Rainfall, Fire, and Plant Abundance

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Introduction

The idea that rainfall increases plant abundance appears to be intuitive; after all, water is required for all natural life to thrive. Researchers have been studying the amount, duration, and seasonal patterns of rainfall for years, and have found that the answer to this question varies dramatically between regions and even between individual species[1,5,6,8]. Additional questions involve regions that have recently been involved in wildfires: does fire change plant diversity[2], or does fire merely encourage selection for species that germinate after fires[6]? Understanding these important questions helps aid conservation scientists in preserving natural wildlife and flora, which makes this area of science increasingly vital as the world faces difficult challenges, such as global warming.

Several studies have investigated the effect of fire on ecosystem diversity[2,4,5]; other studies have examined the effect rainfall has on plant diversity and abundance[1,8,9]. However, research has be very limited in examining the effect of these two important variables together. Many studies examining fire and plant biodiversity have taken place in Australia[3,7], which is a region with wide biodiversity and frequent wildfires[3,6,7,9]. Furthermore, there are countless Australian ecological records of rainfall, plant diversity, and fire history available online[11]. By accessing one of these datasets, we are able to provide a unique analysis describing the different effects rainfall has on plant abundance in regions that have or have not recently been involved in a wildfire.

The selected dataset describes three variables: above-ground plant abundance, seed abundance, and rainfall amounts. These abundance measurements only focused on the desert herb, *Trachymene glaucifolia*. Also known as wild parsnip, or wild carrot, *T. glaucifolia* prefers to grow in moist soil. However, the areas studied are in the center of the Simpson Desert, which varies in terrain from rocky outcroppings to bright orange sand dunes. This desert is a unique ecosystem that has been the subject of many studies. The selected dataset contained information about four sites: Field River, Carlo Shitty, South Site, and Main Camp. Each of these sites had both a unburned and burned location. The average rainfall measurements at these sites were similar, so much so that we could average the values at all four of these sites to get a more complete picture of the rainfall amount[14].

We predicted that species diversity and abundance will increase in regions that have just recently experience fires. In particular, we are interested in understanding the differences between sites that have or have not been burned, and hope to be able to draw information on these locations to hopefully draw conclusions that may strengthen our hypothesis that rainfalls increase plant diversity after fire. However, our results were inconclusive and warrant further investigation. Despite the inconclusiveness of the results, we believe that our findings may help contribute to the knowledge surrounding fires, rain, and plant diversity.

Methods

We accessed our data through the TERN AEKOS data portal[11] on February 8, 2017. The dataset contained information on rainfall measurements, above-ground plant abundance, and seed abundance for four different sites in western Australia. See *Figure 1* for a diagram depicting our general approach.

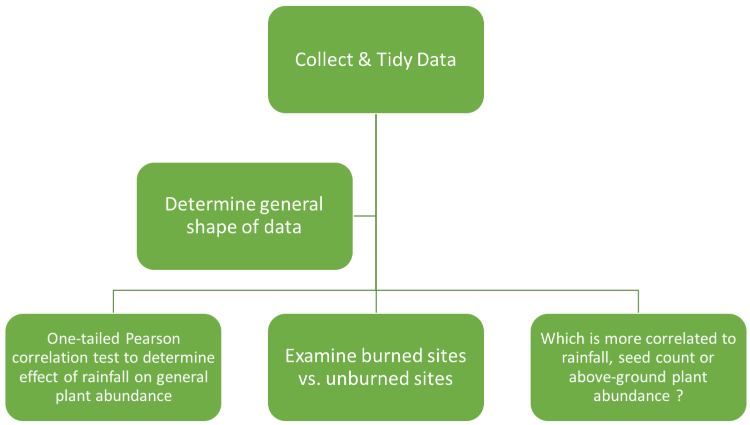

Figure 1: **General workflow of presented analysis**. After tidying the data,and examining the general shape, there were several different analysis tracks that we examined in order to determine the relationship between rainfall, plant abundance, and fire.

We analyzed our data using R version 3.3.2 (Sincere Pumpkin Patch), following the example of many other studies involving ecological datasets[1,2,5,9]. Our first step involved tidying the data using R packages that included tidyr (version 0.6.1)[12] and dplyr (version 0.5.0)[13]. After organizing the data into tidy formats, we decided that we would average together all of the values between sites that corresponded to the same time period in order to ease analysis. We created several different averages for each site that corresponded to the different correlation tests described below. After removing incomplete and missing data points, we averaged together the rainfall measurements at all four sites that corresponded to the same dates. We then averaged each site's measurements to create an overall picture of what the seed and above-ground plant abundance was over all four sites.

We proceed to roughly plot the data in order to determine its general shape. Since the general shape of the data was linear, we decided to conduct Pearson correlation tests. In addition, since we were only interested in a positive effect of rainfall on plant abundance, we decided to only use one-tailed tests.

We conducted the following correlation tests: (1) a general correlation test to determine if rainfall has an effect on total plant abundance; (2) a correlation test to test whether or not there is a relationship between total plant abundance, rainfall, and fire; and (3) separate correlation tests to determine if there is a relationship between either seed abundance or above-ground plant abundance, rainfall, and fire; this resulted in five general correlation tests. Following these correlation tests, we then ran two more determining the effect rain had on seed abundance and above-ground plant abundance in burned sites; this brought the number of correlation tests conducted up to 7.

We decided that multiple-test corrections would not be absolutely necessary, as the number of tests conducted was low enough. However, we did conduct a post-hoc false discovery rate (FDR) correction method in order to follow the common practice found within the literature. We display both *p*-values in the tables below. We then plotted different combinations of the three measurement values for burned sites using ggplot2[14] in order to determine whether or not our results could be graphically verified. All of the code used in this analysis is publically available in an R Markdown file generated using the knitr package (version 1.15.1)[15]. This R Markdown file may be found at the following github repository in addition to the data files used to complete the analysis: https://github.com/sagemwright/rainfall-fire-plant-abundance-bio465.

Results

In *Table 1*, we report the results of a Pearson correlation test. We found that the average combined seed and aboveground plant abundance at burned sites was seen to have a significant correlation with rainfall with the significance cut-off level of 0.05 (*p*-value = 0.016). However, aftering performed an FDR correction, this correlation was no longer significant (FDR adjusted *p*-value = 0.059). All other correlations were not found to be statistically significant. Interestingly, we noticed that for aboveground plant abundance, the Pearson correlation coefficient was negative (-0.062), which seems to indicate that rainfall had a negative effect on aboveground plant abundance.

	Combined Seed and Aboveground Plant Abundance	Seed Abundance	Aboveground Plant Abundance	Combined Abundance at Burned Sites	Combined Abundance at Unburned Sites
p-value	0.296	0.237	0.583	**0.016**	0.272
FDR adjusted *p*-value	0.414	0.414	0.636	0.059	0.414
correlation coefficient	0.131	0.298	-0.062	0.573	0.178

Table 1: **Results of the Pearson Correlation tests.** Each column was tested against the average rainfall reported for the date of data collection. Each column represents the average between all four sites within the Simpson Desert. FDR stands for false discovery rate, which is a multiple test correction method. **Bold** indicates statistical significance.

Despite there not being statistical significance after adjusting for multiple tests, we plotted the correlation between rainfall and combined abundance at burned sites (see *Figure 2*) in order to see if there was a visible correlation.

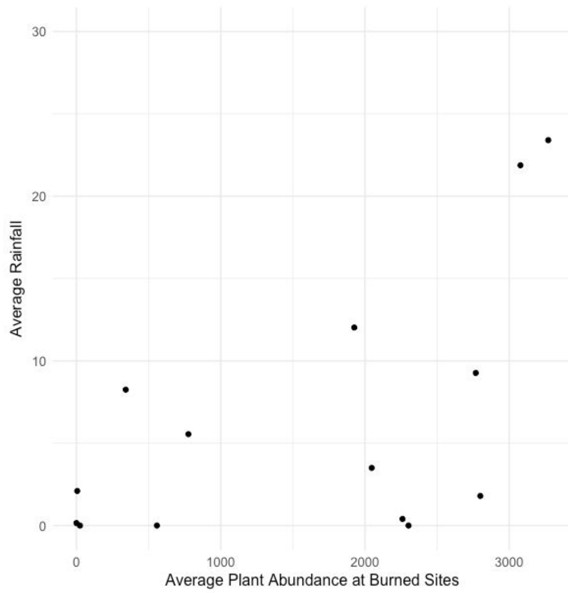

Figure 2: **Rainfall vs. General Plant Abundance**. This is a scatterplot showing the correlation between average rainfall and average (seed and aboveground) plant abundance at burned sites within the Simpson Desert (*p*-value = 0.016; FDR adjusted *p*-value = 0.059).

The plot shown in *Figure 2* doesn't seem to correspond with the unadjusted *p*-value; however, we can observe an upward trend present here. Since we were able to identify a significant correlation at burned sites, we examined which factor, above-ground plant abundance or seed abundance, was the major contributor to this correlation (see *Table 2*).

	Seed Abundance	Aboveground Plant Abundance
p-value	**0.017**	0.636
FDR adjusted *p*-value	0.059	0.636
correlation coefficient	0.744	-0.102

Table 2: **Burned Sites Correlations**. Results of the Pearson correlation test on burned sites within the Simpson Desert. individual seed and aboveground plant abundance for burned sites only; each column was tested against the average rainfall reported for the date of data collection. FDR stands for false discovery rate, which is a multiple test correction method. **Bold** indicates significance.

We noticed a significant correlation between seed abundance and rainfall at burned sites (unadjusted *p*-value = 0.017). Again, after correcting for multiple tests, this *p*-value was no longer significant at 0.059. We decided to plot out this relationship in *Figure 3* in order to visualize this relationship.

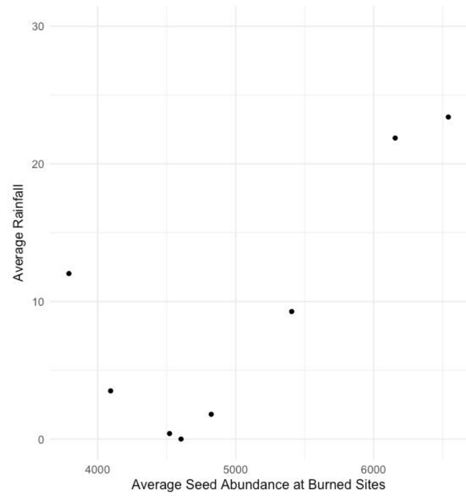

Figure 3: **Rainfall vs. Burned Site Seed Abundance**. Scatterplot showing the correlation between average rainfall and average seed abundance at burned sites within the Simpson Desert (p-value = 0.017; FDR adjusted p-value = 0.059).

The lack of data points is likely due to many missing values for such a specific subsection. However, there is a prominent upward trend which corresponds with the p-value obtained. The p-value is not statistically significant, likely due to the outliers where seed abundance is less than 4,500 in addition to the lack of data points.

Despite finding discouraging results, we visually plotted the relationship between rainfall, seed abundance, and above-ground plant abundance at burned sites. After log-adjusting the scale, we were able to note that there were several interesting trends (see *Figure 4*).

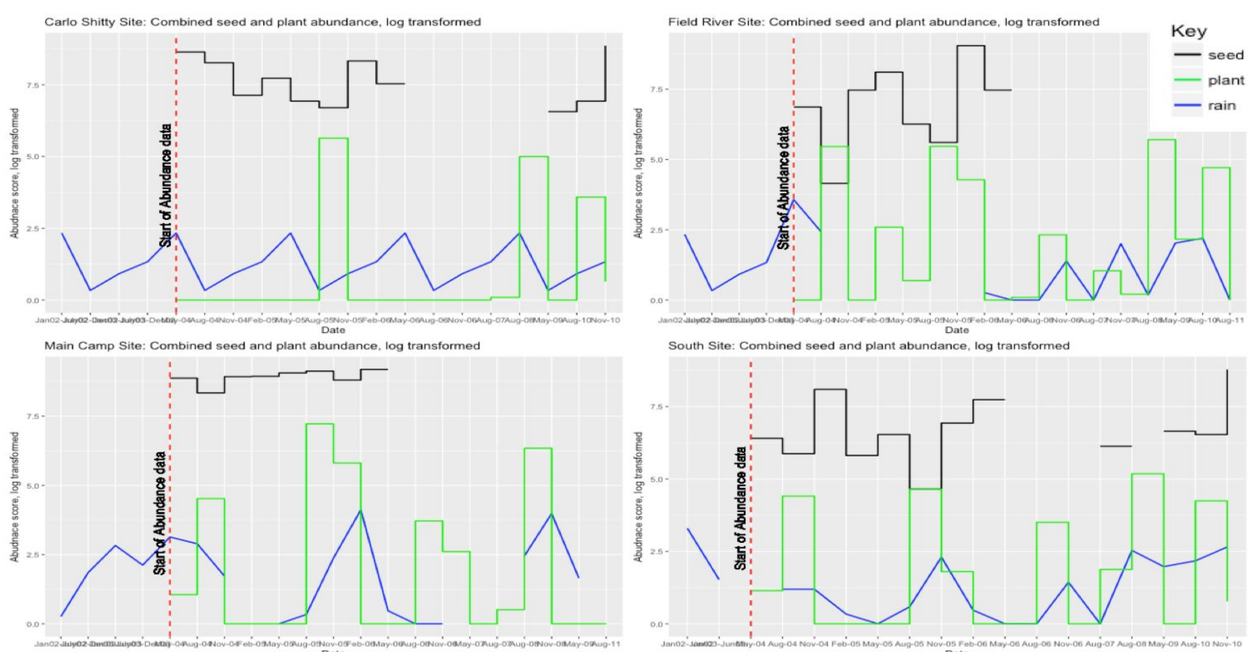

Figure 4: **Combined Rainfall, Plant and Seed Abundance**. These four charts depict all of the data provided for the four burned sites within the Simpson Desert, log transformed. Note the large gaps in data for both rainfall and seed abundance. Where above-ground plant abundance is 0, it also represents missing data values.

Noticeably evident in *Figure 4* is the amount of missing data present at each site. The low *p*-values obtained are likely due to this large gap in the data. Furthermore, it is interesting to note that typically, every rainfall event is followed by an increase of above-ground plant growth of *T. glaucifolia*. This corresponds to the plant's preference of moist soil. In addition, the relative lack of movement within the seed measurements leads us to believe that the correlation observed there is insignificant with the amount of data currently present.

To further investigate if plants abundance could be, or was, increased by the wildfire we combined the plant abundance for each of the four regions and plotted it with rainfall. The data was log adjusted in order to better see the trends of abundance against rainfall (see *Figure 5*).

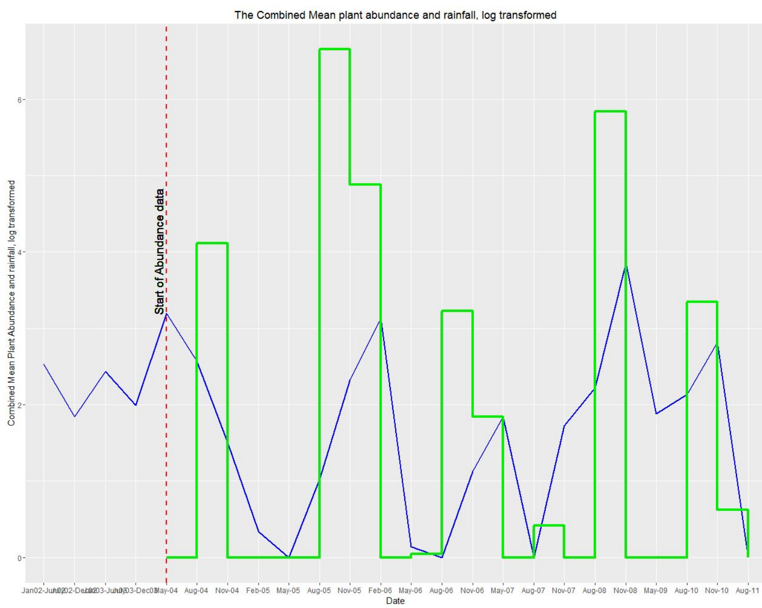

Figure 5: **Combined Rainfall and Combined Abundance**. The combined rainfall and combined plant abundance in burned sites, with the two years of rainfall between wildfire and collection of abundance data added. We see a trend of increased plant abundance during the flowering season of *T. glaucifolia*, August, and a rise in rainfall prior to the abundance increase.

Note that the plant abundance increase each year in August, which is the start of the growing season in Australia, in addition to being the flowering season for *T. glaucifolia*. In addition, rainfall generally increases prior to the increase in plant abundance. This trend would be expected; however, it does not reveal any information regarding the hypothesis that plant abundance is increased through fire pressure.

Discussion

The major limiting factor within this study is from the inconsistency of the data collection. Unfortunately, we were unable to find any additional datasets that have similar data values and regions, as was our initial goal at the beginning of this study. However, the one dataset that was of a similar nature was unfortunately embargoed and made inaccessible until 2018.

There is an increasing need for time series data in many areas of ecological work. With the increasing availability of observational data over longer time periods, research into ecological systems will be enhanced. With the release of the 2018 data, there will be a large addition of data to a study involving fire, rainfall, and plant abundance to see if fire pressure encourages enriched biodiversity; this data may help improve the research we present here.

Despite this setback of restricted data, upon further research, we were able to identify *T. glaucifolia* as an obligate seeder[16,17]. An obligate seeder is a plant that dies in a fire, but its seeds receive a signal to germinate after a fire has passed through the area[17]. This connection of *T. glaucifolia* to fire ecology presents an interesting direction for further research to examine.

We were initially surprised by the lack of significance shown the multiple-test corrections. After examining the data more closely, we were able to understand that the inconsistent data probably only served to contribute to the lack of statistical significance obtained. Due to the lack of significance, our results were inconclusive and require further tests in order to determine whether or not there is an actual difference of plant growth between burned and unburned locations.

We anticipate that further analyses can take place in order to determine the effect rainfall has on plant abundance in burned and unburned areas with the increasing availability of appropriate data. Regardless, this area of biology will continue to increase in importance as our world continues to change due to climate change and further habitat destruction.

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Author Contributions

Task	Overall Time	Mike	Sage
Obtain Data	8 hours	60%	40%
Tidying Data	13 hours	100%	0%
Correlation Tests	1.5 hours	60%	40%
Create Figures & Tables	5 hours	50%	50%
Write Paper	10 hours	0%	100%
Edit Paper	1 hour	90%	10%
R Markdown	6 hours	50%	50%