The effect that climate conditions have on male and female Silver Spotted Skipper butterflies

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Introduction

This report looks into the universal ecological responses to climate change in univoltine butterflies. A univoltine species means that they only breed offspring once a year, in many cases for butterflies they are chrysalis over winter before emerging for the summer months according to the Amateur Entomologists' Society. This specific study is looking at museum specimens of the Silver Spotted Skipper, Hesperia comma, to look at how size varies with annual temperature.

The Silver Spotted Skipper is an easy butterfly to identify according to UK Butterfly, 2023, as they are the only skipper that can be found in the British Isles that have distinctive white spots on the underside of their hindwings. The male and female butterflies are distinguished by the sex brand presented on their forewings - a line of specialized scent scales.

The status and distribution of the Silver Spotted Skipper have posed interesting questions for conservationists and ecologists (Thomas et al, 1986). The improving status of them is mainly down to good habitat management and climate warming which has improved the quality and increased the availability of habitats that are suitable. Hesperia comma female butterflies have specific ecological requirements when it comes to where they lay their eggs (individually on leaf blades of small tufts of F. ovina adjacent to the ground). Climate change in general, is most commonly known for destroying the planet and therefore posing a threat to some of our most treasured species, however here we present a species that is going against this analogy and since early 2000's has had a large increase in its population (Davies et al, 2005). The time period this report focuses on is June, just before their flight period takes place in July and September to allow their eggs to hatch the following March (Lawson et al, 2013).

Analysis

In order to analyse and explore my data further I created a least-squares model 1 (lsmodel1), this is a linear model using forewing length as the numerical value and sex as the interaction term as this was the best suited to use. A linear model is often made so that one can better describe mathematical relationships and make predictions from the data. It provides a better understanding behind the biological relationship that the forewing length and the sex of the butterfly have and provides deeper knowledge of the data that is presented. The R version used is R.4.2.3.

A variety of packages were used in order to complete my lsmodel1 including the emmeans package that calculates the 95% confidence intervals, the GGally function in order to create attractive scatter plots and the performance function to compare the observed and inferred outputs for this data set. I created plots such as the Quantile-Quantile plot to look at the quantiles of the first data set compared to the quantiles of the second data set and Cooks distance plot that identifies any outliers in the X variables. I also created a normal distribution plot, to look at whether the residual of the data was normally distributed.

Table 1: Summary statistics of Male and Female butterflies born in years ranging from 1880 - 1973

year	forewing_length	sex	jun_mean	rain_jun
1880	14.64700	Females	13.8	87.9
1892	14.35800	Females	13.4	83.1
1892	13.06400	Males	13.4	83.1
1896	14.70400	Females	16.2	54.7
1898	14.71200	Females	13.6	44.9
1899	13.77100	Males	15.7	37.7
1903	13.62875	Females	13.0	55.3
1904	14.23375	Females	13.3	14.1
1904	12.79400	Males	13.3	14.1
1905	14.40100	Females	14.7	69.9
1905	13.07200	Males	14.7	69.9
1906	14.51800	Females	14.3	74.2
1906	12.76975	Males	14.3	74.2
1907	12.01750	Males	12.4	55.6
1908	14.08700	Females	14.3	37.7
1908	12.54475	Males	14.3	37.7
1909	14.15150	Females	11.8	81.8
1911	14.38275	Females	14.5	72.1
1914	13.06300	Males	14.5	577.0
1916	13.77950	Females	11.8	60.9
1916	12.35775	Males	11.8	60.9
1917	14.43675	Females	15.2	47.8
1917	12.86975	Males	15.2	47.8
1920	13.70350	Males	14.4	56.2
1923	14.39150	Females	12.5	16.5
1924	14.49050	Females	13.9	48.8
1924	13.23900	Males	13.9	48.8
1925	13.93600	Females	15.0	5.8
1927	12.29125	Males	12.6	96.6
1928	12.62225	Males	12.9	70.4
1929	13.06975	Males	13.3	30.3
1932	12.65150	Males	14.1	15.4
1936	14.10500	Females	14.7	89.2
1937	14.78500	Females	14.1	32.0
1937	13.21400	Males	14.1	32.0
1938	13.46250	Females	14.4	31.7
1939	13.26450	Females	14.2	52.1
1939	12.93150	Males	14.2	52.1
1941	14.03550	Females	15.1	22.7
1941	13.81450	Males	15.1	22.7
1944	12.63875	Males	13.5	47.1
1945	15.10550	Females	14.6	57.6
1946	12.91700	Males	13.1	70.8
1947	14.53250	Females	15.5	46.5
1947	13.33400	Males	15.5	46.5
1951	14.67700	Female	14.0	30.8
1951	13.46425	Males	14.0	30.8
1961	14.68750	Female	14.4	28.9
1963	15.20025	Female	14.9	62.0
1964	14.94650	Female	13.8	77.8
1965	13.59350	Female	14.7	51.0
1966	14.35675	Female	15.4	73.2
1966	13.37425	Males	15.4	73.2
1969	12.85775	Maes	13.9	39.4
1970	12.65775	Males	16.4	27.1
1971	13.52750	Females	12.4	71.5
1971	12.18450	Males	12.4	71.5
1973	13.93875	Males	14.8	76.1

Main Hypothesis

After analysis of some of the data through the lsmodel1 we can determine that although not perfect, our data set is reasonably accurate. The linear models make a diverse range of assumptions about the data set, which provides further information that I couldn't have gained from looking at the table of data itself.

All together, this has allowed for the creation of the main hypothesis and null hypothesis I will be working towards throughout this report, as well as considering already published data about Silver Spotted Skipper butterflies: Hypothesis: The temperature and rainfall have an effect on the forewing length of male and female butterflies. Null Hypothesis: The temperature and rainfall doesn't have an effect on the forewing length of male and female butterflies. It can also be expressed as two other hypothesis that we can explore within the main hypothesis: 1. The temperature in June affects the rainfall and therefore the number of male and female butterflies. 2. The rainfall in June across different years affects the number of male and female butterflies.

Results and Discussion

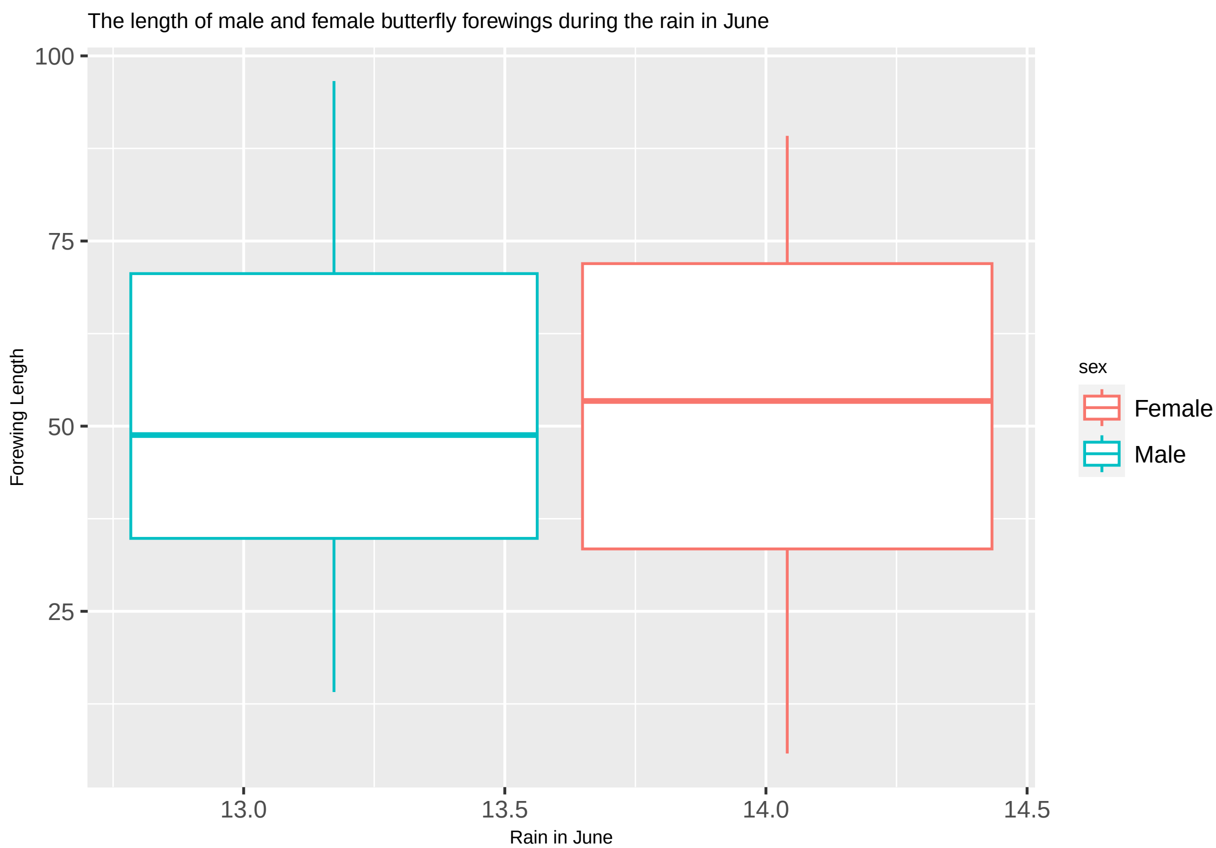

Figure 1: This plot shows the length of male and female forewings in June is relatively similar to each other. Looking at the mean values we can see that females have a slightly larger forewing length of around 55mm, male butterflies being slightly shorter with a value of 50mm. This helps to identify their similarities and differences.

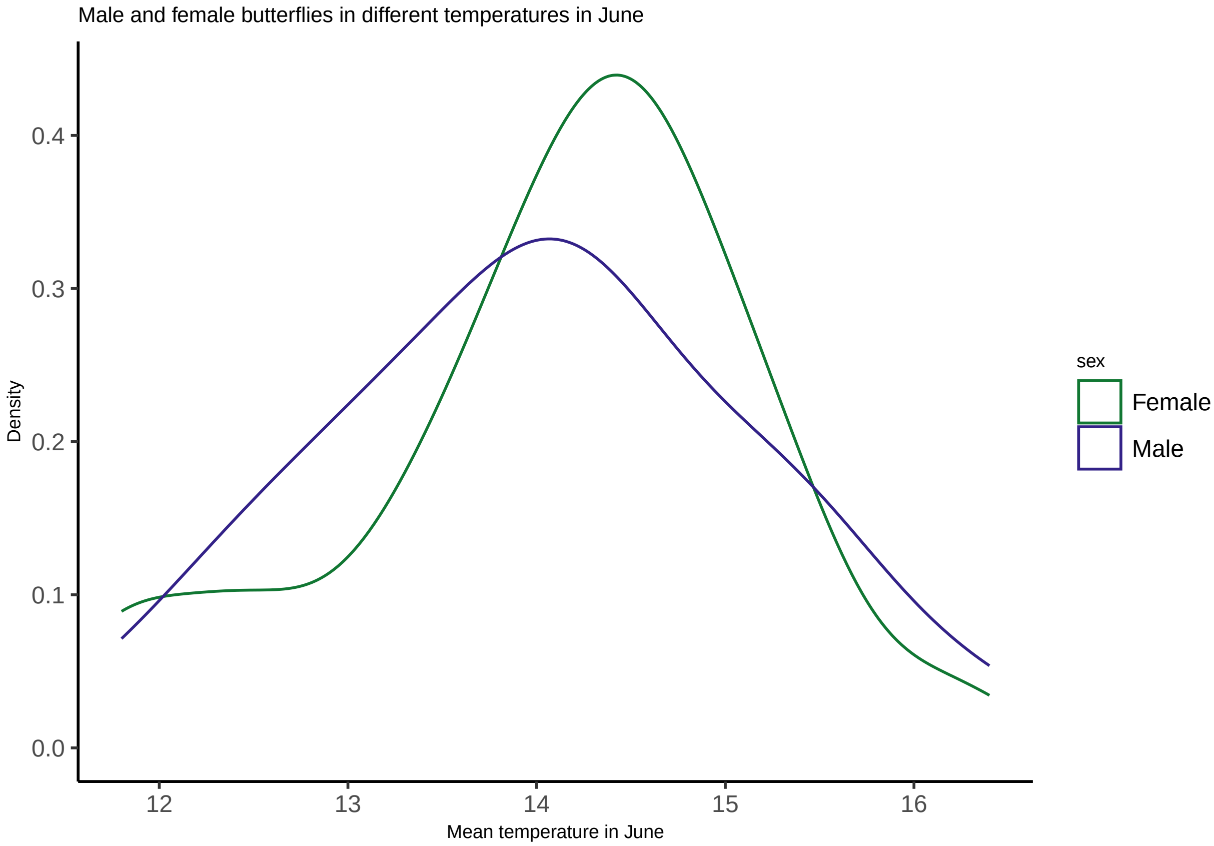

Figure 2: This plot shows the density of male and female butterflies in the month of June. It shows that at temperatures around 12-14 degrees Celsius there are more male butterfly's providing data of forewing length, but then at around 14-15.5 degrees Celsius there are nearly double the amount of female to male butterflies. As the temperature then drops to 16 degrees Celsius the number of male butterfly's increases. This shows that when we are studying temperature females provide more data than males do around the medium temperatures in June.

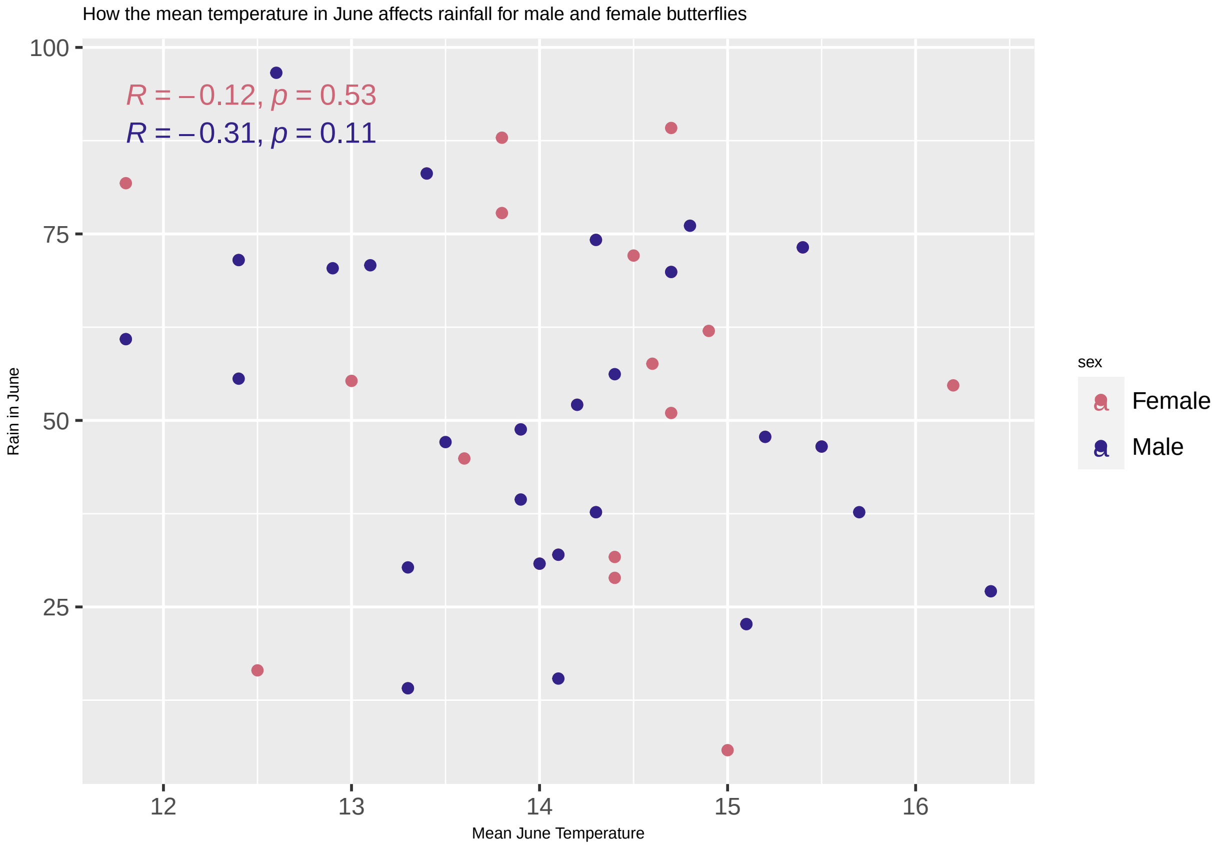

Figure 3: This plot shows how the temperature in June affects the rainfall in June for male and female butterflies. Both the R values are negative indicating a negative correlation, meaning the values of one variable increase when the values of the other variable decrease. Both R values are close to zero, females have a closer R value to zero than the males do with an R value of -0.12, compared to the males who's R value is -0.31 meaning females have a weaker linear relationship than the male butterfly's do. The p value indicates whether or not a correlation will be statistically significant. Both of the p values for male and female butterflies are above 0.05 (>0.05), meaning that for both sexes we can accept the null hypothesis and reject the test hypothesis, claiming that the temperature in June doesn't' have an affect on the rain or the number of male and female butterflies.

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## `geom_smooth()` using method = 'loess' and formula = 'y ~ x'
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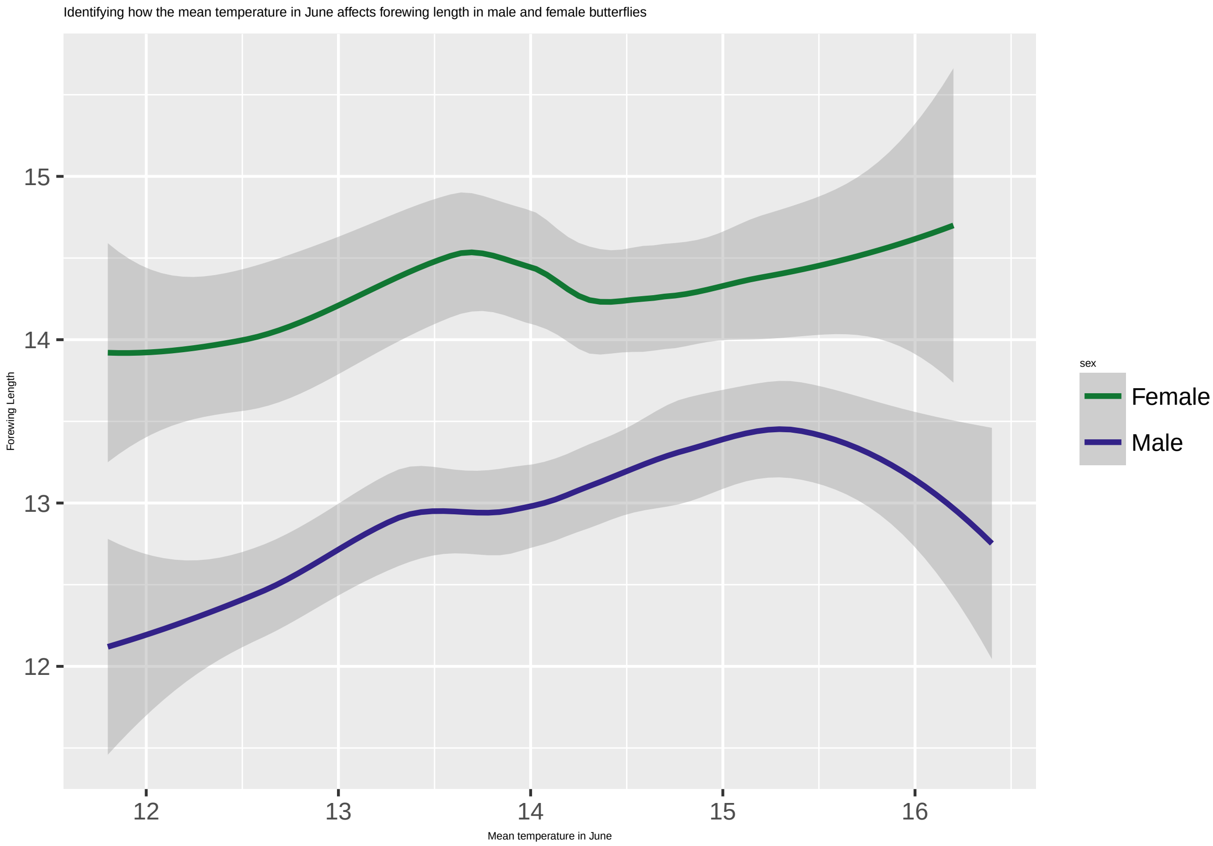

Figure 4: This graph shows the relationship between the mean temperature in June and the forewing length of male and female butterflies. Visually the graph shows that as mean temperature increases the forewing length of both male and female butterflies also increases. As the temperature reaches around 15 degrees, it continues to increase for males but for females we can see where it starts to decrease. Looking at this data alone it shows that it is accepting the null hypothesis due to the increase in temperature resulting in an increase in the forewing length. It also provides information on the fact that female butterfly's have overall longer forewing length to the male butterflies.

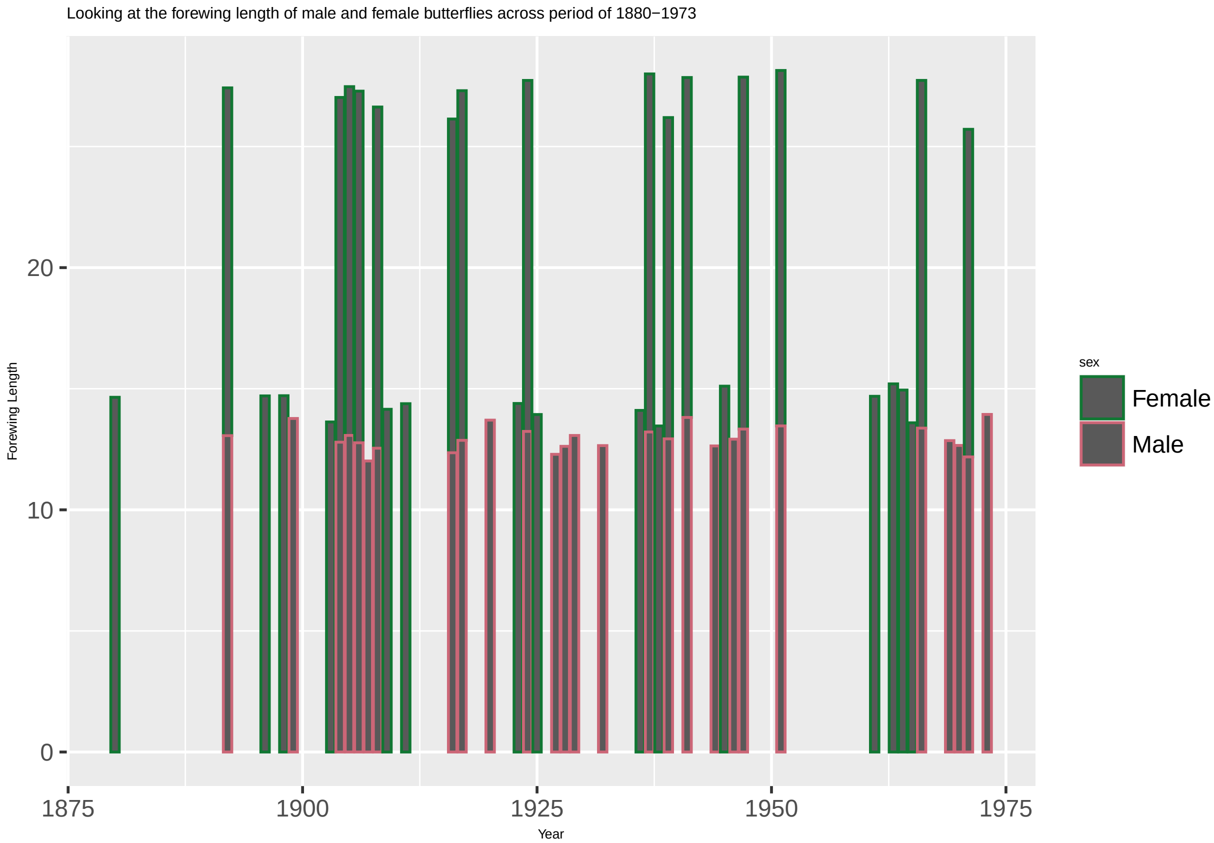

Figure 5: This graph shows that the forewing length of females is much longer than males and the data stays relatively consistent despite the fact that there is a distance of 100 years between the start and the end, this means that overall females have longer forewing length to males and it stayed consistent for 100 years. This is despite biological concepts such as evolution that would have taken place during this time. The majority of male and female values are consistent through the years, even though the female forewing length values range more as they range from their lowest value being around 14 mm, to their highest value being around 28mm, they are still relatively similar which could provide evidence that we can reject the test hypothesis because temperature doesn't have an effect on forewing length.

```
## `geom_smooth()` using formula = 'y ~ x'
```

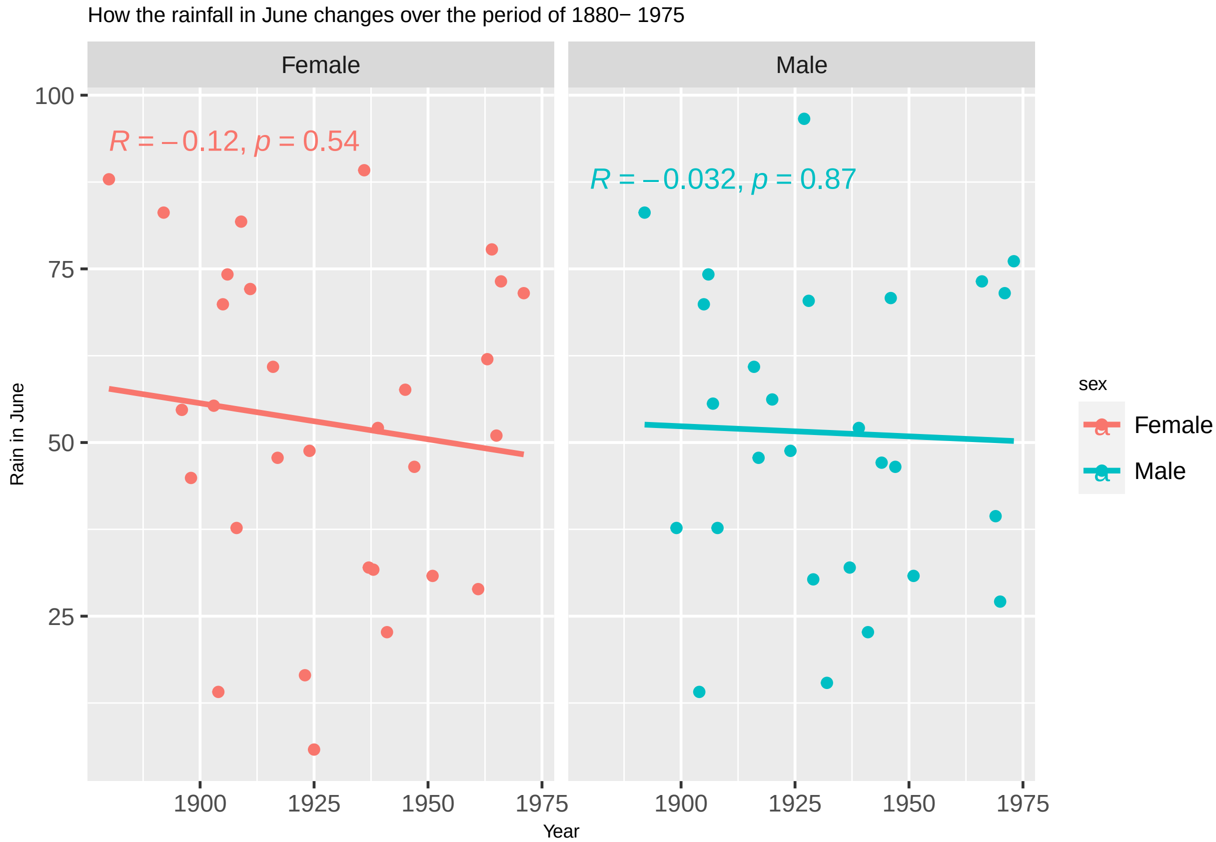

Figure 6: This graph shows that the female and male butterflies are relatively not affected by the rain during the month of June. The R values for both are negative which indicates a negative correlation, this means that as the values of one variable increase the value of the other variable decrease for both male and female. Both the R values for male and female are close to zero, the male butterflies have a closer R value to zero with the number -0.0032 and the females is slightly larger with a value of -0.12. This defines that the female butterflies have a weaker linear relationship to the rain in June than male butterfly's do because its closer to zero. The p value indicates whether a correlation will be statistically significant. Both of these p values are positive and both p values are above 0.05 (<0.05) because female butterfly's p value is 0.54 and male p value is 0.87. This means that we consider this study as positive and means that the test hypothesis is false and should be rejected and therefore we should accept the null hypothesis for both male and female butterflies.

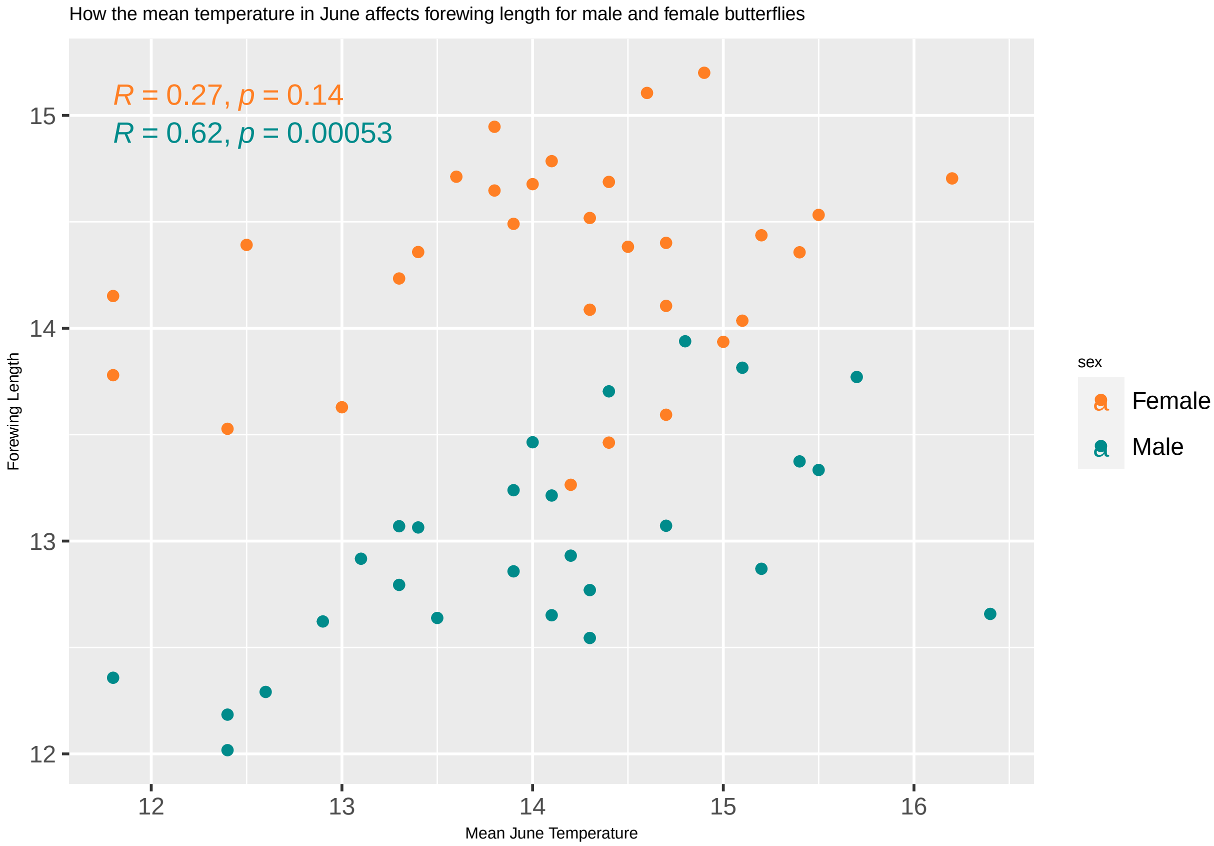

Figure 7: This plot is showing how the temperature in June affects the forewing length of male and female butterflies. The R value for both male and females is positive which means that it indicates a positive correlation, a positive correlation means that when one variable increases so does the other, or when one variable decreases so does the other. Both R values for male and female are close to zero, the female butterfly's have a closer R value to zero with a value of 0.27 and males have a slightly larger value of 0.62. This means that females have a weaker linear relationship because their value is closer to zero. The p value is indicating, as already stated above, whether a correlation will be statistically significant. Both of these p values are positive, one being above 0.05 and the other being below this. For male butterfly's, they have a p value of 0.00053 meaning that they have a value below 0.05, this means that we can accept the test hypothesis and we reject the null hypothesis. For female butterfly's their value is above 0.05 (0.14) - this means that we accept the null hypothesis and we reject the test hypothesis.

```
## `geom_smooth()` using formula = 'y ~ x'
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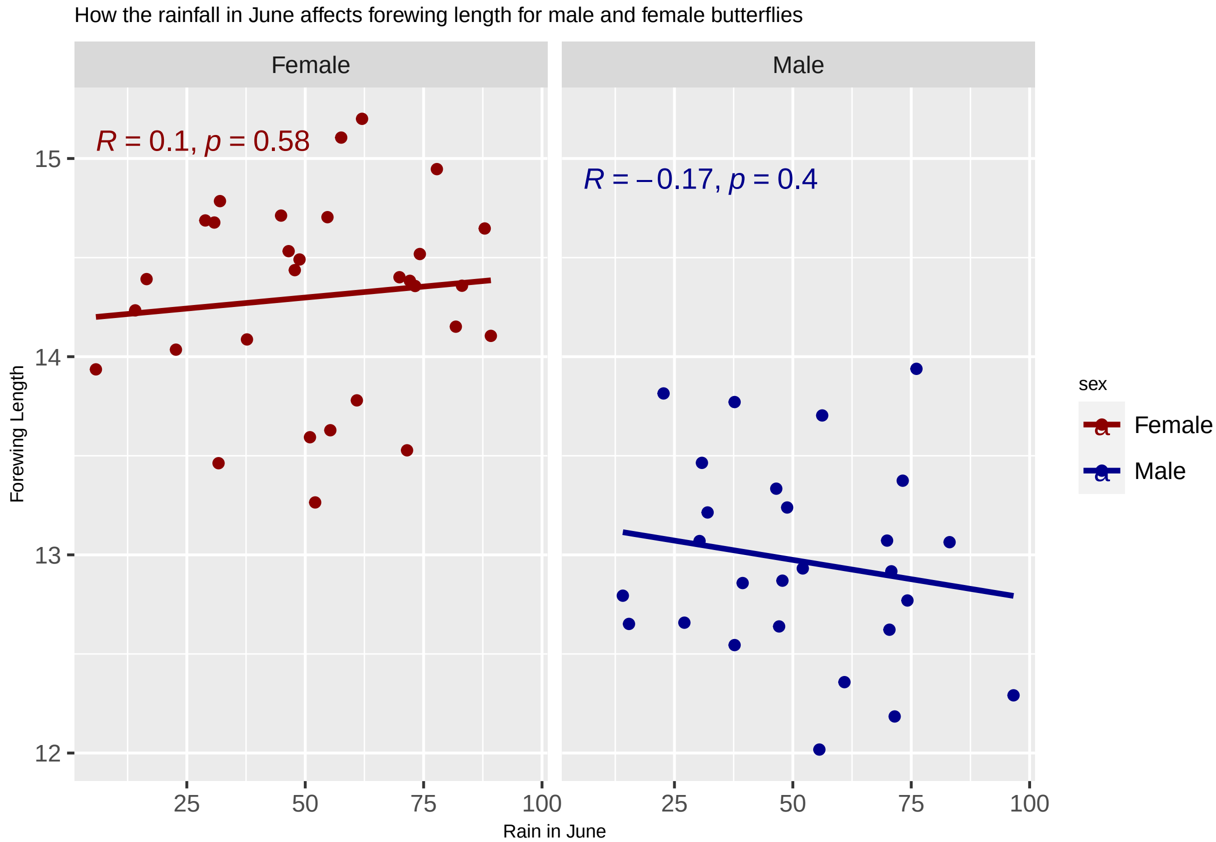

Figure 8: This graph shows how the rainfall in June affects the forewing length of male and female butterflies. The R value for female butterfly's is positive (0.1) which means it indicates a positive correlation, this that as the values of one variable increase, so does the values of the other variable and it means that as the values of one variable decrease so does the values of the other variable. For male butterflies the R value is negative (-0.17) which means that it indicates a negative correlation, this means that as the values of one variable increases the value of the other variable decreases. The closer to zero the R value is the weaker the linear relationship which means that females have the weaker linear relationship. The p values for male and female are both positive and are both above the value 0.05 (>0.05), because of this it means that we consider this study as positive and means that the test hypothesis is false and should be rejected and therefore we should accept the null hypothesis for both male and female butterflies.

After the creation of multiple different graphs, it provides us with more detail around the data and the results to the hypothesis that were created in the introduction of the report. All the graphs in this report were created with a 95% confidence interval. I used the Pearson Correlation Coefficient test to test how linear the relationships are. Part of the hypothesis that I investigated was whether the temperature affected the rainfall in June for male and female butterflies. The scatter plot created, figure 3, shows that we can say that female butterflies p value is 0.53, a statistically non-significant test result above 0.05 (>0.05), so we can accept the null hypothesis and reject the test hypothesis, temperature has no effect on rain and female butterflies. For male butterflies they also presented a p value that was above 0.05 (>0.05), a non-significant test result, meaning that we can accept the null hypothesis and reject the test hypothesis. This tells us that the temperature does not have an effect on rainfall and male butterflies. The R values for both male and female butterflies are negative meaning that this indicates a negative correlation.

Figure 6 looks at the effect that rain has on female and male butterflies. Both of the p values for male and female butterflies were positive, for males the P value was a statistically non-significant test result above 0.05 (>0.05), 0.87, and for females it was the same, 0.54. This result means we can consider this a positive study and we can reject the test hypothesis initially presented in the introduction of this report and accept the null hypothesis that rain has no effect on male and female butterflies during the month of June. The R values for male and female butterflies were both negative, meaning that this indicates a negative correlation.

The main hypothesis that was being tested throughout this study was proving whether the temperature and rainfall had an effect on the forewing length of both male and female butterflies. Figure 7 was created in order to determine whether the temperature during the month of June affected the forewing length of male and female butterflies. The p value of male butterfly's was a statistically significant test result below 0.05 (0.00053), resulting in for male butterfly's the test hypothesis can be accepted and the null hypothesis rejected, the temperature has an effect on the forewing length of male butterflies. For female butterfly's in figure 7 their p value is a statistically non-significant result that is above 0.05 (>0.05) with a value of 0.14, therefore meaning that we reject the test hypothesis and can accept the null hypothesis that temperature doesn't have an effect on the forewing length of females. The R value for both male and female butterflies is positive, 0.27 for females and 0.62 for males meaning that it shows a positive correlation for both butterfly sexes.

Figure 8 in the report shows how the rainfall in June affects the forewing length of male and female butterflies. Both of the p values for male and female butterflies are positive and are both statistically non-significant test results above 0.05 (>0.05), the females value is 0.58 and males value is 0.4. Due to this it means that the test hypothesis is false and should be rejected and we should accept the null hypothesis, resulting in the rainfall not having an effect on forewing length for male and female butterflies. The relationship between female butterfly's forewing length and rainfall showed a positive correlation, however the relationship between male butterfly's forewing length and rainfall showed a negative correlation.

Conclusion

To conclude, another study that was undertaken discussed that June temperatures are important for predicting adult male wing length. This is part of the reason why I decided to make the main hypothesis for this study about looking at the forewing length of both male and female butterflies and how these are affected by both the temperature and the rain (Fenberg et al, 2016). A study undertaken found that wing length increased as temperatures increased at certain distinct points in the early and midpupal periods (Davies, 2019). Another study undertaken provided general background information to insects stating that they change phenology in response to how much climate warming they experience and how through evolution they adapt (Buckley et al, 2022). Understanding the concepts behind the climate change that is adapting the life of Silver Spotted Skipper butterflies is incomplete due to limited knowledge of how and if the adaptions are taking place, hence the importance of this study in adding to the global research needed to help this species survival (Berrang-Ford et al, 2011).

The conclusion of this study matched with what was found in the study that was presented above, as it shows that temperature has an effect in June on the forewing length of male butterfly's but not the female butterfly's. It also showed that rainfall doesn't have an effect on forewing length of male or female butterflies.

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