Eman Butterfly Monitoring Report by Jessica Grealey 2006

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Introduction

Environment Canada's Ecological Monitoring and Assessment Network (EMAN) is a network of government agencies, academic institutions, aboriginal groups, volunteer organizations, not-for-profit organizations, and individuals involved in Canadian ecological monitoring to detect, examine, and report on changes in the environment. EMAN's Coordinating Office (EMAN CO) is mandated to coordinate and work with these partners in order to inform decision makers and educate the public on changing ecological trends.

The NatureWatch program series is a suite of volunteer or "citizen science" ecological monitoring protocols administered through a partnership between the EMAN CO, Nature Canada, and the University of Guelph. Existing NatureWatch programs include IceWatch, FrogWatch, PlantWatch, and WormWatch. They are designed to engage everyday people from school children and community members to nature enthusiasts to get involved in monitoring air, water, soil, and other aspects of the environment to collect valuable data.

I was contracted by EMAN CO to develop a ButterflyWatch program designed to compliment the existing NatureWatch programs. In addition to ButterflyWatch, I was also responsible for determining the best way to monitor the abundance and diversity of butterflies across Canada. In order to complete this task I was sub-contracted by the ***rare*** Charitable Research Reserve which provided the ideal location to test and refine the butterfly monitoring methodology.

An extensive literature and web review was undertaken in order to determine what butterfly abundance and diversity monitoring methodologies were being used presently or have been used in the past around the globe (Appendix A). I also consulted with known butterfly experts from across Canada and the United States. Upon completion of these tasks I determined that a modification of the "Pollard Transect Method" also called the "Transect Walk Method" was the most appropriate method for monitoring butterflies in Canada. The reliability of transect counts has been fully tested (Pollard, 1977; Pollard et al., 1986; Pollard & Yates, 1993; Sparrow et al., 1994) and to date is the most commonly cited method used to monitor butterflies.

Purpose of Study

The purpose of this study is to examine the feasibility of using transect walks to examine butterfly abundance and diversity as ecological indicators of the effects of human disturbances in Canada. The butterfly monitoring initiative undertaken at ***rare***, piloted the chosen methodology for EMAN CO and provided the beginning of a butterfly monitoring program at ***rare***. A training day was held at ***rare*** to educate interested participants on how to monitor the transects in order to continue the pilot program. The methods outlined in this report are designed to be simple and replicable for volunteers interested in monitoring butterflies on ***rare***'s property.

Methodology

Transect counts are used to monitor butterflies around the world, most notably in Britain's Butterfly Monitoring Scheme which began in 1976. It provides an index of population size and therefore can be used to measure changes in abundance. Unlike some other methods, this method does not affect butterfly behavior, disturb them, or demand a lot of time and labor. The methodology requires the recorder(s) to walk along a fixed route (transect) while recording all the butterflies seen within a fixed distance.

Two transect routes, each 2-3km long, were mapped out on ***rare***'s property and divided into sections, which, as much as possible, coincided with changes in the nature of the habitat (Figure 1). The transects take approximately 2-2 ½ hours to walk and require long pants and appropriate footwear. Descriptions of each section are provided in Appendix B for the first monitoring season. Descriptions of the sections should be made at the beginning of each monitoring season or in the event of a major alteration to the section, in order to record changes in the habitats. Annual photographs are to be taken of the transect routes to document changes in vegetation structure.

The recorder(s) should imagine themselves inside a 10m box as they walk at a uniform pace along the transect route and record all the butterflies seen within the prescribed limits in their peripheral view (Pollard et al., 1986). A 10 minute stop at the approximate centre of each section should be made and all butterflies seen within 10m should be recorded. (GPS readings are provided for each section centre for both transects in Appendix B).

Each butterfly species is counted separately from all other species and the number of each species seen in each transect section is counted separately. For example, the number of monarch butterflies in each section should be counted separately because this provides information on what habitat types they occupy (refer to sample recording form in Appendix C).

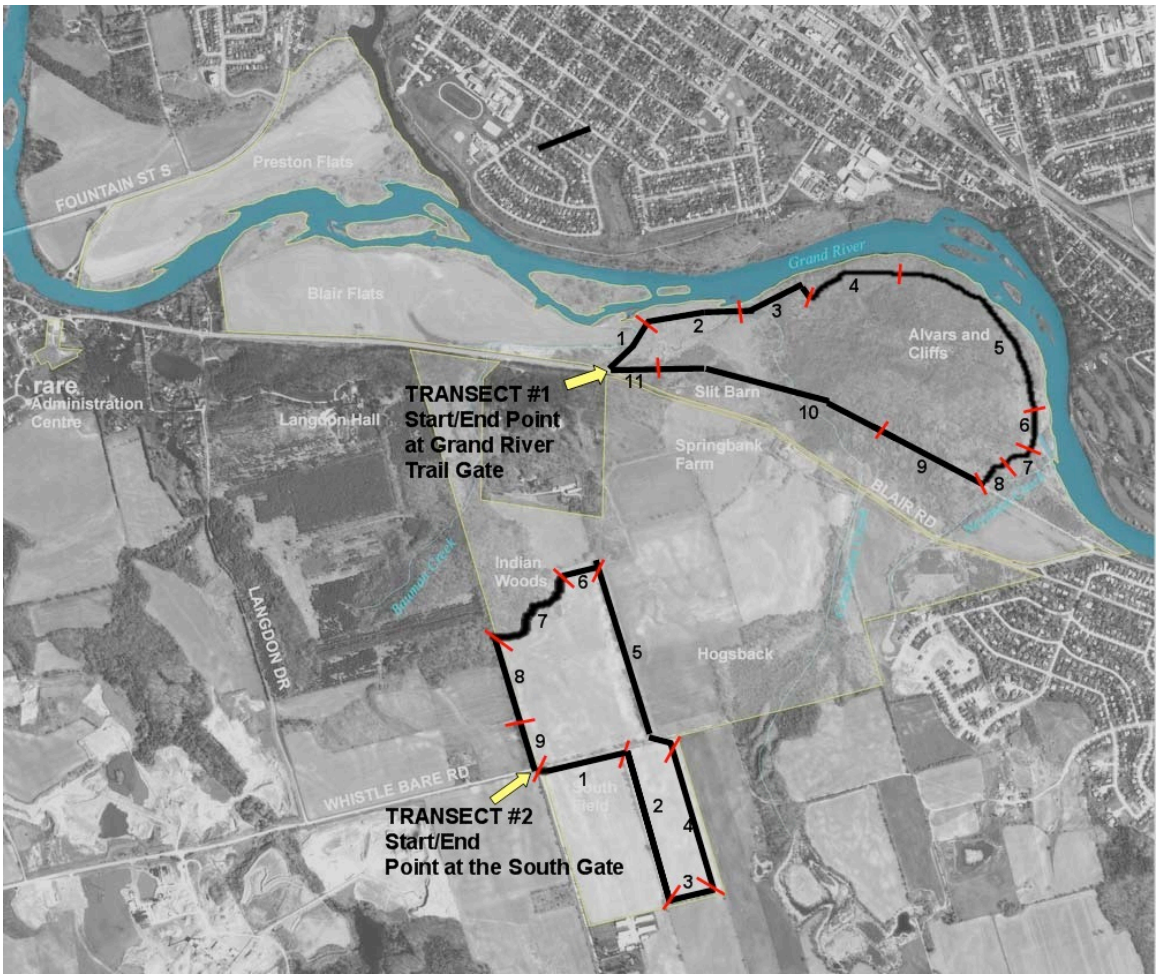

Figure 1. Transect Map

Transect Route ——————

Section Division ——

Numbers = Section number

*NOTE: The side of the hedgerow that is to be walked by the recorder on transect #2 is indicated by the side of the transect line the section numbers are indicated on.

The recording form should be filled out carefully. It is important to include the start and end time of the transect walk as well as the temperature and wind speed. The Beaufort wind scale (Appendix D) has been employed for the first season of monitoring and it is suggested that this scale be used in the future for consistency from year to year. The "sunshine" section on the bottom of the recording form requires an "s" for sunny or a "c" for cloudy and should be recorded for each section of the transect. The species currently listed on the recording form are the species that have been identified on ***rare***'s property to date. When new species are identified, the form should be modified to include them.

Stops may be made to resolve identification problems and recording should resume from the point where the walk was interrupted. Pollard & Yates (1993) recommend that the recorder take a butterfly net to ensure accurate identification. In the absence of an expert opinion, and if the recorder is unsure of the species they are observing, they should record which is more common of the possible options (Pollard & Yates, 1993). For example if there is confusion between two species, the more common species to the area should be recorded. If possible it would also be desirable for recorders to have a digital camera on hand so in the event of a misidentification, it can later be corrected.

The recording season is approximately 26 weeks, beginning the first week of April and ending the last week of September. The minimum recording necessary is at least one walk of each route per week (Pollard & Yates, 1993; Oostermeijer & Van Sway, 1998). The middle of the day is the best time for recording and warm weather is required. Wind speed should not exceed a force of 5 on the Beaufort Wind Scale. This can make recording at the beginning and end of the observation season difficult sometimes.

Butterfly counts can be used to calculate an index of abundance. This involves stratified random sampling and the sum of the mean weekly counts, which will allow comparisons between sites to be made. Each butterfly species is monitored independently from all other species. This is because abundance indices cannot be easily used for comparison between species due to differences in their behaviors (Pollard &Yates, 1993). For example, one butterfly species may be conspicuous while another is not.

The Shannon-Weiner Index may be used to calculate the amount of diversity within the community type at the stressed sites and the

reference sites. This index will calculate both species richness and evenness of distribution for each species of butterfly, providing an indication of which species are proportionally abundant or rare. This index was chosen because if a large number of samples are calculated, the values will have a log-normal distribution (Booth et al., 2003). The formula to calculate the Shannon-Weiner Diversity Index may be seen in Appendix E.

Annual Butterfly Count

An annual butterfly count for the North American Butterfly Association was held at ***rare*** on July 16, 2006. A total of 38 species and 727 individual butterflies were counted.

Pollard and Yates (1993) recommend that a butterfly inventory be taken prior to transect monitoring and this butterfly count served that purpose. Eleven volunteers covered five areas of rare's property including Preston Flats, Blair Flats, the cliffs and alvars, the hogsback/south field and Spring Bank Farm. The count provided a good estimation of the species present on the property as well as where the transects should be located.

Transect Monitoring Results (year 1)

Between the butterfly count and weekly transect monitoring 43 butterfly species have been found on the property to date, but several others may be present. For example, it is assumed that the spring azure (*Celastrina ladon*) will be present in the spring but due to the late start in the recording season it was not seen.

Due to time limitations and a late start in the season, the monitoring data for the entire season is incomplete. However, there was enough data collected to establish the transects and collect accurate baseline conditions. Figure 2 represents butterfly abundance calculated from the sum of the mean weekly counts for transect #1 (2006). This graph was included to give an idea about how the abundance data may be visually displayed for future reporting.

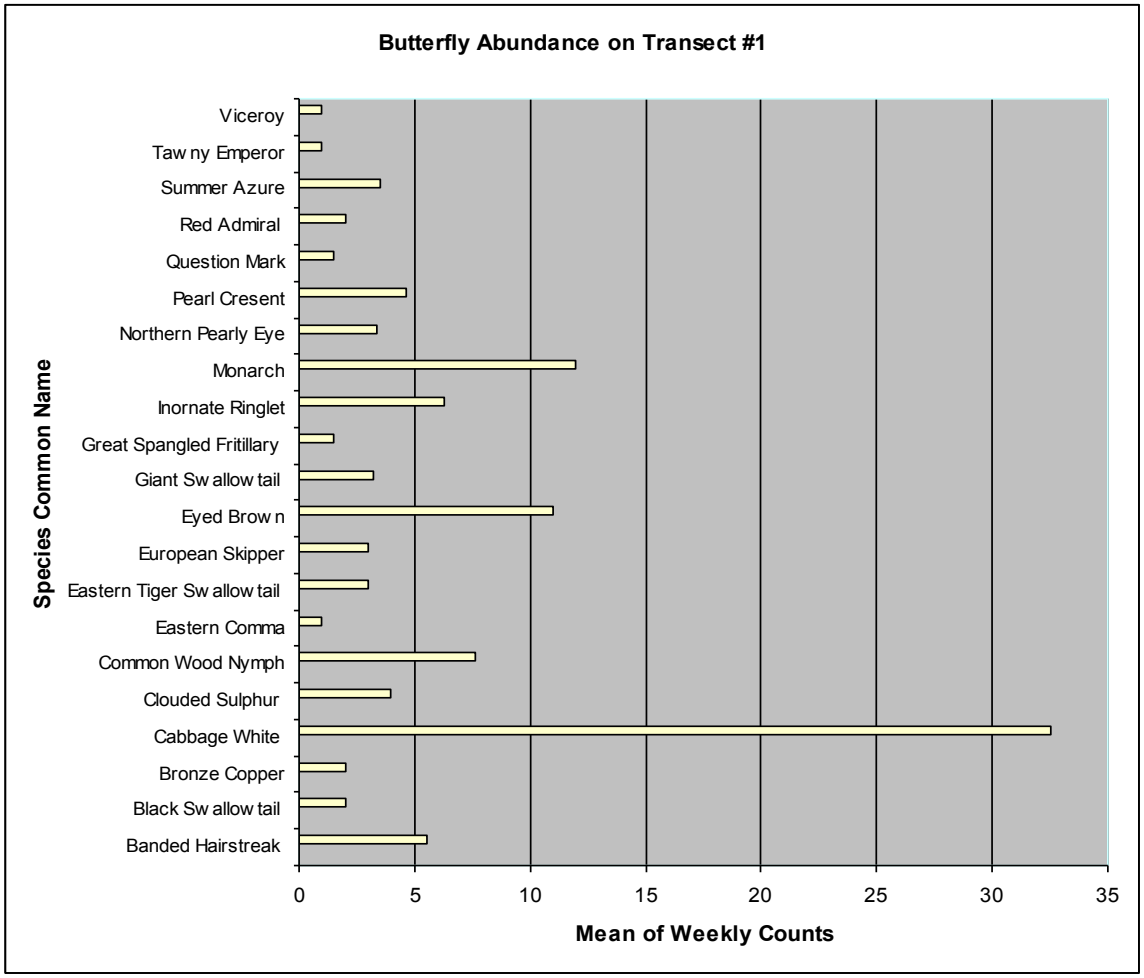

Figure 2. Sum of the mean weekly counts for transect #1 (2006)

Transect #1 covers a variety of habitat types including meadow, riparian, shrub land, cliffs and alvars, forest, and edges. In sections one and two of the transect the land was previously used for agriculture and was taken out of commission approximately 3 years ago. ***Rare*** has let the vegetation restore naturally, providing excellent butterfly habitat. Monitoring these areas over several years will provide data on how sucessional changes to butterfly habitat effect abundance and diversity. Many other areas of transect #1 are used for research projects and recreation. Monitoring butterflies in these areas may provide important insights into how these activities are affecting the vegetation structure and ecosystem as a whole.

Transect #2 covers two agricultural areas. The first area is the South Field, a transitional organic parcel of land where oats were grown in this recording season by ***rare organics***. The second is a soy field farmed by an outside party which is not transitional organic, using pesticides and fertilizers. Annual butterfly data collected at these

sights should provide very interesting data about differences between an organic farm and a non-organic farm as well as the effects of crop rotation on butterfly abundance and diversity.

Conclusions/Recommendations

It should be noted that several species of butterfly that were identified during the butterfly count were not recorded on either transect at any time. This reflects butterfly habitat specificity on the property. It is recommended that annual butterfly counts on the property continue so that data is collected on species presence/absence on the whole property, not just the transects.

A transect map, the blank recording form, pictures of the transects taken in 2006, completed transect forms, and all related documents to this project may be found on rare's network at:
Z:\Level5\JGrealey\Butterfly Monitoring at rare.

For butterfly monitoring at rare to be scientifically valid, it is very important to be consistent. Baseline data has been collected through transect monitoring and it is now imperative that monitoring continue in order to gather comparative data from year to year. Monitoring may be limited by the number of volunteers available and weather conditions which can make gathering enough data difficult.

This program requires dedicated volunteers to collect data in a consistent manner by using the outlined methodology. Volunteers who have good identification skills are an asset to insure accurate information is collected.

The butterfly monitoring training event held in September 2006 was a good way to drum-up interest in the program. It is suggested that a similar event be held in the spring (May 2007) to bring back interested volunteers and spark interest for new volunteers to get involved. A summary of the methodology created for the training event is available for volunteers on the network called "transect methods."

I attempted to email all members of **rare**'s Environmental Advisory Team (EAT) for suggestions, ideas, or critiques of the butterfly monitoring program that has been established on the property. There was very limited response, the only suggestion being that in order for this project to be considered "scientific" there needed to be a defined research question. This year the program was established and

baseline data was collected. In subsequent years it is possible to refine research questions related to butterfly monitoring. For example, how does the use of pesticides and fertilizers affect butterfly abundance and diversity (which in turn affects the entire ecosystem)? If the south field remains transitional organic this may act as a control site.

The rest of the EAT was either too busy, disinterested, or had no suggestions for the program. It is recommended that they continue to be informed about the results of butterfly monitoring on the property, particularly rare or endangered species that are identified.

References

Booth, B.D., S.D. Murphy and C.J Swanton. 2003. Chapter 14: Studying Community Structures and Dynamics. In: Weed Ecology in Natural Agricultural Systems. CAB International. Pp. 255-274.

Oostermeijer, J.G.B and C.A.M Van Swaay. 1998. The relationship between butterflies and environmental indicator values: a tool for conservation in a changing habitat. Biolgoical Conservation 86:271-280.

Pollard, E. 1977. A Method of Assessing Change in the Abundance of Butterflies. Biological Conservation 12:115-132.

Pollard, E., M.I. Hall, and T.J. Bibby. 1986. Monitoring the Abundance of Butterflies 1976-1985. The Nature Conservancy Council, Petersborough, England.

Pollard, E. and T.J. Yates. 1993. Monitoring Butterflies for Ecology and Conservation. Chapman and Hall, London, United Kingdom.

Sparrow, H.R., T.D. Sisk, P.R. Ehrlich, and D.D. Murphy. 1994. Techniques and Guidelines for Monitoring Neotropical Butterflies. Conservation Biology 8(3): 800-809.

Appendix A

Existing Butterfly Monitoring Programs

EUROPE

The British Butterfly Monitoring Scheme (BMS)

- Commenced on a national scale in 1976
- Coordinated by the Centre for Ecology and Hydrology and Joint Nature Conservation Committee.
- Monitoring methodology based on transect-walk counts (Pollard & Yates, 1993)
- Most transects were at protected sites (i.e. nature reserves)
- The BMS has provided:
    - a standardized annual measure of the changing status of butterfly species, which have been used to generate short-term trends;
    - information on how land-use, landscape and habitat changes affect butterflies;
    - information to policy makers on how effective national-scale agri-environment schemes are;
    - results that have allowed scientists to assess the impacts of global warming on biodiversity through the discovery of butterfly dependencies on the climate

The Butterfly Transect Project
(http://www.butterfly-conservation.org/bc/index.html**)**

- Based on the BMS
- Independent transect walks coordinated by Butterfly Conservation
- Allowed for an increased number of monitoring sites
- Recorders are trained volunteers

The United Kingdom Butterfly Monitoring Scheme
(http://www.ukbms.org/about.htm**)**

- Commenced in 2006 when the Butterfly Transect Project and the BMS were merged into a single scheme
- Run as a consortium between the **Centre for Ecology and Hydrology** (CEH)**, Butterfly Conservation** (BC) and the **Joint Nature Conservation Committee** (JNCC)**.**
- Addressing some of the limitations of the BMS such as increasing the number of monitoring sites and habitat types being monitored
- The large number of monitoring sites has allowed for the calculation of reliable population trends for threatened and endangered species
- Monitoring methodology provided on the web (http://www.ukbms.org/methods.htm) as well as instructions on how to set up and record a transect (http://www.ukbms.org/resources.htm)

- Between 2005 and 2008, the scheme is undergoing major re-development and expansion through funding by a multi-agency consortium

Butterfly Monitoring Scheme (France) - Suivi Temporel des Rhopalocères de France

- No web page available
- Commenced in 2006
- Organized by the Museum National d'Histoire Naturelle
- Scheme aims at monitoring population trends, distribution trends, and community/ecosystem trends
- Perform counts using stratified random sampling techniques at 75 sites, some on protected land
- Expert and volunteer involvement
- 100 species monitored
- Causes of change monitored include climatic and land-use

Garden Butterfly Counts (France) - Observatoire des Papillons des Jardins

- No web page available
- Commenced in 2006
- Organized by the Museum National d'Histoire Naturelle
- Citizens count butterflies in their garden but there is no specific protocol provided
- Expert co-ordination and 10,000 volunteers
- 41 species monitored
- Monitoring sites include: constructed, industrial and other artificial habitats regularly cultivated agricultural, horticultural and domestic habitats
- Causes of change monitored include climatic and land-use

Dutch Butterfly Monitoring Scheme (Netherlands)

- Commenced in 1990

- Expert and volunteer participation
- Scheme aims at monitoring population trends of 50 species
- Perform transect counts using exhaustive techniques at 1300 sites, some in protected areas
- Causes of change monitored include pollution and land-use

Long-term Butterfly Monitoring in the Ukraine

(http://www.alexanor.uzhgorod.ua/ALEPRO00.HTM)

- Commenced in 1997
- Scheme aims at monitoring population trends, distribution trends, and community/ecosystem trends
- Methods based on the BMS
- 115 sites are monitoring and all are located on protected lands
- One volunteer and one expert monitor 130 species
- Causes of change monitored include pollution, land-use, climatic change, invasive species, and habitat fragmentation
- Also monitored at site: natural events, land management practices, and flowering plants

Monitoring of Species in the Biebrza National Park in Poland

- Commenced in 2000
- Scheme aims at monitoring population trends
- One expert monitors 3 sites within the park involving visual counts of 9 species to detect environmental trends resulting from habitat fragmentation

Monitoring of the Clouded Apollo Butterfly (Poland- Pieniny National Park)

- Commenced in 2005
- Mark-recapture techniques are used to monitor population and distribution trends at one site and land-use affects
- Exhaustive sampling techniques are performed by one person and only taken every 3 years

Monitoring of the Baltic Grayling Butterfly (Poland- Wigry National Park)

- Commenced in 2004 and will run until 2008
- Scheme aims at monitoring population trends, distribution trends, and community/ecosystem trends
- Data on phenology
- Three experts monitor one species at one site in the park
- Causes of change monitored include land-use, climatic change, and habitat fragmentation

European Butterfly Indicator

(http://www.bc-europe.org/category.asp?catid=10**)**

- Information from European butterfly monitoring projects (described above) is coordinated by Butterfly Conservation Europe**,** participating countries include: Belgum, Estonia, France, Germany, Netherlands, Spain, Switzerland, Ukraine and the United Kingdom

United States

The Chicago Park District Butterfly Monitoring Program
(http://www.chicagoparkdistrict.com/)

- Citizen based monitoring program designed to monitoring the health of butterfly populations in the park district

The Ohio Lepidopterists Long-term Monitoring of Butterflies

(http://www.ohiolepidopterists.org/bflymonitoring/)

(http://www.nps.gov/cuva/management/rmprojects/butterflies.htm)

- Commenced in 1995 but the program was expanded in 1996
- Uses methods based on the BMS and is designed for people with little experience monitoring butterflies
- A workshop on Long Term Butterfly Monitoring was held in April of 1998
- The website provides an instruction booklet on how to use and interpret the results from volunteer monitoring

Butterfly Monitoring Program at the Tallgrass Prairie Preserve, Osage County, Oklahoma (paper available online)

- Initiated in 1993
- Program was developed to evaluate the effectiveness of prescribed burning, bison grazing and other possible threats to the biota in the preserve
- Monitoring methods based on transect counts and involved experts and trained volunteers

Illinois Butterfly Monitoring Network

(http://www.bfly.org/**)**

- Commenced in 1987
- Citizen science program designed to monitoring the health of butterfly populations in 42 sites
- Created by the Nature Conservancy to examine the effects of land-management on biota
- Based on transect methods of BMS and recorders are trained volunteers
- Also have sites in Northwest Indiana

The Florida Butterfly Monitoring Network

(http://www.flbutterflies.net **)**

- Statewide citizen science based monitoring program that aims at monitoring butterfly populations on selected protected land areas
- Involves public volunteers, academics, zoologists and state and federal land managers
- Model pilot for similar initiatives across the nation

Myrtles Silverspot Butterfly Monitoring (Point Reyes National Seashore, Cailfornia)

(http://www.nps.gov/pore/science_current_resmgt.htm**)**

- Program began in 2002 to monitor populations of *Speyeria zerene myrtlea*, an endangered butterfly
- Program includes monitoring nectar plans and larval food plant densities

Grand Canyon Arthropod Inventory and Monitoring (Northern Arizona University, Colorado Plateau Museum of Arthropod Biodiversity)

(http://bugs.bio.nau.edu/grand_canyon/index.htm **)**

- Monitoring Lepidoptera is part of a larger terrestrial ecosystem monitoring project involving plants, vertebrates and arthropods
- Riparian zone monitoring along the Colorado River and Grand Canyon
- Monitor 34 sites using malaise traps and black light traps (for moths)

Monarch Watch (University of Kansas)

(http://www.monarchwatch.org/**)**

- Education outreach program that engages citizens in a large-scale monarch butterfly monitoring project
- Tagging kits may be purchased on their website by the public, schools, nature centres, etc.
- They estimate over 100, 000 students participate in tagging monarch butterflies every fall
- An online database is available as well as a suite of information on butterfly conservation, gardening, rearing, and ongoing research projects

South and Central America

The Tropical Ecology, Assessment and Monitoring Initiative

(http://www.teaminitiative.org/application/resources/index.html**)**

- Established in 2002 and is part of the Center for Applied Biodiversity Science (CABS) at Conservation International (CI)
- Provide protocols for several different monitoring initiatives including mammals, insects, primates, soil, climate and avian
- Methodologies include transect walks and baited traps to assess community composition (this works best in tropical habitats where many butterfly species feed on rotting fruit)
- Involves more experienced recorders
- Have sites in Costa Rica, Brazil and Surinam

Asia

Tiger Mountain Pokhara Lodge Butterfly Monitoring (Nepal)

(www.tigermountain,com**)**

- Guides at the lodge take monthly counts of butterflies within the lodge compound and record all new species sighted
- A leading expert on Nepal's butterflies lives within the compound for part of the year assisting with training, counts and butterfly identification
- Counts are logged in a database available to researchers, conservationists and the public

Earthwatch Institute Butterfly Monitoring (Tam Dao National Park and Vinh Phuc Province, Vietnam)
(www.earthwatch.org**)**

- Research objective is to identify and develop ecological indicator butterfly species that can identify habitat changes in Tam Dao and Vietnam
- Recording status of rare butterflies
- Monitoring long-term changes in butterfly populations
- Principal investigators are PhD, undergraduate and graduate students

Other Resources

The Butterfly Conservation Initiative (http://www.butterflyrecovery.org/**)**

- Created in 2001
- Focus on research, recovery and education for endangered, vulnerable or threatened North American butterflies and their habitat

The Journal of Research on the Lepidoptera
(http://www.doylegroup.harvard.edu/~carlo/JRL/contents.html**)**

- 1962-2005 available online

Appendix B

Transect Descriptions

Transect One Descriptions: Meadow/Cliffs & Alvars

Section one (N 43° 22.980 W 80° 21.475)
- Grasslands
- Milkweeds
- Goldenrod

Section two (N 43° 23.053 W 80° 21.254)
- Riparian Meadow
- South side of transect- shrubs and trees

Section three (N 43° 23.053 W 80° 21.254)
- Riparian area with trees on south side
- Grasses/sedges
- Small shrubs
- Goldenrods

Section four (N 43° 23.119 W 80°21.037)
- Forest trail with open canopy areas
- Mainly conifers
- On cliffs

Section five (N 43° 22.966 W 80°20.605)
- Deciduous forest trail

Section six (N 43° 22.767 W 80°20.625)
- Open shrub land

Section seven (N 43° 23.016 W 80° 20.650)
- Deciduous forest trail

Section eight (N 43° 22.709 W 80° 20.694)
- Open shrub land

Section nine (N 43° 22.812 W 80° 20.892)
- Blair trail-deciduous forest

Section ten (N 43° 22.912 W 80° 21.303)
- Blair trail-dense shrub growth on both sides of trail

Section eleven (N 43° 22.927 W 80° 21.552)

- Wetland on either side of trail

Transect Two Descriptions: Agricultural and Hedgerow

Section one (N 43° 22.192' W 080° 21.703')
- Meadow-south side of transect
- Deciduous trees & shrubs- north side of transect
- Bordering Oat fields

Section two (N 43° 22.043' W 080° 21.555')
- Hedgerow along a soy bean field edge
- Mostly open with some shrubs

Section three (N 43° 21.915' W 080° 21.411')
- Hedgerow of deciduous trees along soy bean field edge

Section four (N 43° 22.058' W 080° 21.401')
- Open Soy bean field

Section five (N 43° 22.359' W 080° 21.585')
- Deciduous hedgerow of mostly Oak spp.
- Bordering straw field

Section six (N 43° 22.551' W 080° 21.735')
- Hedgerow with deciduous trees, grapevines and tall grasses
- North of transect is straw
- South of transect soy

Section seven (N 43° 22.459' W 080° 21.855')
- Meadow bordered by deciduous trees (Indian Woods) to the North and Soy to the south of transect

Section eight (N 43° 22.296' W 080° 21.888')
- Hedgerow of deciduous trees, mostly maple bordering soy bean field
- Shady areas

Section nine (N 43° 22.215' W 080° 21.861')
- Hedgerow of shrubs, vines, and grasses bordering soy bean field.

Appendix C

Sample Recording Form

Butterfly Recording Form- Southern Ontario																
Year: 2006	Date: 02/08		Recorder: J. Grealey													
Site Name: rare Charitable Research Reserve Transect #1																
Start Time: 11:45 a.m.	End Time: 1:30 p.m.		Start Temp: 29 C		End Temp: 30 C											
Sun. 95%	Wind Speed: 0-3															
SECTION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Appalachian Brown																
Banded Hairstreak																
Black Dash																
Black Swallowtail		1														1
Broad-winged Skipper																
Bronze Copper																
Cabbage White	25	7	2					1			1					36
Clouded Sulphur	1															
Common Sooty Wing																
Common Wood Nymph	1				1	1		1	1							5
Crossline Skipper																
Delaware Skipper																
Dun Skipper																
Eastern Comma			1													1
Eastern Tailed Blue																
Eastern Tiger Swallowtail																
European Skipper																
Eyed Brown				5	10	1										16
Giant Swallowtail			4	1					1							6
Great Spangled Fritillary																
Hickory Hairstreak																
Inornate Ringlet		4														4
Little Wodd Satyr																

Little Yellow																
Long Dash																
Monarch	7		2						1		1					11
Mourning Cloak																
Northern Broken Dash																
Northern Crescent																
Northern Pearly Eye		4	1						1							6
Orange Sulphur																
Painted Lady																
Pearl Crescent																
Peck's Skipper																
Question Mark																
Red Admiral																
Red Spotted Purple																
Striped Hairstreak																
Summer Azure					3				3							6
Tawny Emperor																
Tawny-edged Skipper																
Viceroy			1													1
White Admiral																
SECTION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Sunshine	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	93

Notes:

Appendix D

The Beaufort Wind Scale

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	--

Appendix E

The Shannon-Weiner Diversity Index

The Shannon-Weiner Diversity index may be calculated as follows:

- $H' = -\sum(pi(\text{In } pi))$.
    - Where pi = proportional abundance of a given species (call this species "i")
    - $pi = ni/N$
    - N = total number if individuals of all species in the community
    - "In" means the "natural logarithm"

To understand the value of this index, higher numbers indicate a more diverse community, however it is an arbitrary scale. There is no predetermined value of H' that tells you if a community is "diverse" or not (Booth et al., 2003).

Using species richness (S) and the Shannon-Wiener index (H), you can also compute a measure of evenness:

- $E = H/\log(S)$.

Evenness (E) is a measure of how similar the abundances of different species are. When there are similar proportions of all subspecies (the habitat is extremely even), then the value is approaching 1, but when the abundances are very dissimilar (some rare and some common species) then the value decreases (REWHC, 2000). A value of 0 indicates that habitat is extremely uneven, or dominated by one species.