Change in Species Diversity and Population Number of Butterflies in the Beaverhill Natural Area (1996-2023)

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Introduction

Founded in 1984, the Beaverhill Bird Observatory (BBO) gained the title of stewards of the Beaverhill Natural Area (BNA) 3 years after its official foundation. With a focus on bird populations, this area has been subject to habitat enhancement protocols, trail maintenance and regular bird banding protocols (Beaverhill Bird Observatory, n.d.). Although bird monitoring by volunteers and biologists has taken place in the observatory for over 40 years, it wasn't until 2013 that a standardized surveying protocol was put in place for butterfly populations (Beaverhill Bird Observatory, n.d.). Though the North American Butterfly Association (NABA) had been collecting data of the Beaverhill Natural Area previous to 2013, data collection was not standardized, since the distance walked, hours of surveying and number of observers were inconsistent for each year. This paper analyzes the changes in species diversity and individual numbers in the BNA from 1996 to 2023. To check if the survey method has an effect, I also compared the results of including and excluding NABA data, which involves more observers for a singular day of surveying all season, compared BBO's standardized intern protocol established in 2013 of a single observer completing multiple surveys throughout the summer months. It is hypothesized that by not including data from NABA counts, the average species and individual counts will be significantly different due to variation in sampling mechanisms altering the results.

Methods

Data from NABA surveys were used for the years 1996, 1998, 1999, 2001, 2007, and 2014. NABA surveys consist of a multiple-person team going to the Beaverhill Natural Area for a single day during the May-August season. Counts were done by foot and by car; specific paths and locations of where these surveys were made are unknown (NABA 1996). For the years 2000, 2002, 2015, 2016, 2017, 2018, 2019, 2021, 2022, 2023, data from volunteers and interns of the BBO were used. Years where distance was unknown and most of the survey process was lacking were discarded (years 2006 and 2013). The BNA surveys consist of a single observer completing weekly surveys throughout the season on a pre-defined trail in two habitat types around the BNA (Figure 1). The survey method was a Pollard Transect, where the observer counts all identifiable individual butterflies within a 5-meter transect. The distance travelled on the BNA trails was measured using an Apple Watch during a complete survey of two loops (Figure 1): this was assumed to be the distance travelled by all interns from the BBO with an exception for 2014 which had a different trail system for its survey.

The data collected was naturalized as species/km for alpha diversity and individuals/km for total population count. This was done by multiplying the number of survey days during the season times the length walked per day, both species diversity and total individual count were divided by this total distance. The data was plotted in four scatter plots: species per kilometer including NABA data, species per kilometer excluding NABA data, total individual count including NABA data, and total individual count excluding NABA data. Trendlines and their respective equations were also plotted to check for slope differences between included and excluded NABA data. Two different Two-sample T-tests assuming unequal variances (alpha value = 0.05) were conducted to test for significant differences between species per kilometer including and excluding NABA data and between individuals per kilometer including and excluding NABA data.

The dataset collected for the current season (May-August 2023) can be found in Appendix A.

Figure 1. Map of the loops walked by the BBO interns that completed butterfly surveys, provided by the Beaverhill Bird Observatory (2023)

Results

Including data from NABA, from 1996 to 2023, species diversity per kilometer (spp/km) averages 0.71, with a standard deviation of 0.34. The year with the highest spp/km was 2007 with 1.48 spp/km, and the lowest year was 2017 with 0.12 spp/km (Table 1 and Table 3). The trendline shows a drop in species per kilometer during the 27-year period with a slope of -0.002 (R^2=0.0033) (Figure 2). By excluding NABA data, the year with the highest spp/km was 2021 with 0.93 spp/km, the lowest was still 2017, the average spp/km decreased to 0.557, with a lower standard deviation of 0.23 (Table 2 and Table 3). The trendline without NABA data had a positive slope of 0.0048 (R^2=0.0114) for the 23-year period (Figure 3). The difference between excluded and included data for spp/km was not significant (t=1.4226, df=26, p=0.1667) (Table 3).

The individual count including NABA data averaged at 27.737 individuals per kilometer (ind/km), with a standard deviation of 31.246, the year with the highest ind/km was 2017 with 84.85 ind/km while the lowest year was 2016 with 5.33 ind/km (Table 1 and Table 3). The trendline has a slope of -1.37 (R^2=0.12825) for the 27-year period (Figure 4). Excluding NABA data lowered the average to 13.24 ind/km with a 6.72 standard deviation, the year with the highest count was 2021 with 27.47 ind/km while the lowest count was 2016 again (Table 2 and Table 3). Individuals per kilometer, without NABA counts had a trendline with -0.1031 slope (R^2= 0.0012) (Figure 5). The difference between including and excluding NABA data for individuals per kilometer was not significant (t=1.8005, df=17, p=0.0895) (Table 3).

Table 1 (left). Species and individuals per kilometer including NABA data (years highlighted in orange represent data from NABA: 1996, 1998, 1999, 2001, 2007, 2014)

Year	Spp./km	Ind./km
1996	0.759669	7.872928
1998	0.764818	115.153
1999	0.81262	55.97514
2000	0.52381	15.45238
2001	0.352645	15.48279
2002	0.497141	18.71738
2007	1.476301	84.84848
2014	1.333333	26.44444
2015	0.6	17.3
2016	0.866667	5.333333
2017	0.122093	6.848837
2018	0.740741	8.925926
2019	0.575758	9.181818
2021	0.933333	27.46667
2022	0.527778	20.05556
2023	0.484848	8.727273

Table 2. Species and individuals per kilometer excluding NABA data from 2000-2023

Year	Spp./km	Ind./km
2000	0.52381	15.45238
2002	0.497141	18.71738
2015	0.6	17.3
2016	0.866667	5.333333
2017	0.122093	6.848837
2018	0.740741	8.925926
2019	0.575758	9.181818
2021	0.933333	27.46667
2022	0.527778	20.05556
2023	0.484848	8.727273

Table 3. Summary statistics for measurements of species per kilometer and individuals per kilometer including and excluding dataset from NABA.

	Species/km	Individuals/km
Mean (NABA included)	0.710722161	27.73661986
Mean (NABA excluded)	0.557208545	13.24394001
Std Dev (NABA included)	0.340044723	31.24645867
Std Dev (NABA excluded)	0.230238117	6.720659989
t-value	1.422620182	1.800572387
df	26	17
p-value	0.16673417	0.08953857
Critical t-value	2.055529439	2.109815578

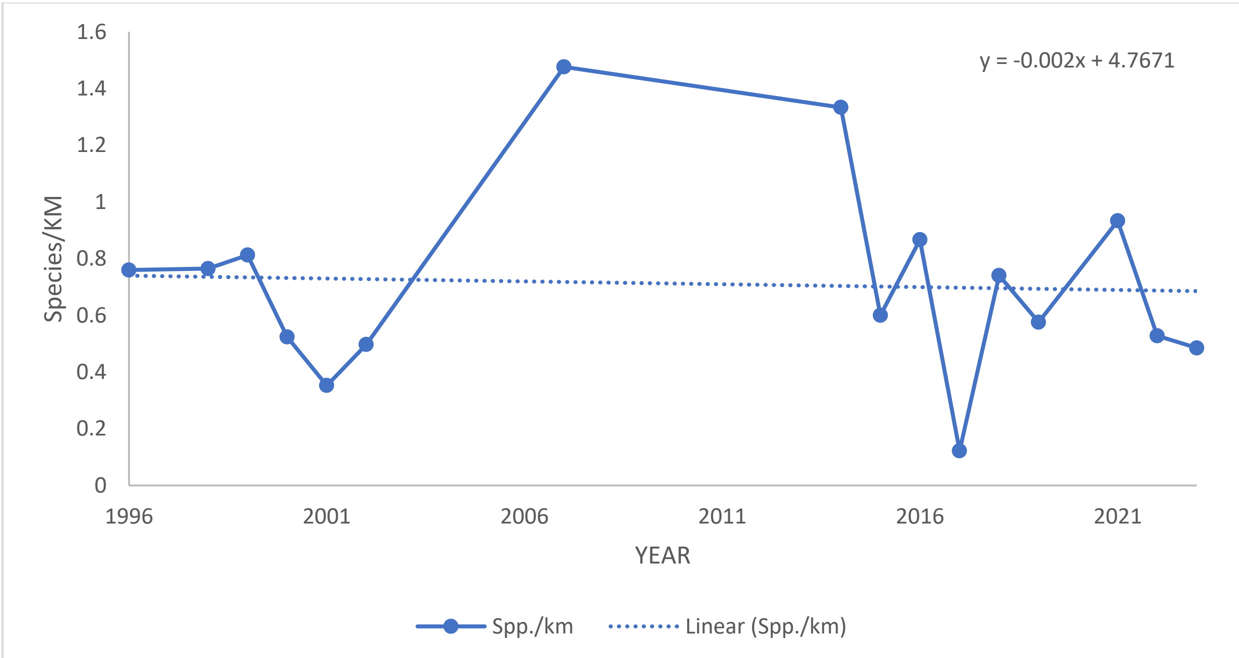

Figure 2. Species per kilometer per year between 1996 to 2023, including NABA data. Surveys were naturalized into species/kilometer.

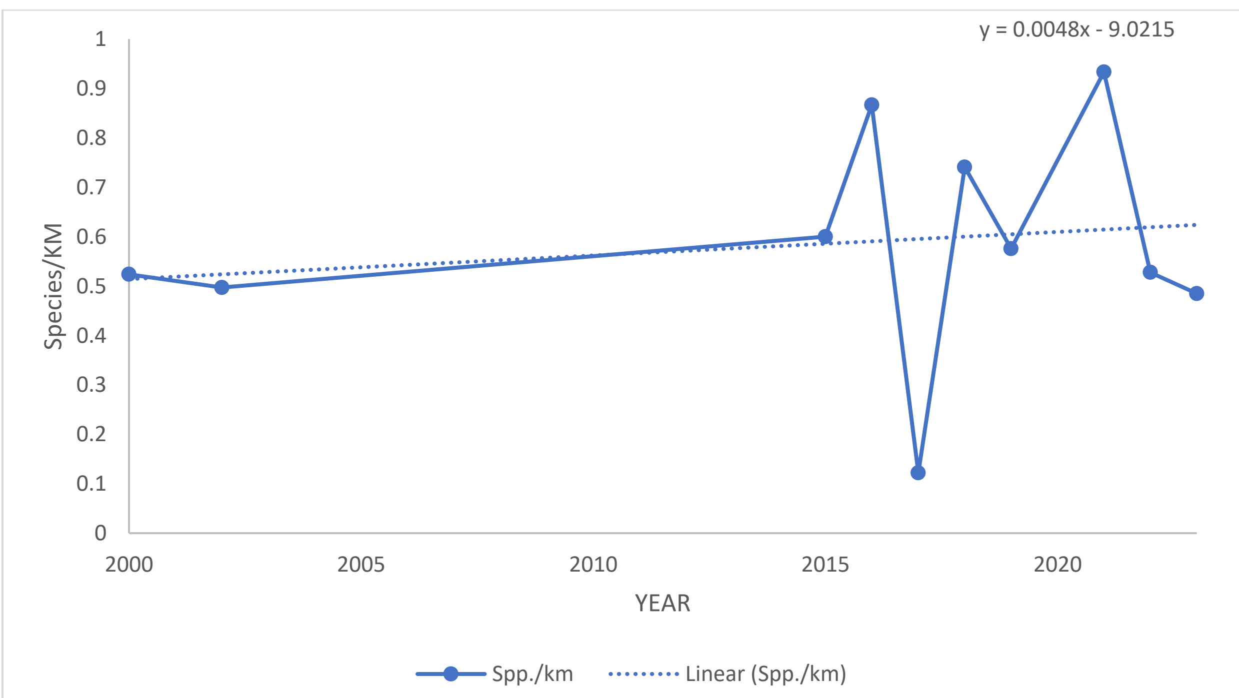

Figure 3. Species per kilometer per year between 2000 to 2023, excluding NABA data. Surveys were naturalized into species/kilometer.

Figure 4. Individuals counted per kilometer per year between 1996 to 2023, including NABA data. Surveys were naturalized into individuals/kilometer.

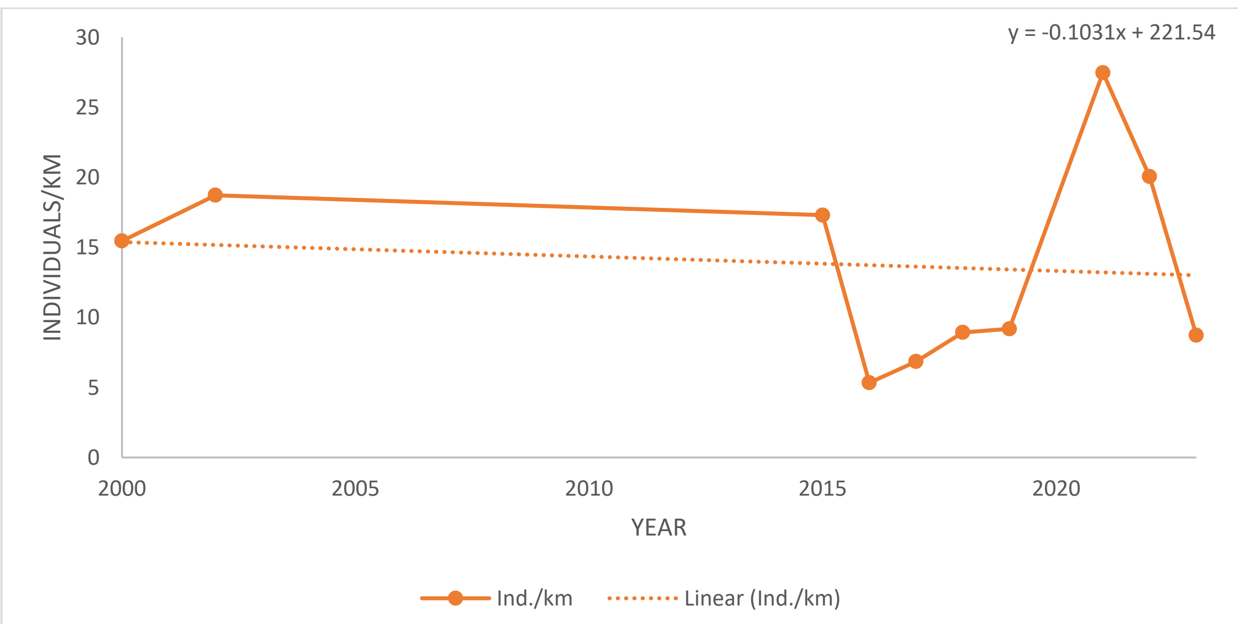

Figure 5. Individuals counted per kilometer per year between 2000 to 2023, excluding NABA data. Surveys were naturalized into individuals/kilometer.

Discussion

The trends for both butterfly numbers and species diversity exhibit a negative slope trendline when NABA data is incorporated. This negative trend suggests a decline in these factors, though the specific cause remains unknown. It is worth noting that when we exclude this data, the slope for individuals per kilometer (ind/km) becomes notably flatter, while the line for species per kilometer (spp/km) shows an upward trend. This divergence leads to a differing interpretation of the change in spp/km, indicating an increase in species per kilometer. By excluding NABA data, although the differences were not significant, the trend of species diversity changes to be positive while individual numbers have a less negative trendline; a likely correlation for this includes the change in survey method as well as recent harsh weather seasons due to climate change.

Ubach et al. (2022) studied the impact of climate and seasonal precipitation to butterfly populations. Different species tended to respond differently to precipitation, however, higher precipitation during winter and lower precipitation during the spring was a general preference for species in the area studied (Ubach et al. 2022). It's important to note that this study was conducted in a Mediterranean context. Consequently, while these results may not directly reflect the conditions at the BNA, they do provide evidence that a mechanism altering these numbers was related to seasonal precipitation amounts. Weather data from a township nearby BNA shows variation in precipitation millimetres (mm) during the 1996-2023 period, with a standard deviation of 79.35mm, and a difference of 48.83mm between the average precipitation of the first and last decade of this period (Government of Alberta n.d.). This variation in precipitation levels is a possible cause for variation in butterfly number and species counts.

The variation in results for spp/km when excluding data from NABA also shows the importance of having a more standardized surveying process for long-term data collection. A source of error for this paper is the fact that NABA had multiple observers on their counts, additionally, the survey method is unknown which adds even more uncertainty to that set of data (NABA 1996). Having surveys completed throughout the season and on standardized loops helps with data consistency, which is now standard for BBO interns. Some error for BBO data is due to some surveys occurring for only 2 months of the season and other occurring past the May-August time frame, the naturalization of data in this paper was done to reduce those sources of error, but since butterfly numbers are not the same throughout the season, some of the statistics overestimate or underestimate the butterfly counts for that year.

Future research should involve diversity indexes, such as beta or gamma diversity as this would also indicate the presence of new species or absence of previous species. Species-specific research should also be done for the individuals/km index to show population changes per species. Given that surveying protocol remains for future years and interns are encouraged to survey for all the may-august time frame, it is likely that these analyses will be more accurate.

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Appendix A. Spring/Summer 2023 butterfly surveys completed by Laura Azzolini Correa.

	Survey Date	20/05/23	27/05/23	03/06/23	11/06/23	24/06/23	03/07/23	09/07/23	16/07/23	30/07/23	07/08/23	12/08/23	Total
	Start Time:	12:35	1:56	12:35	2:30	2:00	3:30	1:11	2:10	1:40	2:20	2:09	
	End Time:	2:45	3:45	1:55	3:50	3:15	4:20	2:15	3:30	2:20	3:09	3:00	
	Temperature:	17 C°	24 C°	20 C°	26 C°	25 C°	16 C°	27 C°	22 C°	23 C°	24 C°	21 C°	
	Cloud%	100	15	80	30	10	100	0	85	0	45	60%	
	Wind	1	1	1	2	1	6	1	3	4	1	4	
Skippers	European Skipper					2		7	6		1		16
	Hobomok Skipper			1									1
	Long Dash Skipper												0
	Peck's Skipper												0
Swallowtails	Canadian Tiger Swallowtail		3										3
Whites & Sulphurs	Cabbage White	1	2				1	1	1	2	1	1	10
	Western White												0
	Clouded Sulphur			3				1	1	9	2	4	20
Gossamer Wings	Grey Copper												0
	Greenish Blue												0
	Silver Blue												0
	Spring Azure			3									3
Brushfoots	Aphrodite Fritillary												0
	Great Spangled Fritillary									1			1
	Meadow Fritillary												0
	Mormon Fritillary												0
	White Admiral				19	12	1						32
	Green Comma												0
	Milbert's Tortoiseshell							1					1
	Mourning Cloak	2	11	1	1			1	3	1	1		21
	Northern Crescent				18	29	2	45	49	7	3	6	159
	Satyr Comma												0
	Tawny Crescent												0
	Common Alpine			4									4
	Common Wood Nymph								3	2	1	2	8
	Common Ringlet				1	1							2
	Red-Disked Alpine												0
Write-Ins	Mustard White	2	1										3
	Arctic Skipper		4										4

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