needed to really see if hydromulch has an effect on plant growth, especially since *Brassica nigra* was the only species present every sampling time in both a hydromulched and non-hydromulched transect. However, the significance of the findings on species diversity and plant density can extend beyond the first growing season. Research has shown that the initial density and composition of herbs can be critical to establishing seed sources for future years (Barro and Conard 1991, Keeley et al. 1981). The continuous carpet of hydromulch may prevent new seeds from reaching the soil, and fire-responsive seeds that germinated but were unable to push through the surface during the first growing season may now be lost. High species diversity supports the biotic integrity of ecosystems, so the low density and diversity could have an impact. It is natural in chaparral vegetation for diversity to decrease over time. However, a starting point of 4 and 10 total species in high and low fire intensity hydromulched plots compared to 6 and 21 in non-hydromulched does not provide a satisfactory starting point. Returning to the study site after next season's rains will allow provide further insight into the status of the ecosystem recovery.

Because results reject the null hypothesis, that hydromulch has no effect on post-fire vegetation re-growth, alternatives to hydromulch as a form of large-scale erosion prevention should be considered. One alternative is artificial seeding of the burned area. A significant amount of research supports that seeding can have a detrimental effect on chaparral native plant species and that very specific conditions must be met for seeding to be effective (California Native Plant Society ????). Hydromulch, on the other hand, was not found to have an effect on chaparral species diversity in this study or in the past Cedar Fire study (Hubbert 2006), and has proven to provide adequate protection against erosion in past studies (Wohlgemuth, Robichaud). Therefore, it cannot be concluded that seeding is a better alternative.

Another alternative to hydromulch as a form of large-scale erosion prevention is a dry mulch such as straw mulch. No studies were found examining the effect of dry mulch on post-fire vegetation recovery, so effectiveness as an alternative to hydromulch can only be determined on the bases of erosion prevention and cost. Aerial hydromulching costs $2000 per acre while straw mulching only costs $750 per acre (Hubbert 2006). Moreover, in a comparison study of erosion prevention strategies, straw-mulched areas produced 63% less eroded soil than untreated areas, whereas hydromulched areas only produced 19% less soil than the untreated areas (Robichaud 2006). Based on these parameters, dry mulch seems to be the more effective form of erosion prevention. However, until further study is done on the impact that both dry mulch and hydromulch have on post-fire vegetation recovery, one cannot conclude which method is most effective from an ecological standpoint.

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