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

Gemma Thompson

2023-05-10

Introduction

This report looks into the universal ecological responses to climate change in univoltine butterflies. 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 and annual temperature vary.

The Silver Spotted Skipper is an easy butterfly to identify to find as according to UK Butterfly, 2023 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 the distribution of the Silver Spotted Skipper have posed interesting questions for conservationists and ecologists (Thomas et al, 1986). The improving status of this butterfly species is mainly down to good habitat management and climate warming which has improved the quality and increased the available 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 so called destroying the planet that we live on today and therefore posing a threat to some of our most treasured species, however here we are presented with a species that is in fact going against this analogy and since early 2000's has had a large increase in its population (Davies et al, 2005). The time that these weather conditions were reported 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.

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

Main Hypothesis

After analysis of some of the data through the lsmodel1 we can determine that although not totally perfect, our data set is reasonably accurate in aspects - the linear models make a diverse range of assumptions about the data set, which provides further hidden 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 doesn't have an effect on the forewing length of male and female butterflies. Null Hypothesis: The temperature and rainfall has 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

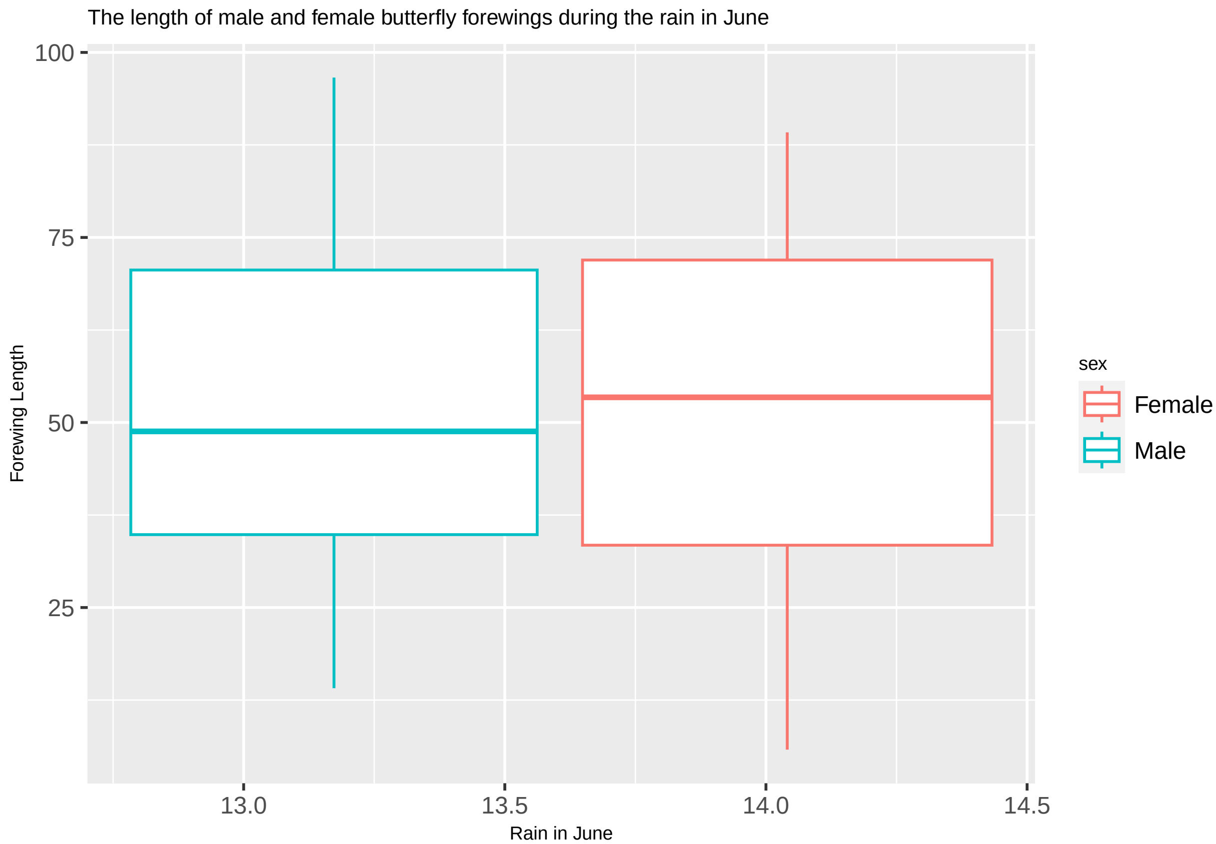

Figure 1: This plot shows the length of male and female forewings in June is realtivley similar to each other shown by box plot graph displayed. Looking at the mean values we can see that females have a slightly larger forewing length of around 55mm, male butterflies being slightly shorter with a value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

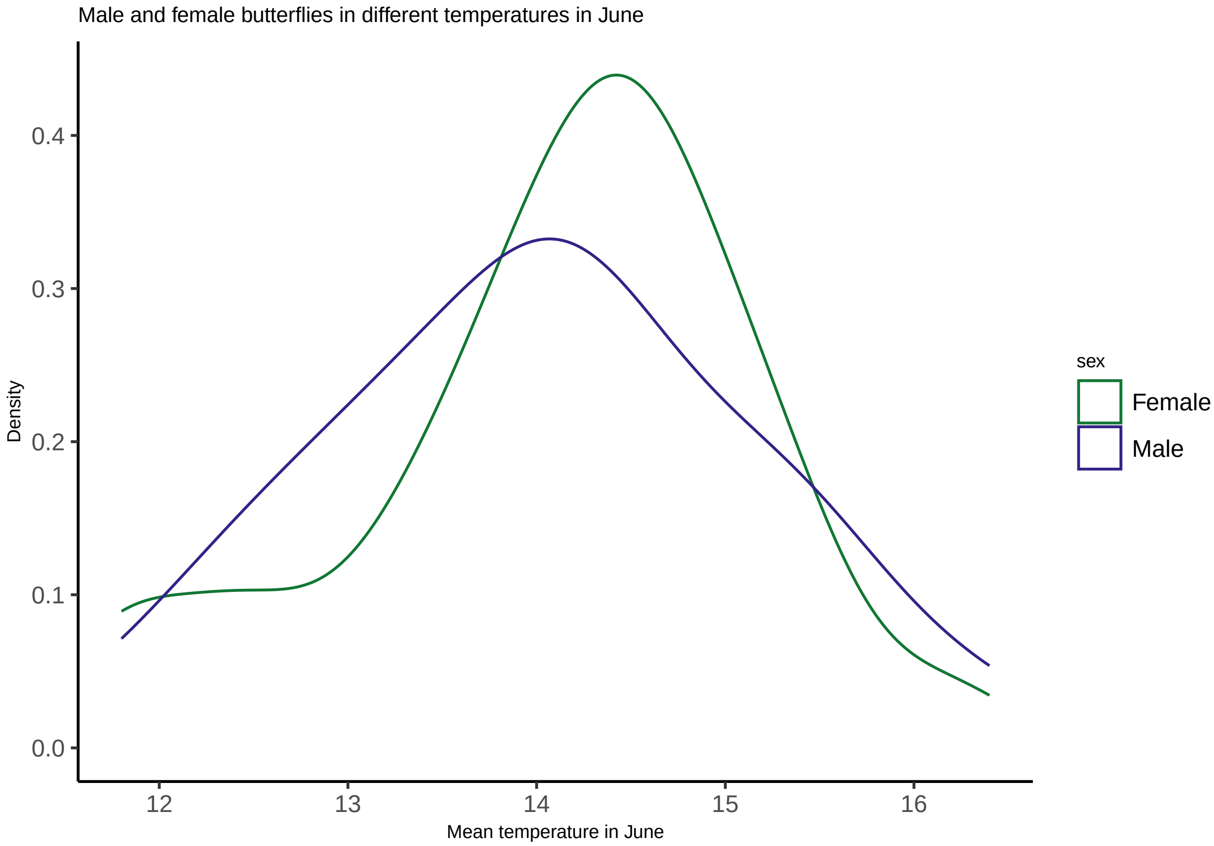

Figure 2: This plot shows the density of male and female butterflies in the month of June. It shows that at temperatures around 12-14 degrees Celsius there are more male butterflies providing data of forewing length, but then at around 14-15.5 degrees Celsius there are nearly double the amount of female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

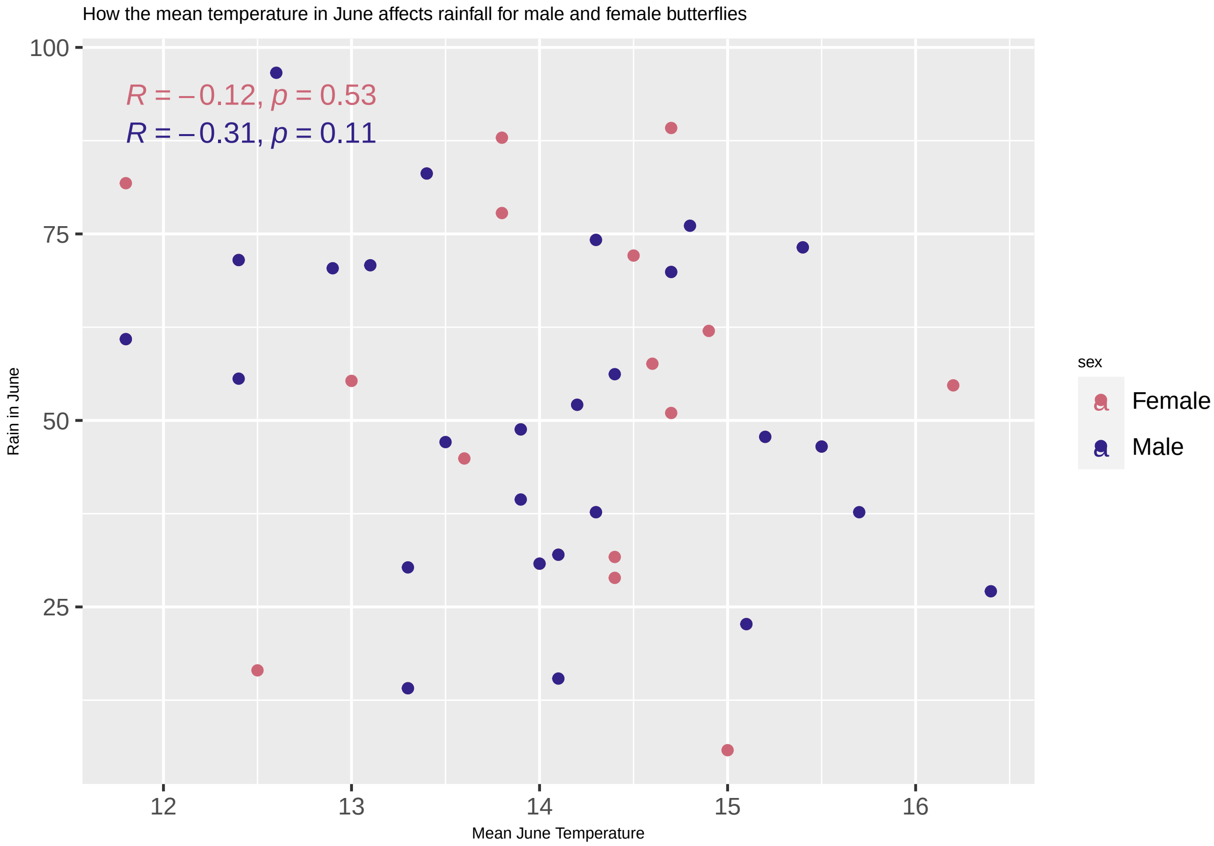

Figure 3: This plot shows how the temperature in June affects the rainfall in June for male and female butterflies. Both the R values are negative indicating a negative correlation, meaning the values of one variable increase when the values of the other variable decrease. Both R values are close to 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 butterflies do. The p value gives a further understanding as to whether we can conclude that the correlation coefficient is different from zero, and from what we can observe the female butterflies has the furtherst away value from zero. The p value indicates whether or not a correlation will be statistically significant. One of the P values is presented as a negative value (-0.31 for females) and the other is presented as a positive value (0.11 for males). One of the p values is above 0.05 and the other p value is below 0.05, this means that for females we accept the null hypothesis meaning that the rainfall in June doesn't affect the number of female butterflies and for males, because the value is above 0.05 we reject the null hypothesis, claiming that the rainfall in June does affect the number of male butterflies.

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

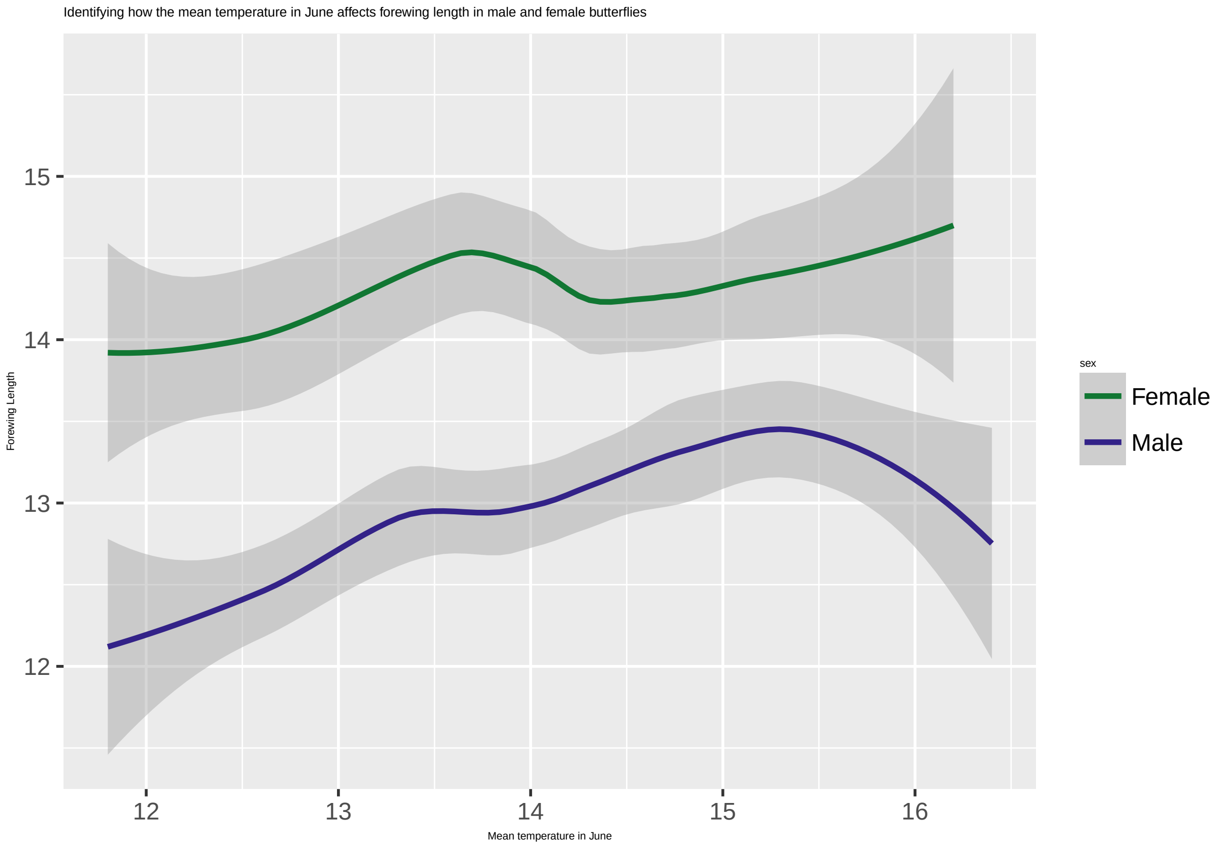

Figure 4: This graph shows the relationship between the mean temperature in June and the forewing length of male and female butterflies. Visually the graph shows that as mean temperature increases the forewing length of both male and female butterflies also increases. As the temperature reaches around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

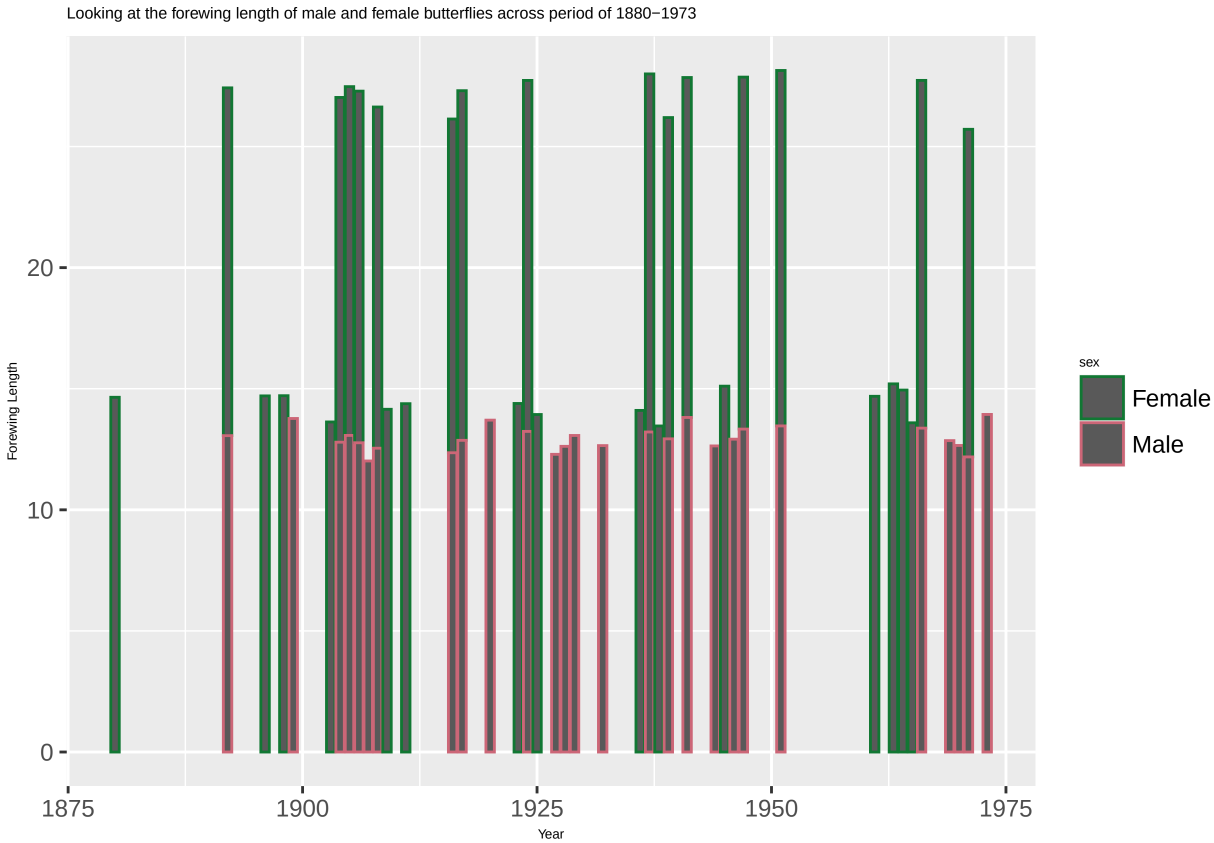

Figure 5: This graph shows that the forewing length of females is much longer than males and the data stays relatively consistent despite the fact that there is a distance of 100 years between the start and the end, this means that overall females have longer forewing length to males (supporting the evidence that we collected in the graph above) and it stayed consistent for 100 years, 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 null hypothesis because temperature doesnt have an effect on forewing length.

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

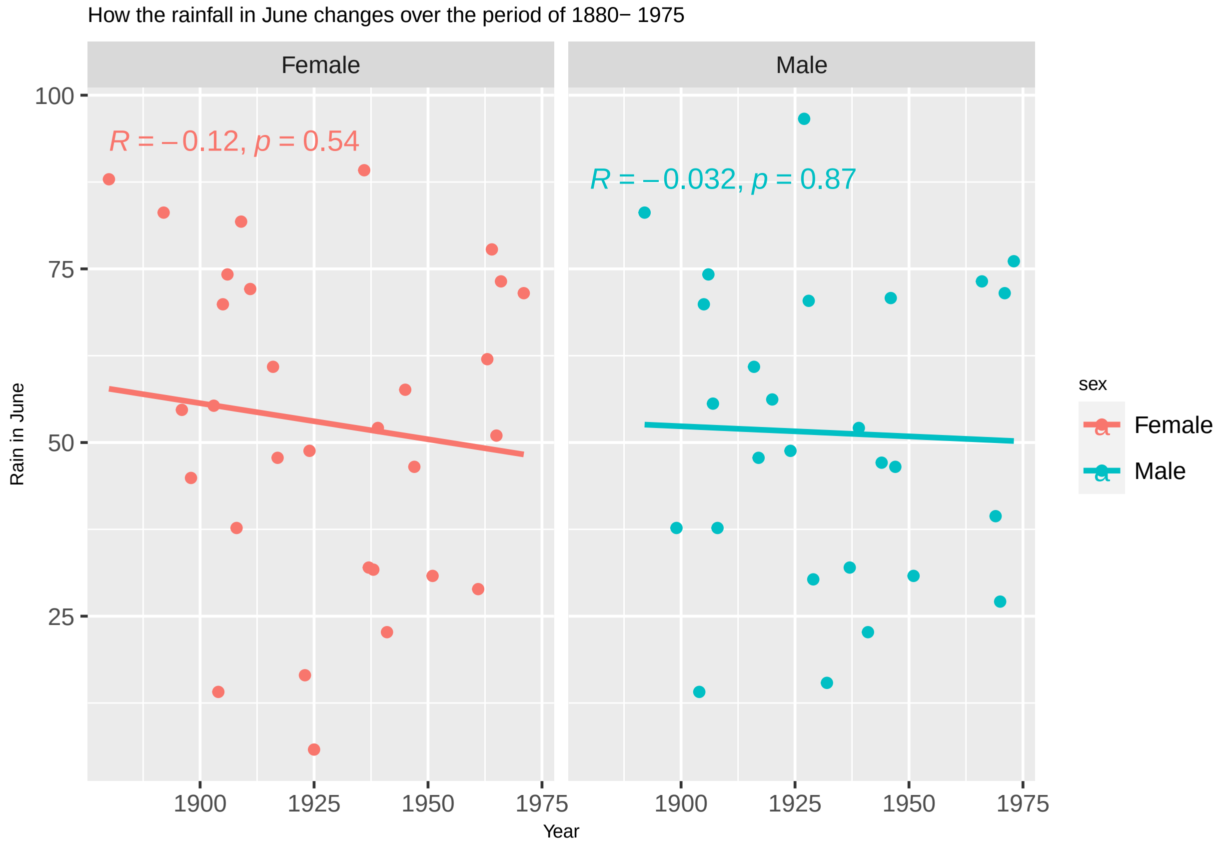

Figure 6: This graph shows that the female and male butterflies are relatively not affected by the rain during the month of June. The R values for both are negative which indicates a negative correlation, this means that as the values of one variable increase the value of the other variable decrease 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 male butterflies have a weaker linear relationship to the rain in June than female butterflies do. 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 butterflies 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.

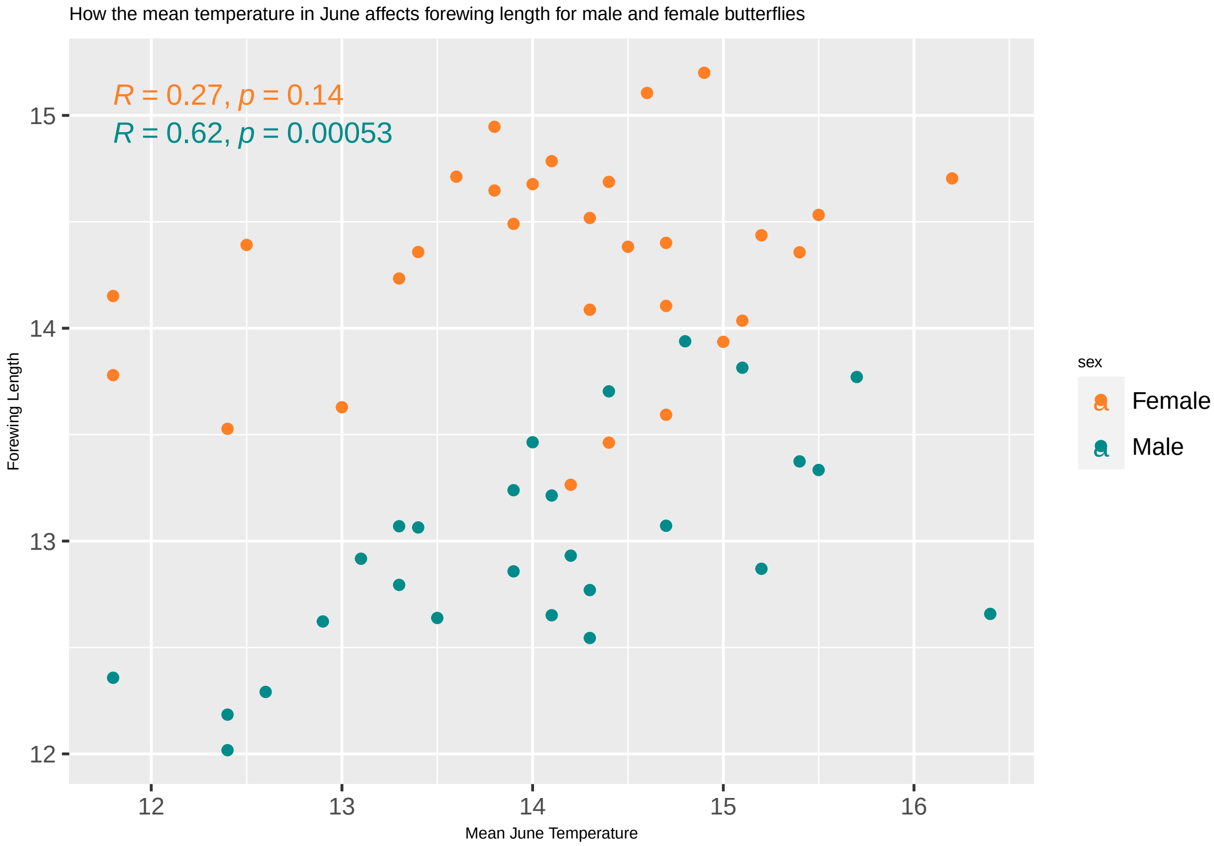

Figure 7: This plot is showing how the temperature in June affects the forewing length of male and female butterflies. The R value for both male and females is positive which means that it indicates a positive correlation, a positive correlation means that when one variable increases so does the other, or when one variable decreases so does the other. Both R values for male and female are close to zero, the female butterflies 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 they have a strong linear relationship. 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 butterflies, they have a p value of 0.62 meaning that they have a value above 0.05, this means that we consider this study for male butterflies as positive and means the test hypothesis is false and should be rejected and therefore we should accept the null hypothesis. For female butterflies their value is below 0.05 (0.00053) - this means that we reject the null hypothesis and we accept the test hypothesis.

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

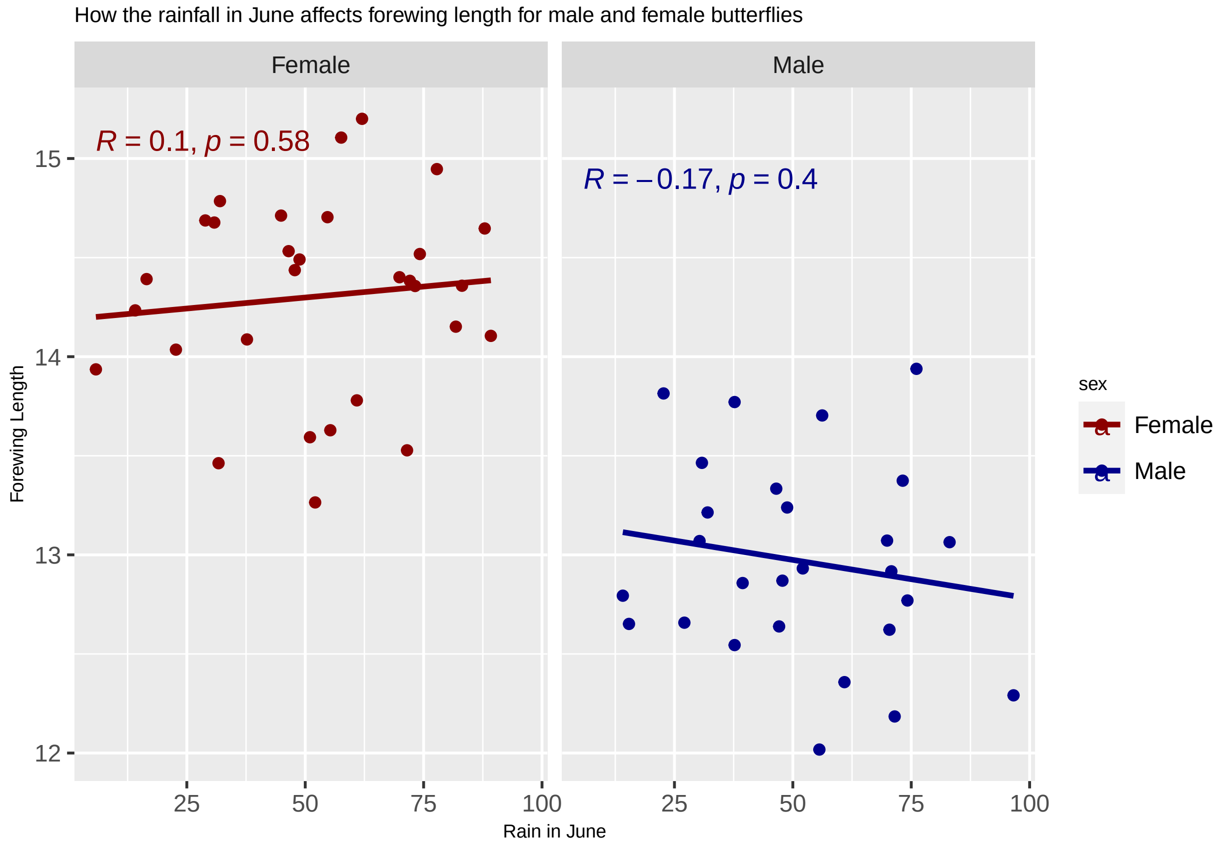

Figure 8: This graph shows how the rainfall in June affects the forewing length of male and female butterflies. The R value for female butterflies is positive (0.1) which means it indicates a positive correlation, this that as the values of one variable increase, so does the values of the other variable 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 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, 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.

Results and Discussion

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. Part of the hypothesis that I investigated whether the temperature affected the rainfall in June for male and female butterflies. All the graphs in this report were created with a 95% confidence interval. The scatter plot created, figure 3, shows that we can say that female butterflies P value presented a value of -0.31, a statistically significant test result below 0.05, so we can accept the null hypothesis and reject the test hypothesis, temperature has no effect on rain and female butterflies. However for male butterflies they presented a P value that was above 0.05, a non-signicant test result, meaning that we can reject the null hypothesis and accept the test hypothesis that tells us that the temperature does affect rainfall and male butterflies. The R values for both male and female butterflies was negative meaning that this indicates a negative correlation.

Figure 6 looks at the effect that just rain alone 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 - 0.87 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 I 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. The hypothesis in the introduction of this report claims that temperature and rainfall don't have an effect on the forewing length. 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 both male butterflies on this scatter plot was a statistically non-significant test result above 0.05 (0.62), resulting in for male butterflies this being a positive study and the test hypothesis can be rejected and the null hypothesis accepted, the temperature has an effect on the forewing length of male butterflies. For female butterflies in figure 7 their P value is a statistically significant result that is below 0.05 (0.00053), therefore meaning that we reject the null hypothesis and accept the test hypothesis that temperature doesnt have an effect on the forewing length of females, making this significant. 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 is the last figure that i presented in the report and it 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, 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 having an effect on forewing length for male and female butterflies. The relationship between female butterflies forewing length and rainfall showed a positive correlation, however the relationship between male butterflies forewing length and rainfall showed a negative correlation.

Conclusion

To conclude this report, 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). Temperature-induced alterations to body size and phenology are common responses to climate change. 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 theychange 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 a limited knowledge of how and if the adaption are taking place, hence the importance of this study in adding to the global research needed to help this species overall 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 affect in June on the forewing length of male butterflies but not the female butterflies. It also showed that rainfall has an effect on the forewing length of both male and female butterflies.

Reference List

Amateur Entomologists' Society; Univoltine; Accessed: 10th May 2023

Berrang-Ford, L., Ford, J.D. and Paterson, J., 2011. Are we adapting to climate change?. Global environmental change, 21(1), pp.25-33.

Davies, W.J., 2019. Multiple temperature effects on phenology and body size in wild butterflies predict a complex response to climate change. Ecology, 100(4), p.e02612.

Davies, Z.G., Wilson, R.J., Brereton, T.M. and Thomas, C.D., 2005. The re-expansion and improving status of the silver-spotted skipper butterfly (Hesperia comma) in Britain: a metapopulation success story. Biological Conservation, 124(2), pp.189-198.

Fenberg, P.B., Self, A., Stewart, J.R., Wilson, R.J. and Brooks, S.J., 2016. Exploring the universal ecological responses to climate change in a univoltine butterfly. Journal of Animal Ecology, 85(3), pp.739-748.

Lawson, C.R., Bennie, C.D., Thomas, J.A., Hodgson, T., Bernhard, P.A., Budd, A., Daish, A., Edwards, M., Gray, T., Holloway, C. and Hoyes, R., 2013. The status and conservation of the silver-spotted skipper Hesperia comma in South-East England 2000-2009. University of Exeter, Exeter, UK.

Thomas, J.A., Thomas, C.D., Simcox, D.J. and Clarke, R.T., 1986. Ecology and declining status of the silver-spotted skipper butterfly (Hesperia comma) in Britain. Journal of applied Ecology, pp.365-380.

UK Butterflies; 2023; Silver Spotted. Skipper, Hesperia Comma, Accessed: 10th May 2023