Washington State Moth Elevation in the Midst of Global Climate Change

Greg Coan – Paige Lanham – Linda Peart – Alix Whitener
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Moth Group 2 – Pacific Northwest Moth Project
Robin Kodner – Merrill Peterson

Acknowledgements

Contents

Photo Credit: http://www.ehow.com/info_8669704_luna-moth-habitat.html

Background

Moths of the PNW

Moth	Butterfly
No club tip on antennae	Club-tipped antennae
Usually plain in color	Usually bright colored
Bulky abdomen	Slender abdomen

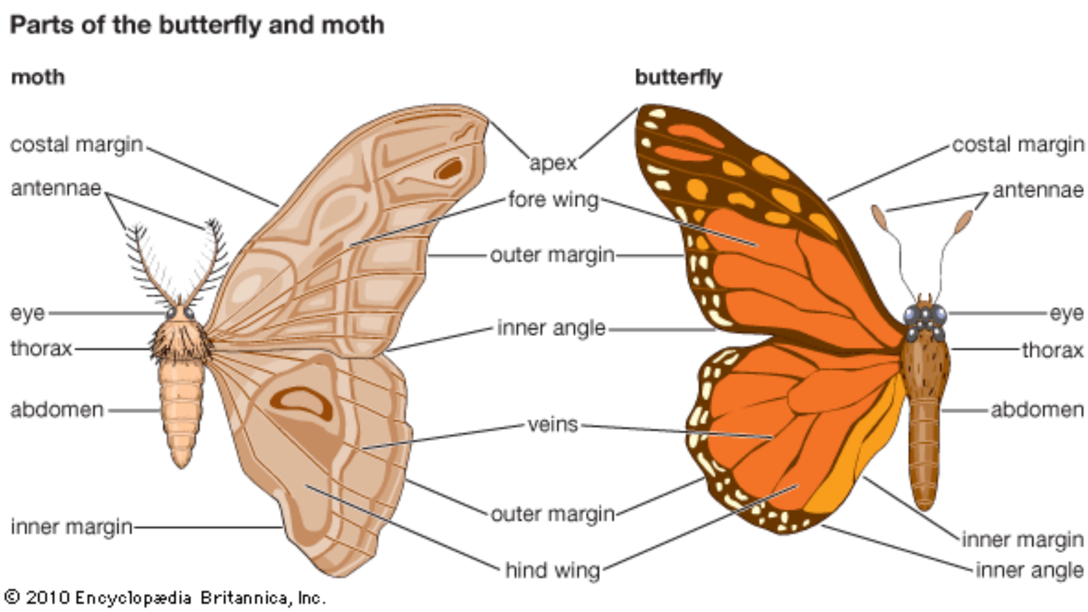


Photo credit: www.brittanica.com

Project Methods

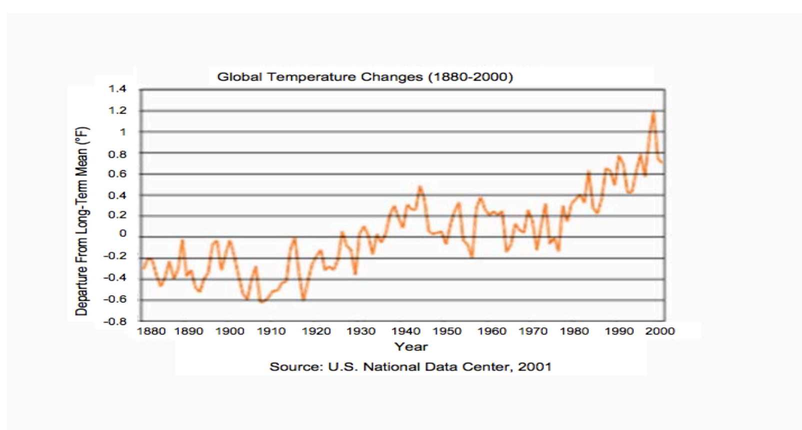
Moths were either collected in the field via nets or light traps along with data including date, location, elevation, GPS coordinates, and other information. Some moths were reared out from caterpillars. Moths were then identified to genus and species.

Data Analysis

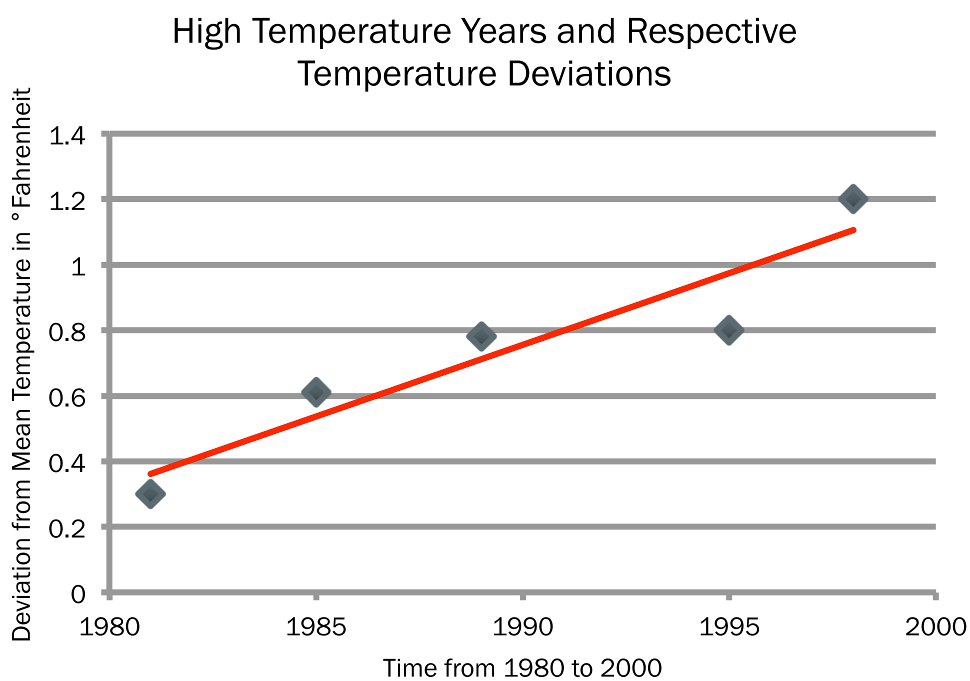
We analyzed the moth data to determine at which point sufficient samples were taken. The significant breakoff begins around 1960 but increases again in 1980. We wanted to ensure a large enough sample size to establish accurate and consistent results.

Analysis of Climate Data to Determine Focus Years

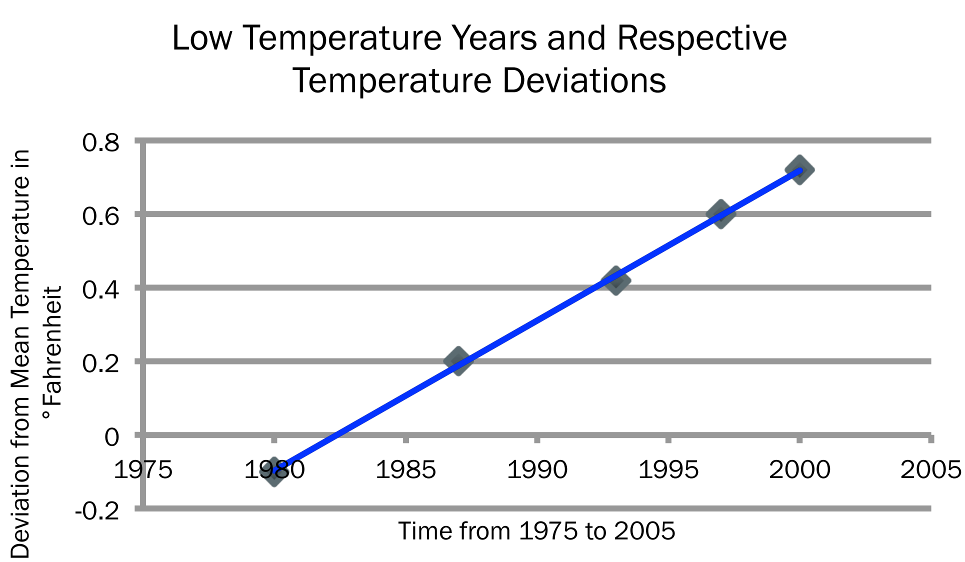
After observing climate data from the US National Data Center on Climate Data dating from 1880, eliminating years without sufficient data and identifying key high and low temperatures, we made this table to show important years for data.



High		Low	
Year	Temperature Deviation	Year	Temperature Deviation
1981	0.3	1980	-0.1
1985	0.61	1987	0.2
1989	0.78	1993	0.42
1995	0.8	1997	0.6
1998	1.2	2000	0.72



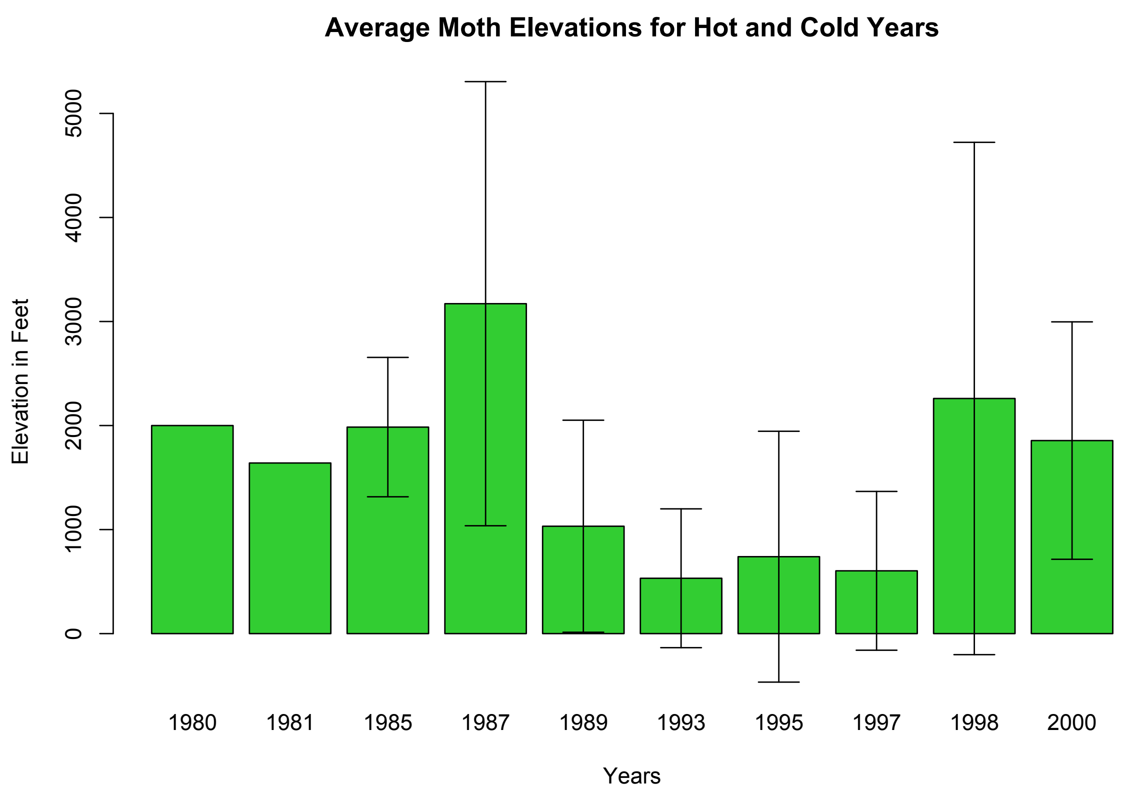
The trend in temperature deviations from the mean global temperature are increasing, even the low temperature deviations. These trends show that, despite the high and low spikes in temperature, the mean temperature is still on the rise.



Analysis of Raw Data

The question we were interested in answering was whether moths are found at different elevations in hot years than cold. We thought that moths would be found at higher elevations in hot years and lower elevations in cold years. Our null hypotheses were that there is no difference between the number of species or the counts of specific species at each elevation level during hot years than during cold years. Our alternative hypotheses, therefore, were that there are differences.

Results



Low years: 1980, 1987, 1993, 1997, and the year 2000 are all low temperature deviation years. High years: 1981, 1985, 1989, 1995 and the year 1998 are all high temperature deviation years. The best examples of support for our hypotheses are the comparison between 1993 (low) and 1993 or 1997. There are, however, anomalies, such as 1987, a low year, and 1995, a hot year.

Results

A two-way ANOVA was run in R to analyze our raw data and test the relationships between the number or counts of species (our continuous variable) and the climate (hot or cold) and elevation at which those samples were collected. We were unable to reject the null hypotheses of our diversity data and eight of the twelve species we analyzed. We were able to reject the null hypotheses for *Caradrina multifera*, *Drasteria howlandii*, *Grammia ornate*, and *Orthosia hibisci*.

Diversity:

H_0 = There is no difference between the number of species found across different elevations in hot years and cold years.

H_A = The number of species found across different elevations in hot years and cold years are different.

F value = 0.760

Pr(>F) = 0.7180

Result: Failed to reject the null hypothesis

Species-Specific analyses:

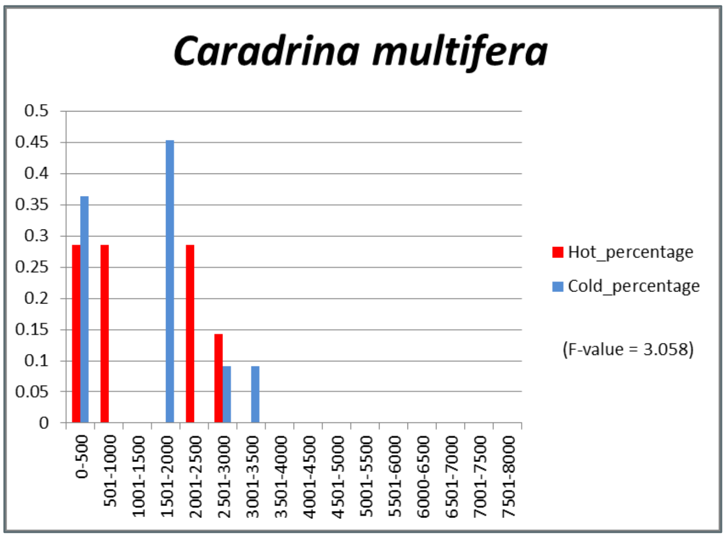
H_0 = There is no difference between the number of each species found across different elevations in hot years and cold years.

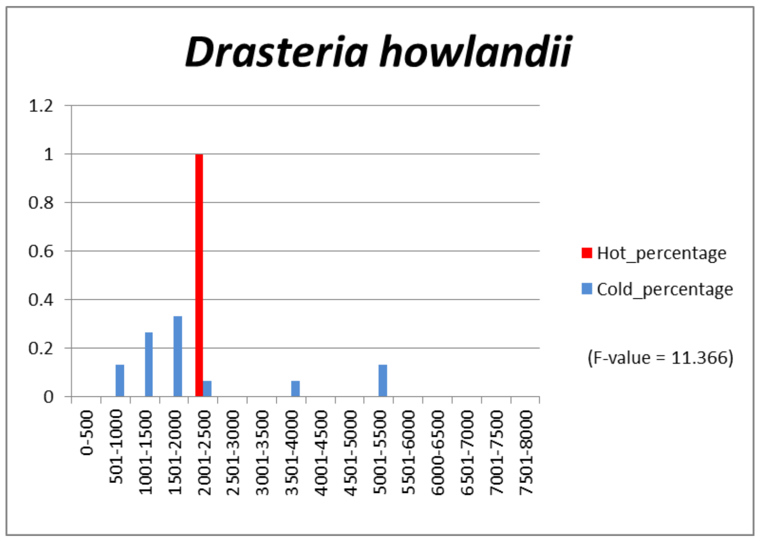
H_A = The number of each species found across different elevations in hot years and cold years are different.

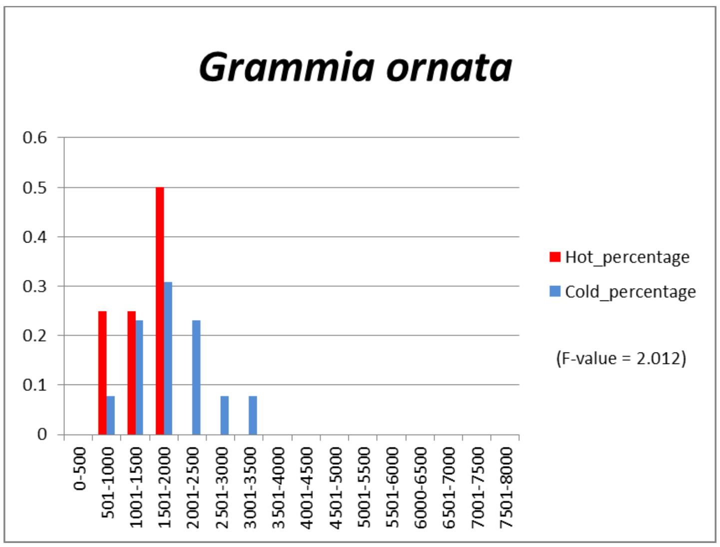
Species	F value	Pr(>F)	Result
Autographa californica	1.214	0.27517	Failed to reject the null hypothesis
Caradrina multifera	3.058	0.000468	Rejected the null hypothesis
Diarsia esurialis	0.120	1.000	Failed to reject the null hypothesis
Drasteria howlandii	11.366	2.26e-15	Rejected the null hypothesis
Egira rubric	0.207	0.999	Failed to reject the null hypothesis
Grammia ornate	2.012	0.02187	Rejected the null hypothesis
Leucania farcta	0.351	0.9873	Failed to reject the null hypothesis
Malacosoma californicum	1.028	0.434	Failed to reject the null hypothesis
Mythimna oxygala	0.142	1.000	Failed to reject the null hypothesis
Orthosia hibisci	4.777	8.44e-07	Rejected the null hypothesis
Panthea virginarius	0.182	0.9997	Failed to reject the null hypothesis
Phyllodesma americana	0.466	0.9519	Failed to reject the null hypothesis

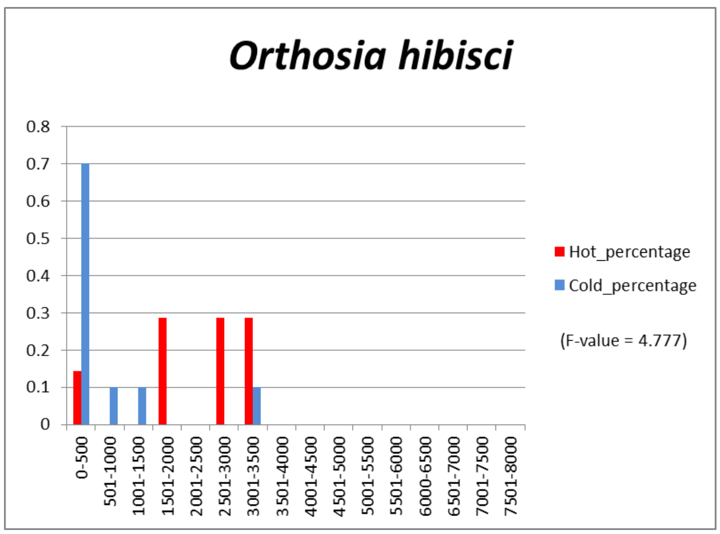
Visualization of Results

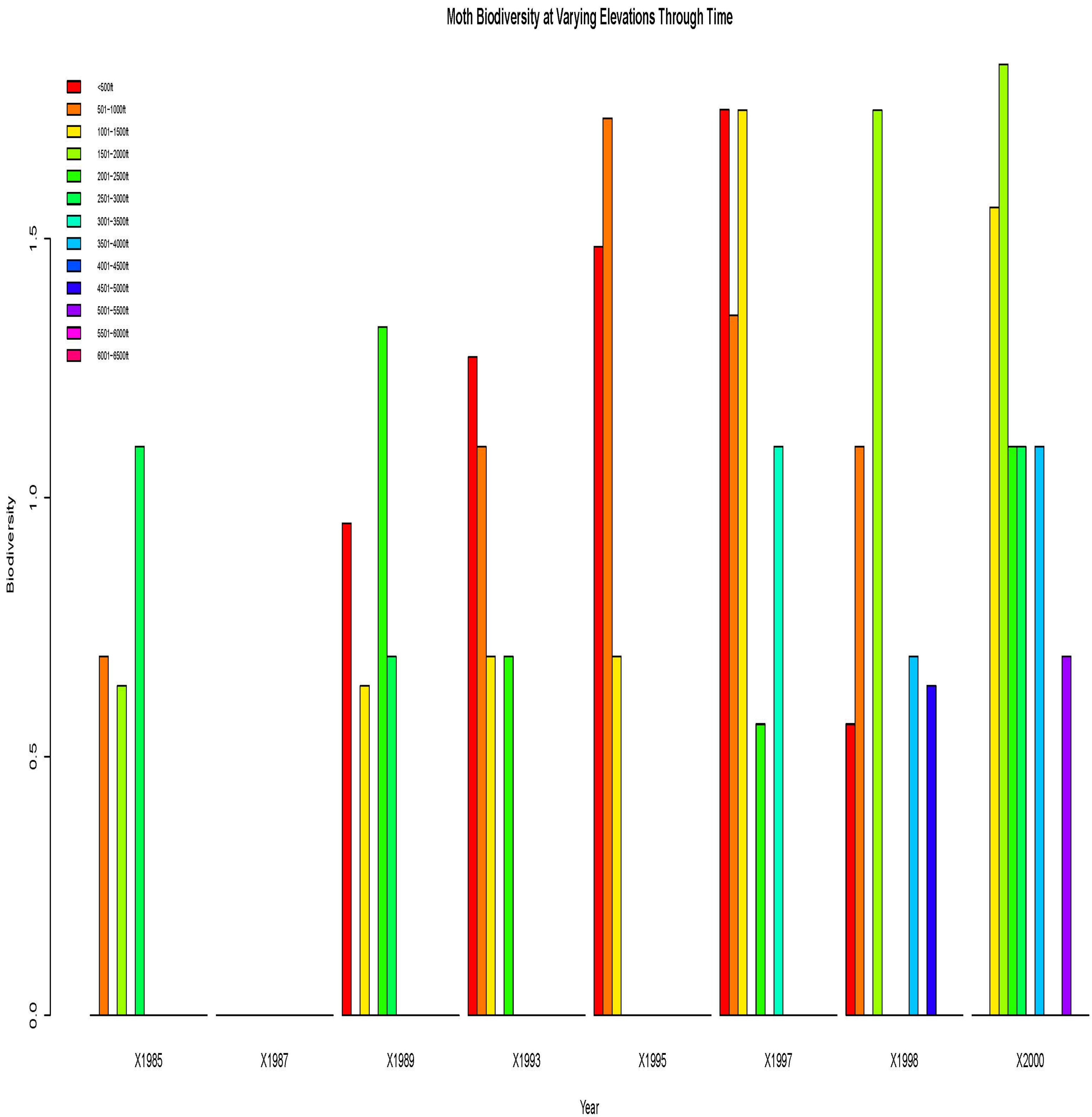
Although ANOVA is able to determine that a difference exists between the elevations at which moths were found in the hot and cold years, it doesn't say whether the elevations are higher or lower. In order to determine the direction of difference, we plotted the percent distribution of each species over the levels of elevation.







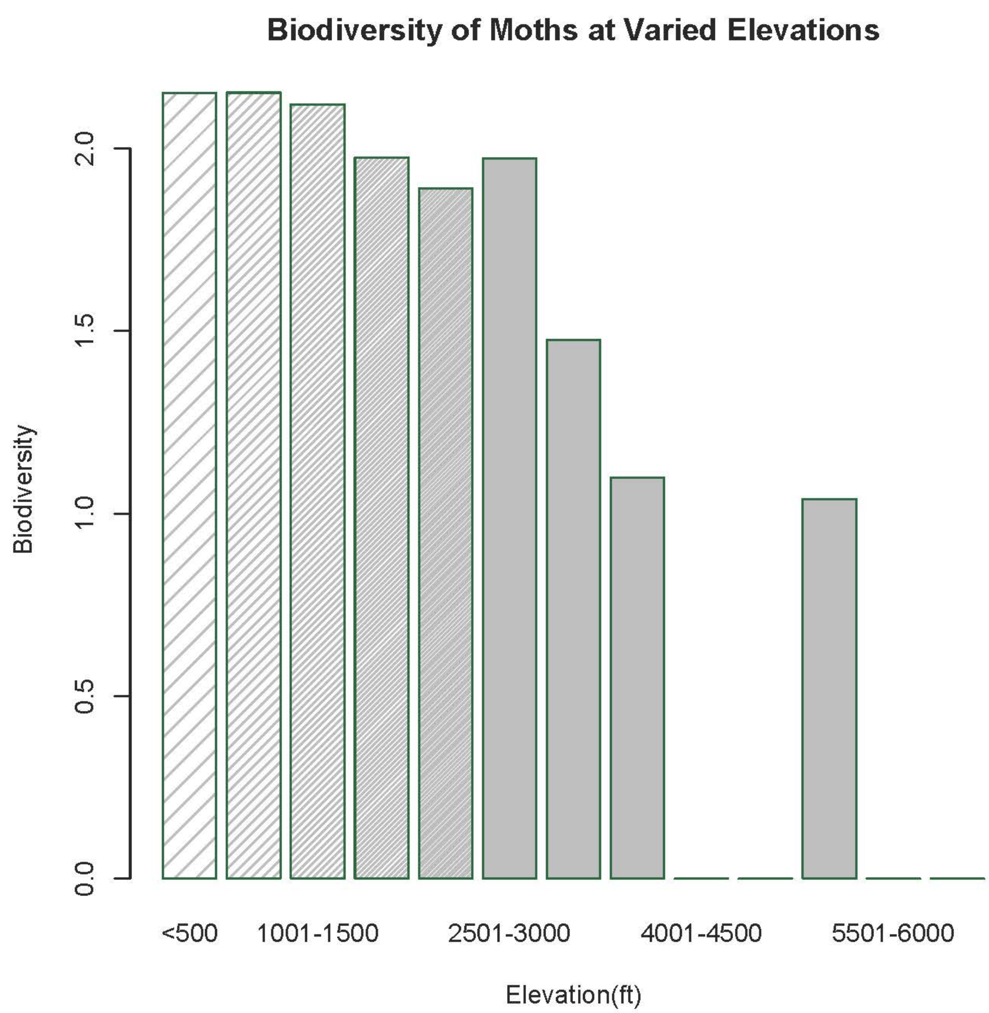


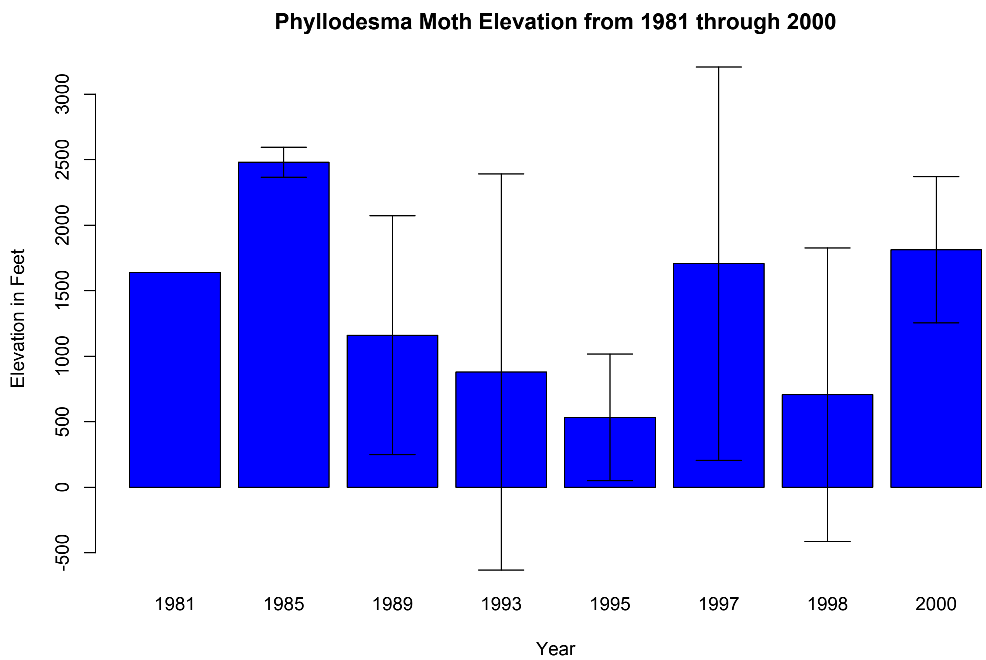

Moth Biodiversity at Varying Elevations Through Time
<500ft
501-1000ft
1001-1500ft
1501-2000ft
2001-2500ft
2501-3000ft
3001-3500ft
3501-4000ft
4001-4500ft
4501-5000ft
5001-5500ft
5501-6000ft
6001-6500ft
Biodiversity
0.0
0.5
1.0
1.5
X1985
X1987
X1989
X1993
X1995
X1997
X1998
X2000
Year

Biodiversity… What Does it Mean?

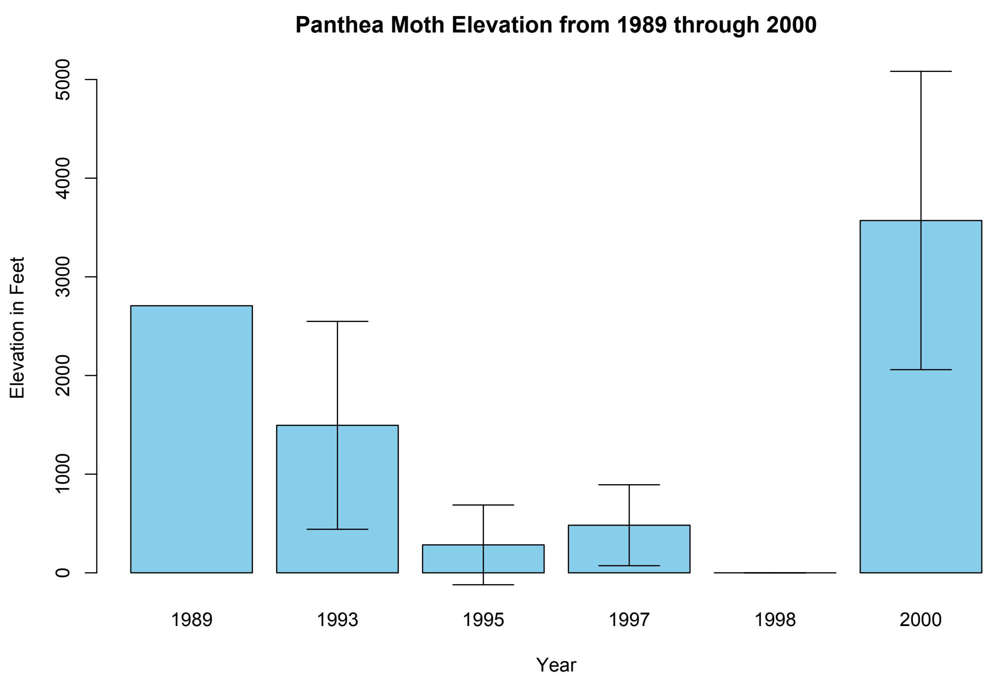
$H = -\Sigma\, p_i \ln(p_i)$

Biodiversity is the summation of the proportion of individuals from each individual species and the total number of individuals in the defined area. In this case, we looked at 12 different species and the biodiversity proportions found at different elevations. We are interested in how these proportions changed over time. The first graph is a breakdown of biodiversity proportions at each elevation for each year. The biodiversity proportions were zero for both 1980 and 1981. There could be a few reasons for this; not as many samples were collected for these years, and samples that were collected didn't always have a recorded elevation included. The second graph shows the total biodiversity proportions for species collected in this ten-year period.

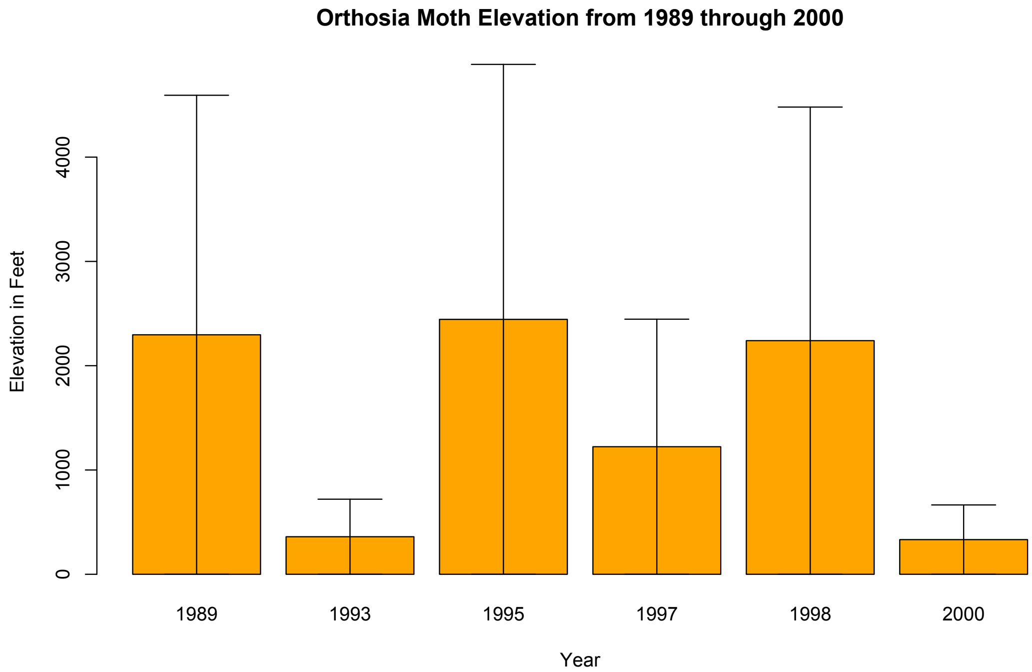




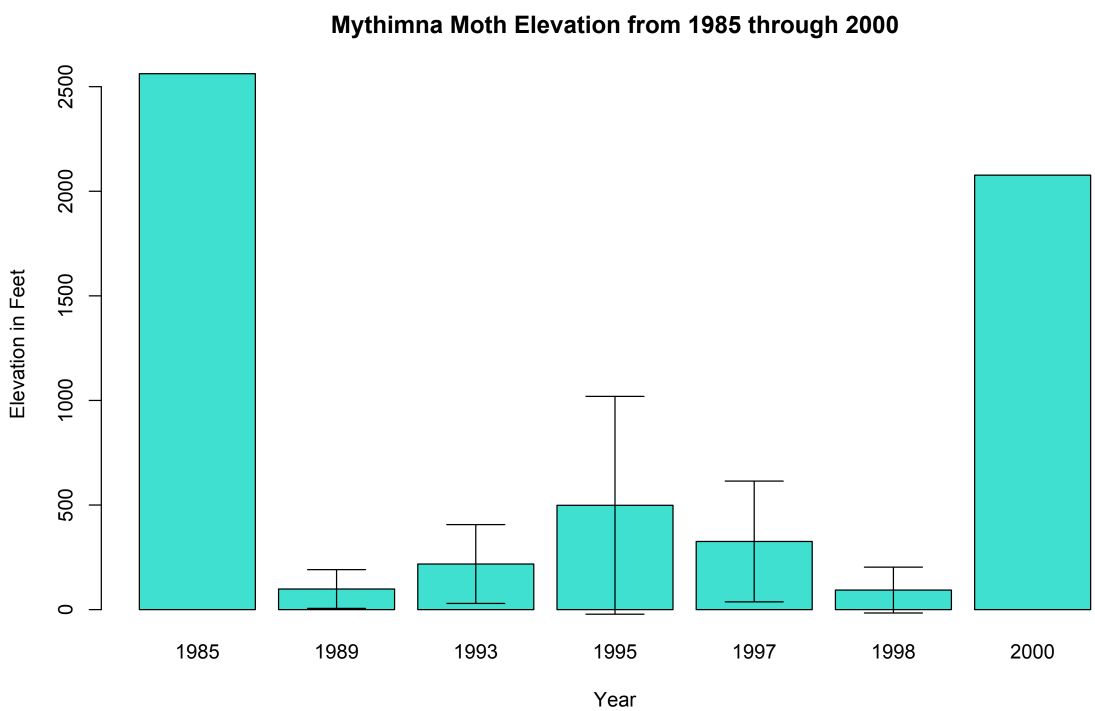
Low years: 1993, 1997, and the year 2000. High years: 1981, 1985, 1989, 1995 and the year 1998. Only counts from 1993 for the low years and 1089, 1995, and 1998 of the high years support our hypothesis. Error bars are fairly large because of insufficient sample size.



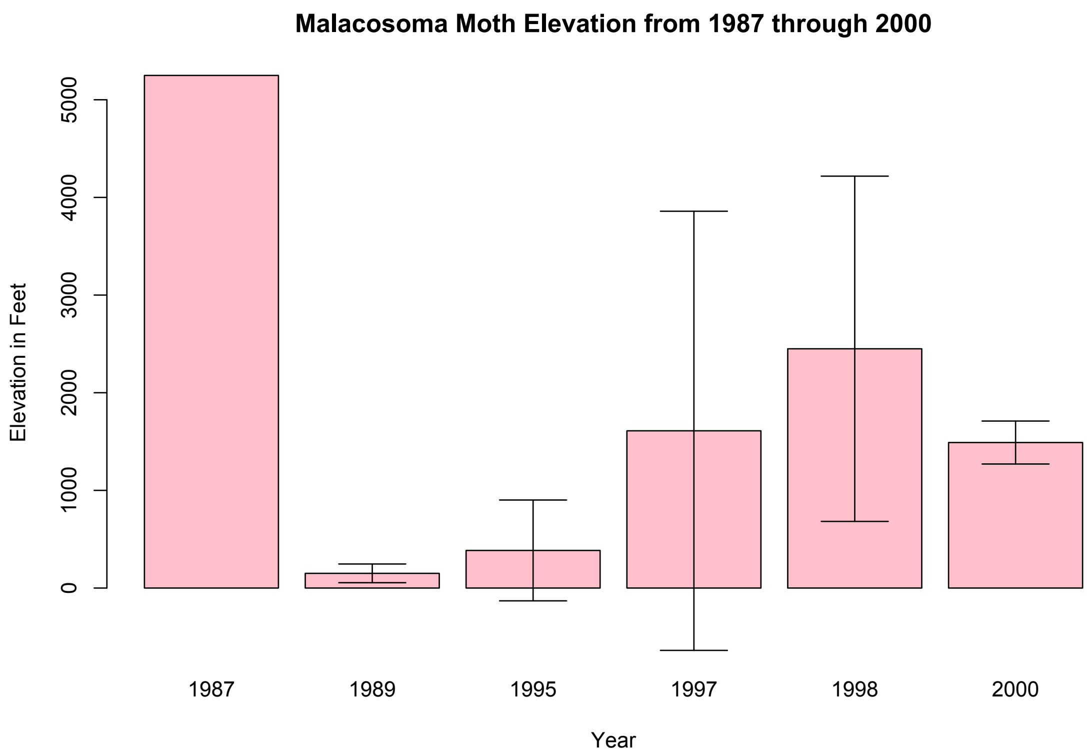
Low years: 1997, and the year 2000. High years: 1989, 1995 and the year 1998. Our hypothesis is supported particularly by years 1995 and 1998, however the year 2000 is a particularly strong case against our hypothesis. Again, the error bars are indicative of a severe sample size deficit.



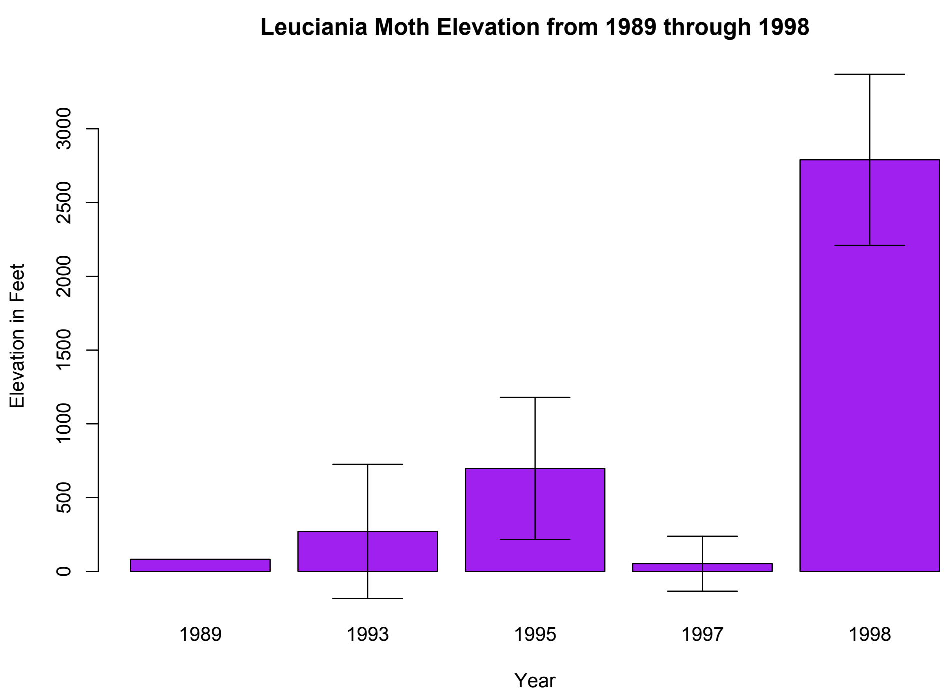
Low years: 1993, 1997, and the year 2000. High years: 1989, 1995 and the year 1998. This particular graph shows beautifully how our hypothesis can be supported, despite the error bars. More sampling to investigate whether this particular moth species differs from the others would be interesting. The data for years 1989, 1995 and 1998 are all from three high temperature deviation years and suggest much higher elevation for the location of this species.



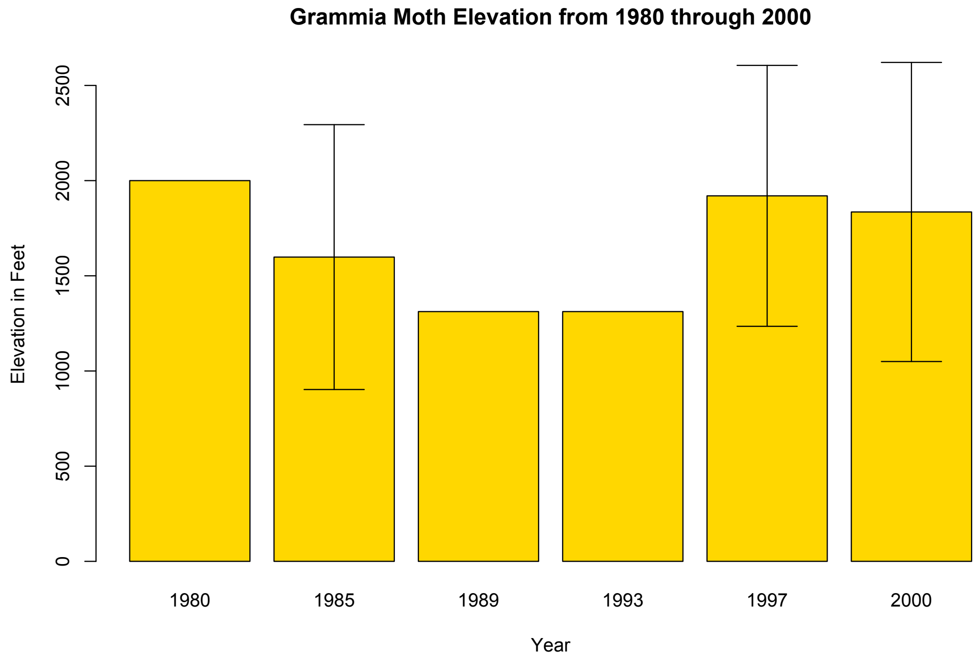
Low years: 1993, 1997, and the year 2000. High years: 1985, 1989, 1995 and the year 1998. This species didn't pass our ANOVA test and did not support our theory.



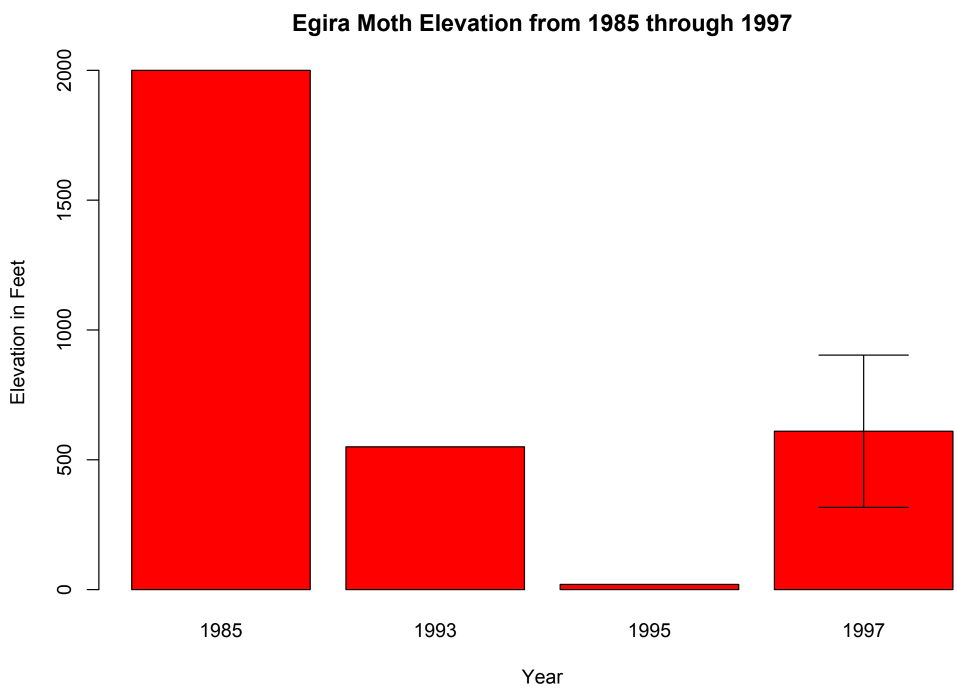
Low years: 1987, 1993, 1997, and the year 2000. High years: 1989, 1995 and the year 1998. Another anomaly, this species didn't pass our ANOVA and doesn't support our theory.



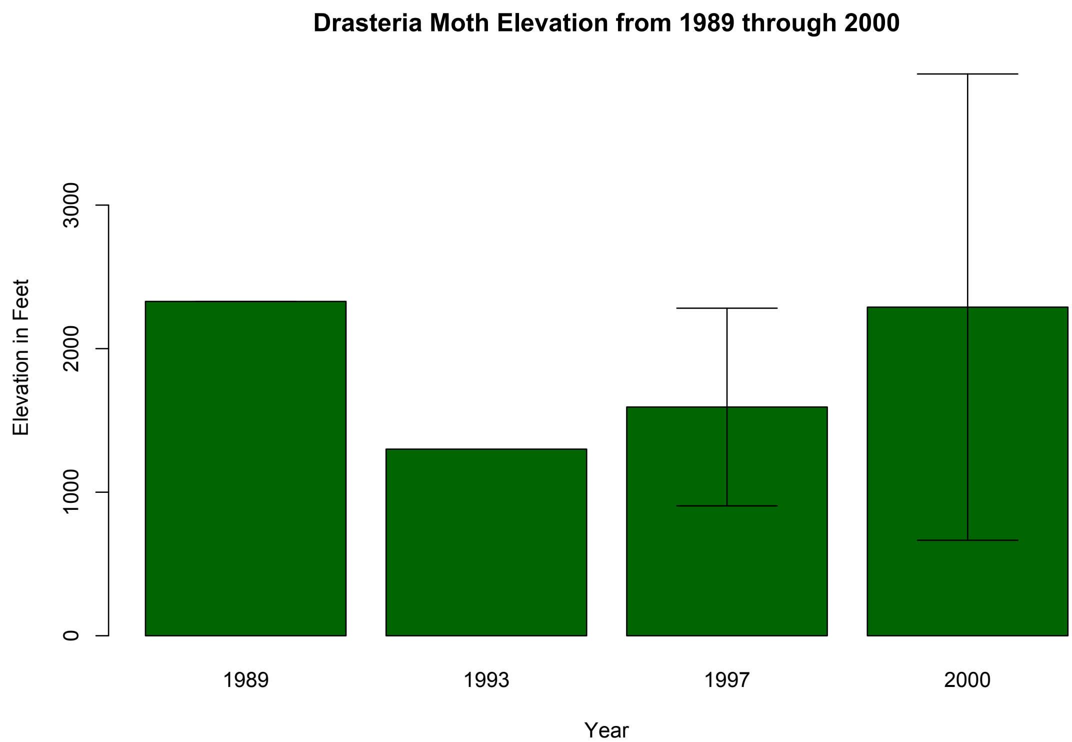
Low years: 1993, and the year 1997. High years: 1989, 1995 and the year 1998. 1989 doesn't support our hypothesis, however, 1998 does support our theory.



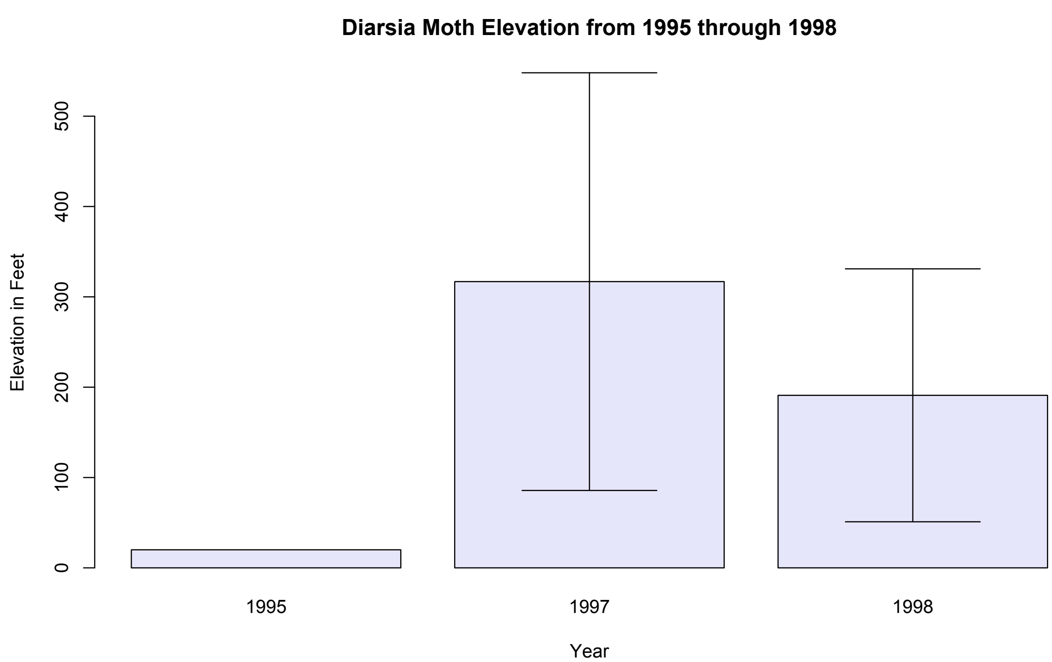
Low years: 1980, 1993, 1997, and the year 2000. High years: 1985 and the year 1998. These elevations are all very close to each other, suggesting that this particular species didn't vary much in elevation throughout the years despite temperature changes. This could suggest more adaptability and hardiness, or our sample size might not allow this to be true.



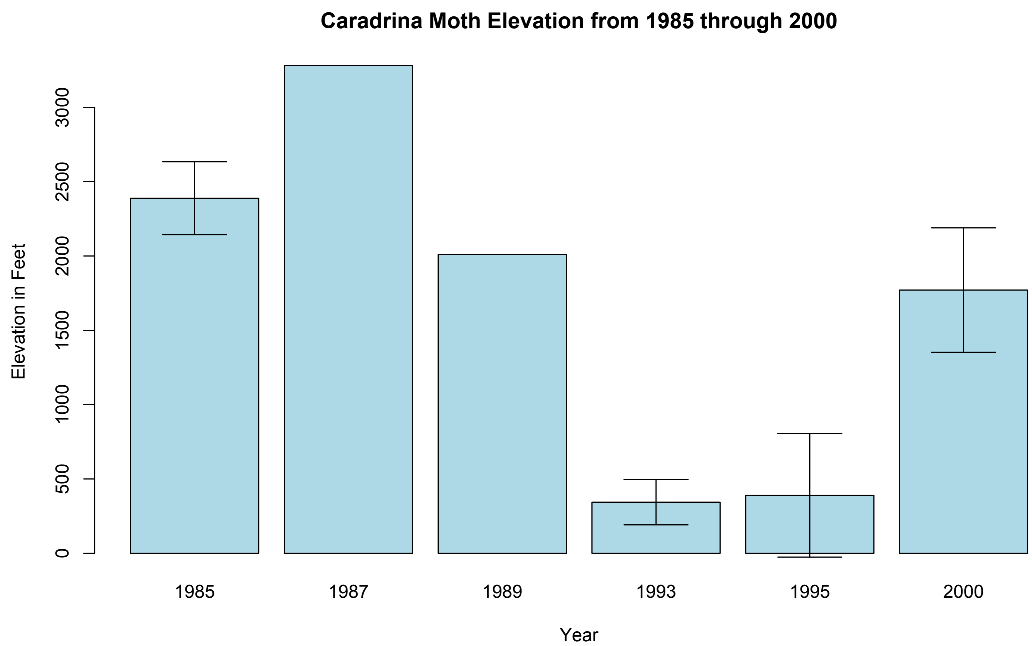
Low years: 1993 and 1995 and 1997. High years: 1985. We don't have much data for this species, but 1985 is a high year, and the elevation is consistent with our theory. The other three years are low deviation years and have similar elevation data.



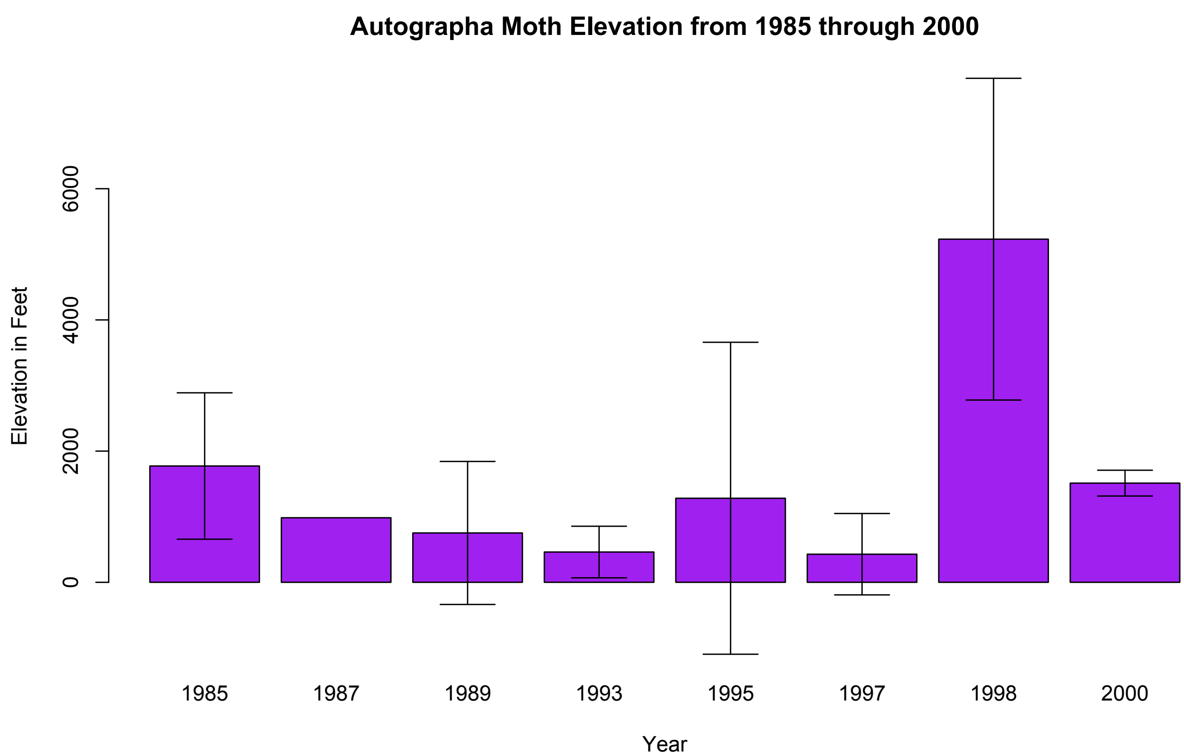
Low years: 1993, 1997, and the year 2000. High years: 1989. Again, this is a low-data species for our analysis. The elevations are all fairly similar, however 1989 and the year 2000 (high and low deviation years, respectively) both deviate .78 and .72 degrees Fahrenheit, respectively. While this temperature trend isn't shown by the graph, it needs to be noted from the temperature data.



Low years: 1997. High years: 1995 and the year 1998. Our theory is supported with this data, too.



Low years: 1987, 1993, and the year 2000. High years: 1985, 1989 and 1995. Relatively, these temperature deviation years and their respective elevations don't support of hypothesis of relating temperature deviation to elevation.



Low years: 1987, 1993, 1997, and the year 2000. High years: 1985, 1989, 1995 and the year 1998. This species is another example of accepting the null hypothesis due to the similarities in elevation between years, despite temperature deviation.

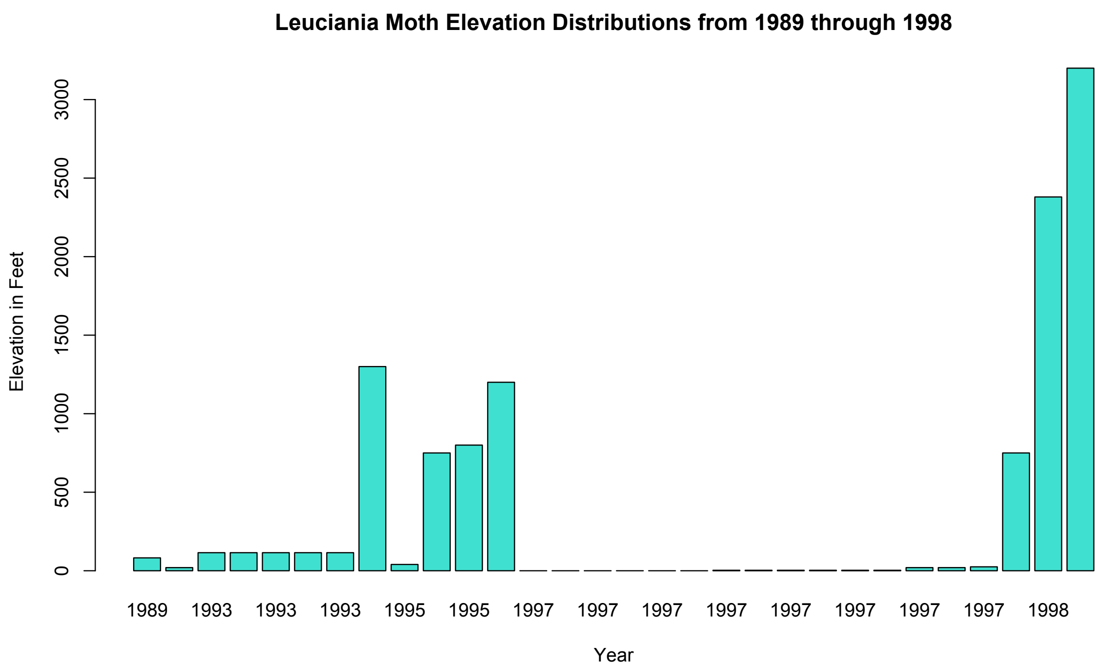
Summary Conclusion

While only four species' tests allow us to reject the null hypothesis of there being no correlation between climate change and elevation of where moths were found, more data and larger sample size could indicate a relationship. In the future, we could combine data from other states from the Pacific Northwest since the same species are spread out across the PNW and test the built up data set with ANOVA again.

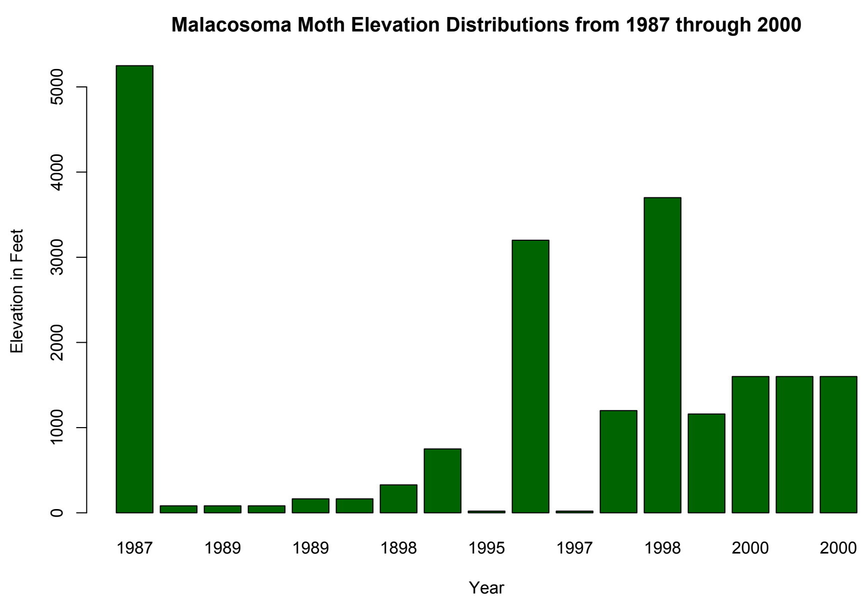
The data on biodiversity shows us that more species are found living together in lower elevations. We could further test our hypothesis of climate change and elevation against diversity to see if this species-diverse elevation rises when temperature deviations rise. It would also be helpful to look at actual temperature increases over time as well as looking at the hot and cold peaks. The biodiversity data, although showing a trend in hot years of more species at lower elevations, starts to show a move towards lower elevations, but there is not enough data to show a true correlation. In the last few decades, as global warming has become an environmental concern, we have experienced increasingly higher record temperatures. With more data, we could look at the patterns of temperature increases up to modern day and the changes in biodiversity at different elevations. Again, more data and much larger sample size would be needed to make any correlation.

It should also be noted that while sample size could be increased, the way samples were collected could also be altered. Netting a single sample, rearing a single larvae or catching a handful of moths in a light trap over the course of a weekend or a day is not necessarily the most effective way to measure a population for a given location or region. Actual population data should be obtained by mass sampling (hopefully non-destructively) across elevations throughout the whole season of availability. Even though we chose the most prominent species from the data, some elevations were still lacking. Better collection methods could ensure a larger sample size as well as show distribution across all elevations for a given hot or cold year.

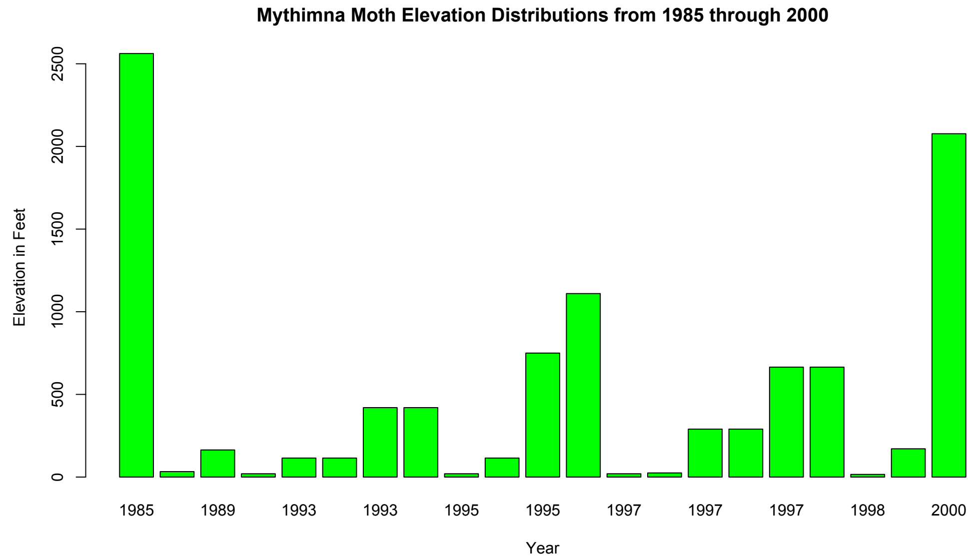
Appendix of Raw Data and Specific Factors



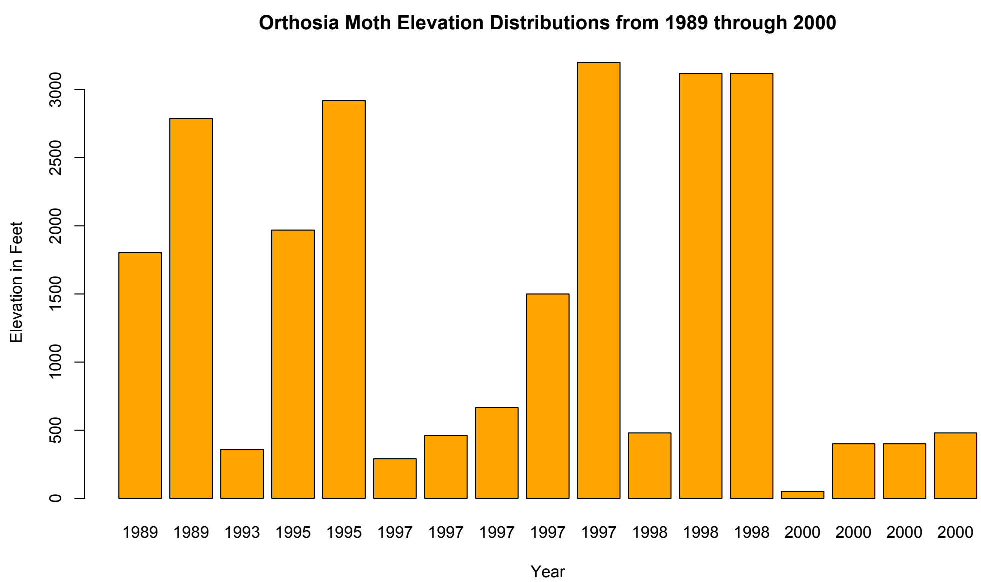
Leuciania Moth elevation



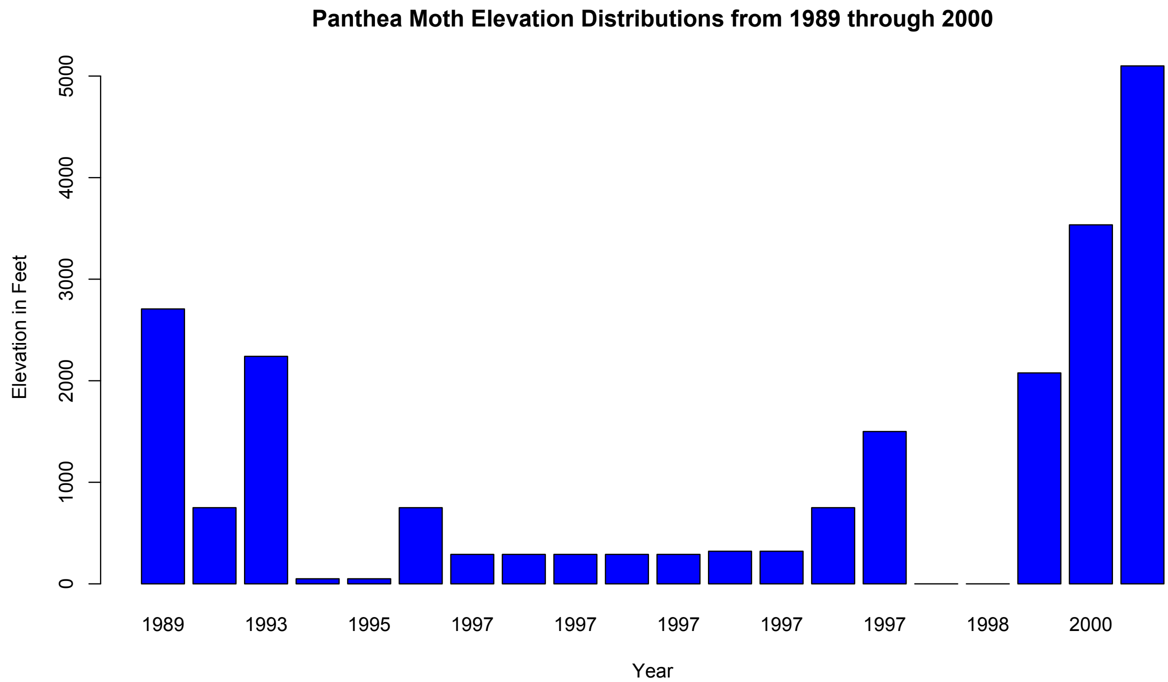
Malacosoma Moth elevation



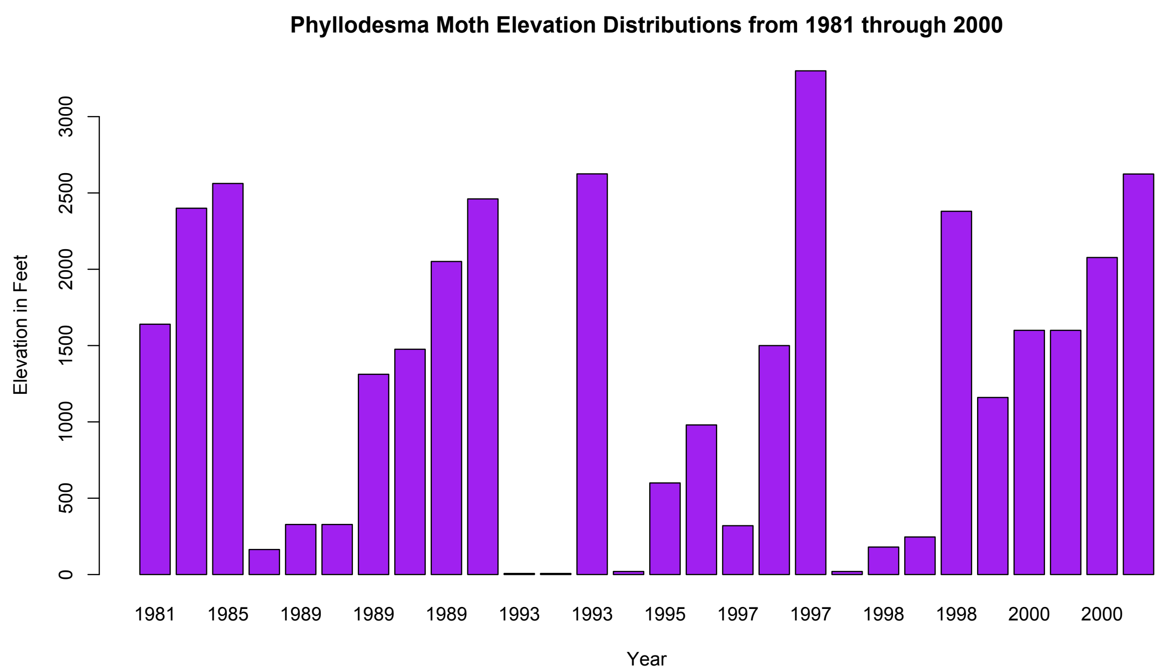
Mythimna Moth elevation



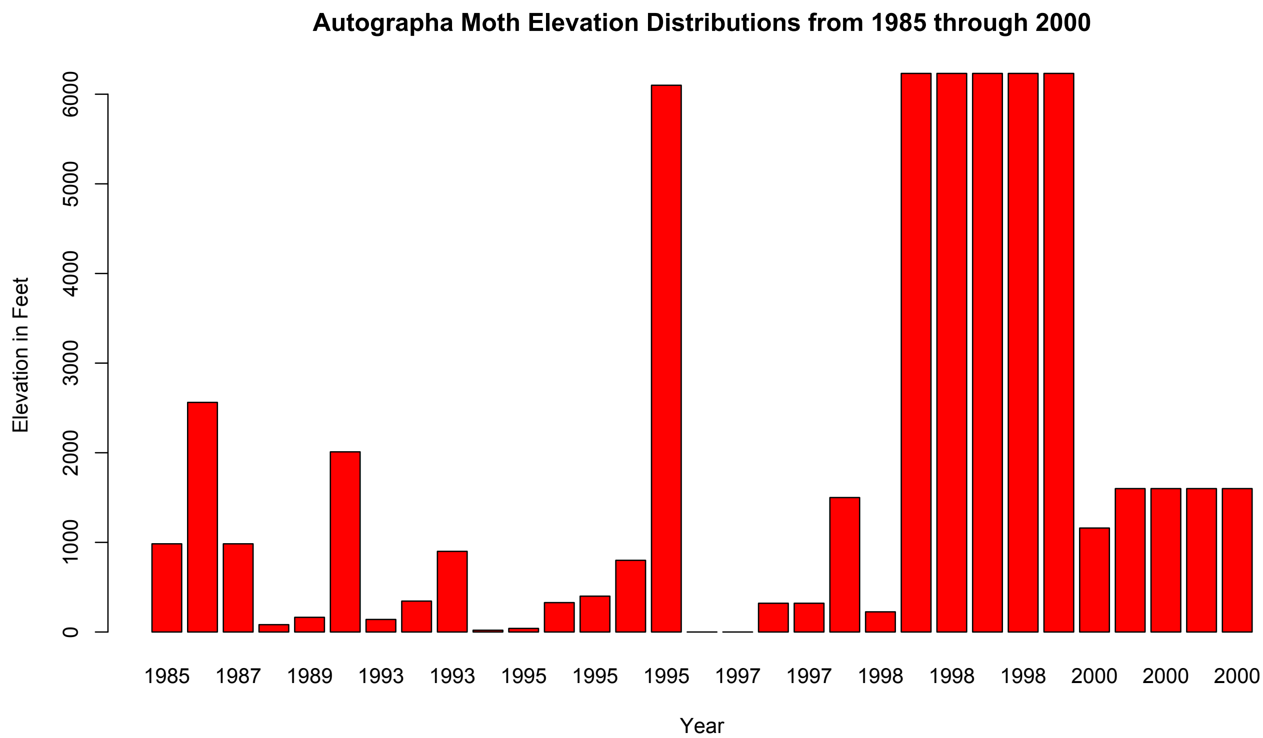
Orthosia Moth elevation



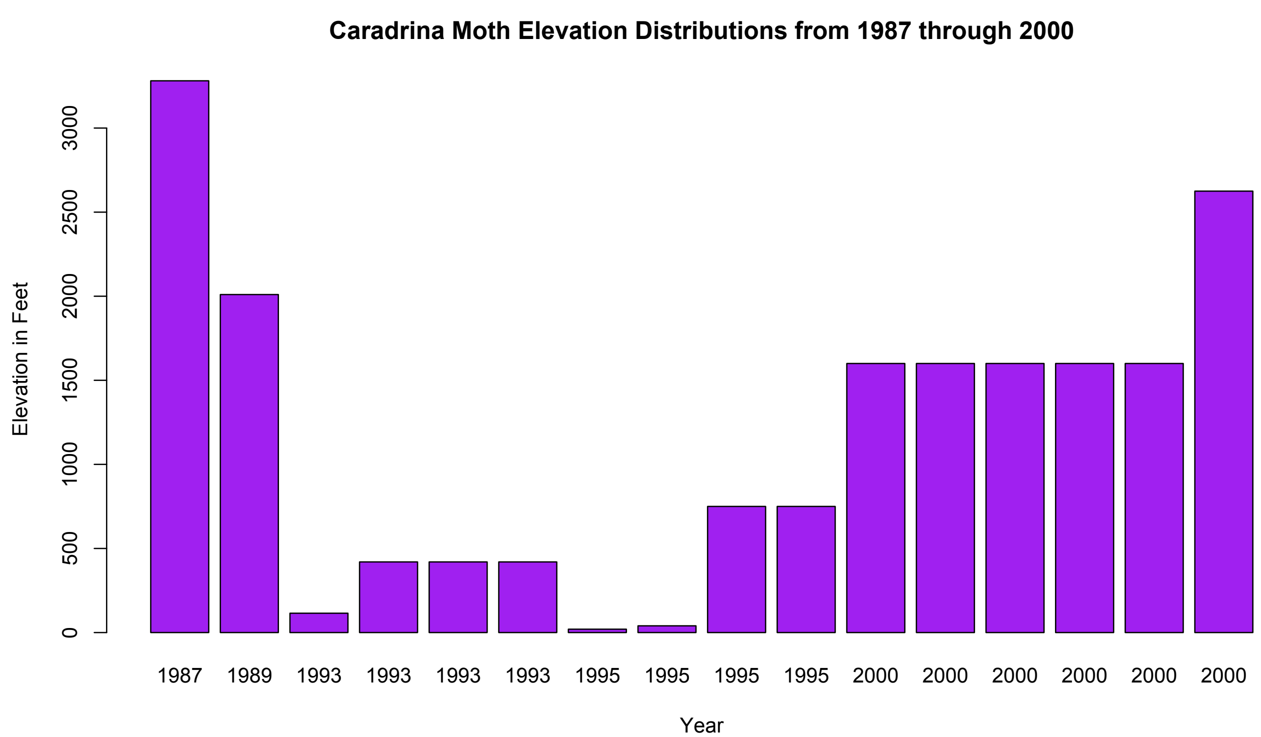
Panthea Moth elevation



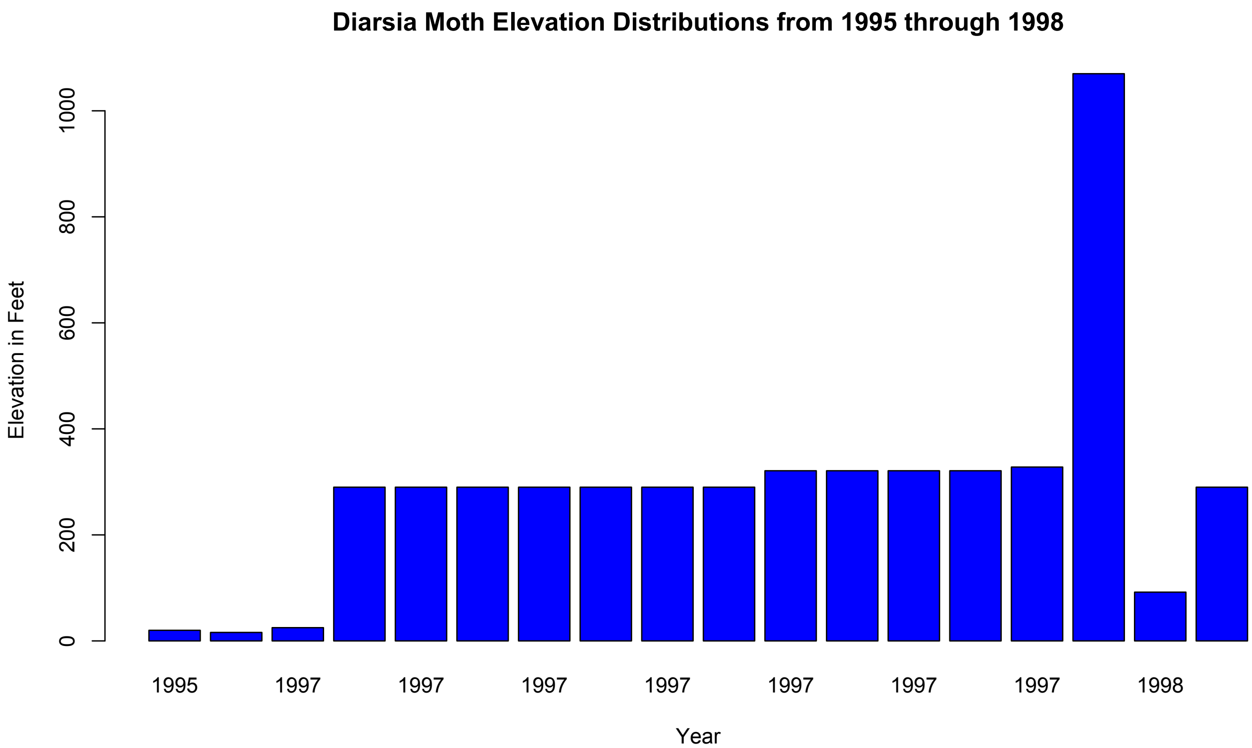
Phyllodesma Moth elevation



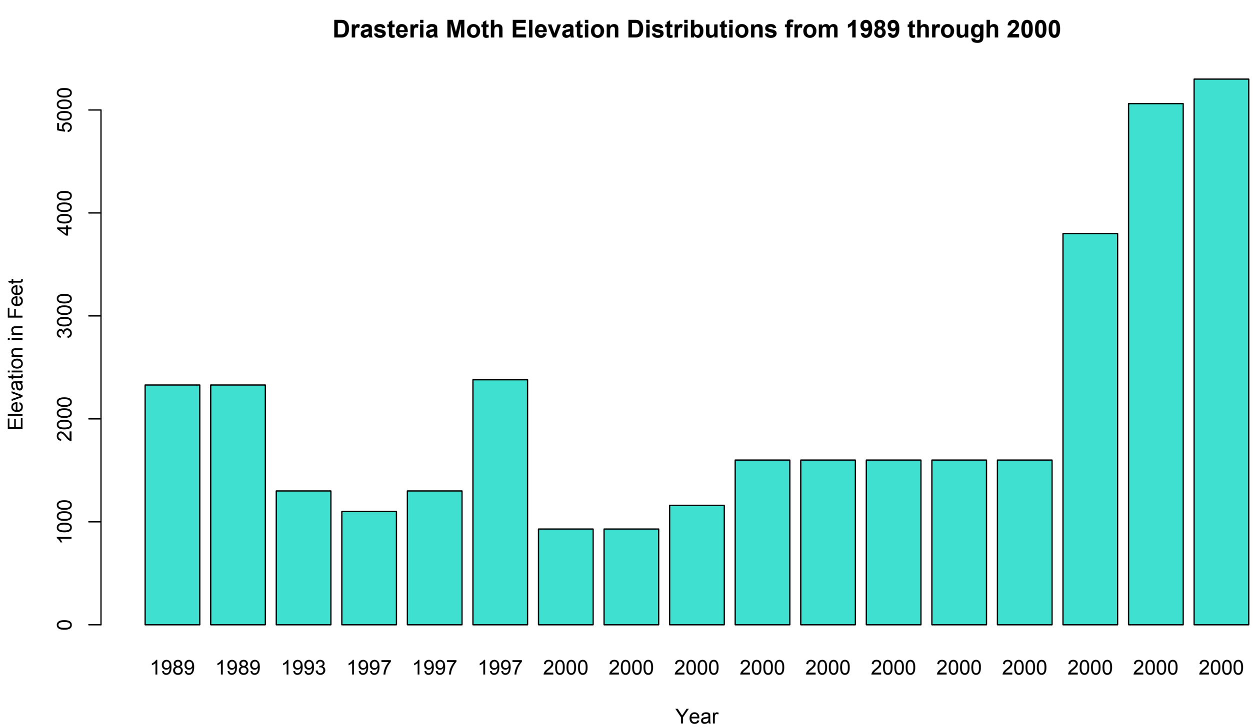
Autographa Moth elevation



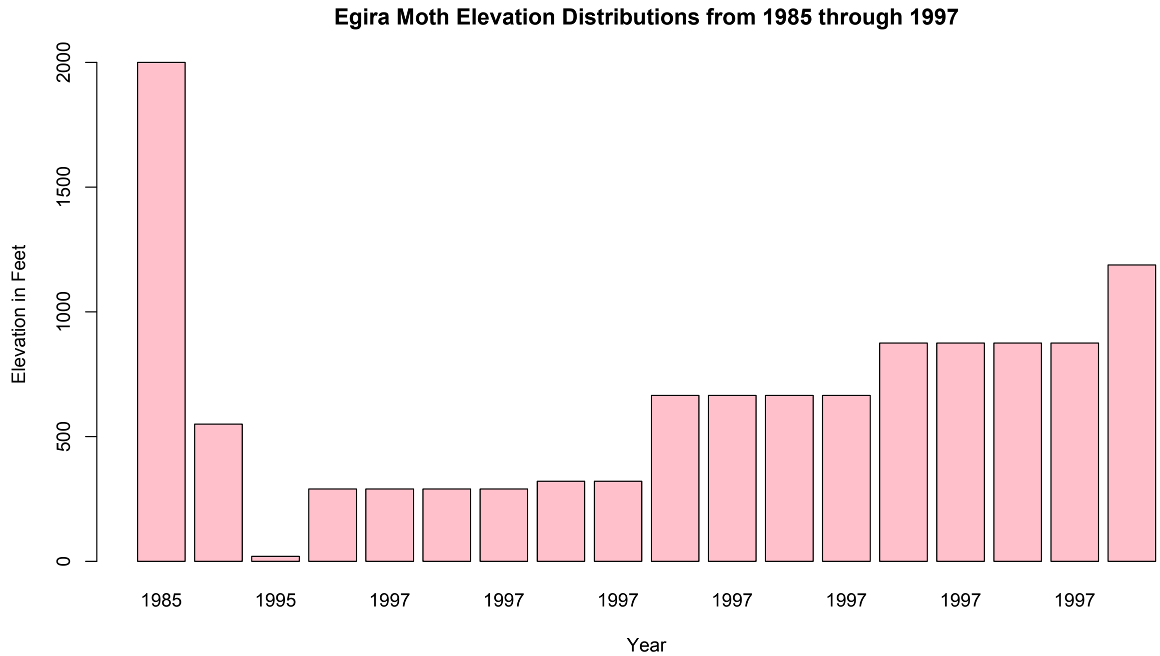
Caradrina Moth elevation



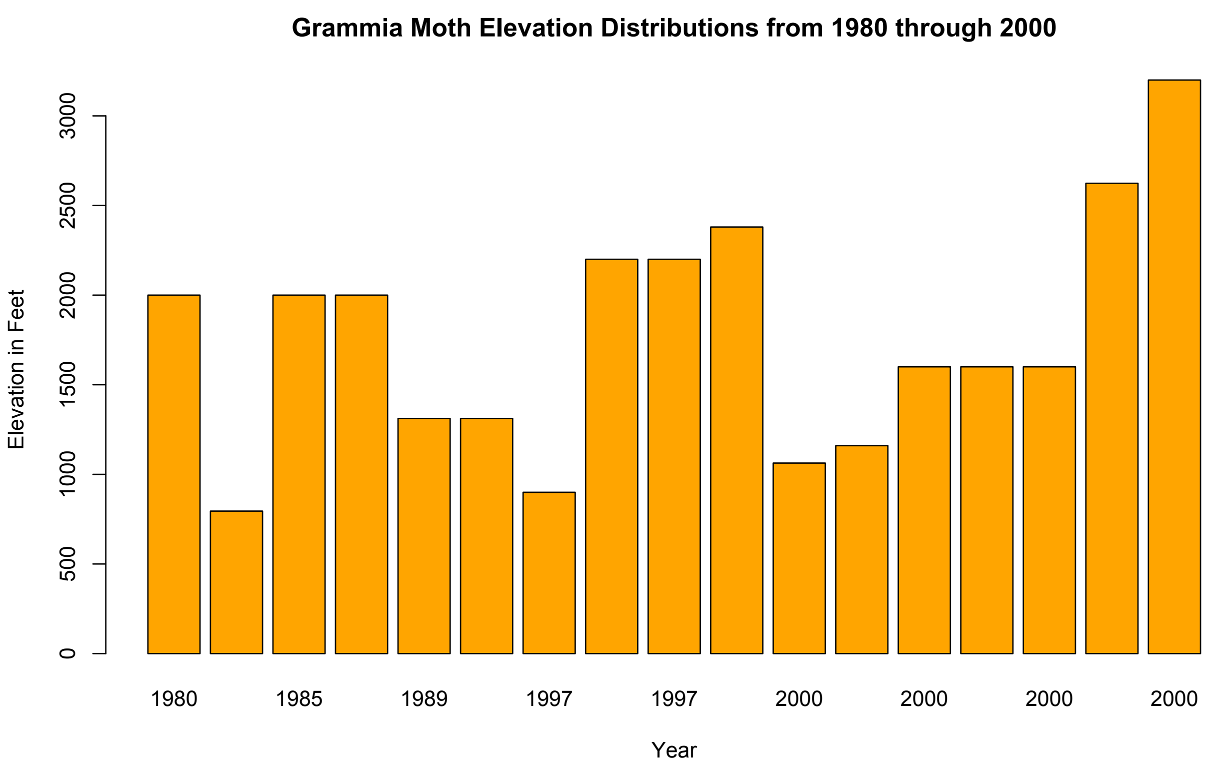
Diarsia Moth elevation



Drasteria Moth elevation



Egira Moth elevation



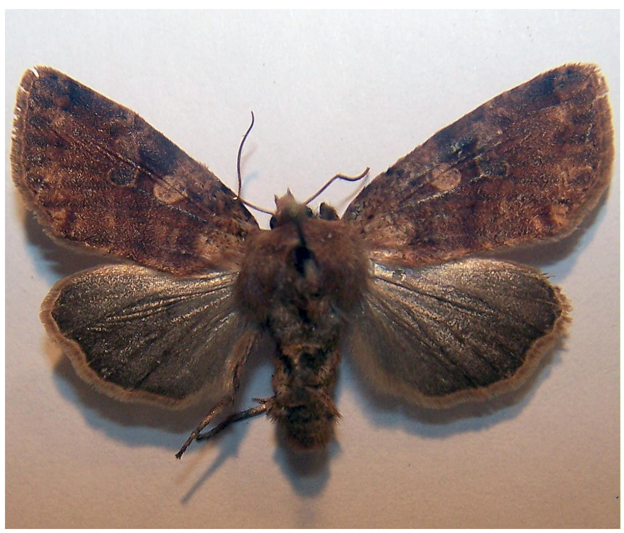
Grammia Moth elevation

Moth Species

Phyllodesma americana

Malacosoma

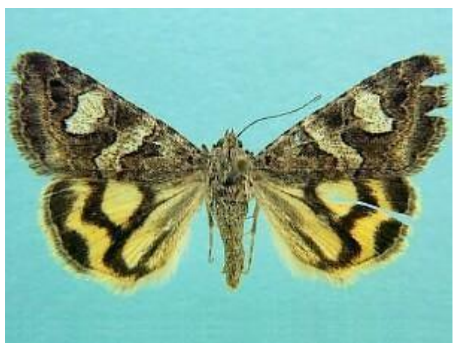
Mythimna



Orthosia

Grammia

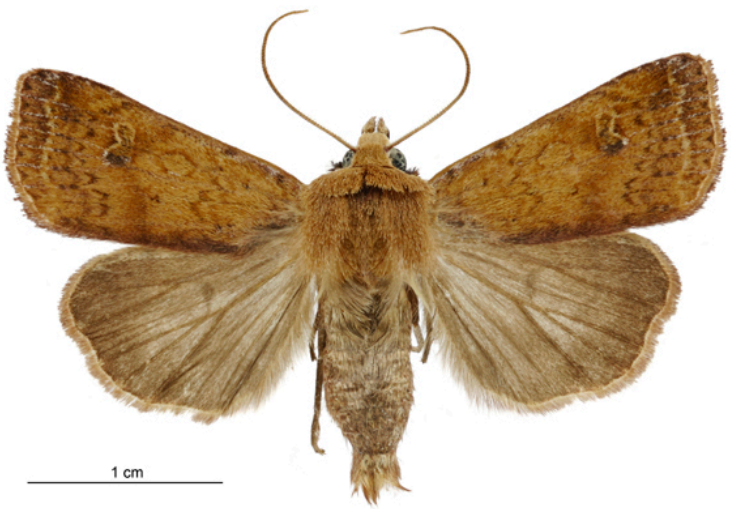
Autographa



Drasteria

Egira

Caradrina



Diarsia

Panthea

Moth photo credit: Biopix.com & North American Moth Photographers Group & Butterflies & Moths.org