Butterfly Monitoring 2014

***rare* Charitable Research Reserve**

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Acknowledgements

Many thanks to Employment Ontario and Natural Resources Canada (NRCan) Science and Technology Internship Program for funding the Ecological Monitoring Intern position; without their support, this monitoring program and report would not have been possible.

I would also like to thank the all of the ***rare*** staff. Jenna, thank you for your guidance and assistance along the way; you have taught me so much more than just how to monitor butterflies. Thank you to my committed volunteers: Gillian Preston, Monika Goetz, and Divya Mehan. And a final thank you to Tristan Long for your assistance in generating statistical models in R.

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1.0 Introduction

1.1 Lepidoptera Taxonomy

The order Lepidoptera, meaning “scaled wings”, is made up of butterflies and moths. There are six families of butterflies, including five true families (*Papilionidae*, *Nymphalidae*, *Pieridae*, *Lycaenidae*, and *Riodinidae*) and the skipper family (*Hesperiidae*). An estimated 17,500 species of butterfly species exist, with approximately 13,750 of those being true butterflies (Robbins and Opler 1997). Although exceptions do exist, there are some general rules regarding their appearance and behaviour that can be used to distinguish moths and butterflies from one another. Butterflies are predominately diurnal, have clubbed antennae, and fold their wings vertically over their body while at rest, whereas moths are predominately nocturnal, have feathered or tapering antennae, and hold their wings out flat when resting (Pyle 1981).

1.2 Why Monitor Butterflies?

Long term monitoring of butterfly populations can provide valuable insight into the overall health of ecosystems and environmental change. Butterflies have short life spans, allowing them to respond quickly to various ecological pressures, both locally and on a broader scale. They are sensitive to regional weather conditions, as unseasonably cold or wet periods can delay development and reproduction. Further, global climate change can result in an extension or shift of butterfly populations outside of their typical ranges. The presence or absence of butterfly species within geographic regions could provide useful information to better understand environmental change.

Throughout their life cycle, butterflies have specific requirements, namely the host plants they require for egg laying and feeding as both caterpillars and adults. Changes in the availability of host plants through both natural and human-caused disturbances (i.e. habitat loss) can have negative effects on butterfly populations. Invasive plant species can out-compete the native plants butterfly require. However, some butterfly species are now taking advantage of these alien plants, using them as effective hosts. Take for example the Wild Indigo Duskywing (*Erynnis baptisiae*); this butterfly species historically was uncommon, and restricted to habitats in southwestern Ontario where its larval food plant, Wild Indigo (*Baptisia tinctora*), was found (Hall 2009). However, its range has been expanding as a result of it utilizing a non-native foodplant, Crown Vetch (*Coronilla varia*), and since 2010, it has been more commonly observed in the Waterloo Region (Linton 2012) and at ***rare***.

In addition to their rapid responses to ecological change, butterflies make good indicator species because of the ease in which they can be monitored. Their size and the colourful distinctions between species make observation and identification relatively

simple. Finally, butterflies invoke a positive response from the public, allowing for recruitment of volunteers and the promotion of citizen science programs.

1.3 Butterfly Monitoring at **rare *Charitable Research Reserve***

The standardized EMAN protocol for long term butterfly monitoring was developed and piloted at ***rare*** in 2006. The purpose of this pilot program was to determine if the Transect Walk Method was a feasible technique to examine butterfly abundance and diversity in Canada (Grealey 2006), and it marked the start of the long term monitoring program at ***rare***.

In 2006, two transects were established: one located in the Cliffs and Alvars and one in South Field/Sparrow Field. Baseline data were collected over a five week period during the initial pilot study. Butterfly monitoring at ***rare*** continued in 2009 and subsequent years, during which time two more transects were established: one in 2009 in the newly acquired Thompson Tract, and one in 2010 in Blair Flats. It is important to note that due to a change in property boundaries, the South Field/Sparrow Field transect had to be slightly altered in 2014; the changes are described below (Section 2.2).

2.0 Methods

2.1 Monitoring Protocol

One of the most commonly used monitoring methods around the world is the Transect Walk Method, originating in Britain in 1976 (Pollard 1977; Pollard and Yates 1993). This method involves walking established routes (i.e. transects) at a uniform pace, and making observations within a given radius (Pollard 1977). Butterfly monitoring at the ***rare*** **Charitable Research Reserve** is conducted using the Transect Walk Method, as it does not require extensive effort or time, and limits disturbances to the butterflies' behaviour.

Ideally, butterfly monitoring programs should take place over a 26 week period, from April to September (Layberry et al. 1998). At ***rare***, this time period has been reduced due to both time and monetary constraints. In 2006, monitoring took place over a five week period in mid-July and August. In 2009, the monitoring period was expanded to thirteen weeks. Starting in 2010 and for all subsequent years, monitoring has taken place over fourteen weeks, starting mid-May and ending mid-August. Monitoring typically begins on the third Monday of May; however, this may be either advanced or delayed, depending on weather conditions (i.e. particularly cold or warm local temperatures). Butterflies are most active during the warmest part of the day, and thus monitoring is completed between the hours of 10am and 3pm. It is also recommended that monitoring be completed on sunny days, when the temperature is above 13°C; if it is overcast, the temperature must be at least 17°C (UK Butterfly

Monitoring Scheme; Butterfly Monitoring Scheme Germany). Wind should also be less than five on the Beaufort Wind Scale.

Butterfly monitoring at ***rare*** took place at four transects. Each transect is broken into sections, each section with a stopping point, as described in Appendix A. Prior to beginning monitoring, the observer walked the transects and flagged the section breaks and stopping points, as required. Observations were recorded during optimal weather conditions; in the absence of rain, observations were recorded in suboptimal conditions, as this is more valuable than not collecting data at all. In order to minimize observer bias, all observations were made by one individual with occasional assistance from volunteers.

In 2014, monitoring began on the third Monday in May, and each of the four transects were walked once weekly for fourteen weeks. A recommended list of field equipment can be found in Appendix B. At the start and end of each transect, the time was recorded, and a hand-held Kestrel 3000© (Nielson-Kellerman, Boothwyn, PA, USA) was used to determine air temperature. The transects were walked at a uniform pace, and butterflies observed within a ten metre radius were recorded. Halfway through each section, ten minute stops were made at predetermined locations, again recording any butterflies observed within a ten metre radius. At the stopping points, the percent of blue sky was estimated (0-100; 0 being full cloud cover), and the Kestrel 3000© was used to determine average wind speed. Butterflies were visually identified in the field, and caught with a net when necessary to aid in identification. Unknown species were photographed and sent to local experts for identification. If identification was not possible, the individual was recorded as the most common possibility. While walking the transects, occasional stops were permitted to properly identify butterflies, and recording continued from where the stop was made. All observations were recorded in a standard field form, found in Appendix C and on the ***rare*** server.

2.2 Transect Descriptions

Butterfly monitoring occurred over a fourteen week period, with each of the following transects at the ***rare*** **Charitable Research Reserve** being walked once weekly. Refer to Appendix A for a map of the property which outlines the transect routes.

The **Cliffs and Alvars** transect (Transect 1) is 3.5 km and follows primarily the River and Grand Trunk trails. A large part of the transect consists of mature hardwood forest stands, dominated by American Beech (*Fagus grandifolia*) and Sugar Maple (*Acer saccharum*). This transect also passes through deciduous swamps, limestone cliffs, open alvar habitats, and an extensive floodplain.

The **South Field/Sparrow Field** transect (Transect 2) is 2.9 km, running along the edge of agricultural fields, hedgerows, and through an active tall grass prairie research site. Several fields in the area are currently in agricultural production, including

wheat clover crop in South Field West and winter wheat in South Field East in 2014. The boarders of Sparrow Field were removed from agriculture and have been left to naturalize, while the interior consists of tall grass prairie islands (part of the ongoing research project). Prior to the 2014 monitoring year, this transect traveled along the south-eastern perimeter of Indian Woods. However, due to a change in the ***rare*** property boundary in early 2014, this part of the transect (formerly section 6 and 7) was eliminated and an alternative route was used. To minimize the effects of this change, the new section is referred to as 6/7, allowing the succeeding sections to remain as they were originally numbered.

The **Thompson Tract** transect (Transect 3) is 2.2 km and follows established trails through meadows, plantations, and lowland and upland forest dominated by American Beech and Sugar Maple. Thompson Tract is located at the western boundary of the ***rare*** property.

The **Blair Flats** transect (Transect 4) is a 1.3 km loop that walks the perimeter of a restored tall grass prairie. Prior to 2010, Blair Flats was in agriculture production. As part of a long term study, the area was restored to a tall grass prairie, and is currently dominated by Goldenrod (*Solidago*), Queen Anne's Lace (*Daucus carota*), Black Eyed Susan (*Rudbeckia hirta*), as well as grass species, including Big Bluestem (*Andropogon gerardi*). Beginning at the large Bur Oak (*Quercus macrocarpa*) just off of Blair Road, the transect heads north towards the river, turns west and runs parallel to the river, then turns south and follows the property boundary, and finally traveling eastward, parallel to the road and ending at the Bur Oak.

2.3 Data Analysis

All data were analyzed using R Commander Version 3.0.1 (The R Foundation for Statistical Commuting) and Microsoft Excel 2010. Butterfly data from 2009 to 2014 were included in the analysis; since the 2006 pilot study took place for only five weeks, data were not included. Data were compared across years within transects, as each transect varies in length and habitat type and so direct comparison would not accurately reflect trends in butterfly populations. First, a generalized linear model was fit to data from a single transect. An ANOVA was performed using the generalized linear model to determine if there were any differences between the individual butterfly observations at each transect across monitoring years. Where results of the ANOVA were significant, pairwise comparisons (Tukey HSD tests) were performed in order to determine where differences occurred. An alpha value of 0.05 was used to determine significance.

The Shannon Diversity Index and species evenness for 2014 were calculated and compared with those from previous years (Figure 2.1). Species evenness refers to the relative abundance of individuals of different species, and the Shannon Diversity Index takes into account the evenness and the total number a species to produce a

score from 0-4. Zero (0) indicates very low diversity, while 4 is very high diversity; real world values typically fall between 1.5 and 3.5 (Margalef 1972).

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

Shannon Diversity Index: Where p_i is the proportion of individuals belonging to the *i*th species and S is the number of species.

$$E_H = H/\ln(S)$$

Species Evenness: Where H is the Shannon Diversity Index and S is the number of species.

Figure 2.1: Formulas used for calculating Shannon Diversity Indices and Species Evenness Values.

3.0 Results

3.1 Overall Abundance and Diversity

During the fourteen week monitoring period, a total of 4105 individual butterflies and 53 different species were observed across the four transects at the ***rare* Charitable Research Reserve**. The most abundant species observed in 2014 were: Cabbage White (N=783), Clouded Sulphur (N=655), Common Wood Nymph (N=484), European Skipper (N= 400), and Inornate Ringlet (N=340). The top three most abundant species (i.e. Cabbage White, Clouded Sulphur, and Common Wood Nymph) were also the top three most abundant species during the 2013 monitoring season, and in 2012, Cabbage White and Clouded Sulphur were the two most abundant species. The total number of individuals observed by species in 2014, as well as the Waterloo Regional Status for each species, can be seen in Table 3.1. The total number of individuals and species in each transect, the Shannon Diversity Index, and species evenness values from 2014 are compared to those from previous monitoring years in Table 3.2. Overall, butterfly diversity at ***rare*** was higher in 2014 than in previous years.

Table 3.1: Summary of all observed butterflies in the 2014 monitoring season at the ***rare*** **Charitable Research Reserve.** The Waterloo Regional Status for each of the observed species is also included (Grealey et al, 2010).

Species	Transect				Total	Regional Status
	1	2	3	4		
American Lady	0	1	0	0	**1**	**Common**
Appalachian Brown	3	0	1	0	**4**	**Uncommon**
Arctic Skipper	0	0	1	0	**1**	**Rare**
Banded Hairstreak	6	0	6	0	**12**	**Uncommon**
Black Dash	6	0	0	0	**6**	**Uncommon**
Black Swallowtail	5	26	0	14	**45**	**Very Common**
Broad-winged Skipper	4	0	1	0	**5**	**Common**
Bronze Copper	1	0	0	0	**1**	**Very Common**
Cabbage White	316	272	146	49	**783**	**Very Common**
Clouded Sulphur	86	398	108	63	**655**	**Very Common**
Common Sootywing	1	4	0	0	**5**	**Rare**
Common Wood Nymph	130	42	277	35	**484**	**Very Common**
Delaware Skipper	1	0	2	2	**5**	**Common**
Dun Skipper	42	0	8	2	**52**	**Very Common**
Eastern Comma	2	2	6	0	**10**	**Very Common**
Eastern Tailed Blue	0	0	0	2	**2**	**Uncommon**
Eastern Tiger Swallowtail	16	14	4	6	**40**	**Very Common**
European Skipper	211	21	141	27	**400**	**Very Common**
Eyed Brown	91	0	0	2	**93**	**Very Common**
Giant Swallowtail	6	3	2	1	**12**	**Uncommon**
Great Spangled Fritillary	21	2	23	1	**47**	**Very Common**
Harvester	0	0	1	0	**1**	**Rare**
Hobomok Skipper	3	6	1	0	**10**	**Common**
Inornate Ringlet	60	147	122	11	**340**	**Common**
Juvenal's Duskywing	7	5	32	1	**45**	**Rare**
Least Skipper	4	0	2	0	**6**	**Uncommon**
Little Glassywing	1	0	0	0	**1**	**Uncommon**
Little Wood Satyr	101	8	92	3	**204**	**Very Common**
Long Dash	9	0	0	0	**9**	**Uncommon**
Meadow Fritillary	1	0	0	1	**2**	**Very Common**
Milbert's Tortoiseshell	2	2	0	0	**4**	**Uncommon**
Monarch	12	26	20	4	**62**	**Very Common**
Mourning Cloak	5	11	7	0	**23**	**Very Common**
Northern Broken Dash	4	0	0	0	**4**	**Common**
Northern Crescent	42	11	128	6	**187**	**Uncommon**
Northern Pearly Eye	41	18	102	0	**161**	**Common**
Orange Sulphur	5	33	17	5	**60**	**Very Common**

Painted Lady	1	7	0	2	**10**	**Common**
Pearl Crescent	13	36	2	5	**56**	**Common**
Peck's Skipper	8	0	5	0	**13**	**Very Common**
Question Mark	0	0	1	0	**1**	**Very Common**
Red Admiral	16	9	11	5	**41**	**Very Common**
Red Spotted Purple	32	7	28	5	**72**	**Common**
Silver-Spotted Skipper	1	2	21	0	**24**	**Uncommon**
Silvery Checkerspot	1	0	1	0	**2**	**Rare**
Spring Azure	25	1	20	2	**48**	**Common**
Stripped Hairstreak	2	0	0	0	**2**	**Uncommon**
Summer Azure	15	4	9	1	**29**	**Very Common**
Tawny Emperor	1	0	2	0	**3**	**Uncommon**
Tawny-edged Skipper	1	1	0	0	**2**	**Common**
Viceroy	3	10	2	0	**15**	**Very Common**
White Admiral	0	0	1	0	**1**	**Uncommon**
Wild Indigo Duskywing	1	1	1	1	**4**	**Unknown**
TOTAL	**1365**	**1130**	**1354**	**256**	**4105**	

Table 3.2: Summary of butterfly observation for each transect by year, the Shannon Diversity Index, and Species Evenness for every 14 week monitoring period.

Measures	Transect One						Transect Two						Transect Three					Transect Four				
	2009	2010	2011	2012	2013	2014	2009	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014
Number of Individuals (n)	620	1063	1453	2826	1494	1365	717	1778	1146	2427	1751	1130	938	911	2116	1636	1354	270	298	497	381	256
Species Richness (S)	25	33	35	46	43	47	24	26	30	37	35	31	30	35	38	36	38	14	20	35	21	26
Species Evenness (E)	0.59	0.59	0.50	0.57	0.65	0.71	0.52	0.44	0.47	0.49	0.57	0.62	0.70	0.72	0.71	0.71	0.72	0.49	0.42	0.60	0.63	0.74
Shannon-Diversity Index (H)	1.90	2.07	1.77	2.19	2.45	2.72	1.65	1.42	1.60	1.76	2.02	2.12	2.37	2.56	2.56	2.55	2.62	1.30	1.26	2.12	1.93	2.42

3.2 Transect One: Cliffs and Alvars

A total of 1365 individual butterflies and 47 different species were observed in the fourteen week monitoring period in 2014 on Transect One. The total number of individuals observed on Transect One in 2014 was less than half (48%) of that for the highest monitoring season (2826 in 2012). However, 47 species is the highest number recorded for any of the transects in any given monitoring year. The 2014 species evenness for Transect One was 0.71 and the Shannon Diversity Index was 2.72; both values being an increase from all other monitoring years (Table 3.2).

There was a significant difference between the total number of butterflies observed across years within this transect (X^2=28.674, df=5, p<0.001). A pairwise comparison revealed that the total number of observations in 2014 was only significantly different from the number observed in 2012 (p=0.033). The total number of observations in 2012 was also significantly different from those in 2009 and in 2010 (p<0.001 and p=0.003, respectively; see Figure 3.1).

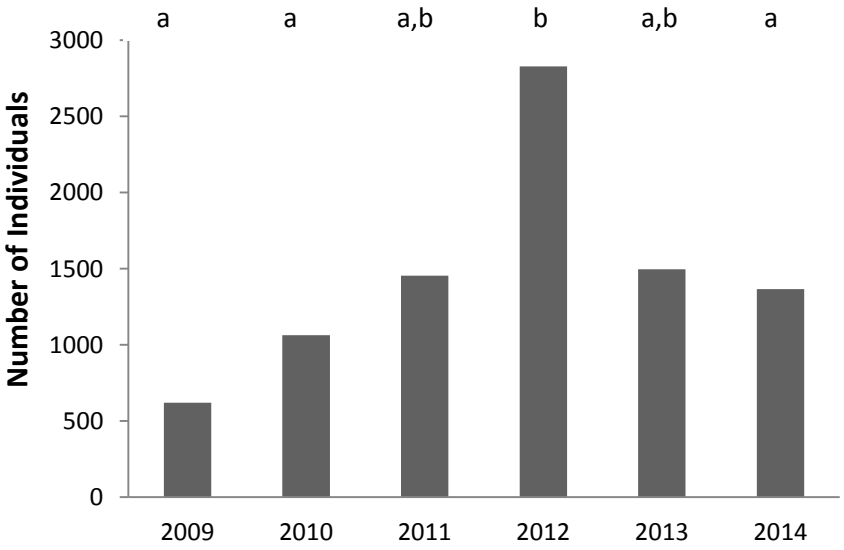

Figure 3.1: Total number of butterflies observed each year on Transect One for all the monitoring seasons. Matching letters correspond to years with total butterfly abundances that are not significantly different (alpha = 0.05).

The most abundant species on Transect One were the Cabbage White (N=316), European Skipper (N=211) and Common Wood Nymph (N=130), accounting for 48.2% of the total observations here. These three species were also the three most dominant species observed in the 2013 monitoring season (although Common Wood Nymph was more dominant then European Skipper in 2013). A total of eight species (Black Dash, Dun Skipper, European Skipper, Eyed Brown, Spring Azure, Great Spangled Fritillary,

Northern Pearly Eye, and Red-Spotted Purple) had their highest abundance in 2014, compared to any other monitoring year. Figure 3.2 and Figure 3.3 show abundances of butterfly species for Transect One.

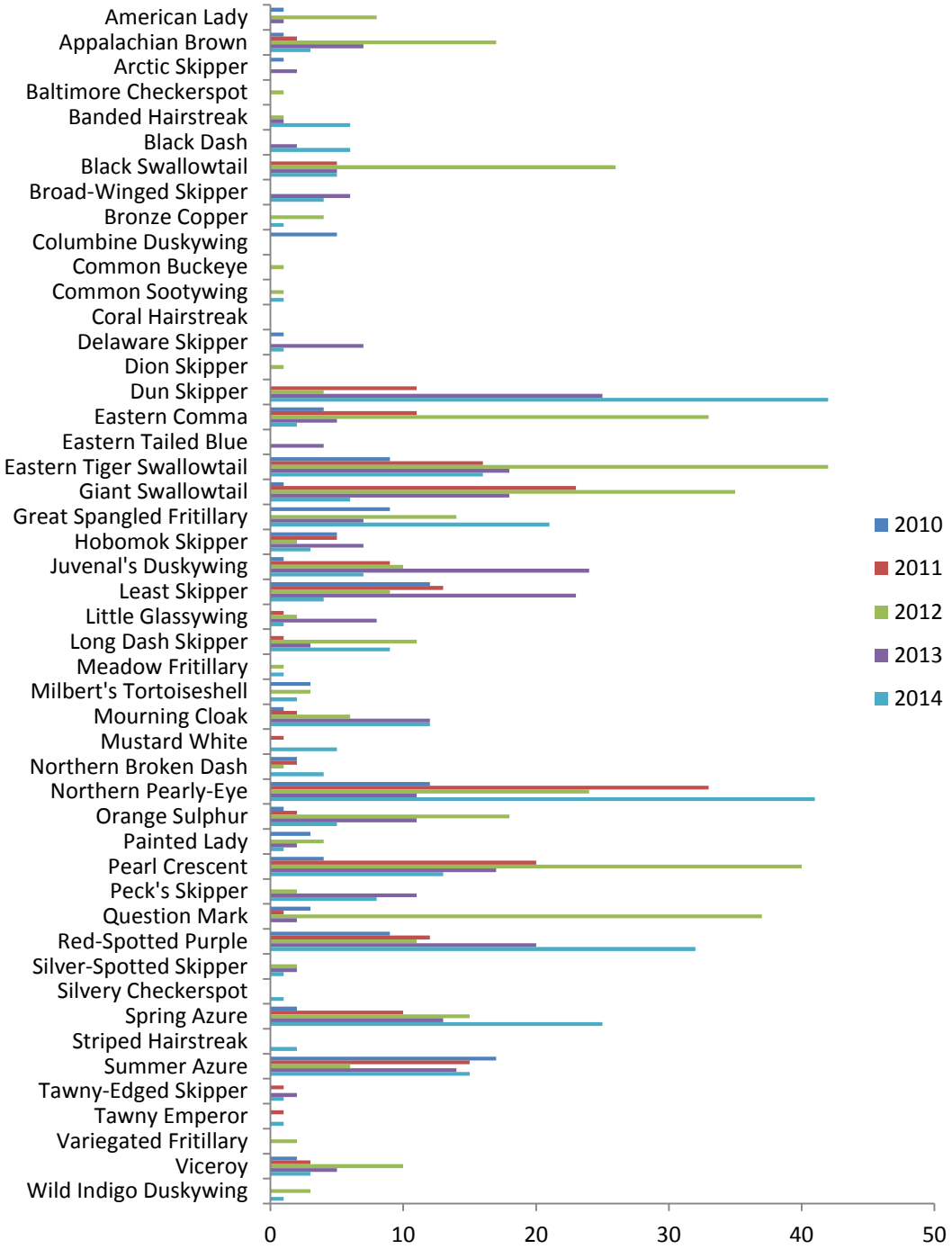

Figure 3.2: Comparison of the species observed on Transect One across years that had consistent monitoring efforts. Species with less than 50 observations are shown.

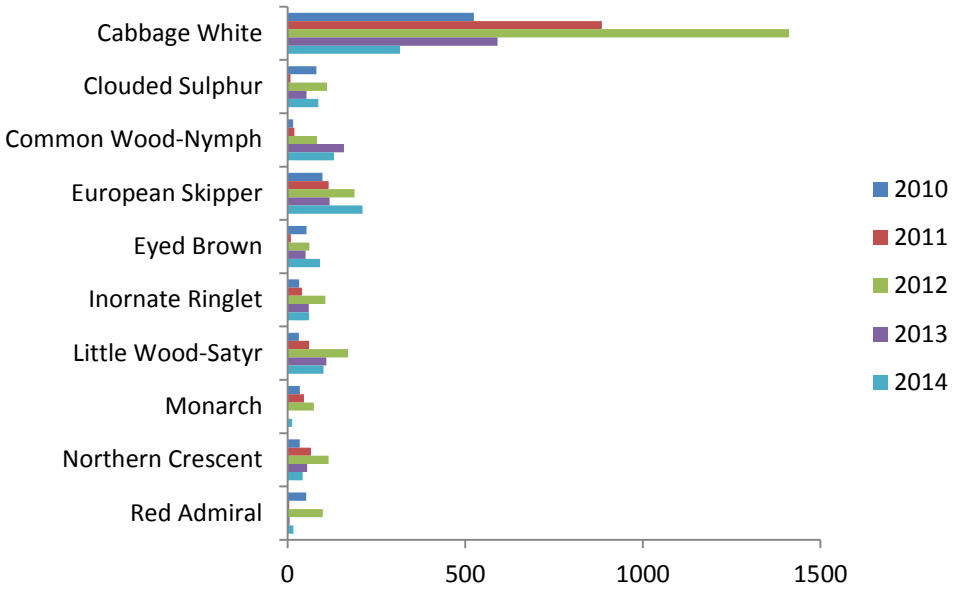

Figure 3.3: Comparison of the species observed on Transect One across years that has consistent monitoring efforts. Only species with more than 50 observations are shown.

3.3 Transect Two: South Field/Sparrow Field

A total of 1130 individuals and 31 different species were observed in 2014 on Transect Two; a decrease in both values from the previous four monitoring years. However, similarly to that of Transect One, the species evenness and Shannon Diversity Index were the highest recorded on Transect Two for any monitoring year (0.62 and 2.12, respectively; Table 3.1).

Although the total number of observation on Transect Two has been fluctuating across years (X^2=16.182, df=5, p=0.006), only 2009 and 2012 data differed significantly from one another (p=0.017) (Figure 3.4).

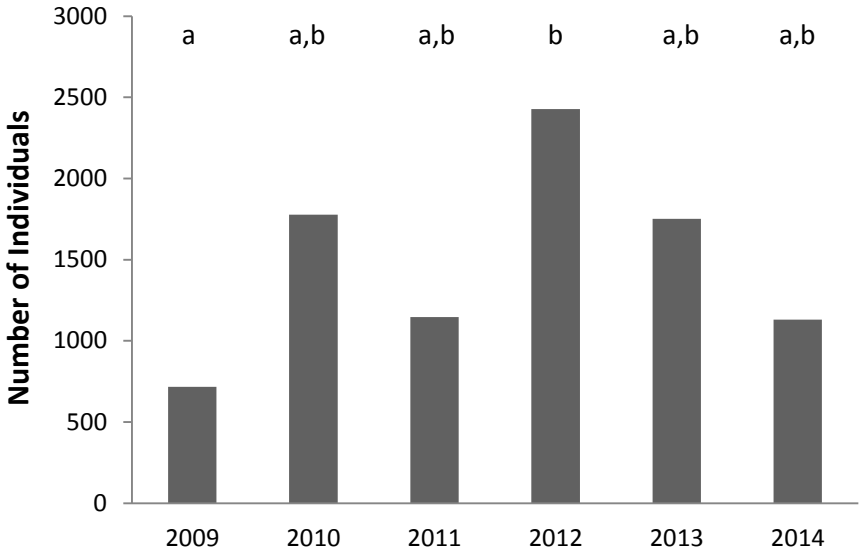

Figure 3.4: Total number of butterflies observed each year on Transect Two for all the monitoring seasons. Matching letters correspond to years with total butterfly abundances that are not significantly different (alpha = 0.05).

The most abundant species on this transect were the Clouded Sulphur (N=389), the Cabbage White (N=272) and the Inornate Ringlet (N=147), accounting for 72% of the total observations. Cabbage Whites and Clouded Sulphurs have been consistently dominant on Transect Two, although Clouded Sulphur populations have experienced more variation from year to year. Historically, Monarchs have been among the most abundant species on Transect Two, but there has been a decrease in their populations over the last two years. Although the total number of Monarchs observed on Transect Two in 2014 was only 11% of that in 2012, it was still 6.5 times greater than it was in 2013. Figure 3.5 and Figure 3.6 show abundances of butterfly species for Transect Two.

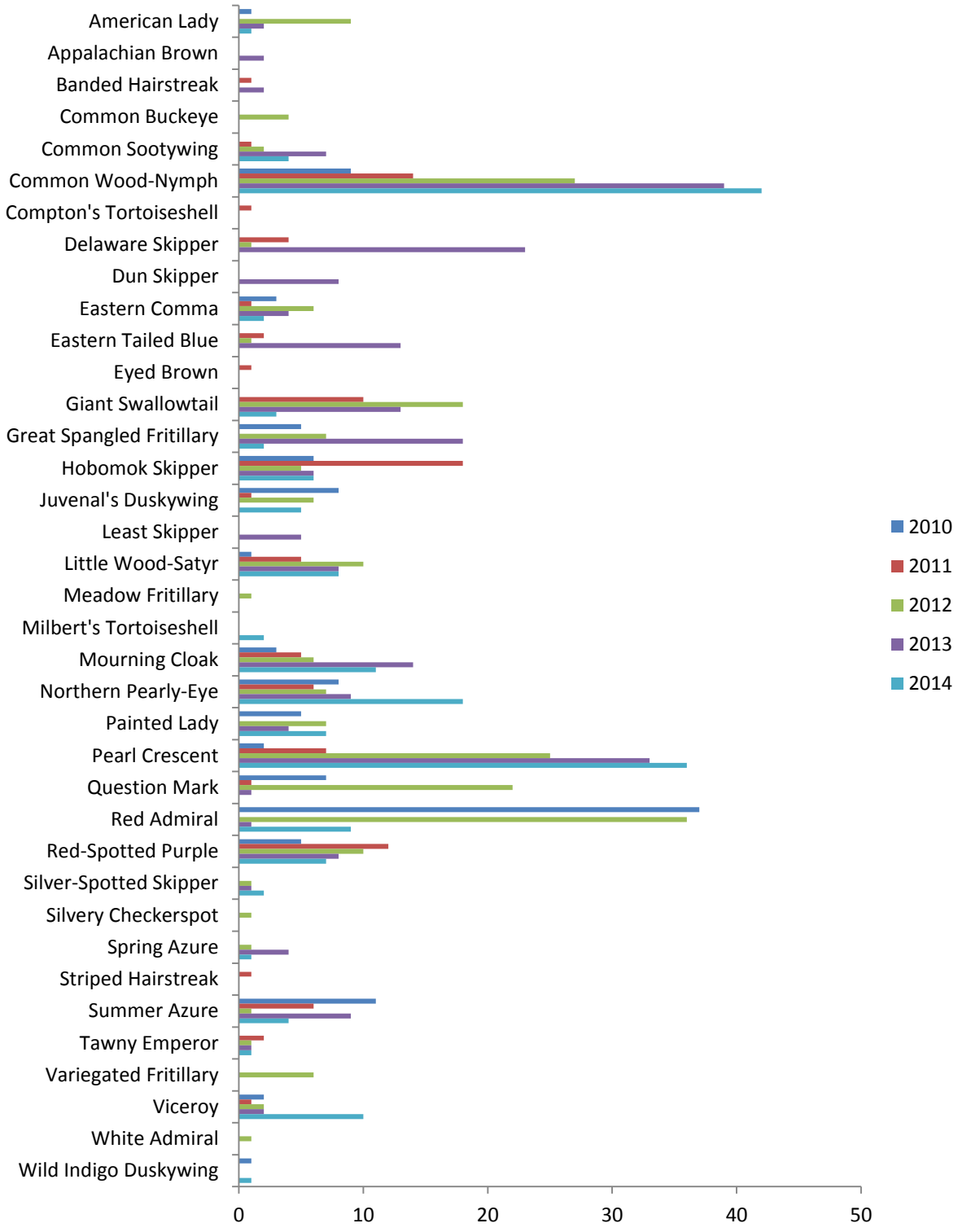

Figure 3.5: Comparison of the species observed on Transect Two across years that had consistent monitoring efforts. Only species with less than 50 observations are shown.

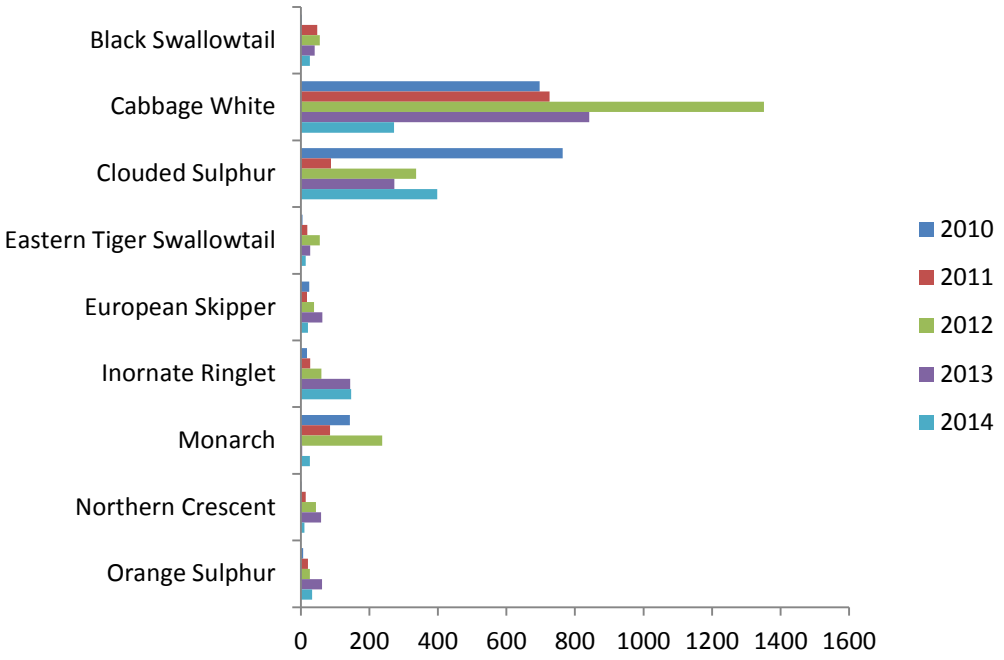

Figure 3.6: Comparison of the species observed on Transect Two across years with consistent monitoring efforts. Only species with more than 50 observations are shown.

3.4 Transect Three: Thompson Tract

There were a total of 1354 individuals and 38 different species observed in 2014 on Transect Three. Although the total number of butterflies observed is less than recent monitoring years, the number of species detected matched the highest number ever recorded here. Species evenness has remained consistent across years (0.72), which, paired with a high species richness, resulted in the highest recorded Shannon Diversity Index for this transect at 2.62 (Table 3.2).

The 2014 monitoring season did not significantly differ from any previous years. However, some significant differences did exist across all monitoring years (X^2=22.610, df=5, p<0.001). The total number of individuals observed in 2012 significantly differed from that of 2009 (p=0.046), 2010 (p=0.008), and 2011 (p=0.006) (Figure 3.7).

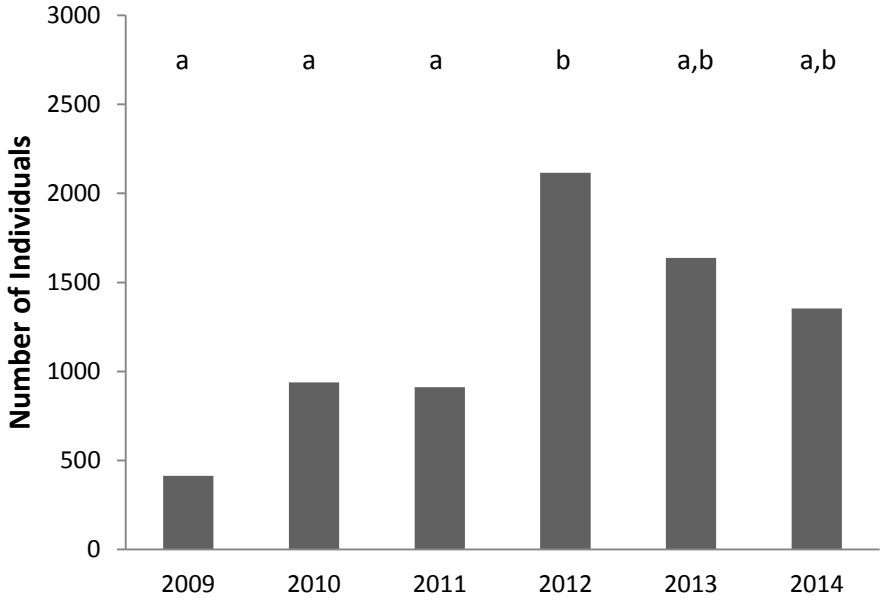

Figure 3.7: Total number of butterflies observed each year on Transect Three for all the monitoring seasons. Matching letters correspond to years with total butterfly abundances that are not significantly different (alpha = 0.05).

For the second year in a row, the Common Wood Nymph was the most abundant species on this transect (N=277). Cabbage Whites (N=146) and European Skippers (N=141) were the next most abundant species. These three species combed accounted for 42% of the total number of observations. The European Skipper has not been one of the top three most abundant species on this transect since 2009. Figure 3.8 and Figure 3.9 show abundances of butterfly species for Transect Three.

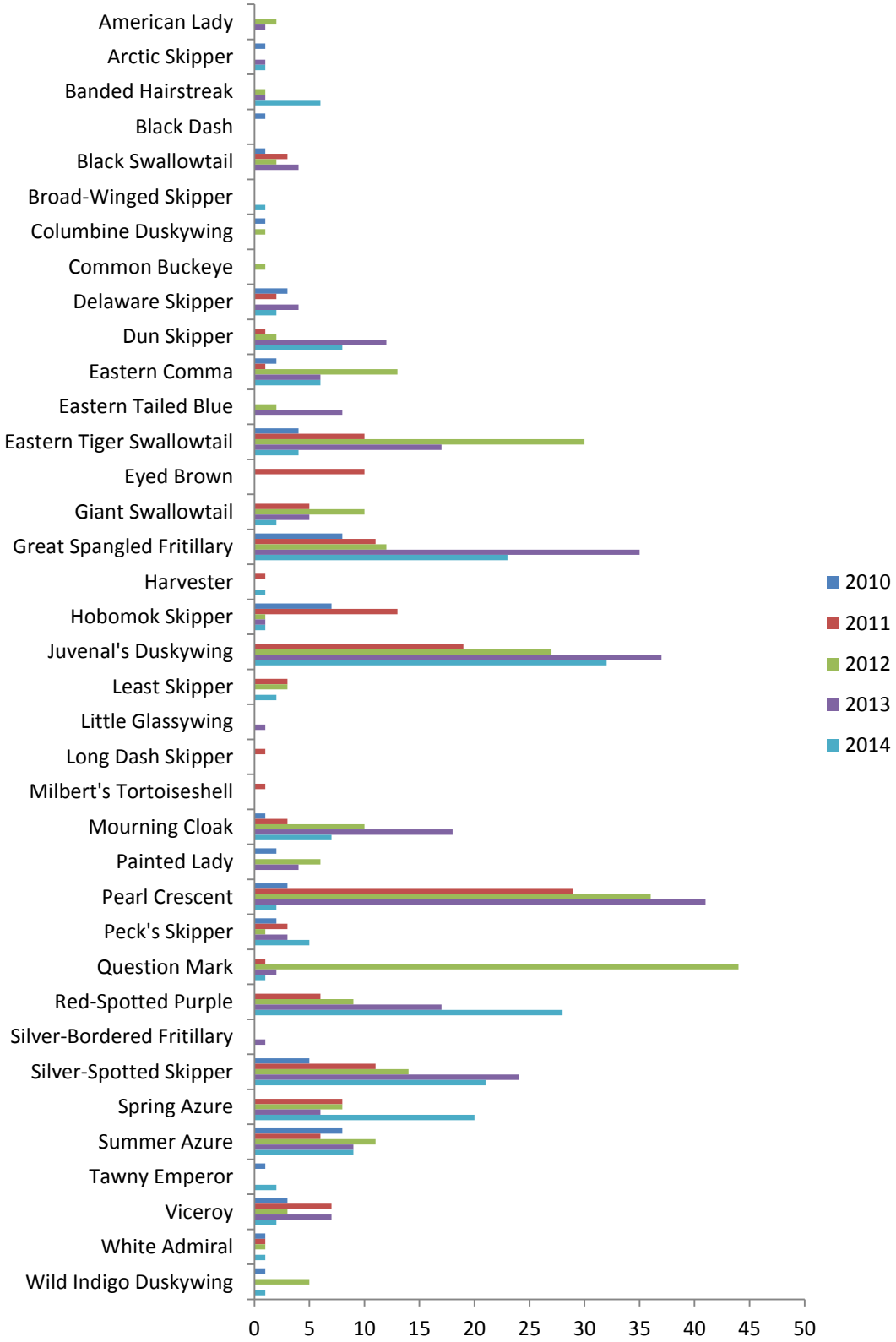

Figure 3.8: Comparison of the species observed on Transect Three across years that had consistent monitoring efforts. Only species with less than 50 observations are shown.

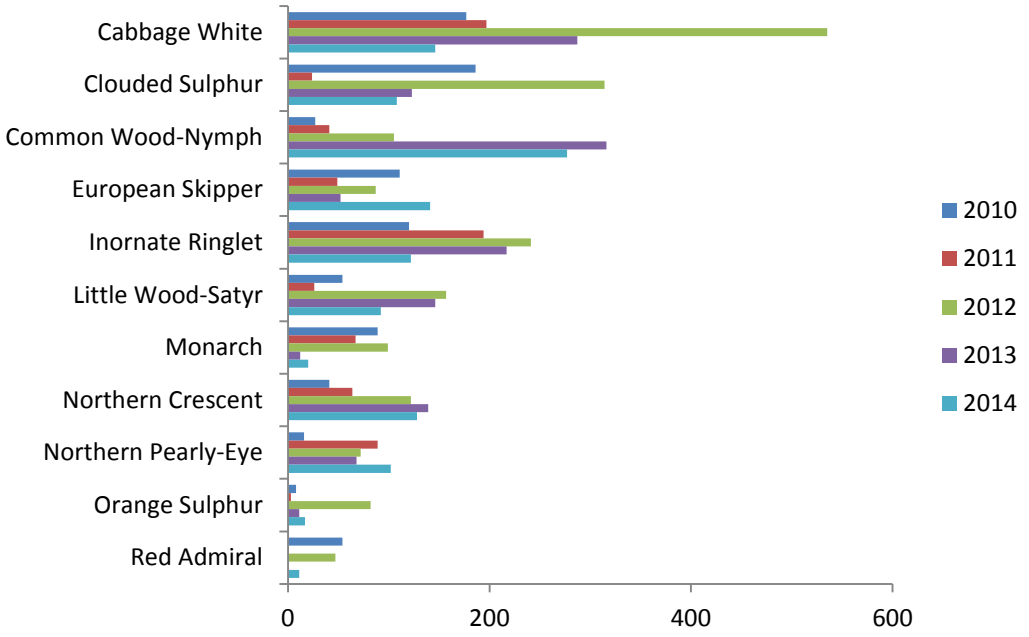

Figure 3.9: Comparison of the species observed on Transect Three across years that had consistent monitoring efforts. Only species with more than 50 observations are shown.

3.5 Transect Four: Blair Flats

The total number of butterflies observed in 2014 on Transect Four was the lowest of all monitoring years, at 256 individuals. Twenty-six species were observed with greater evenness than in previous monitoring years (0.74) resulting in a Shannon Diversity Index of 2.42; the highest ever recorded here (Table 3.2).

No significant differences exist in butterfly abundance by year at Blair Flats (X^2=4.289, df=4, p=0.368) (Figure 3.10).

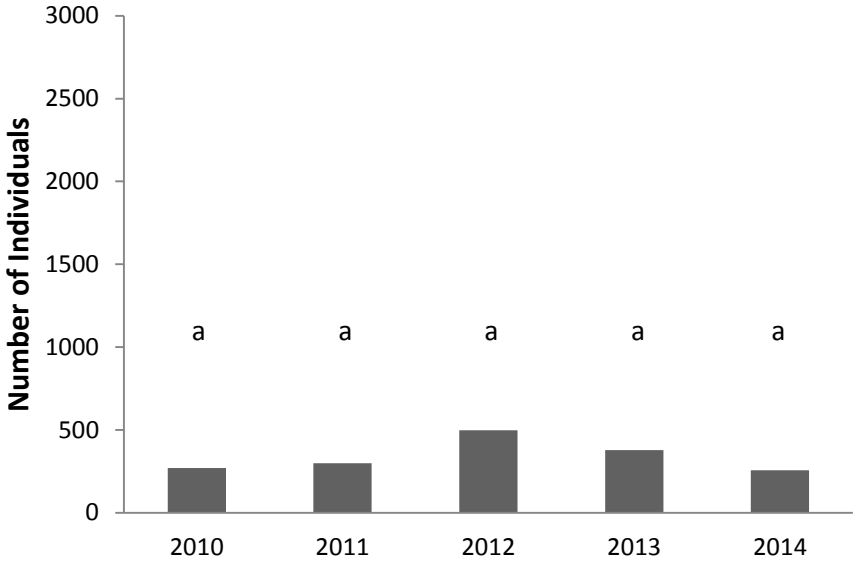

Figure 3.10: Total number of butterflies observed each year on Transect Four for all the monitoring seasons. Matching letters correspond to years with total butterfly abundances that are not significantly different (alpha = 0.05).

The most abundant species observed on this transect were the Clouded Sulphur (N=63), the Cabbage White (N=49), and the Common Wood Nymph (N=35), accounting for 57% of the total observations. These three species were also the most abundant in 2013. Figure 3.11 and Figure 3.12 show abundances of butterfly species for Transect Four.

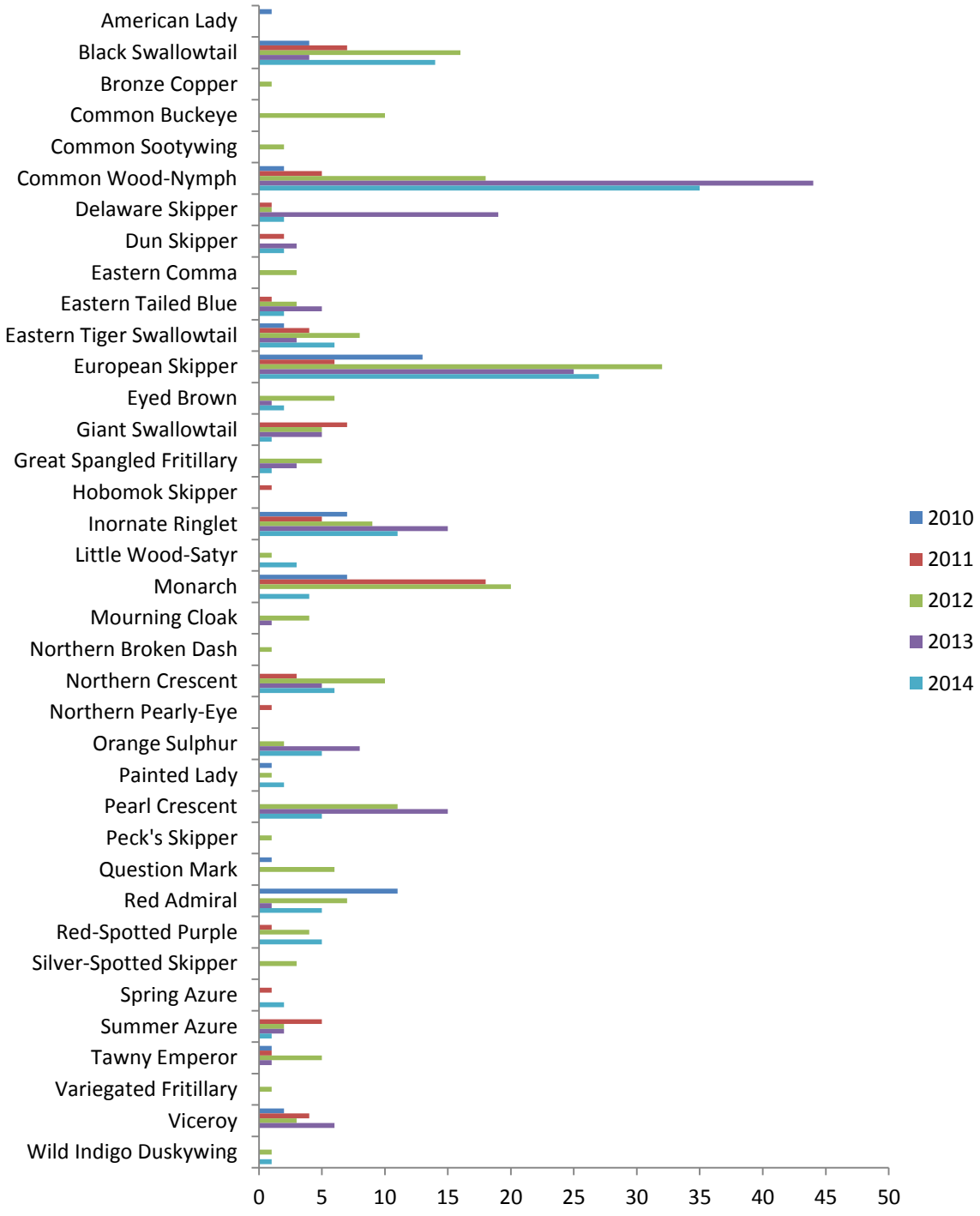

Figure 3.11: Comparison of the species observed on Transect Four across years that had consistent monitoring efforts. Only species with less than 50 observations are shown.

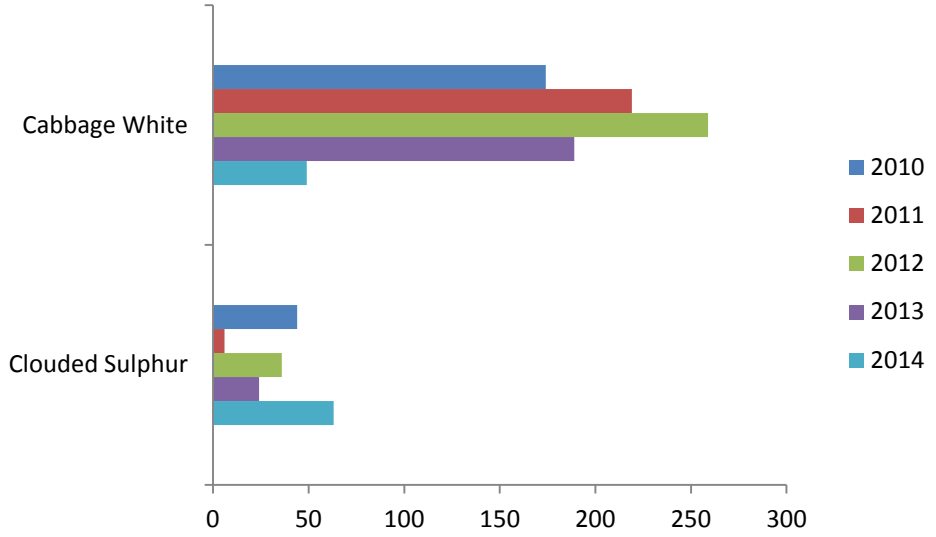

Figure 3.12: Comparison of the species observed on Transect Four across years that had consistent monitoring efforts. Only species with more than 50 observations are shown.

3.6 Weather Conditions

The 2014 butterfly monitoring season was unusual in its weather patterns. Average temperatures were recorded for June, while May, July, and August were on average colder than previous years. In fact, May, July, and August 2014 all had the lowest average temperatures for their respective months compared to all other monitoring years with consistent efforts. When comparing within month averages across years, none of the differences were statically significant ($p>0.9$ for all months). A comparison of temperature data for all years with consistent monitoring efforts can be found in Figure 3.13.

Precipitation also varied across the four months of monitoring. May had the second lowest total precipitation of all years, June had the lowest precipitation of all years, and July and August both had the highest total precipitation of all years (all for their respective months). Within month comparisons revealed that the differences in total precipitation that occur across years are more significant than those which would occur by random chance ($p<0.001$ for May, June, and July, $p=0.001$ for August). Precipitation data for monitoring years that had consistent efforts can be visualized in Figure 3.14.

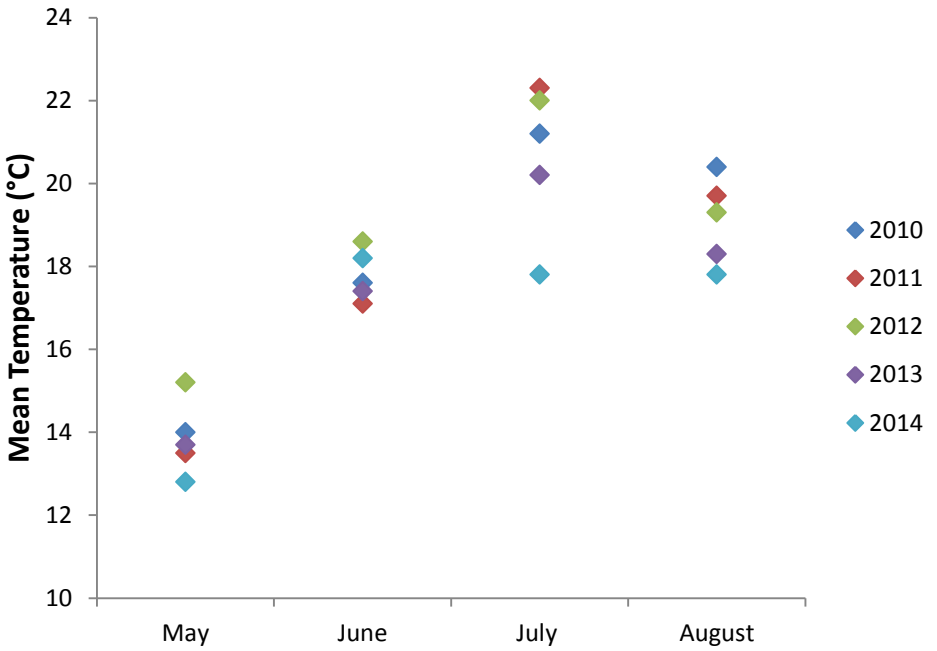

Figure 3.13: Mean monthly temperatures for Kitchener/Waterloo for all months of all butterfly monitoring seasons at the ***rare*** **Charitable Research Reserve**. Data are from the Kitchener Waterloo Weather Station (Accessed from Environment Canada 2014).

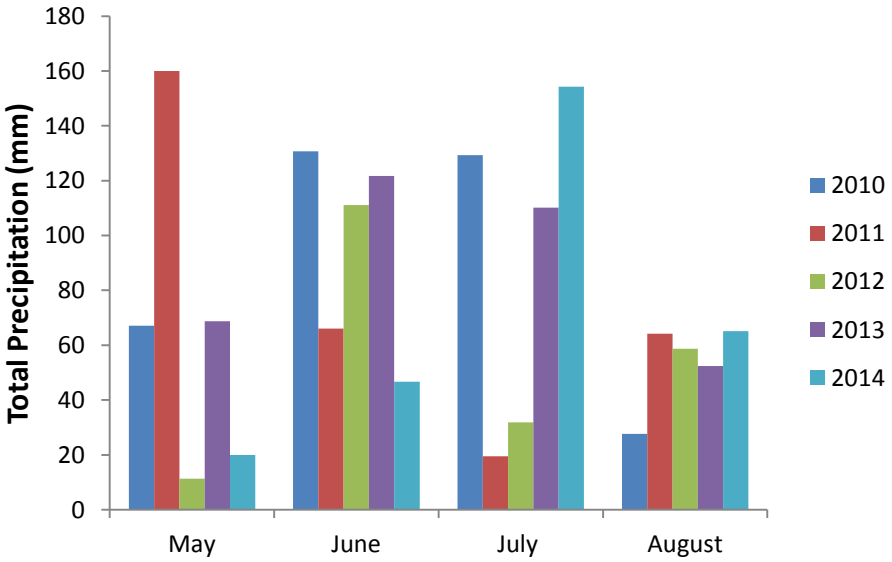

Figure 3.14: Total monthly precipitation for Kitchener/Waterloo for all months of all butterfly monitoring seasons at the ***rare*** **Charitable Research Reserve**. Data are from the Kitchener Waterloo Weather Station (Accessed from Environment Canada 2014).

3.7 Annual Butterfly Count

Unfortunately due to inclement weather, the annual butterfly count for 2014 was cancelled. The butterfly count at ***rare*** has occurred annually, in mid-July since 2006, with the exception of 2007 and now, 2014. Results from all previous annual butterfly counts can be found in Appendix D.

4.0 Discussion

4.1 Overall Abundance and Diversity

Results of the 2014 monitoring season revealed that the total number of butterflies this year (N=4105) was less than that of the previous two years (2013: N=5263 and 2012: N=7688). Although total numbers in 2014 were significantly less than that of 2012, it is important to note that 2012 was an extremely successful year for butterfly species in the Waterloo Region (see Butterfly Monitoring Report 2012; Quinn 2012). These yearly fluctuations in butterfly populations are due in part to the weather patterns of the particular monitoring season. This year in particular had atypical weather patterns; compared to previous monitoring years, June was warmer than average with lower than average precipitation, while July and August were both colder than average with July having above average precipitation. Butterflies are very sensitive to local weather conditions and patterns (Wikström et al. 2009). These weather patterns could have greatly affect individuals' reproduction ability and development time, causing some of these notable differences in total abundances.

Although there was an evident decrease in the number of individuals observed in 2014, species richness was the highest ever recorded at 53 species across all weeks and transects. This represents 76% of the total butterfly species that have been recorded on the ***rare*** property since 2006 (see Appendix E), and 65% of all the butterfly species known to inhabit the Waterloo Region (based on Linton 2012). Parmesan (2006) discusses how increases in global temperatures may lead to shifts in the typical ranges of certain butterfly species. This could be particularly true for seasonal colonists (butterflies that migrate into the region to reproduce but do not overwinter here; Linton 2012).Climate change has affected ranges of migrating fauna, and thus species richness at seasonal grounds, as seen in long-distance migrating birds (Lemoine and Böhning-Gaese 2002). However, this is not likely the cause of the increased species richness for 2014 butterfly monitoring at ***rare***, as the five seasonal colonists observed were also noted in all previous monitoring years. Local weather conditions likely had a greater influence on overall species richness than global patterns. Models predicate that it may be decades before species richness actually adjusts to the current climate change (Menendez et al. 2006). Continuous annual monitoring may reveal these changing trends in the future.

Similarly to previous years, Cabbage Whites were the most abundant species observed during monitoring in 2014. This butterfly species is non-native; it originates from Europe and was introduced to Canada in the 1860's in Quebec. As with other invasive alien species, it spread rapidly, quickly out-numbering native butterflies across many areas of Canada. It can utilize many habitat types, and has a lengthy flight season (Layberry et al. 1998). This butterfly's required host plants belong to the Mustard Family (Brassicaceae), including garden vegetables such as broccoli, cauliflower, and cabbage. Although other host plants are preferred, Cabbage White populations in North America have also been documented to oviposit on the non-native species Garlic Mustard (*Alliaria petiolata*) (Firebaugh and Collins 2010). Both the community gardens at ***rare*** and the widespread population of Garlic mustard on the ***rare*** property (Invasive Exotic Plant Removal and Monitoring Strategy; Cymbaly 2008) have provided above average host plant availability to the Cabbage White butterfly.

It is important to note that in 2014, although still the most abundant species, Cabbage Whites did not account for as large of a percentage of the total population as in previous years. In 2014, Cabbage Whites represented 19% of the total butterflies observed, where as in 2013, they made up 36%, and 2012, they represented over 45% of the total population. There was a period of a few weeks in the middle of monitoring where very few Cabbage Whites were observed; this trend has not been reported in previous years. As a result, the relative abundance of all species was more evenly distributed. This is also reflected in the Shannon Diversity Index and evenness values for each individual transect. It is currently unknown if this Cabbage White population trend was experienced across North America, and what the cause may be. For transparency, it is important to note that during the months of July and August, 48 Cabbage White butterflies were captured, euthanized, and submitted as part of the Pieris Project, a citizen science project investigating several questions regarding Cabbage White abundance around the world (http://www.pierisproject.org/). No Cabbage Whites were captured or removed from the monitoring transects, and it is unlikely that this small number impacted the overall population in this area.

4.2 Transect One: Cliffs and Alvars

The Cliffs and Alvars is the longest of the four transects, travelling through various habitat types including wet sedge meadow, floodplain, forest, and alvar. For this reason, it is not surprising that observations on this transect commonly total the highest abundance of butterflies during monitoring. However, when taking distance into account, 390 butterflies were observed per kilometre, ranking only second among transects along with Transect Two. The multitude of habitat types included on this transect results in a high diversity of butterflies, but is not well suited to a high abundance. Many of the sections include walking through forested or partially forested areas where considerably fewer individuals are observed compared to open or partially

treed areas, resulting in a lower average for butterflies per kilometre on this transect overall. While abundance may be lower, species richness and evenness are higher than other transects resulting in the greatest butterfly diversity. The high diversity of habitat types throughout this transect meets the needs of a wide variety of butterfly species.

4.3 Transect Two: South Field/Sparrow Field

Even with the changes on Transect Two in 2014 (see section: 2.2 Transect Descriptions), it remains the second longest transect. Traversing through naturalized forest buffers and around agricultural fields, this transect has a lower diversity of habitats resulting in a fewer number of both species and individuals observed being here. The species which are supported here, however, are very abundant and include the Clouded Sulphur and Inornate Ringlet. The number of individuals per kilometre for Transect Two was identical to Transect One, at 390 individuals per kilometre.

The species evenness and Shannon Diversity Index for Transect Two were both the highest values of any monitoring year at this transect. Similarly to Transect One, this is likely a result of the decrease in relative abundance of the Cabbage White butterflies at this transect, increasing the evenness of species observed. In fact, 2014 saw the lowest number of Cabbage Whites at Transect Two since 2006, when monitoring only took place for five weeks.

Being the first year of walking the modified transect route, it is difficult to determine if this had an impact on the overall abundance and species composition of this transect. The total number of butterflies observed at this transect in 2014 was the lowest it has been since 2009; this is not surprising however, given the overall trends for the 2014 monitoring year. Property boundary changes resulted in the loss of half of section 5, all of section 6 and half of section 7 on this transect. In 2013, 247 butterflies of 25 different species were observed on these lost portions. Two species were observed on the lost sections that were not observed elsewhere on this transect: the Silver-Spotted Skipper (one individual) and the Dun Skipper (eight individuals).This year on the newly created boundary 6/7, 142 butterflies of 15 different species were observed. No species were unique to this new section. It is important to note that in 2014, two Silver-Spotted Skippers were observed elsewhere on the transect, but no Dun Skipper were observed. The changes made at this transect may have resulted in a loss of this species' specific host requirements (sedges), and thus its presence on Transect Two. Future years' data will be needed in order to confidently determine whether or not this alteration has significantly impacted the collected data.

4.4 Transect Three: Thompson Tract

Transect Three offers a diversity of habitats, including forests and vast meadow areas which support a variety of species. This transect also has some swampy areas

that were often quite wet this year, given the above average total precipitation in July, offering more water resources for butterflies than other transects. Water is important as it creates mud, and mud is essential to “puddling”- a feeding behaviour of adult butterflies. Puddling often provides a much needed source of sodium and potentially other nutrients for butterflies (Boggs and Dau 2004), as their main source of nutrition (flower nectar) is rich in sugar but lacks other important nutrients. Although butterfly abundance has never been highest at this transect, it consistently has the highest number of individuals observed per distance travelled of any transect; this year, 615 individuals were observed per kilometre.

The species evenness and Shannon Diversity Indices have remained relatively constant through all monitoring years. This indicates that the butterfly population at Transect Three has been stable over the last five years. Unlike other transects which have undergone some land use changes (ongoing research projects, naturalization, etc.), there has been no land use changes on this part of the property. This may explain why populations at Transect Three have remained more consistent from year to year.

Common Wood Nymphs were the most abundant butterfly at this transect for the second year in a row. Their larval host plant includes various grass species (Layberry et al. 1998) which is extremely common throughout the meadow at Thompson Tract. Northern Pearly-Eye butterflies also require grasses (specifically woodland grasses; Layberry et al. 1998) as their larval host plant. This butterfly was more abundant on Transect Three than any other transect in 2014.

4.5 Transect Four: Blair Flats

Over the course of butterfly monitoring at ***rare***, Transect Four has been undergoing a transition from an agriculture field to a native tall grass prairie. This transect has had the lowest abundance and species richness of all transects over all monitoring years. This is due in part to the history of the site, as less diversity of plant species and habitat types are available. This has resulted in a low species richness as well as a low total observation per distance travelled, at 197 butterflies per kilometre. The species evenness and Shannon Diversity Index for this transect were the highest of all monitoring seasons, meaning that the relative abundance of species as well as the overall biodiversity within this transect seems to be improving.

With the ongoing restoration of this area of the ***rare*** property, the number of different native species should continue to increase, thus increasing the number of butterfly species this area can support. However, this transect does consist of only one habitat type, so it is not likely that individuals per distance travelled will increase over that of other transects.

4.6 Noteworthy Observations

Of the 53 butterfly species observed in 2014, 33 species are considered Very Common or Common is the Waterloo Region. Fourteen species are considered Uncommon, and five species are considered Rare (one species' status is considered "Unknown"; Grealey et al. 2010).

One Arctic Skipper (*Carterocephalus palaemon*) was observed at Transect Three in 2014. Although this species is considered Common throughout its Canadian range, it has been observed in limited spots around the Waterloo Region, and is thus consider Rare (Grealey et al. 2010). This species has previously been observed during monitoring in 2013 and 2010, and during the Annual Butterfly Count in 2010.

Common Sootywings (*Pholisora catullus*) were observed at Transect One and Transect Two in 2014. Although considered Rare in the Region of Waterloo, this butterfly has been observed somewhat consistently during butterfly monitoring at ***rare*** (with the exception of 2010).

A single Harvester (*Feniseca tarquinius*) was observed during monitoring at Transect Three. This species has only been observed in 2011 during monitoring and the Annual Butterfly Count. Harvester larvae are carnivorous and feed on Woolly Aphids on alder bushes (Layberry et al. 1998). Due to the extremely specialized host requirements, it is not surprising that they are not often observed during monitoring.

From 2010 to 2013, the number of Juvenal's Duskywing (*Erynnis juvenalis*) observed during monitoring had been increasing. Although still relatively abundant for a species considered Rare in the region, there was a slight decrease from 2013 to 2014. This species was not observed in the Waterloo Region after the 1960's until 2010. Its early flight period (May and June) may have resulted in the species being overlooked during monitoring programs that began later in the season.

Two Silvery Checkerspot (*Chlosyne nycteis*) butterflies were also observed during this monitoring season; one was observed at Transect One and one at Transect Three. Prior to this year, observations of this species on the ***rare*** property were limited to one individual in 2012 during monitoring. Silvery Checkerspot is considered Rare is Waterloo Region, with few observations made after 1965.

There were two Rare species that were incidentally observed at the ***rare*** **Charitable Research Reserve** in 2014, but not on a specific transect during monitoring. Firstly, an Acadian Hairstreak (*Satyrium acadica*) was observed on July 10th, 2014 by Erin Sonser and Jenna Quinn near the ECO Centre and a Baltimore Checkerspot (*Euphydryas phaeton*) was observed by Lucas Short on July 17th, 2014 at Thompson Tract. The Acadian Hairstreak has only ever been observed one other time on the ***rare*** property, during the 2008 Annual Butterfly Count. The Baltimore Checkerspot has only been observed one time during monitoring (2012 at Transect One). It was also observed during the 2011 and 2012 Annual Butterfly Counts.

Although Monarchs (*Danaus plexippus*) are considered Very Common in the Waterloo Region, their population trends constantly catch the attention of ecologists and the general public alike. The Monarch is listed as a species of Special Concern (Government of Canada 2014), and recent research by Flockhart et al. (2014) has been instrumental in determining the actual cause of their decline. Although previously believed to be a result of climate change and deforestation in their wintering grounds, the decline in Milkweed (their required host plant) throughout the Monarchs' breeding grounds has had the most detrimental effect (Flockhart et al. 2014). Butterfly monitoring in 2012 revealed the highest number of Monarch of any year at ***rare*** (N=430); but this was short lived, as Monarch populations in 2013 were only 4% of that in 2012 (the lowest number ever recorded in monitoring). Monarch populations this year were up from 2013, although not nearly what they have been in previous years.

An increase in Monarch sightings in the last year suggests that their populations have recovered, even if only slightly, from 2013. Once considered a noxious weed in Ontario, removal of Milkweed was required in both public green spaces and on private land. In March of 2014, Milkweed was removed from Ontario's noxious weed list, and eradication is no longer necessary (OMAFRA 2014). This has resulted in a greater host plant availability and thus more successful reproduction for Monarch butterflies in Ontario. However, as Monarchs migrate south, their populations are still at risk because of the significant decrease in their host plant in the Corn Belt region of the United States, which has coincided with increased herbicide and genetically modified crop use (Pleasants and Oberhauser 2012). The consequences of this milkweed decline are observed in all geographic areas the Monarchs inhabit throughout their annual migration.

4.7 Comparison with Transect Averages

In order to accurately identify trends and averages for populations, EMAN protocol suggests the first five years of data collection be used to create a baseline for monitoring programs. 2013 was the fifth year that butterfly monitoring at ***rare*** took place for either thirteen or fourteen weeks, and thus data from these years were used to identify averages and standard deviations for both abundance and species richness across the four transects (Table 4.1).

Using these data, we can compare the 2014 results to the averages for each transect to determine if this monitoring season fell within or outside of these averages. Values that are outside of the given ranges may indicate environmental change that has potentially had either positive or negative impacts on the populations. The acceptable average ranges (i.e. standard deviations) reflect the large amount of variation seen in total observations from year to year.

Table 4.1: Average butterfly abundance and species richness, with standard deviations, for monitoring seasons 2009-2013.

Transect	Number of Individuals		Species Richness	
	Average	Standard Deviation	Average	Standard Deviation
Transect One	1491	+/- 825	36	+/- 8
Transect Two	1563	+/- 655	30	+/- 6
Transect Three	1203	+/- 670	35	+/- 3
Transect Four	361	+/- 101	23	+/- 9

The number of individuals observed on Transects One, Two, and Three in 2014 are all considered average, as they fall within the average range of the baseline data. The total number of individuals at Transect Four in 2014 was below average (only by four individuals). This is likely a result of poor/unusual weather conditions throughout the monitoring season. Although care was taken to randomize the order in which transects were completed on a weekly basis, Transect Four (being the shortest transect and taking the least amount of time to complete) was often completed in less than optimal weather conditions compared to other transect that required more time (if it was going to rain later that day, for example). In fact, Transect Four had the lowest average percent of blue sky and the highest average wind speed of all transects (Average Percent Blue Sky= 67% and Average Wind Speed= 0.76). Both of these weather variables can greatly affect the number of individuals observed at a given time, and is likely the reason that Transect Four had lower than average results this year. Care should be taken in the future to avoid this potential source of error.

Transect One had a higher than average species richness value, while the three other transects all had species richness values that fell within the average ranges. The species richness value for Transect One may be an early indicator of environmental change, such as global climate changing flight patterns of migrating species so that a greater number of species are observed within the monitoring period. Although the species richness values for the other three transects fell within the average ranges, it is important to note that they too all fell at the higher end of those ranges.

4.8 Long Term Effects of Climate Change

Recent research has utilized various resources, including naturalist club records and museum archives in order to determine how climate change has historically influenced butterfly flight patterns. The timing of flight seasons across Canadian butterfly species has been significantly earlier in warmer years (Kharouba et al 2013). Increasing temperature in the months prior to and during flight seems to have the greatest influence on the variation in sighting dates (Polgar et al. 2012). In addition, the timing of flight seasons of earlier fliers and less mobile species are most sensitive (Kharouba et al 2013). It is hypothesized that with increasing global temperatures, long

term trends at ***rare*** will show spring fliers, such as the Spring Azure and Northern Crescent, being observed at earlier dates than they have in the past six years of monitoring (See Appendix E).

Temperature changes do not only effect the flight times of butterflies, but also development of all life stages and survivorship. Radchuck et al (2013) found that increases in temperature positively affected egg, larva, and pupa survival rates, as well as the number of eggs laid by a female. However, the survival of overwintering larvae was negatively affected by increasing temperatures, and overall population viability was most affected by this negative relationship (Radchuck et al 2013). Taking these relationships into consideration, it is predicted that some butterfly species in the Waterloo Region may be more affected than others by climate change, specifically those that overwinter as caterpillars such as the Common Wood Nymph.

5.0 Conclusions and Recommendations

The butterfly monitoring program at ***rare*** has been successful in collecting data and creating a baseline dataset to be used to determine changes in the butterfly community that go beyond local weather conditions. Although atypical weather patterns resulted in fewer observations than previous years, the results of the 2014 monitoring season overall shows an increase in the diversity of butterflies, and a more even relative abundance of all the species present, compared to that of other monitoring years.

Given the recent trends at Transect Four, it is hopeful that this recently restored tall grass prairie will continue to increase in the species it can support in the coming years. Plans of completing a controlled burn on the Blair Flats Prairie in spring 2015 will most definitely have an effect on the overall abundance of butterflies at Transect Four over the next few years. The first years after the burn, the number of individuals may be reduced as the number of flowering plants is reduced. However, the butterfly abundance and species richness should increase after that time, given that native species become more abundant and plant biodiversity continues to increase. It is recommended that the impact on butterfly populations of the controlled burn is accurately documented.

Furthermore, the changes to Transect Two should be considered when analyzing future data collected from this transect. The averages from the baseline data may need to be adjusted in order to account for the changes made in 2014.

It is recommended that the monitoring program at ***rare*** continue in its full capacity in the years to come. With a constant urban growth surrounding the ***rare*** property, including new subdivisions, increased vehicle traffic, and continued aggregate mining, the butterfly monitoring program will play a key role in detecting changes in ecosystem health. Identifying potential issues early on will also allow for further creation and implementation of management plans for the property. The data collected during butterfly monitoring at the ***rare*** **Charitable Research Reserve** will also continue to be

useful on a broader scale, adding to the knowledge of environmental health in the Region of Waterloo as a whole.

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Appendix A: Maps and Transect Descriptions

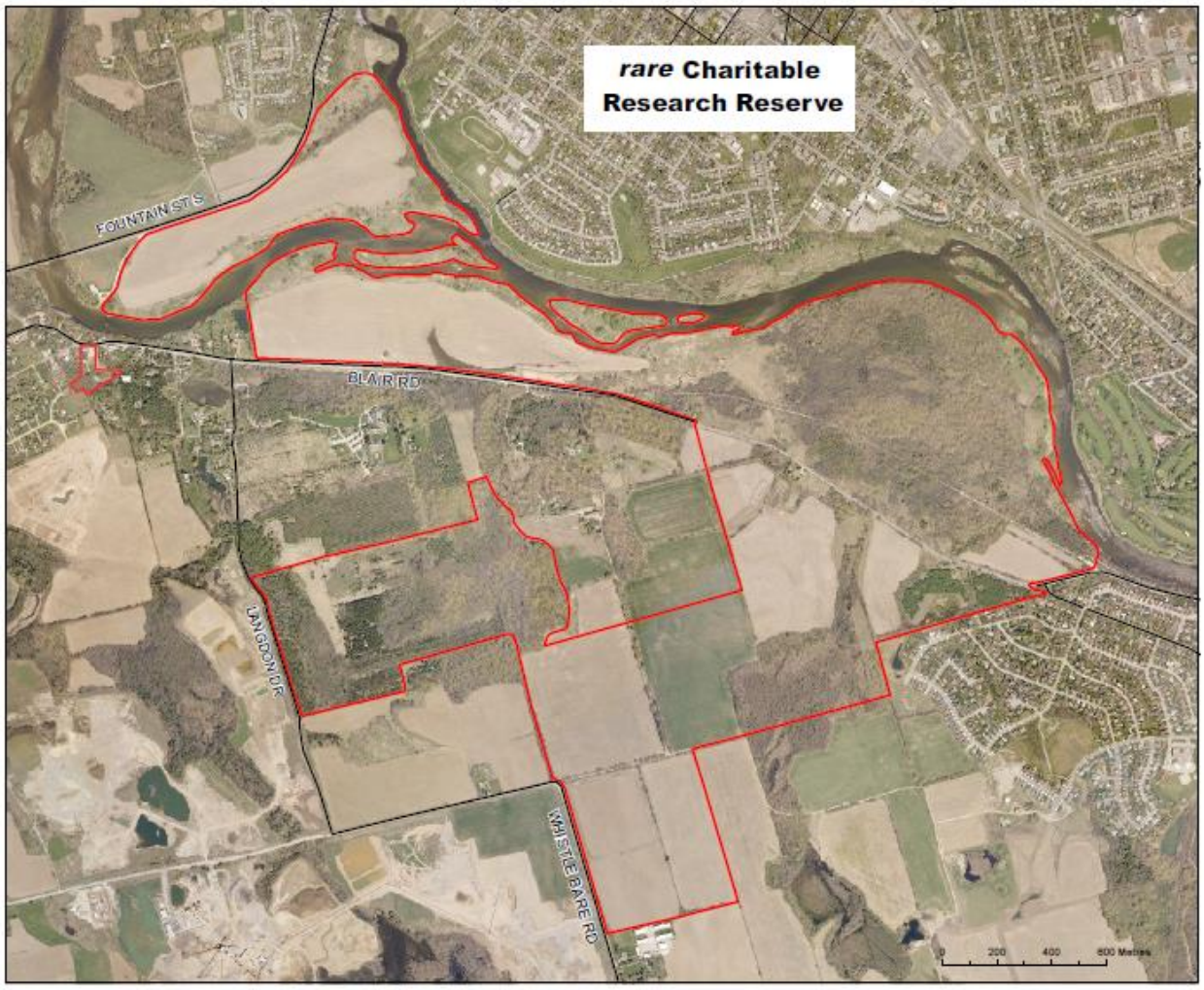

Figure A.1: Property boundaries of the ***rare*** **Charitable Research Reserve**.

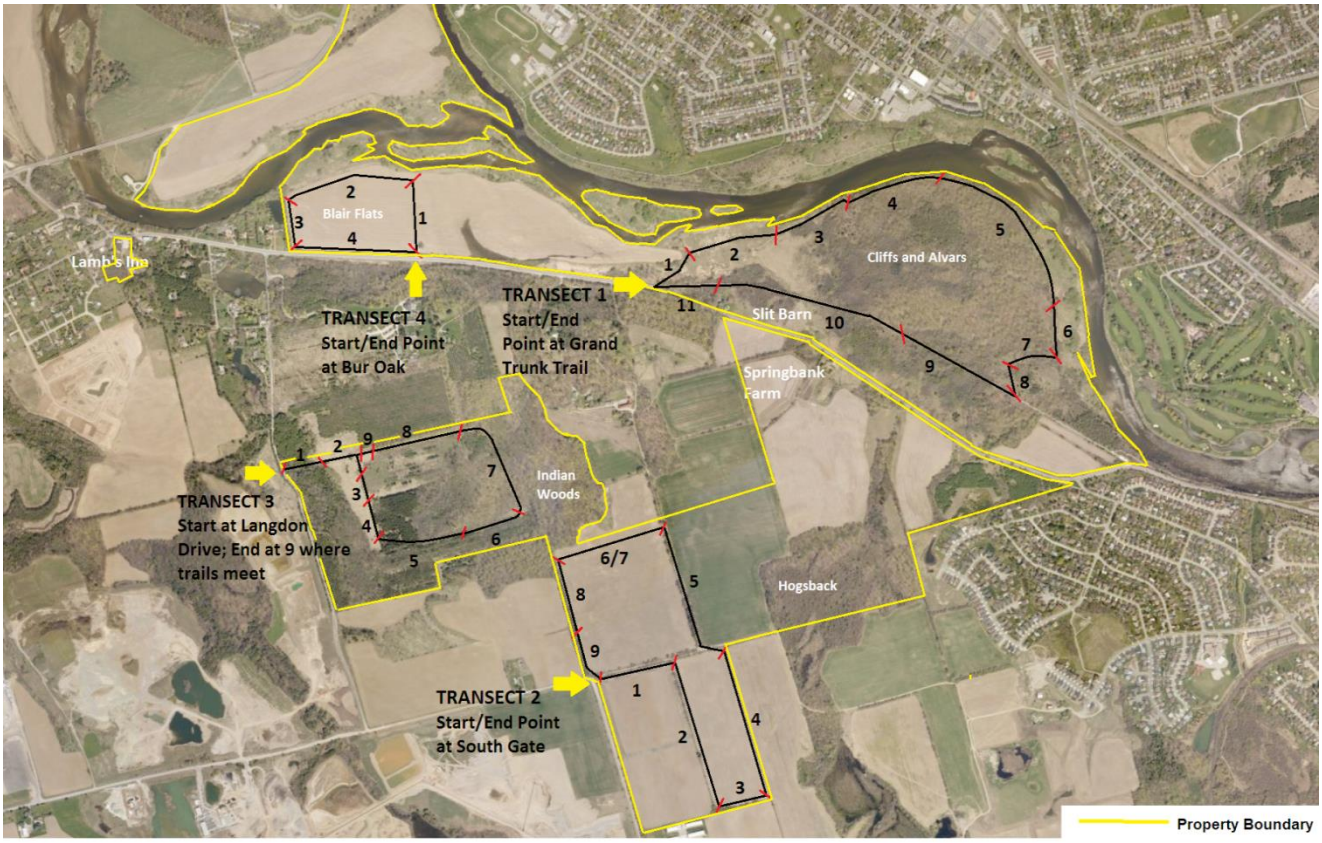

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Figure A.2: Location of the four butterfly monitoring transects at the ***rare*** **Charitable Research Reserve** with start/end points and section breaks.

List A.1: Description of Transect One sections with stopping point coordinates (GPS coordinate accuracy less than 10m).

Section one (N 43° 22.980' W 80° 21.541')
- Riparian grassland (milkweed, goldenrod, grasses)
- Stop past the sedge wetland, toward the river at the solitary shrub

Section two (N 43° 23.025' W 80° 21.426')
- Riparian meadow with trees and shrubs on south side
- Stop at old fallen tree in middle of field, within direct view of the osprey tower, 100m

Section three (N 43° 23.058' W 80° 21.222')
- Riparian area with trees on south side (grasses, sedges, small shrubs, goldenrod)
- Stop in open grass area with small hill on right hand side just after trail turns away from river, before continuing into forest

Section four (N 43° 23.120' W 80°21.017')
- Mainly coniferous forest trail with open canopy areas, on cliffs
- Stop when path forks to small lookout over the river to the left, break in cedar dominance

Section five (N 43° 22.986' W 80°20.625')
- Deciduous forest trail
- Stop at large fallen tree over trail, trail has moved around log; cliffs on south side and open meadow (milkweed, raspberry, goldenrod, one Oak) on north side

Section six (N 43° 22.761' W 80°20.617'
- Open shrub land
- Stop at alvar on the left hand side of trail right after the old car on the right hand side, large red pine on the trail edge and large white pine further back near alvar

Section seven (N 43° 22.767' W 80° 20.697')
- Deciduous forest trail
- Stop at large alvar, ~10m after tall Oak tree

Section eight (N 43° 22.749' W 80° 20.734')
- Open shrub land
- Stop on second boardwalk

Section nine (N 43° 22.793' W 80° 20.901')
- Grand Trunk Trail, deciduous forest
- Stop at culvert in wetland

Section ten (N 43° 22.901’ W 80° 21.250’)

- Grand Trunk Trail, dense shrub growth on both sides of trail
- Stop at entrance to Osprey Tower path to the north, and path to Slit Barn to the south

Section eleven (N 43° 22.927’ W 80° 21.546’)

- Grand Trunk Trail, wetland on either side of trail (sedges, cattail, milkweed, goldenrod, purple loosestrife)
- Stop at culvert near Blair Road entrance to Grand Trunk Trail, several Trembling Aspen trees, direct line of sight to stopping point for section one

List A.2: Description of Transect Two sections with stopping point coordinates (GPS coordinate accuracy less than 10m).

Section one (N 43° 22.177' W 080° 21.691')

- Agricultural field (mix of alfalfa, red fescue, perennial wild rye, buckwheat, winter wheat and oats) to south of transect, deciduous trees and shrubs to the north
- Stop at north side of South Field West in naturalized buffer, directly across from silo at farm to the south

Section two (N 43° 22.048' W 080° 21.560')

- Hedgerow along winter wheat field edge, mostly open with some shrubs
- Stop halfway along west side of South Field East, near solitary Buckthorn shrub & old collapsed wooden structure

Section three (N 43° 21.909' W 080° 21.438')

- Hedgerow of deciduous trees along edge of winter wheat field
- Stop halfway along south side of South Field East, at the end of the tree line to the north, before the row of three single trees

Section four (N 43° 22.050' W 080° 21.404')

- Hedgerow on east side of winter wheat field, mostly open with few shrubs along fence
- Stop halfway along field edge, blue post on east side of fence

Section five (N 43° 22.402' W 080° 21.620')

- Deciduous hedgerow of mostly Oak trees; bordering winter wheat field on east side and naturalized agricultural field on west side
- Stop after open canopy, once there is partial canopy coverage again

Section six/seven (N 43° 22.423' W 080° 21.771')

- Naturalized agricultural field, with grasses, wildflowers, and some saplings (maple)
- Stop halfway across field, just before the bird boxes to the south

Section eight (N 43° 22.299' W 080° 21.892')

- Hedgerow of deciduous trees (mostly Maple) bordering naturalized agricultural field
- Stop at top of hill at fallen tree, can see apartment building to the east

Section nine (N 43° 22.212' W 080° 21.857')

- Hedgerow (east of Grand Allee Trail) of mainly shrubs, vines and grasses bordering naturalized agricultural field
- Stop on incline past large group of young maple trees, 20 meters before path to Grand Allee

List A.3: Description of Transect Three sections with stopping point coordinates (GPS coordinate accuracy less than 10m).

Section one (N 43° 22.584' W 080° 22.569')
- Coniferous forest (Ash trees, Cedar trees, shrubs)
- Stop at swampy meadow just past culvert (goldenrod, cattails, milkweed)

Section two (N 43° 22.601' W 080° 22.469')
- Meadow (milkweed, goldenrod, grasses, sedges)
- Stop at junction of trails

Section three (N 43° 22.541' W 080° 22.454')
- Black Locust plantation and meadow
- Stop halfway through plantation area, where tree has grown around top wire of fence on east side

Section four (N 43° 22.482' W 080° 22.430')
- Meadow (milkweed, goldenrod, grasses, sedges) on west side of transect, Spruce tree forest on east side
- Stop at third large Spruce tree on east side, about halfway down the straight portion of the trail

Section five (N 43° 22.424' W 080° 22.301')
- Spruce and deciduous forest
- Stop where wet area ends (will change from year to year), small clearing to the north, several small trees leaning across path

Section six (N 43° 22.476' W 080° 22.064)
- Meadow (grasses, sedges) and Walnut tree plantation
- Stop halfway down straight section of walnut trees, dead and fallen White Pine on north side with young maples around it

Section seven (N 43° 22.568' W 080° 22.158')
- Grand Allee Trail in Indian Woods (deciduous forest of Sugar Maple, Beech and Oak trees with woodland plants and flowers such as may apple, solomon's seal, trillium and ferns)
- Stop on cement bridge over Bauman Creek

Section eight (N 43° 22.635' W 080° 22.273')
- Maple Lane Trail (deciduous forest of Sugar Maple and shrubs)
- Stop near small pile of logs on south side of trail

Section nine (N 43° 22.606' W 080° 22.437')
- Meadow (vetch, goldenrod, grasses, sedges, scattered trees and shrubs)

- Stop halfway before the junction of trails, between two stumps on north side of trail

List A.4: Description of Transect Four sections with stopping point coordinates (GPS coordinate accuracy less than 10m).

Section one (N 43° 23.090' W 080° 22.307')

- Weedy meadow planted for tall grass prairie, recovering from agricultural use (horseweed, black-eyed susan, goldenrod)
- Walk from Bur Oak toward tower in distance, stop halfway before field edge in between two University of Guelph plant enclosures

Section two (N 43° 23.131' W080° 22.523')

- Regeneration area to the north side of transect and planted tall grass prairie to the south (black-eyed susan, burdock, goldenrod, horseweed, tansy, thistles)
- Stop halfway along field edge, just after the bird boxes

Section three (N 43° 23.056' W 080° 22.641')

- Hedgerow of shrubs and trees to the west of transect and planted tall grass prairie to east of transect (black-eyed susan, burdock, goldenrod, horseweed, tansy, thistles)
- Stop halfway along field edge, hot tub on west side of transect

Section four (N 43° 22.998' W 080° 22.473')

- Hedgerow along Blair Road to the south of transect and planted tall grass prairie to north of transect (black-eyed susan, horseweed, Manitoba Maple, tansy, thistles, shrubs)
- Stop halfway along field edge, where shrubs are tallest

Appendix B: Field Equipment

List B.1: Suggested butterfly monitoring field equipment.

- Field data sheet
- Clipboard
- Pencils
- Stopwatch
- Kestrel 3000©
- Butterfly net
- Field guide (Recommended: Carmichael, I. and Vance, A. 2003. Photo Field Guide to the Butterflies of Southern Ontario. St. Thomas Field Naturalist Club Inc., St. Thomas, ON.)
- Clear jar with mesh lid
- Binoculars
- Digital Camera

Appendix C: Field Codes and Data Sheets

Table C.1: Beaufort wind codes for use on land.

Force	Description	Specifications For Use On Land
0	Calm	Calm; smoke rises vertically
1	Light Air	Direction of wind shown by smoke drift, but not by wind vanes
2	Light Breeze	Wind felt on face; leaves rustle; ordinary vanes moved by wind
3	Gentle Breeze	Leaves and small twigs in constant motion; wind extends light flag
4	Moderate Breeze	Raises dust and loose paper; small branches are moved
5	Fresh Breeze	Small trees in leaf begin to sway; crested wavelets form on inland waters
6	Strong Breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty
7	Near Gale	Whole trees in motion; inconvenience felt when walking against the wind
8	Gale	Breaks twigs off trees; generally impedes progress
9	Severe Gale	Slight structural damage occurs, chimney-pots and slates removed
10	Storm	Seldom experienced inland; trees uprooted; considerable structural damage occurs
11	Violent Storm	Very rarely experienced; accompanied by wide-spread damage
12	Hurricane	--

BUTTEFLY MONITORING FIELD NOTES									
DATE:				START:				TEMP_START:	
TRANSECT:				FINISH:				TEMP_END:	
1			S:	SUN:	2			S:	SUN:
W1:				WIND:	W1:				WIND:
W2:					W2:				
3			S:	SUN:	4			S:	SUN:
W1:				WIND:	W1:				WIND:
W2:					W2:				
5			S:	SUN:	6			S:	SUN:
W1:				WIND:	W1:				WIND:
W2:					W2:				
NOTES:									

Figure C.1: Sample butterfly monitoring field data sheet. Available on the ***rare*** server.

Appendix D: Annual Butterfly Count Results

List D.1: Results from Annual Butterfly Count 2012.

Cambridge (*rare* Charitable Research Reserve), ON. Yr. 6, 43.3817°, -80.355°, center at N of Blair Rd. about 1.7 mi E of jct. of Blair Rd. and Fountain St. in Cambridge. See 2006 report for habitats. Imminent threats to habitat: None. Habitat changes since last year: Researchers have planted one area previously which was active agriculture with tall grass prairie. This will be an improvement to habitat. **14 July 2012;** 0900-1500 hrs; sun AM 10%, PM 10%; 82-89°F; wind 2-2 mi/hr. 14 observers in 5 parties. **Total party-hours** 12; **total party-miles on foot** 9. **Observers:** J. Guenther, M. Hulme, S. Hulme, Jessica Linton (245 Rodney Street, Waterloo, ON, N2J 1G7; jlinton@nrsi.on.ca), A. MacNaughton, J. Quinn, G. Richardson, S. Shiplo, A. Turchin, E. Turchin, J. Turchin, B. Wilson, B. Woodman, E. Woodman.

Black Swallowtail 40, Giant Sw. 6, E. Tiger Sw. 18, Cabbage White 169, Clouded Sulphur 39, Orange Su. 29, E. Tailed-Blue 1, 'Summer' Spring Azure 1, Am. Snout 1, Variegated Fritillary 1, Gr. Spangled Fr. 3, Pearl Crescent 7, N. Cr. 2, Question Mark 1, Mourning Cloak 1, Am. Lady 1, Painted La. 4, Red Admiral 12, Com. Buckeye 1, Red-spotted Purple 4, Viceroy 8, Tawny Emperor 1, N. Pearly-eye 1, Eyed Brown 2, Appalachian Brown 5, Little Wood-Satyr 2, 'Inornate' Com. Ringlet 2, Com. Wood-Nymph 29, Monarch 61, Silver-spotted Skipper 3, Wild Indigo Duskywing 12, European Sk. 1, Peck's Sk. 1, N. Broken-Dash 2, Broad-winged Sk. 2, Dion Sk. 2, Black Da. 12, Dun Sk. 11. **Unidentified:** Skipper Species 3. **Total** 39 species, 501 individuals. **Immatures:** Black Sw. 15 eggs; Am. Snout 1 caterpillar. **Field Notes:** 2012 has been exceptionally dry and hot in southern Ontario.

List D.2: Results from Annual Butterfly Count 2011.

Cambridge (*rare* Charitable Research Reserve), ON. Yr. 5, 43.3817°, -80.355°, center at N of Blair Rd. about 1.7 mi E of jct. of Blair Rd. and Fountain St. in Cambridge. See 2006 report for habitats. **03 July 2011;** 0930-1530 hrs; sun AM 76-100%, PM 76-100%; 24-26°F; wind 7-34 mi/hr. 6 observers in 3 parties. **Total party-hours** 10; **total party-miles on foot** 7. **Observers:** E. Damstra, H. Dodds, B. Foell, Jessica Grealey (709 Keatswood Crescent, Waterloo, ON, N2T 2R6), P. Raspberry, G. Richardson.

E. Tiger Swallowtail 1, Cabbage White 95, Bronze Copper 4, Coral Hairstreak 2, Banded Ha. 3, 'Summer' Spring Azure 3, Silver-bordered Fritillary 2, Pearl Crescent 3, N. Cr. 26, Baltimore Checkerspot 12, Red-spotted Admiral 3, Viceroy 1, Tawny Emperor 2, N. Pearly-eye 13, Eyed Brown 62, Appalachian Brown 3, Little Wood-Satyr 13, Com. Ringlet 4, Com. Wood-Nymph 3, Monarch 10, Wild Indigo Duskywing 1, European Skipper 196, Peck's Sk. 2, Tawny-edged Sk. 5, Crossline Sk. 3, Long Dash 2, Little Glassywing 5, Hobomok Sk. 8. **Total** 28 species, 487 individuals.

List D.3: Results from Annual Butterfly Count 2010.

Cambridge (*rare* Charitable Research Reserve), ON. Yr. 4, 43.3817°, -80.355°, center at N of Blair Rd. about 1.7 mi E of jct. of Blair Rd. and Fountain St. in Cambridge. Floodplain; riparian; agricultural field and hedgerow; open meadow; wet meadow; forested; thicket; alvar; gravel trail; marsh. Habitat changes since last year: A large area has been seeded this year for a tall grass prairie restoration project. This will no doubt increase and improve butterfly habitat within the reserve. **10 July 2010;** 0930-1530 hrs; sun AM 76-100%, PM 76-100%; 68-83°F; wind 2-2 mi/hr. 19 observers in 6 parties. **Total party-hours** 25; **total party-miles on foot** 9. **Observers:** R. Beaubien, T. Beaubien, E. Damstra, S. Fogo, G. Grainge, Jessica Grealey (709

Keatswood Cresent, waterloo, ON, N2T 2R6; jgrealey@nrsi.on.ca), J. Grealey, K. Hodder, L. Lamb, A. MacNaughton, G. Michalenko, C. Moore, G. Richardson, B. Snider, E. Snider, E. Turchin, J. Turchin, W. Watson, M. Wolosinecky.

Black Swallowtail 27, E. Tiger Sw. 6, Cabbage White 187, Clouded Sulphur 93, Orange Su. 3, 'Summer' Spring Azure 2, Am. Snout 1, Gr. Spangled Fritillary 5, Meadow Fr. 1, Pearl Crescent 1, N. Cr. 2, Question Mark 8, E. Comma 2, Mourning Cloak 1, Am. Lady 5, Red Admiral 78, Red-spotted Purple 1, Viceroy 2, Tawny Emperor 4, N. Pearly-eye 18, Eyed Brown 7, Appalachian Brown 2, Little Wood-Satyr 8, Com. Wood-Nymph 73, Monarch 70, Silver-spotted Skipper 1, [1]**Wild Indigo Duskywing 9**, Com. Sootywing 1, Arctic Sk. 1, European Sk. 18, Peck's Sk. 1, Tawny-edged Sk. 6, N. Broken-Dash 1, Little Glassywing 2, Delaware Sk. 3, Broad-winged Sk. 1, [2]**Black Da. 24**, Dun Sk. 5. **Unidentified:** Polygonia sp. 3. **Total** 39 species, 683 individuals. **Field Notes:** [1]This species is widespread in Waterloo Region for the first time in 2010. Previously very rare. [2]Local population known from this area but uncommon in the Region of Waterloo.

List D.4: Results from Annual Butterfly Count 2009.

Cambridge (*rare* Charitable Research Reserve), ON. Yr. 3, 43°22.9'N, 80°21.3'W, center at N of Blair Rd. about 1.7 mi E of jct. of Blair Rd. and Fountain St. in Cambridge. Floodplain; agricultural; old field; cliffs & alvars; hedgerows; old growth forest; early successional; roadside. **19 July 2009;** 1030-1530 hrs; sun AM 11-25%, PM 11-25%; 64-70°F; wind 13-24 mi/hr. 16 observers in 5 parties. **Total party-hours** 24; **total party-miles on foot** 9. **Observers:** E. Damstra, G. Grainge, Jessica Grealey (709 Keatswood Cresent, WAterloo, ON, N2T 2R6), K. Hodder, L. Lamb, C. Moore, I. Moore, S. O'Neil, C. Pomeroy, G. Richardson, J. Shea, V. Slocombe, B. Snider, C. Snider, E. Snider, W. Watson.

Black Swallowtail 1, E. Tiger Sw. 1, Cabbage White 151, Clouded Sulphur 25, Orange Su. 3, Coral Hairstreak 1, Banded Ha. 8, Gr. Spangled Fritillary 4, Pearl Crescent 12, N. Cr. 2, E. Comma 3, Gray Comma 1, Red Admiral 1, Red-spotted Admiral 1, Tawny Emperor 2, N. Pearly-eye 20, Eyed Brown 24, Appalachian Brown 11, Little Wood-Satyr 20, Com. Wood-Nymph 75, Monarch 11, Least Skipper 1, European Sk. 62, Peck's Sk. 1, Tawny-edged Sk. 2, Delaware Sk. 6, Broad-winged Sk. 1, Black Dash 1, Dun Sk. 12. **Total** 29 species, 463 individuals. **Field Notes:** Count originally scheduled for July 18th but was re-scheduled for the 19th. Conditions were not ideal (cool, overcast) but were consistent with the unusually cool and rainy weather experienced in southern Ontario this summer. On average, temperatures are 6 degrees Celsius cooler.

List D.5: Results from Annual Butterfly Count 2008.

Cambridge (*rare* Charitable Research Reserve), ON. Yr. 2, 43°22.9'N 80°21.3'W, center at center N of Blair Rd. about 1.7 mi E of jct. of Blair Rd. and Fountain St. in Cambridge. See 2006 report for habitats. Elevation: 928-928 ft. **13 July 2008**; 0930-1500 hrs; sun AM 76-100%, PM 51-75%; 15-28°F; wind 13-17 mi/hr. 14 observers in 5 parties. **Total party-hours** 6; **total party-miles on foot** 9. **Observers:** E. Barkley, M. Burrell, M. Cassidy, Jessica Grealey (709 Keatswood Cresent, Waterloo, ON N2T 2R6), S. Hentsch, C. Humphrey, K. Jackson, L. Lamb, G. Michalenko, M. Muir, G. Richardson, J. Turchin, M. Wolosinecky, L. Work.

Black Swallowtail 4, E. Tiger Sw. 19, Cabbage White 816, Clouded Sulphur 85, Orange Su. 10, Coral Hairstreak 15, Acadian Ha. 4, Banded Ha. 59, Hickory Ha. 1, Striped Ha. 20, E. Tailed-Blue 2, 'Summer' Spring Azure 2, Am. Snout 2, Gr. Spangled Fritillary 8, Meadow Fr. 2, Pearl Crescent 3, N. Cr. 12, Question Mark 2, E. Comma 1, Mourning Cloak 29, Am. Lady 4, Red Admiral 4, Red-spotted Admiral 12, Viceroy 1, Tawny Emperor 1, N. Pearly-eye 23, Eyed Brown 25, Appalachian Brown 3, Little Wood-Satyr 63, Com. Wood-Nymph 154, Monarch 14,

Silver-spotted Skipper 2, European Sk. 127, Peck's Sk. 1, Tawny-edged Sk. 24, Long Dash 1, N. Broken-Da. 3, Delaware Sk. 15, Dion Sk. 2, Black Da. 6, Dun Sk. 8, Polygonia sp. 1. **Total** 42 species, 1,590 individuals. **Note**: Giant Swallowtail butterfly observed at Springbank garden during the summer of 2008

Appendix E: Species Lists

List E.1: Common and scientific names of all butterflies observed at the ***rare* Charitable Research Reserve** during all previous butterfly monitoring seasons and annual butterfly counts since 2006. A total of 70 butterfly species have been observed.

Common Name	Scientific Name
Acadian Hairstreak	*Satyrium acadicum*
American Lady	*Vanessa virginiensis*
American Snout	*Libytheana carinenta*
Appalachian Brown	*Satyrodes appalachia*
Arctic Skipper	*Carterocephalus palaemon*
Baltimore Checkerspot	*Euphydryas phaeton*
Banded Hairsteak	*Satyrium calanus*
Black Dash	*Euphyes conspicua*
Black Swallowtail	*Papilio polyxenes*
Broad-Winged Skipper	*Poanes viator*
Bronze Copper	*Lycaena hyllus*
Cabbage White	*Pieris rapae*
Clouded Sulphur	*Colias philodice*
Columbine Duskywing	*Erynnis lucilius*
Common Buckeye	*Junonia coenia*
Common Sooty Wing	*Philodice catullus*
Common Wood-Nymph	*Cercyonis pegala*
Compton Tortoiseshell	*Nymphalis vaualbum*
Coral Hairstreak	*Satyirum titus*
Crossline Skipper	*Polites origines*
Delaware Skipper	*Anatrytone logan*
Dion Skipper	*Euphyes dion*
Dun Skipper	*Euphyes vestris*
Eastern Comma	*Polygonia comma*
Eastern Tailed Blue	*Cupido comyntas*
Eastern Tiger Swallowtail	*Papilio glaucus*
European Skipper	*Thymelicus lineola*
Eyed Brown	*Satyrodes Eurydice*
Giant Swallowtail	*Papilio cresphontes*
Grey Comma	*Polygonia progne*
Great Spangled Fritillary	*Speyeria Cybele*
Harvester	*Feniseca tarquinius*
Hickory Hairstreak	*Satyrium caryaevorum*
Hobomok Skipper	*Poanes hobomok*
Inornate Ringlet	*Coenonympha tullia*

Common Name	Scientific Name
Juvenal's Duskywing	*Erynnis juvenalis*
Least Skipper	*Ancloxypha numitor*
Little Glassywing	*Pompeius verna*
Little Wood-Satyr	*Megisto cymela*
Little Yellow	*Eurema lisa*
Long Dash	*Polites mystic*
Meadow Fritillary	*Boloria Bellona*
Milbert's Tortoiseshell	*Nymphalis milberti*
Monarch	*Danaus plexippus*
Mourning Cloak	*Nymphalis antiopa*
Mulberry Wing	*Poanes massasoit*
Mustard White	*Pieris oleracea*
Northern Broken-Dash	*Wallengrenia egeremet*
Northern Crescent	*Phyciodes cocyta*
Northern Pearly-Eye	*Enodia anthedon*
Orange Sulphur	*Colias eurytheme*
Painted Lady	*Vanessa cardui*
Pearl Crescent	*Phyciodes tharos*
Peck's Skipper	*Polites peckius*
Question Mark	*Polygonia interrogationis*
Red Admiral	*Vanessa atalanta*
Red-Spotted Purple	*Limenitis arthemis astyanax*
Sachem	*Atalopedes campestris*
Silver-Bordered Fritillary	*Boloria selene*
Silvery Checkerspot	*Chlosyne nycteis*
Silver-Spotted Skipper	*Epargyreus clarus*
Spring Azure	*Celastrina ladon*
Striped Hairstreak	*Satyrium liparops*
'Summer' Spring Azure	*Celastrina neglecta*
Tawny-Edged Skipper	*Polites themistocles*
Tawny Emperor	*Asterocampa clyton*
Variegated Fritillary	*Euptoieta claudia*
Viceroy	*Limenitis archippus*
White Admiral	*Limenitis arthemis arthemis*
Wild Indigo Duskywing	*Erynnis baptisiae*

Table E.1: The earliest record of observation for each butterfly species historically observed at the ***rare*** Charitable Research Reserve. The first date of observation is noted for each previous monitoring year and each annual butterfly count, as well as the overall earliest observation.

Species	Earliest Record By Year							Annual Butterfly Counts	Earliest Record at *rare*
	2006	2009	2010	2011	2012	2013	2014		
Acadian Hairstreak								July 13 (2008)	July 13 (2008)
American Lady			May 20		May 15	May 22	July 17	July 10 (2010)	May 15 (2012)
American Snout					July 11			July 10 (2010)	July 10 (2010)
Appalachian Brown				July 6	June 18	July 2	July 3	July 2 (2011)	June 18 (2012)
Arctic Skipper			June 3			June 4	June 3	July 10 (2010)	June 3 (2010)
Baltimore Checkerspot					June 26			July 3 (2011)	June 26 (2012)
Banded Hairstreak	July 18	July 16		July 12	June 25	July 15	July 3	July 2 (2011)	June 25 (2012)
Black Dash			June 8		July 14	July 30	July 30	July 10 (2010)	June 8 (2010)
Black Swallowtail	July 21	May 20	May 4	May 30	May 14	May 22	May 23	July 10 (2010)	May 4 (2010)
Broad-Winged Skipper		July 24			July 14	July 12	July 18	July 10 (2010)	July 10 (2010)
Bronze Copper	Aug 18				June 6		June 20	July 2 (2011)	June 6 (2012)
Cabbage White	July 18	May 12	May 3	May 19	May 14	May 21	May 21	July 2 (2011)	May 3 (2010)
Clouded Sulphur	July 18	May 22	May 4	May 31	May 14	May 21	May 24	July 10 (2010)	May 4 (2010)
Columbine Duskywing			May 19		May 31				May 19 (2010)
Common Buckeye				Sept 15	June 6				June 6 (2012)
Common Sooty Wing	July 21	June 2		Aug 4	June 7	May 22	June 6	July 10 (2010)	May 22 (2013)
Common Wood-Nymph	July 18	June 16	June 25	June 14	June 18	Jun 13	June 19	July 2 (2011)	June 13 (2013)
Compton Tortoiseshell				July 12					July 12 (2011)
Coral Hairstreak		July 16						July 2 (2011)	July 2 (2011)
Crossline Skipper								July 2 (2011)	July 2 (2011)
Delaware Skipper		June 2	May 24	July 11	July 9	July 4	July 10	July 10 (2010)	June 2 (2009)
Dion Skipper					July 14			July 13 (2008)	July 13 (2008)
Dun Skipper		July 24		July 6	June 26	July 12	July 4	July 10 (2010)	June 26 (2012)
Eastern Comma	Aug 2	June 30	May 14	June 1	May 15	May 27	June 19	July 10 (2010)	May 14 (2010)
Eastern Tailed Blue	Aug 18			July 27	July 14	July 15	Aug 6	July 11 (2006)	July 11 (2006)
Eastern Tiger Swallowtail	July 18	May 21	May 19	June 1	May 14	May 22	June 6	July 2 (2011)	May 14 (2012)
European Skipper	July 18	June 24	May 24	June 14	May 15	May 30	June 10	July 2 (2011)	May 15 (2012)
Eyed Brown	Aug 2	July 16	June 15	July 5	June 8	June 25	June 20	July 2 (2011)	June 8 (2012)
Giant Swallowtail	July 24			June 8	May 15	May 30	June 10	July 11 (2006)	May 15 (2012)

Species	Earliest Record By Year							Annual Butterfly Counts	Earliest Record at *rare*
	2006	2009	2010	2011	2012	2013	2014		
Grey Comma								July 19 (2009)	July 19 (2009)
Great Spangled Fritillary	July 18	July 24	June 21	July 11	June 18	July 2	June 25	July 10 (2010)	June 18 (2012)
Harvester				Aug 19			June 21		Aug 19 (2011)
Hickory Hairstreak	July 18							July 11 (2006)	July 11 (2006)
Hobomok Skipper			May 26	June 1	May 30	June 4	June 6	July 2 (2011)	May 26 (2010)
Inornate Ringlet	Aug 2	June 2	May 19	June 6	May 14	May 21	June 2	July 2 (2011)	May 14 (2012)
Juvenal's Duskywing			May 26	May 25	May 14	May 21	May 23		May 14 (2012)
Least Skipper				Aug 5	May 28	July 30	June 19	July 19 (2009)	May 28 (2012)
Little Glassywing				July 6	July 10	July 12	June 30	July 2 (2011)	July 2 (2011)
Little Wood-Satyr	July 18	June 10	June 3	June 8	May 30	June 4	June 10	July 2 (2011)	May 30 (2012)
Little Yellow								July 11 (2006)	July 11 (2006)
Long Dash				June 14	May 28	July 4	June 27	July 2 (2011)	May 28 (2012)
Meadow Fritillary					July 18		July 22	July 10 (2010)	July 10 (2010)
Milbert's Tortoiseshell			June 21	July 19	June 11		June 16		June 11 (2012)
Monarch	July 18	June 22	June 25	May 30	May 14	June 19	May 30	July 2 (2011)	May 14 (2012)
Mourning Cloak		May 25	May 4	June 7	May 14	May 21	May 24	July 10 (2010)	May 4 (2010)
Mulberry Wing								July 20 (2013)	July 20 (2013)
Mustard White				Aug 12					Aug 12 (2011)
Northern Broken-Dash					June 26		July 4	July 10 (2010)	June 26 (2012)
Northern Crescent		May 21	June 3	June 7	June 4	June 12	June 3	July 10 (2010)	May 21 (2009)
Northern Pearly-Eye	July 18	June 30	June 3	June 20	June 11	June 13	June 19	July 10 (2010)	June 3 (2010)
Orange Sulphur	Aug 24		June 30	July 19	May 14	June 4	May 30	July 10 (2010)	May 14 (2012)
Painted Lady		June 4	May 4		May 15	May 21	July 7		May 4 (2010)
Pearl Crescent	July 18			May 25	May 14	May 22	May 26	July 2 (2011)	May 14 (2012)
Peck's Skipper				July 11	June 18	July 6	July 3	July 2 (2011)	June 18 (2012)
Question Mark	July 18	June 10	May 19	June 7	May 17	June 14	July 21	July 10 (2010)	May 17 (2012)
Red Admiral	Aug 18	May 14	May 3	May 25	May 14	June 4	May 21	July 10 (2010)	May 3 (2010)
Red-Spotted Purple		June 16	June 1	June 14	May 25	June 4	June 19	July 10 (2010)	May 25 (2012)
Silver-Bordered Fritillary						June 3		July 2 (2011)	June 3 (2013)
Silver-Spotted Skipper		July 30	June 8	June 20	June 25	June 13	June 13	July 10 (2010)	June 8 (2010)
Silvery Checkerspot					June 20		July 18		June 20 (2012)
Spring Azure		May 13	May 4	May 20	May 15	May 21	May 21		May 4 (2010)

Species	Earliest Record By Year							Annual Butterfly Counts	Earliest Record at *rare*
	2006	2009	2010	2011	2012	2013	2014		
Striped Hairstreak				July 26		July 12	July 18	July 11 (2006)	July 11 (2006)
Summer Azure	Aug 2	July 22	June 8	July 5	June 11	June 13	June 13	July 2 (2011)	June 8 (2010)
Tawny Emperor	July 21	July 30		Aug 4	July 17	July 25	July 28	July 10 (2010)	July 17 (2012)
Tawny-Edged Skipper		July 16		July 22		July 16	July 17	July 2 (2011)	July 2 (2011)
Variegated Fritillary					July 5				July 5 (2012)
Viceroy	Aug 2	June 10	June 8	June 20	May 25	June 4	May 28	July 10 (2010)	May 25 (2012)
White Admiral		July 14		June 14	Aug 1		Aug 18	July 11 (2006)	June 14 (2011)
Wild Indigo Duskywing			May 17		July 11		July 28	July 2 (2011)	May 17 (2010)