How butterfly species richness and diversity are affected by weather in the Beaverhill Natural Area

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Introduction

The Beaverhill Natural Area is home to at least 38 different species of butterfly, as recorded on the observation database eButterfly (Larrivée et al. 2024). As part of the Beaverhill Bird Observatory (BBO)'s internship program, student interns have conducted surveys of the local butterfly populations since 2013, compiling information including weather conditions and species abundances and phenology. Historical surveys and interest in butterfly fauna at the site date back to 1977 onward (Thormin 1977). This provides a great dataset for analyzing trends over time. Species richness is a useful measure of the number of different species found in a region. Butterflies are well-established as biodiversity indicators, owing to several advantages such as well-understood habitat associations and relatively straightforward identification (McGeoch 1998). They can be used as a proxy for the biodiversity of groups that are more difficult to study directly. Because of the pervasiveness and impact these groups have on the ecosystem, a strong understanding of them is very helpful for understanding other aspects of the local environment.

Weather conditions and climate can have a strong impact on butterfly populations (Kivinen et al. 2007). Species abundances are affected by environmental conditions and climate, with variable conditions being particularly threatening to butterflies (Roland & Matter, 2013). Butterflies become inactive in cold weather, have difficulty flying in heavy winds, and avoid rain. Butterfly abundance patterns have been affected by climate change; the typical faunas have changed over time as a result of weather and temperature patterns (Isaac et al. 2011). Furthermore, diversity has generally decreased as a result – many species will decline in number, but the overall total number of butterflies is projected to rise as few species become more dominant (Isaac et al. 2011). The past several years have had particularly hot, dry summers, whereas 2024 has been subject to more rain early in the summer and has had an especially cool June. This provides us an interesting opportunity to see how the warmer conditions have affected the butterfly populations and if a difference in weather patterns has resulted in a difference in the populations. For this study, I hypothesized that increasing temperatures would result in a decrease in diversity, but not necessarily a decrease in total number of observations.

Methods

Pollard Transects were run on a weekly cycle from late May to the end of August. Pollard Transects are a standardized method for surveying butterfly populations and consist of walking a fixed path and counting all butterflies observed within a set space around the surveyor (Pollard 1977). Student interns at the BBO have been collecting Pollard transect survey data yearly since 2013 which was used in this study. For this study all butterflies within a 5-meter area of the surveyor along the walk were counted. Butterflies were identified visually, with capture for closer identification permitted when necessary. All specimens were released after capture. All surveys were conducted during ideal weather for butterflies, i.e. around midday on days with wind at or below a Beaufort Scale measurement of 4, a temperature above 15°C, and no rain.

Data collected during this year's surveys was analyzed alongside data collected yearly starting in 2013. Data for 2020 and 2021 was not available due to the COVID-19 pandemic halting the internship program. Diversity data was not available for the years 2014 and 2017. A linear regression analysis was conducted in Microsoft Excel to evaluate the impact of summer temperatures (May-June) on diversity. The average temperature of the entire season was calculated from the Edmonton International Airport Station, by taking the average temperature for each month from May to August. Diversity for each year was measured using a Shannon diversity index.

Site Description

Surveys were conducted at the Beaverhill Natural Area between the hours of 11:00 AM to 3:30 PM. The transect paths followed two separate loops (Loop A and Loop B, fig. 1) covering several different environments.

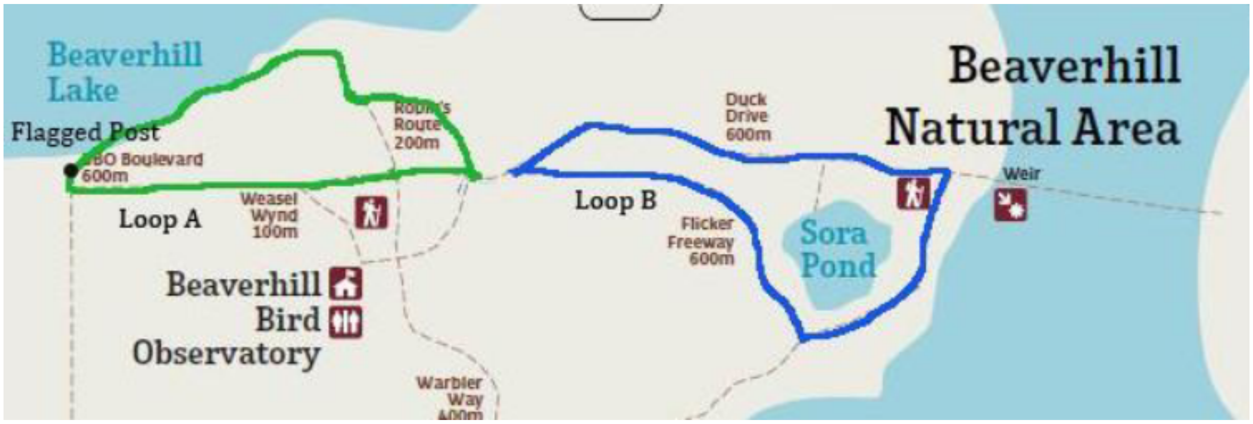

Figure 1. Transect loops in the Beaverhill Natural Area. Loop A is shown in green, and Loop B is shown in blue.

Loop A was followed first on each day of surveys. This loop has approximately an equal mix of grassland and forest. The transect begins on a footpath through moderately thick aspen forest before opening into the grassland along the Beaverhill lakebed. From there, it follows through tall grass until reaching a larger, more open path through forest until the loop finishes.

Loop B was always followed second. This loop is primarily forest, with a short section of grassland and some sections approaching the wetland. It begins in the forest area near the beginning of Loop A and proceeds through forest before eventually reaching a marshier area as it approaches the weir on Lister Lake. Around the weir is a grassland section which turns to forest as the loop turns around back toward where it begins.

Both environments had similar dominant vegetation, consisting of aspen and balsam trees, grasses, clover, and other flowering plants such as thistle and dandelions.

Results

This year's surveys resulted in a total of 616 observations of 15 different species, as summarized in the table in Appendix A. The most common species was the European skipper, with 301 observations making it take up nearly half of all observations. Because European skippers took up a large quantity of the total count, the diversity index for the year was relatively low. A Shannon diversity index was calculated using this year's data, resulting in an index value of 1.63.

A linear regression analysis was performed to determine the causal impact of each year's average summer temperature on diversity, using diversity as the dependent variable and average summer temperature as the independent variable ($p = 0.0715$, fig. 2). This indicates non-significance at the 0.05 level, meaning we cannot definitively state that temperature has a significant impact on diversity. A causal effect is possible but can not be conclusively supported by this data.

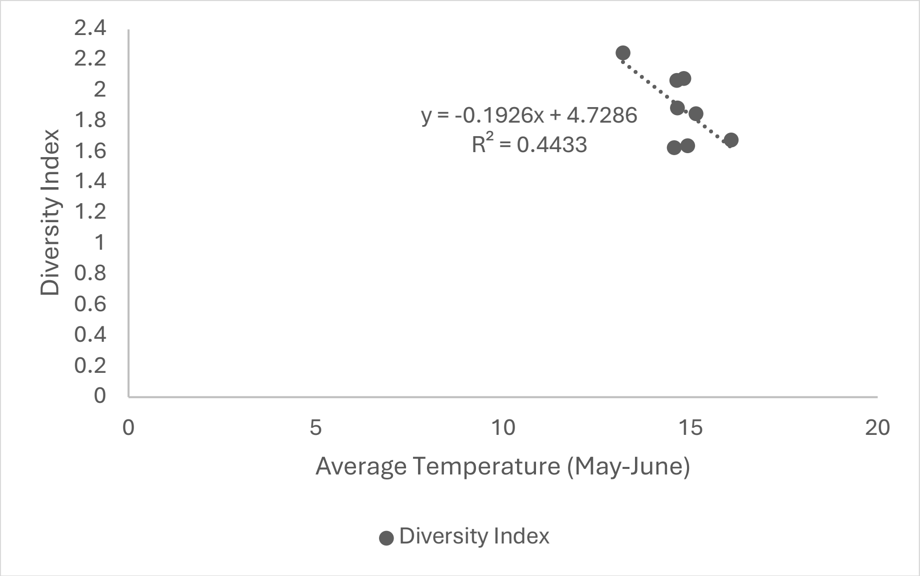

Figure 2. Regression analysis for average temperature and diversity index for 8 years from 2013 to 2024. Diversity index was measured separately for each year, using the number of species observed and the total abundance of each species observed across both loops. Average temperature is calculated using the monthly averages for each summer of survey data. Temperature was found to likely not have a causal effect on diversity; p = 0.0715.

The effect of temperature on species richness was also measured using a linear regression analysis (p = 0.6343, fig. 3). This p-value indicates non-significance at the 0.05 level, so we cannot reject the null hypothesis that temperature does not have a significant impact on species richness.

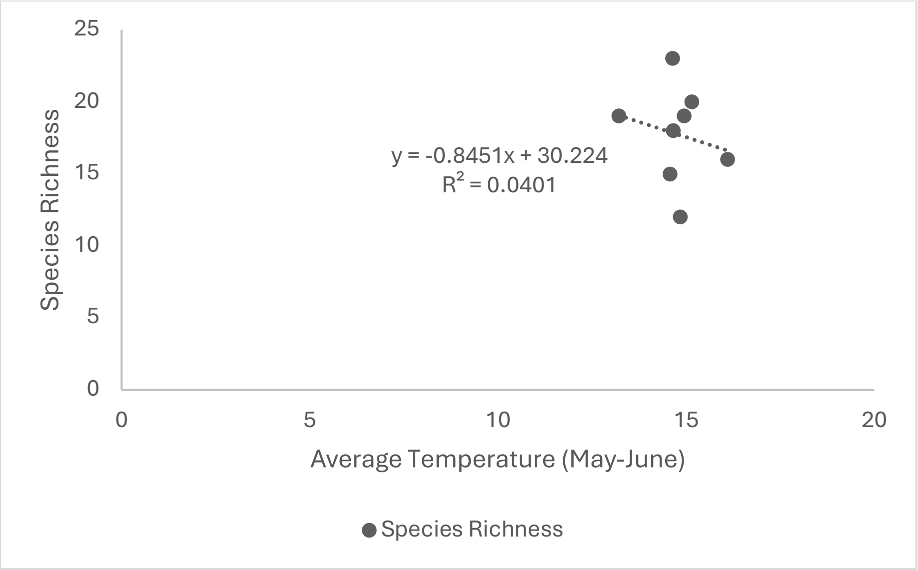

Figure 3. Linear regression results for average temperature and species richness for 8 years from 2013 to 2024. Richness is the total number of species recorded across the surveying season, and average temperature is calculated using the monthly averages for each summer of survey data. Temperature was found to not have a causal effect on richness; $p = 0.6343$.

Diversity indices were calculated for each year of intern surveys, except for 2014 and 2017 which did not have available data. These indices are summarized in Appendix B. An overall downward trend of both diversity and richness can be observed while temperature rose (fig. 4, fig. 5).

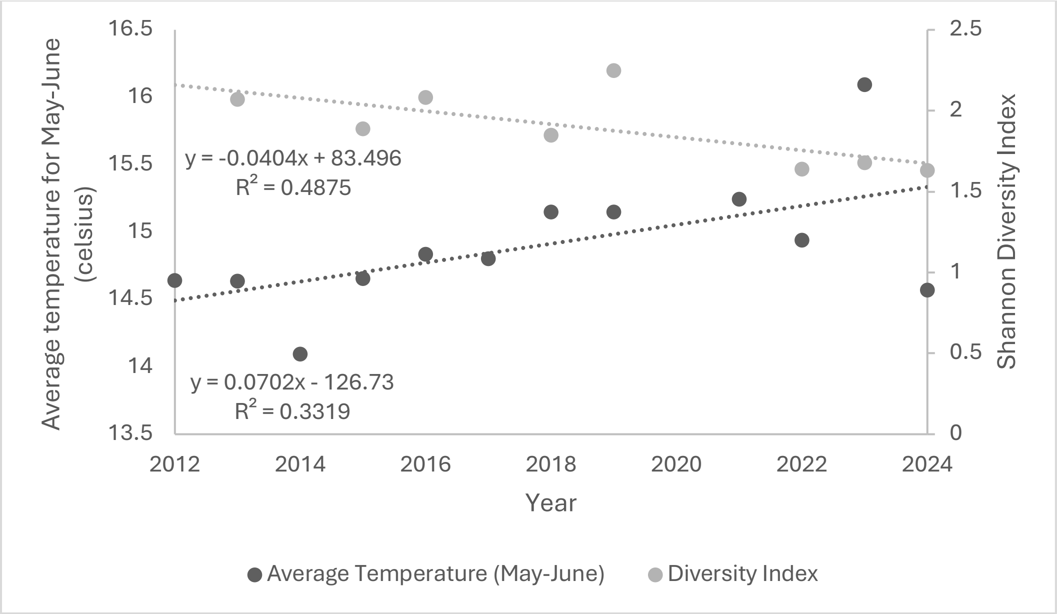

Figure 4. Diversity indices from 2013-2024 alongside average summer temperatures from 2012-2024. Temperatures trended toward increasing each year while diversity decreased.

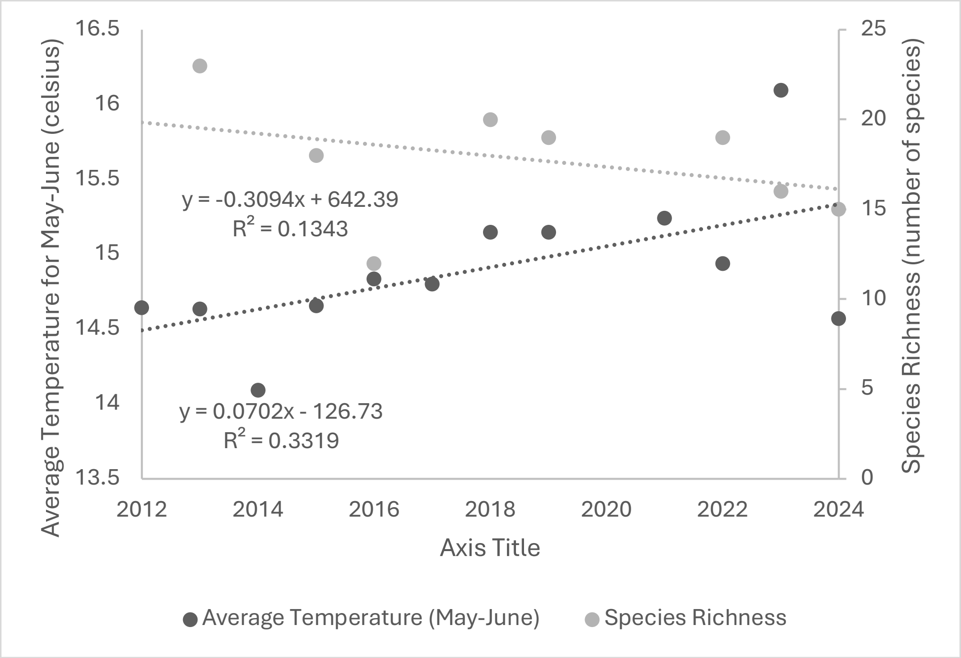

Figure 5. Species richness and temperature for each year of surveys. Richness is recorded from 2013-2024, while temperature is recorded from 2012-2024. Species richness fluctuated

from year to year but a trend towards a reduced number of species can be observed, while temperature increased.

The effects of a time-delayed response to temperature were also analyzed, comparing diversity with the previous year's average summer temperature. For diversity, this produced a p-value of 0.2912, while for richness, this produced a p-value of 0.6057. This indicates that average summer temperatures likely do not have an impact on diversity or richness.

Discussion

The impact of rising temperatures on diversity is well-studied, particularly for insects (Shivanna 2022, Thomas 2005). However, this study did not provide conclusive results that decreasing butterfly diversity was caused by rising temperatures at the study site. However, a p-value near, but not below 0.05 does indicate a trend worth inspecting further. The reason for the non-significant p-value may be due to a limited sample size. This is based on the results of only 8 years of surveys; incorporating a larger data set may indicate a stronger connection. Other factors that could increase sample size include more frequent surveys or longer transects. Most studies indicating this result are conducted over larger time frames or with much greater sample sizes, such as Isaac et al.'s (2011) study which observed over 9000 populations over the course of 4 years in England. They found that butterfly density was higher on sites with a cooler climate in England. Because of this, we cannot disregard the possibility that biodiversity is decreasing over time due to rising temperatures – further study and analysis is needed.

The observed reduced diversity levels for butterflies may indicate a loss of diversity in other insects in the environment (Thomas 2005). Besides average temperature, there may be a number of other possibilities for a loss of diversity, including precipitation, the introduction or prevalence of butterfly predators, and temperate fluctuations. These results only paint a small part of the picture for diversity loss and the effects of human activity and climate change.

This year's results match the findings of Isaac et al.'s 2011 study which found that while biodiversity decreases, the total number of butterflies do not, as communities become overwhelmed by many individuals comprising a small number of species. This was the case with the European skipper and to a lesser extent the northern crescent, which together comprised 74% of this year's observations despite being 2 species out of the total 15 observed. There are alternate explanations for this increase in European skippers, including regular boom and bust cycles. Regardless of the cause, this contributes to the reduced diversity this year, which was lower than the diversity indices calculated using the data for other years.

Species richness did not seem to be impacted by rising temperature, with a p-value of 0.6343. Species richness remained relatively stable across the 8 years of surveys, with fluctuations more likely to be caused by random chance each year rather than due to an actual loss of species. Observer bias should be considered here, as species may be misidentified or overlooked which could also contribute to these results. Both richness and diversity would require larger timescales and sample sizes to make any conclusive statements. Kivinen et al. (2007) note that the primary impact of climate on butterfly species richness is indirect, through the availability of habitat. Because habitat availability has remained relatively stable over the years of surveys, it stands to reason that species richness has not been affected.

For the time-delayed effect, the fact that only summer temperature data was used was likely responsible for the non-significance found in the results. Winter temperatures, as well as earlier development and plant biomass, play a role in butterfly abundance (Isaac et al. 2011). Summer temperatures have less of an impact on the abundance of butterflies for the next season.

Conclusion

The data found points toward possible trends that may be worth further evaluation. A larger data set can provide more conclusive evidence, further supporting the scientific consensus that climate change affects biodiversity. While this study did not conclusively prove the impact of temperature, there are a variety of other factors which could play into diversity as well.

Further research could examine the impact of other climate factors, such as precipitation or temperature fluctuation. The increased prominence of European skippers compared to previous years is an interesting data point for future reference, and it may be valuable to investigate what factors led to their ‘boom’ this year.

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Appendix A – Survey results for 2024.

	28-May-2024	6-Jun-2024	13-Jun-2024	22-Jun-2024	28-Jun-2024	8-Jul-2024	17-Jul-2024	23-Jul-2024	31-Jul-2024	8-Aug-2024	18-Aug-2024	Totals
European Skipper							28	229	40	4		301
Hobomok Skipper			1									1
Canadian Tiger Swallowtail		1	3	2	1							7
Cabbage White	3	4	4		1				5	1	1	19
Western White	1	1						1		3		6
Clouded Sulphur				3				2	13	5		23
Silver Blue			1	2	4	4	4					15
Great Spangled Fritillary						1	3	1	2	1	1	9
White Admiral		1	1	2	1	1	2	1				9
Green Comma									3			3
Mourning Cloak										1	3	4
Northern Crescent						17	65	60	6	4	2	154
Tawny Crescent								24	2	2		28
Common Wood Nymph					1			10	11	8	4	34
Red Admiral	1		1								1	3
Totals	5	7	11	9	8	23	102	328	82	29	12	616

Appendix B – Average temperatures, species richness, and diversity for 2012-2024.

Year	May Average Temp	June Average Temp	July Average Temp	August Average Temp	Average Temperature (May-June)	Diversity Index	Species Richness
2024	9.89	13.08	19.09	16.22	14.57	1.63	15
2023	15.5	16.79	16.4	15.69	16.095	1.68	16
2022	9.93	14.71	17.18	17.94	14.94	1.64	19
2021	10.09	17.19	17.94	15.75	15.2425		
2019	14.27	15.39	16.35	14.59	15.15	2.25	19
2018	14.27	15.39	16.35	14.59	15.15	1.85	20
2017	12.48	15.14	16.69	14.9	14.8025		
2016	11.45	15.71	16.57	15.62	14.8375	2.08	12
2015	10.47	15.84	17.28	15.03	14.655	1.89	18
2014	9.07	13.69	17.8	15.82	14.095		
2013	12.83	14.4	15.32	16	14.6375	2.07	23
2012	10.1	14.67	17.57	16.23	14.6425		