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The Effects of Average Annual Temperature on Flowering Times and Flower Count

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Honors Research Project

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Abstract:

Data collected over a fifteen-year time span used to examine the phenology of three species of flowers. The three species are *Chrysanthemum leucanthemum* (CHRLEU), more commonly known as the oxeye daisy, *Claytonia virginica* (CLAVIR), commonly known as the spring beauty, and *Taraxacum officinale* (TAROFF), more commonly known as the dandelion. These data were recorded by Dr. Randall Mitchell, a professor at the University of Akron. Dr. Mitchell recorded data for each of these three species of plants from 2006 to 2020. Factors analyzed and recorded included whether the land were fertilized, the date, and the number of flowers present for each individual species. This data was obtained by gathering information from the Bath Nature Preserve in Akron, Ohio. The question I address regarding these species is how is phenology affected by climate and variation in weather? This data and research are addressing observations based on weather and species in Akron, Ohio. Analyses of these data show no relationship between average annual temperature and peak flower count; however some evidence suggests a relationship between average annual temperature and first flowering at this Northeastern Ohio site based on the data analyzed for this conclusion.

Introduction:

It is widely accepted in the scientific community that over the past several decades average surface temperatures have steadily increased each year. According to the EPA website, average annual temperatures have increased each year making conditions for different plant species ever changing (4). Depending on the location in the United States, the temperatures may have either have either a large impact or not show any significant effect. This steady change in temperature has been increasingly more concerning since the early 1900s where the increase in average surface temperature was first noticed (4). Since then, the data has been more compelling, and more studies are being conducted as to why and what the effects are/will be (4).

Here I will be examining weather data from Northeast Ohio and its effect on first flower time and peak flower count, important components of flowering phenology. To gain more knowledge about what this research entails, one must understand how to compare the relationship between plants and climate, which is a component of phenology. Phenology is the study of the relationship between climate and periodical biological phenomena such as plant flowering (6). Scientists have been studying patterns of phenological changes to help better understand trends in flowering for many types of plants. From research done by scientists from the EPA, spring flowering events are influenced by the recent trend in warming temperatures across the nation (3). This observation intrigued me and led me to question whether this was true for the plants I was reviewing, so I began comparing the data provided by Dr. Mitchell, and weather data found on the Nation Weather Service website to do an initial comparison of flower count and temperature data (7).

Materials and Methods:

Study Site:

The focus of this research is at the Bath Nature Preserve in Bath Township, Summit County, in Akron, Ohio. This is a 404-acre park that is visited by many locals, students, researchers, faculty, as well as tourists of the area. These data come from an open grassland area (Grandview Alley") of 16 ha, in the center of the preserve (Figure 1, Figure 2). The area is mowed each autumn to maintain grassland habitat. Figure 3 shows twenty-four circle plots on the preserve that were established in 2001 for a study of different fertilization and management techniques. The grassland supports a wide range of species of plants.

Figure 1: picture of the center of a circle plot of land at the Bath Nature Preserve

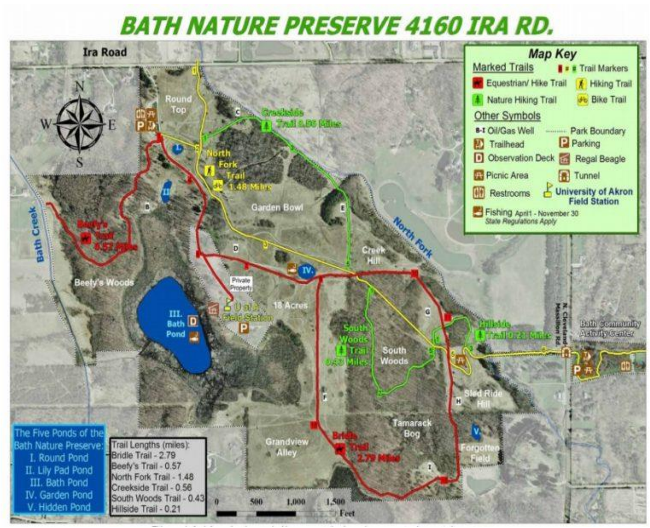

Figure 2: Map of Bath Nature Preserve

[Bath Nature Preserve-Bridle Trail Loop - Birding in Ohio (birding-in-ohio.com)]

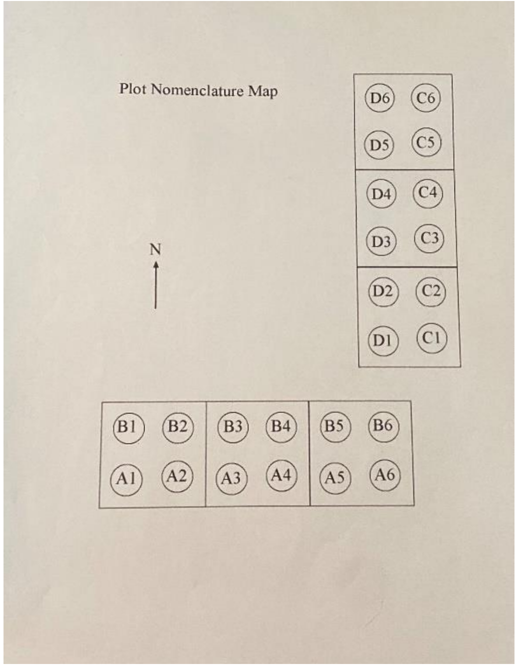

Figure 3: Map of the circle plots located at Bath Nature Preserve. Each plot had a radius of 5 meters.

Data:

From 2006-2020, Dr. Mitchell counted and observed flowering plants in each plot approximately once a week through the growing season. Because there are so many species and a number of them have thousands of flowers, many of the flowering counts are estimates.

The circle plots located at the Bath Nature Preserve are all the same size having a radius of 5 meters. There are twenty-four separate plots and each of these plots were used to count all the open flowers within the circle. For analysis, I calculated the total number of flowers of each species across all 24 plots.

For the weather data in this research, the National Weather Service website was used to find average yearly temperatures, growing season average temperatures (for the purpose of this research the growing season is from March-September for that year) and average monthly temperature one month prior to first flowering date, based off Dr. Mitchell's phenology observations. This date also was different for each of the three species. Another date that was used was the Julian date for the species. The Julian date is the number day of the year, for example a Julian date of 165 would be the 165th day of the year which correlates to June 14th (8).

For each species of plant, six main graphs were constructed to analyze the data and conclude as to whether the rise in temperature over the past fifteen years has impacted the first flowering date for the species at hand. Although this research focuses on only three species, there are many other species for which Dr. Mitchell observed and recorded data. I chose these species because they had the most total data points as well as the most consistent data over the years.

Analysis:

For each graph I used linear regression in Microsoft Excel to test for a significant relationship between the predictor and response variables. In these analyses, each year constituted on data point; I used the various temperature measures as predictor variables, and total flower production and first flowering date as response variables. The R-squared value from these analyses describes the proportion of variance of the dependent variable that can be explained by the variance of the independent variable (5). The formula for finding this value is: R2=1− (Unexplained Variation/Total Variation) (5). The higher the decimal, the R-squared value), the greater the relationship between the two variables of interest.

The P-value is used to tell us whether the pattern being measured, the relationship between flowering time, flower count, and temperature, is statistically significant (2). The statistical significance is a way to describe if we should reject or support the null hypothesis (2). In this case the null hypothesis is that there is no relationship between the variables I am considering. P-values are read in this research as either greater or less than 0.05. When the p-value is less than 0.05 the data is significant and if it is greater than 0.05 the data is not significant (9).

Graphs:

Species one: *Taraxacum officinale*

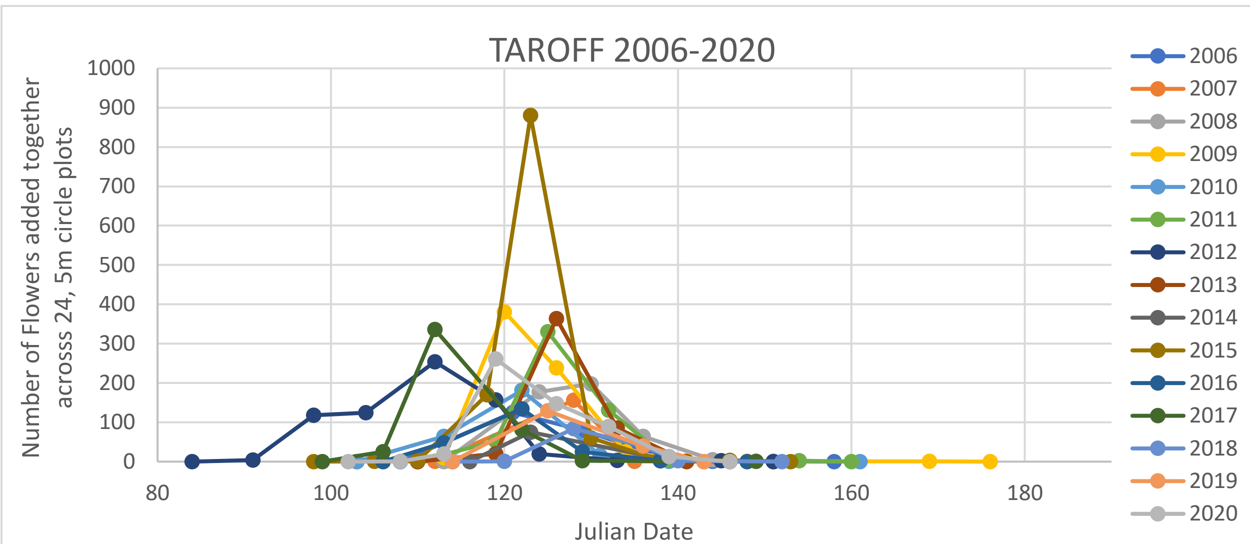

Figure 4: graphical analysis of TAROFF for years 2006-2020 comparing the Julian date to the number of flowers per year

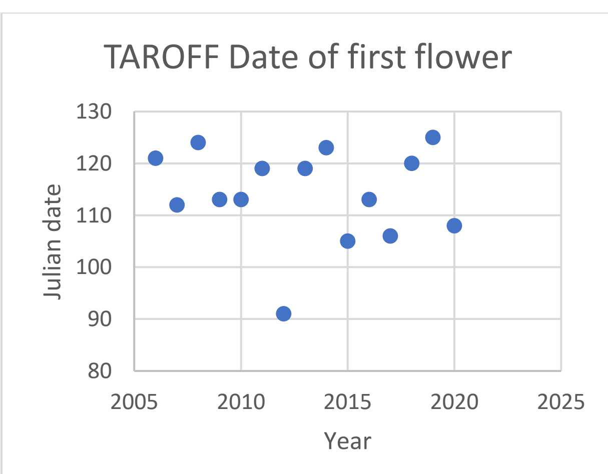

Figure 5: date of first flower for TAROFF for each year based on its Julian date

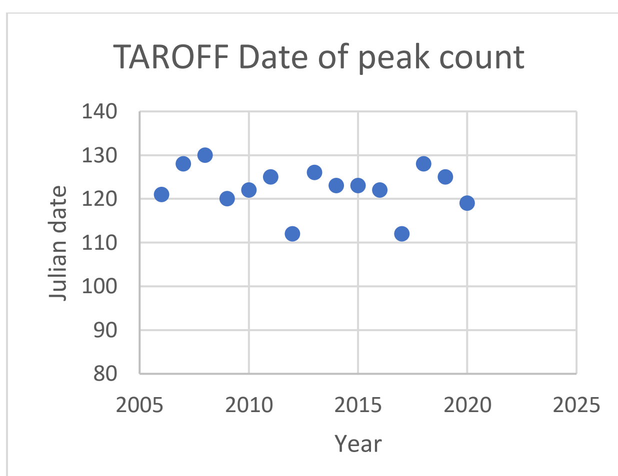

Figure 6: date of peak count for TAROFF for each year based on its Julian date

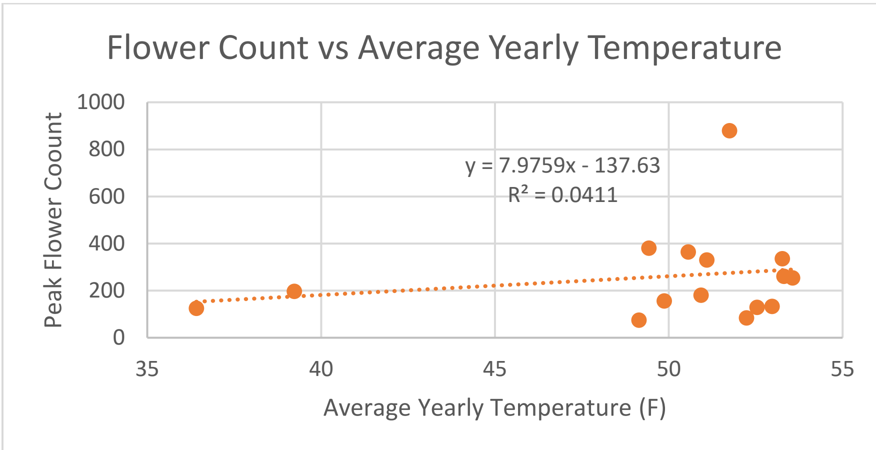

Figure 7: TAROFF peak flower count in comparison to the average yearly temperature from 2006 to 2020

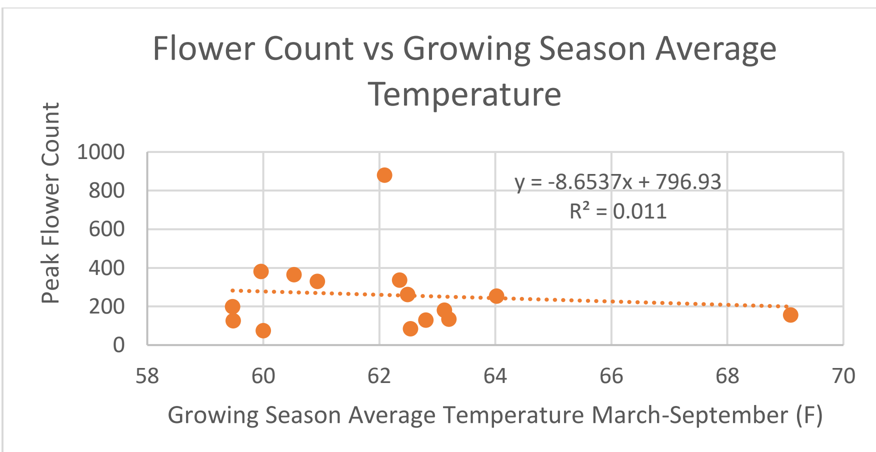

Figure 8: TAROFF peak flower count in comparison to the growing season average temperature from 2006 to 2020

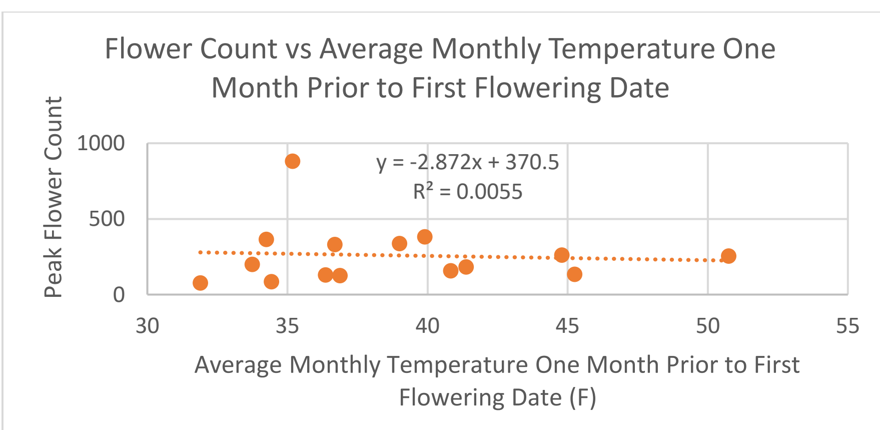

Figure 9: TAROFF peak flower count in comparison to average monthly temperature one month prior to the first flowering date from 2006 to 2020

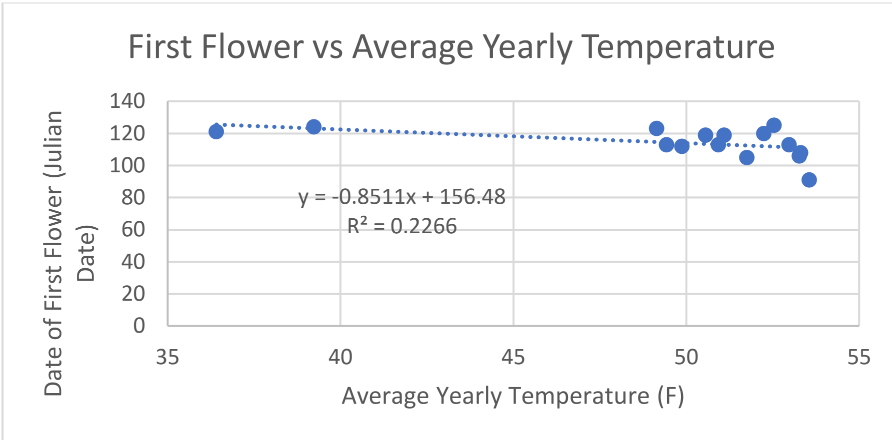

Figure 10: TAROFF date of first flower in comparison to the average yearly temperature from 2006 to 2020

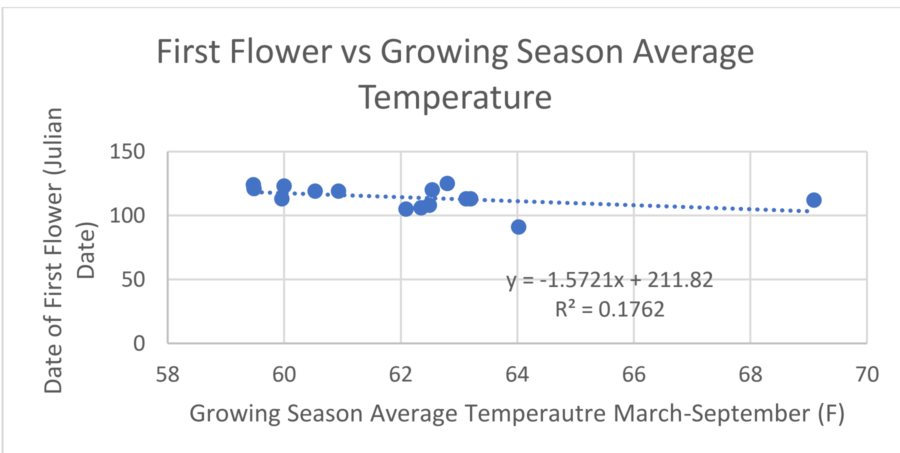

Figure 11: TAROFF date of first flower in comparison to the growing season average temperature from 2006 to 2020

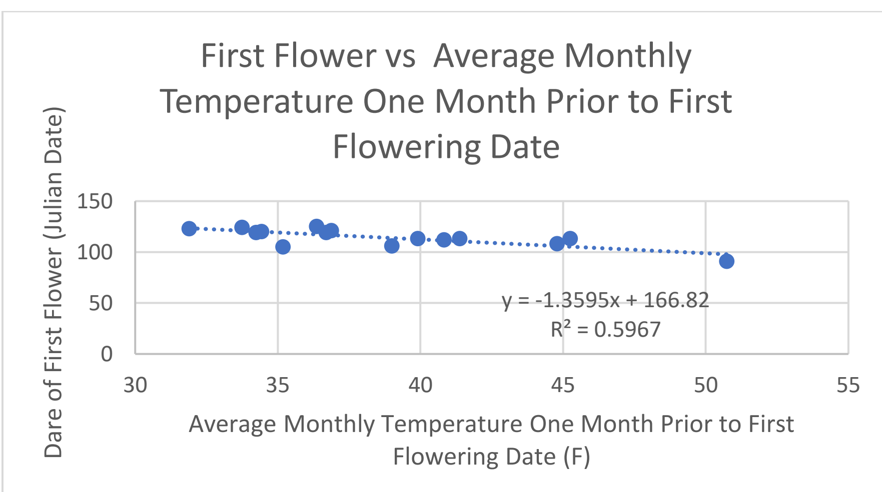

Figure 12: TAROFF date of first flower in comparison to average monthly temperature one month prior to the first flowering date from 2006 to 2020

Species 2: *Chrysanthemum leucanthemum*

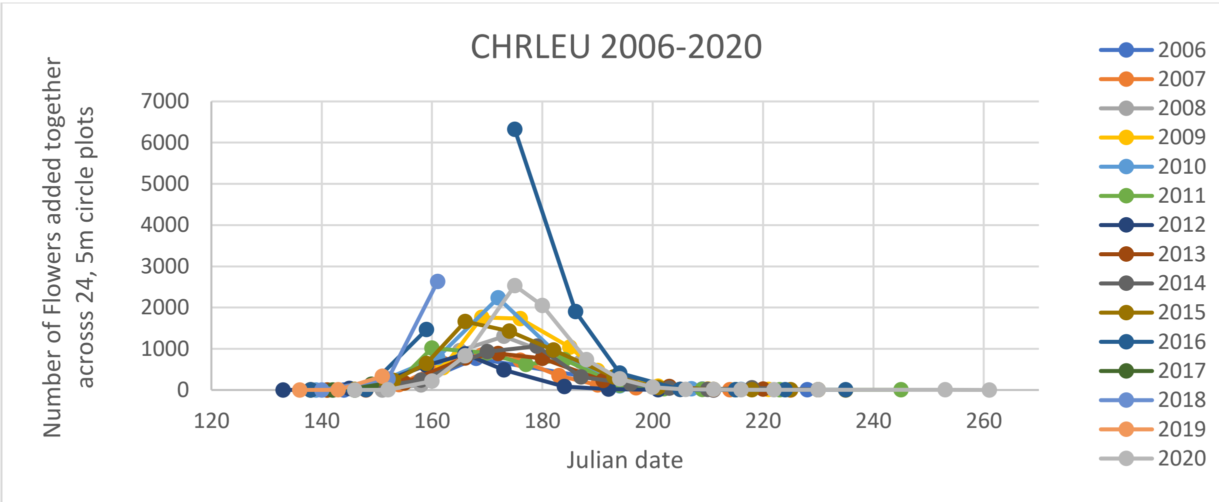

Figure 13: graphical analysis of CHRLEU for years 2006-2020 comparing the Julian date to the number of flowers per year

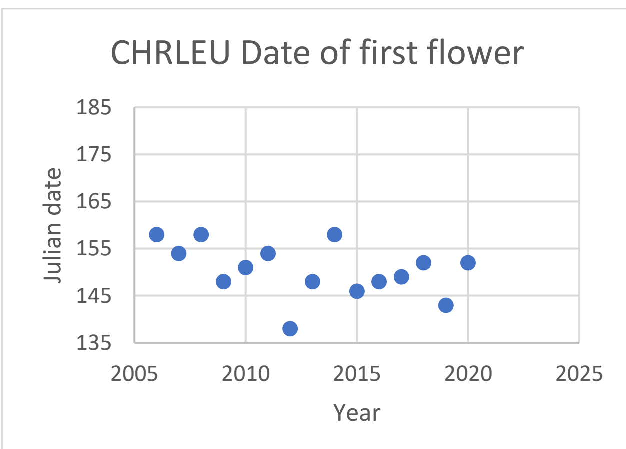

Figure 14: date of first flower for CHRLEU for each year based on its Julian date

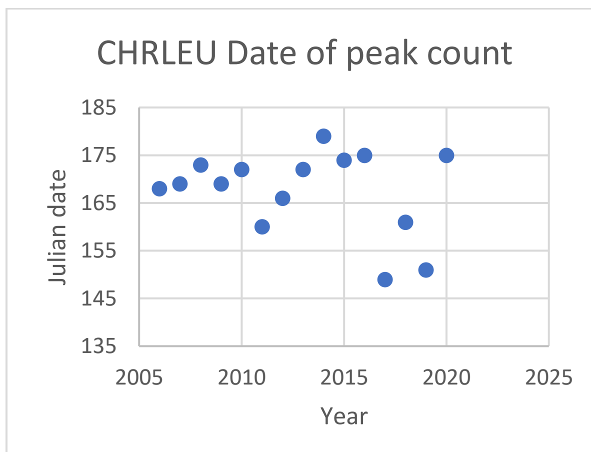

Figure 15: date of peak count for CHRLEU for each year based on its Julian date

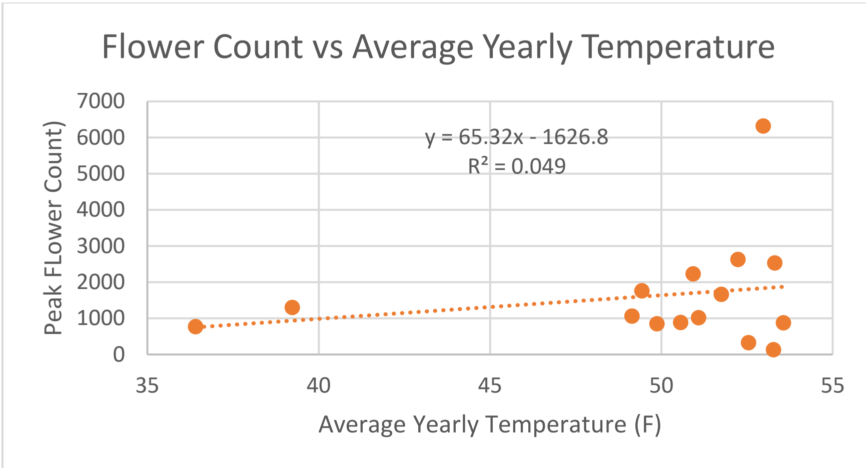

Figure 16: CHRLEU peak flower count in comparison to the average yearly temperature from 2006 to

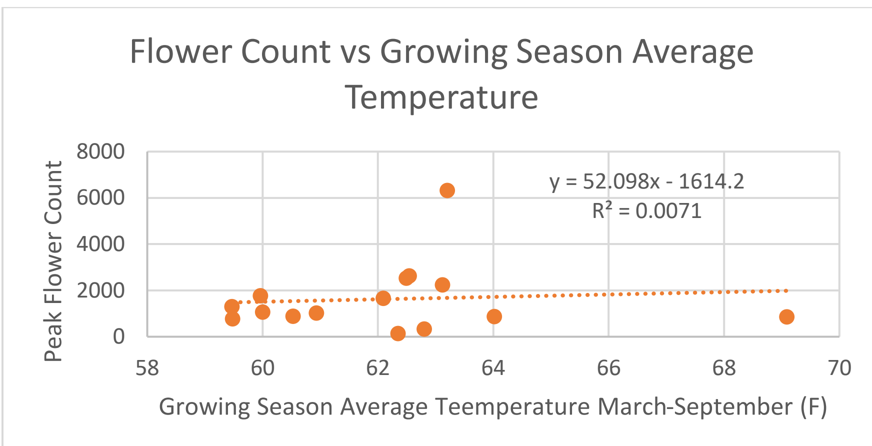

Figure 17: CHRLEU peak flower count in comparison to the growing season average temperature from 2006 to 2020

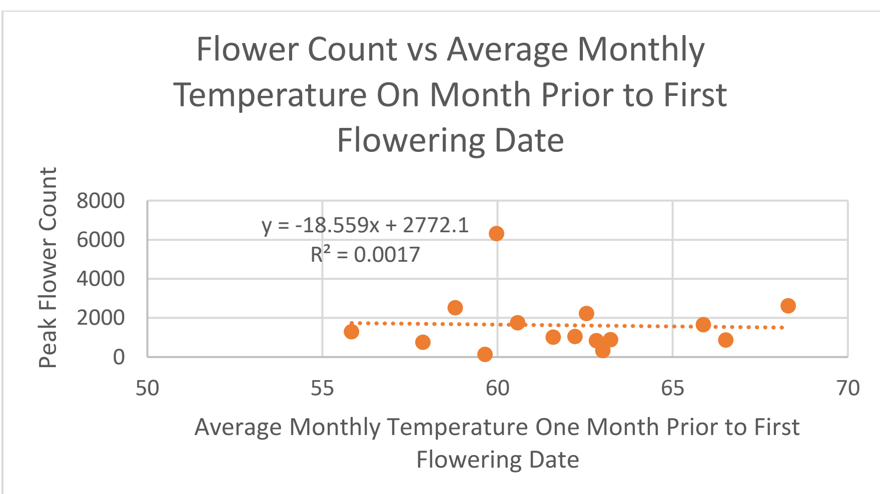

Figure 18: CHRLEU peak flower count in comparison to average monthly temperature one month prior to the first flowering date from 2006 to 2020

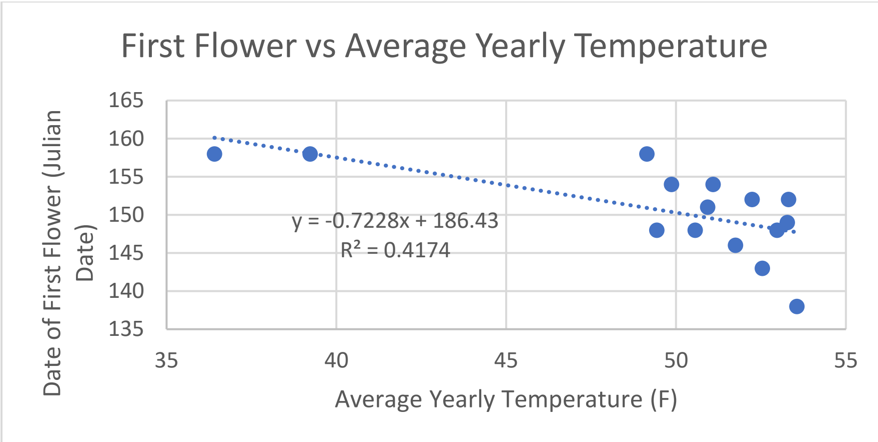

Figure 19: CHRLEU date of first flower in comparison to the average yearly temperature from 2006 to 2020

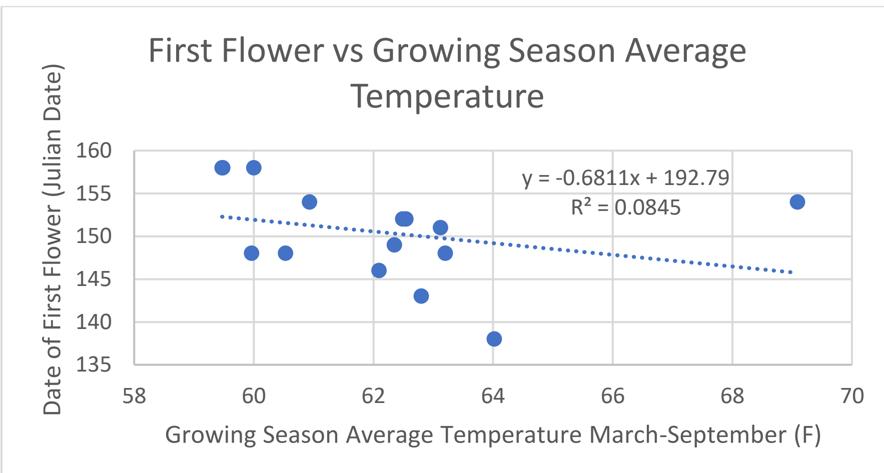

Figure 20: CHRLEU date of first flower in comparison to the growing season average temperature from 2006 to 2020

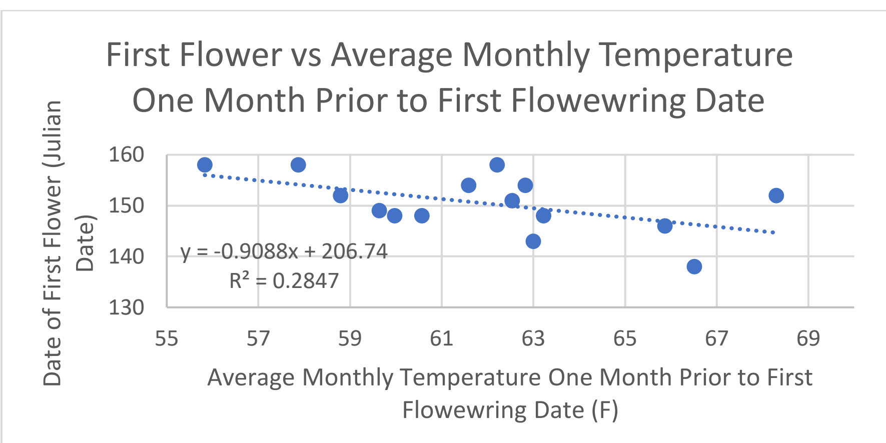

Figure 21: CHRLEU date of first flower in comparison to average monthly temperature one month prior to the first flowering date from 2006 to 2020

Species 3: *Claytonia virginica*

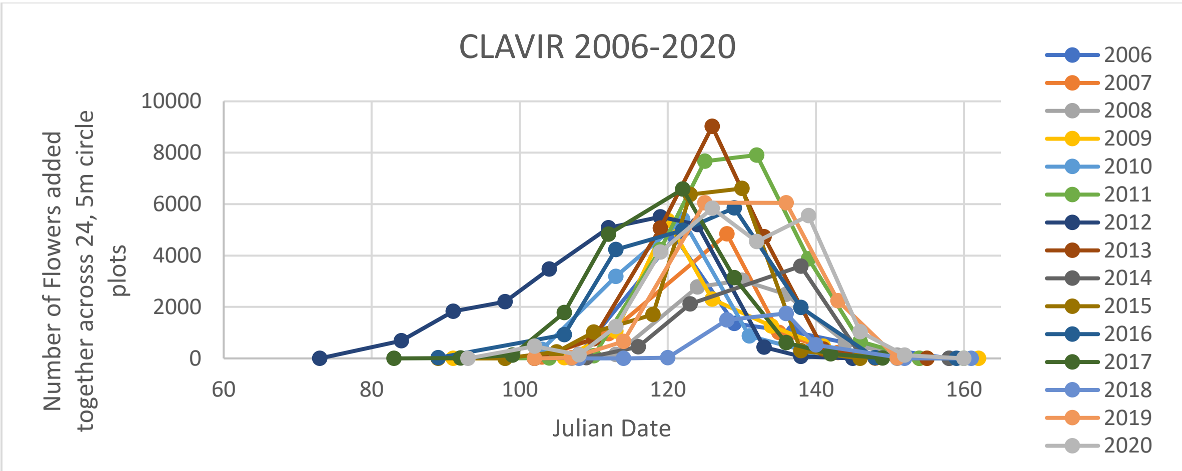

Figure 22: graphical analysis of CLAVIR for years 2006-2020 comparing the Julian date to the number of flowers per year

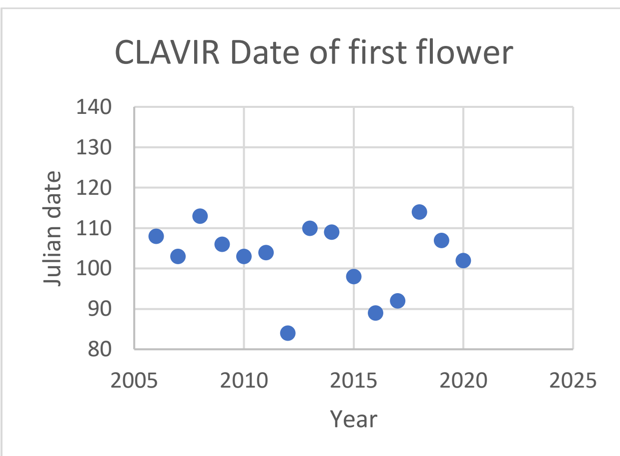

Figure 23: date of first flower for CLAVIR for each year based on its Julian date

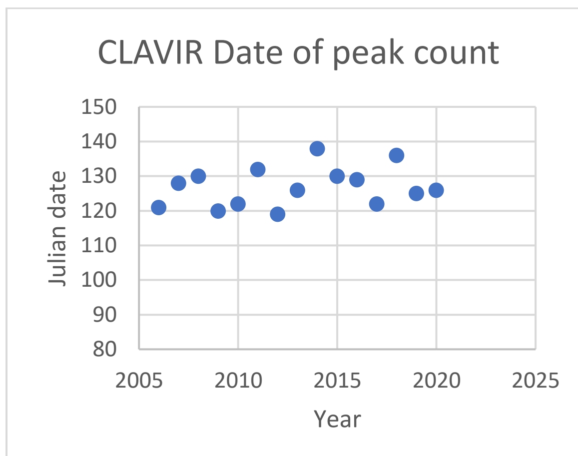

Figure 24: date of peak count for CLAVIR for each year based on its Julian date

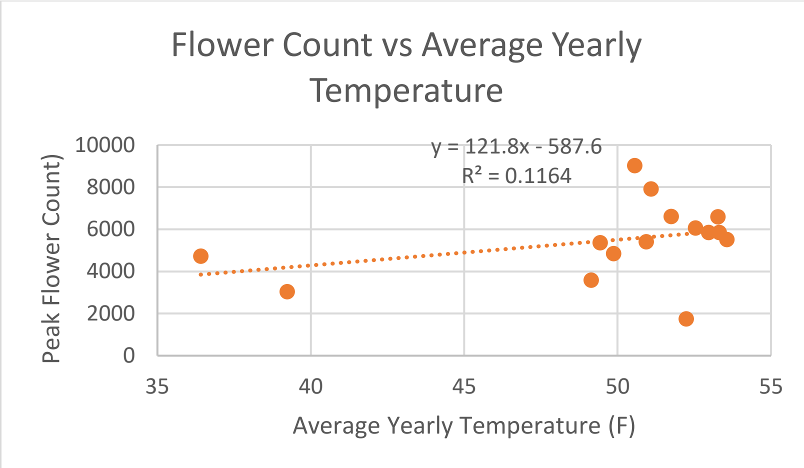

Figure 25: CLAVIR peak flower count in comparison to the average yearly temperature from 2006 to 2020

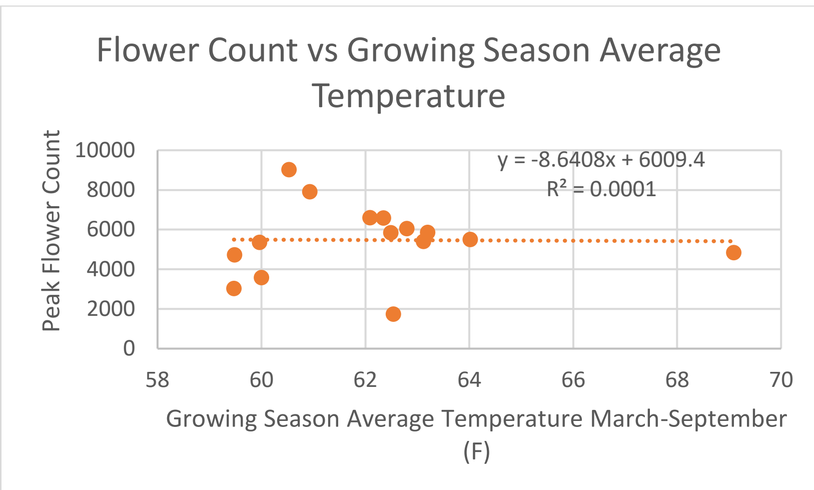

Figure 26: CLAVIR peak flower count in comparison to the growing season average temperature from 2006 to 2020

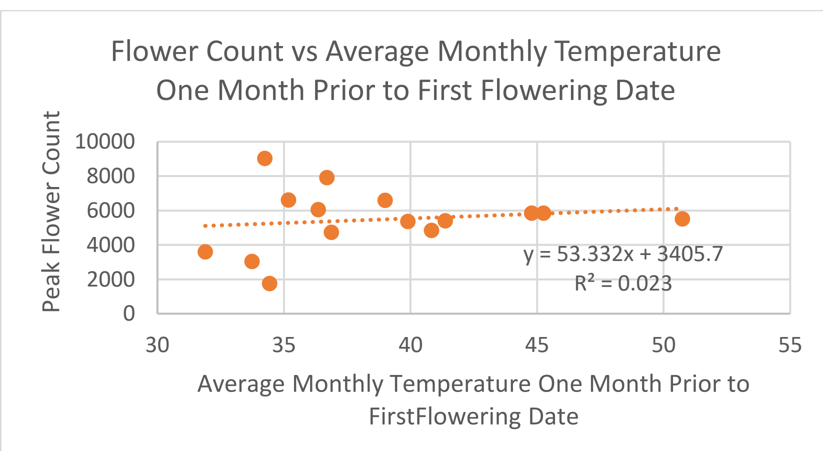

Figure 27: CLAVIR peak flower count in comparison to average monthly temperature one month prior to the first flowering date from 2006 to 2020

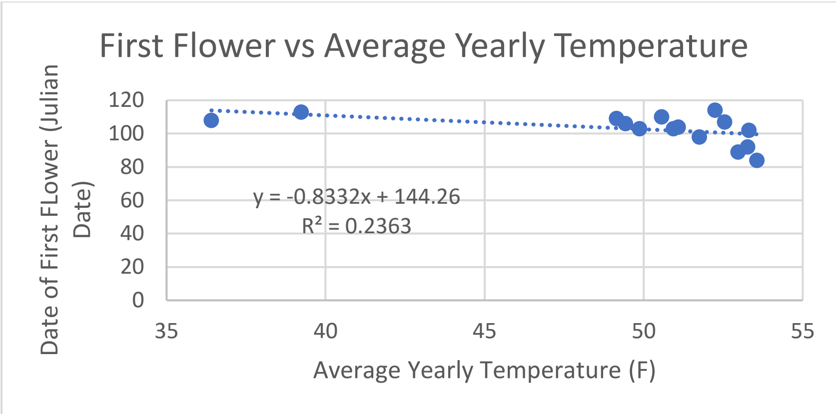

Figure 28: CLAVIR date of first flower in comparison to the average yearly temperature from 2006 to 2020

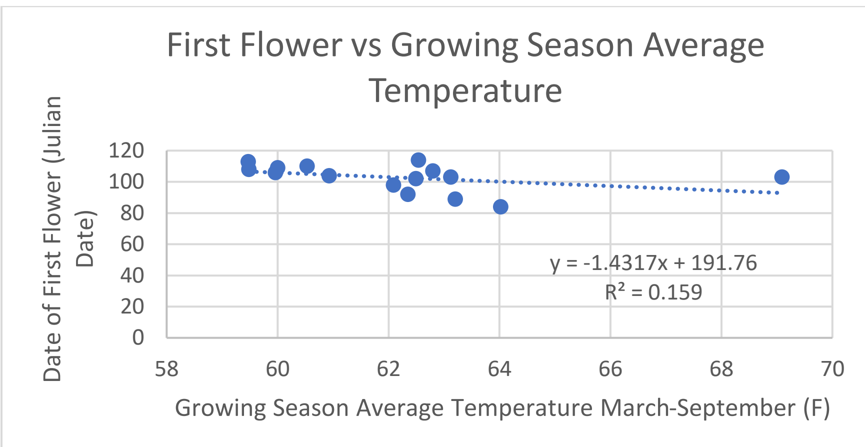

Figure 29: CLAVIR date of first flower in comparison to the growing season average temperature from 2006 to 2020

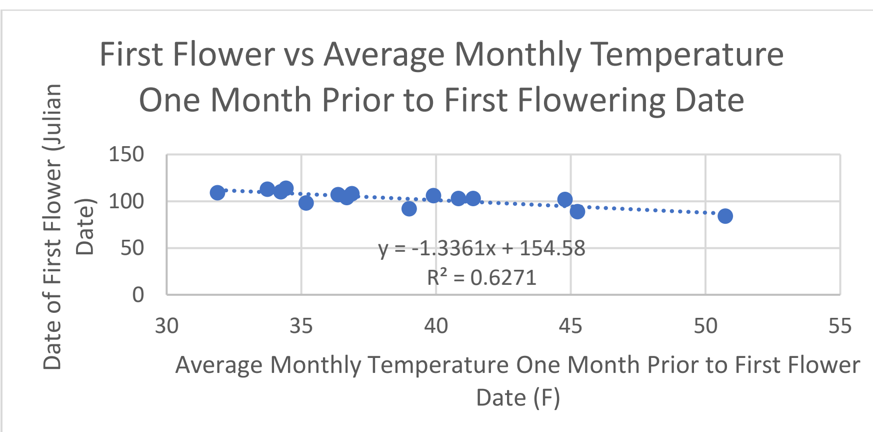

Figure 30: CLAVIR date of first flower in comparison to average monthly temperature one month prior to the first flowering date from 2006 to 2020

***Note: There are two anomalously low temperatures in the average yearly temperature for all three species. These values came from the National Weather Service data site and**

should be noted that this could be skewing some of the information. The same goes for one value in the growing season average temperature that is higher than the rest of the values.

Results:

The general data that was looked at prior to the temperature data can be seen for TAROFF in figures 4-6, CHRLEU in figures 13-15, and CLAVIR in figures 22-24.

For TAROFF the yearly total number of flowers across the 24 circle plots peaked at around 200-400 total flowers across the 24 plots (Figure 4). There was, however, one year that stuck out compared to the others and that was in 2015 when there was a spike in the number of flowers. The date of first flower over the years was also around the same time of the year except for April 1, 2012, where the first flowering date came around fifteen days before the others (Figure 5). The date of the peak count, the day in which there was the highest count of opened flowers added up for all twenty-four plots, was between a Julian date of 120-130 across the years. There were two exceptions to this occurring in 2012 and 2017 and the peak count happened at least 10 days prior to the other years (Figure 6).

For CHRLEU, the total flowers across the 24 circle plots consistently peaked at around Julian Day 175 (Figure 13). The exception was 2018 when there was a peak in the number of flowers at a Julian date of 160. The date of first flower for this species was in the range from 135 to 160. There is a decline in the day in which these days are occurring as the years go on (Figure 14). The date of peak count had no consistent data pattern when referring to Julian date, and the results were in a wide range of around 145 to 175 Julian date.

For CLAVIR, the total flowers across the 24 circle plots consistently peaked at around Julian day 130 (Figure 22). The date of first flower for this species was in the range from 85 to

115. The date of peak count had no consistent data pattern with respect to Julian date, and the results were in a wide range of around 145 to 175 Julian date (Figure 24). From this figure it could be said there is a slight incline in the Julian date over the years for peak count.

Analysis of temperature and peak flower count:

For each species, there was no significant relationship that can be seen when trying to relate peak flower count and in the three different measures of temperature from 2006 to 2020 (Figures 7-9 for TAROFF, 16-18 for CHRLEU, and 25-27 for CLAVIR). This can be seen by looking at the R-squared and P values for each species, none of which are greater than 4%, and none of which are significant (Table 1). This means that there is little to no relationship between the peak flower production and the average annual temperature, the growing season average temperature, and the monthly average temperature one month prior to first flower date.

Analysis of temperature and first flower date:

First flowering date varied significantly with all temperature indicators for all species (Figures 10-12 for TAROFF, 19-21 for CHRLEU, and 28-30 for CLAVIR). In all three species the strongest relationships were with temperature in the prior month. For TAROFF, the average yearly temperature explained about 20% of the variation in the date of first flowering, the growing season average temperature was around 17% related, and the most compelling find for this species was the average monthly temperature one month prior to the first flowering date with a 59% relatedness. For CHRLEU, the average yearly temperature was around 41% related to the first flowering date, the relationship between the growing season average temperature and the first flower date was not related much at all with a percentage of 8%, and lastly the average monthly temperature one month prior to first flower date was on the smaller side with a 28%

relationship. For CLAVIR, the average yearly temperature was related by 23%, the growing season average temperature had smallest relationship with a percent relatedness of 15%, and the average monthly temperature one month prior to first flowering date had the most compelling evidence that there was a relationship with a percentage of 62%.

Table 1: R-squared values and P values from regressions. Significant regressions indicated by boldface type.

Variables Correlated	TAROFF	CHRLEU	CLAVIR
Peak flower count & yearly mean temperature	0.0411 NS	0.049 NS	0.1164 NS
Peak flower count & growing season mean temperature	0.011 NS	0.0071 NS	0.0001 NS
Peak flower count & mean monthly temperature one month prior to first flower date	0.0055 NS	0.0017 NS	0.023 NS
First Flower & yearly mean temperature	**0.2266** *******	**0.4174** ********	**0.2363** *******
First Flower & growing season mean temperature	**0.1762** *******	**0.0845** *******	**0.159** ******
First Flower & mean monthly temperature one month prior to first flower date	**0.5967** ********	**0.2847** ********	**0.6271** ********

NS = Not significant

**** = P< 0.05**

***** = P< 0.0001**

****** = P<0.0001**

Discussion:

After reviewing the linear regression information and figures, I found there to be a wide range of results from peak flower count and first flowering date with respect to their relationship with temperature. I did not find a significant relationship between the rise in temperature over the years and the number of flowers produced by the three species of plants. From the graphs I was able to see that there was a range in number of flowers in which peak flowering count occurred for in each species.

However, when reviewing the temperature and first flowering date, the r-squared values were much higher in comparison to the data from peak flower count. All R values were well below a perfect 1.0, but they are significant, and indicate that temperature can account for a substantial portion of the variation in first flowering date. This effect is the strongest when comparing the first flowering date and the average monthly temperature one moth prior to peak flowering date. This indicates that if the month prior was, on average, warmer than the year before, then the first flower date will happen earlier than in recent years. This is verified by looking at the R-squared value for these graphs for all three species. In contrast, the relationship between temperature and peak flower count is not significant because all the values are greater than 0.05 for all the species. The relationship between temperature and the date of first flower is significant for all the species because the p-values are all lower than 0.05.

There may be other reasons as to why the data for peak flower production does not show more correlation with respect to temperature data, such as insect behavior in the area which could affect number and success of the species, whether a fertilizer was used on the area, and the wildlife surrounding the species. The factors that affect flower counts are not yet clear and deserve more research. To further this research, I will also look at different locations of the same species of the plants examined in this research to determine if location has any effect. I would also examine whether the increase in temperature affects insect life within the area because this could also be a factor that affects the flower count as when counting the flowers, they may not all be present at that specific time. Overall, it can be said that there is not enough research or data provided to definitively say that there is a direct relationship between average annual temperature and flower count, but there is enough evidence to conclude a relationship with first flowering date and temperature for *Taraxacum officinale, Chrysanthemum leucanthemum, or Claytonia virginica.* The data can account for the relationship between first flowering date and temperature change over the 15-year time span that this research is discussing as seen in table 1.

Acknowledgments:

I would like to thank Dr. Randall Mitchell for all his help, work, and dedication to the field of ecology as his work in this field is the sole basis of this research. Without Dr. Mitchell this research would not have been possible and for that I am extremely grateful for this opportunity to work with him.

I would also like to thank Dr. Robert Joel Duff and Dr. Hazel Barton for being readers for this research and another thank you to Dr. Brian Bagatto for signing off as my honors faculty advisor, hence approving this research.

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