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# NORTH AMERICAN BUTTERFLY ASSOCIATION COUNTS AT CONGAREE NATIONAL PARK: A CASE STUDY FOR CONNECTING CITIZEN SCIENCE TO MANAGEMENT

by

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Bachelor of Arts
Capital University, 2014

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Submitted in Partial Fulfillment of the Requirements

For the Degree of Master of Earth and Environmental Resources Management in

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College of Arts and Sciences

University of South Carolina

2016

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# DEDICATION

For all the love and support you showed me throughout the years, and the never ending interest in my work: for my grandma, Shirley Cremeans (1939-2016).

# ACKNOWLEDGEMENTS

Thank you to the University of South Carolina for funding and support of my project; to the Congaree National Park staff without whom this project would have never been possible (NPS permit number CONG-2015-SCI-0010); to the members of the local NABA chapter for welcoming me and allowing me to be a part of their great program; to my major professor Carol Boggs, my committee members Rudy Mancke and Tim Mousseau, and all my colleagues who provided guidance and support throughout my project;  to my field assistants who spent countless hours in the hot, humid South Carolina swamps counting butterflies with me; and last but not least to my parents, Tim and Niki, and fiancé Kristen for the love and support they give me every day.

# ABSTRACT

Citizen science is becoming an ever more popular way for scientists and resource managers to deal with needs for large temporal and spatial scale datasets. It provides a free or low cost means for collection of extensive amounts of data across time and space while acting as a public education and outreach tool, empowering communities to be involved in the management decisions being made in their back yard. Though large, well-known citizen science programs such as the Christmas Bird Counts are being used extensively for peer reviewed literature and management decisions, there are numerous smaller, local counts that have the potential to inform research and decision making at a local scale. Here I examine one of these more typical programs, a single North American Butterfly Association butterfly survey that takes place at Congaree National Park in Richland County, South Carolina. I used this program as a case study to explore means in which scientific research at a much smaller spatial and temporal scale can be used to verify and optimize citizen count data and methods to address research and management goals. In order to achieve this, I collected a comparison dataset across one field season which was used to verify the past citizen science data and explore potential sources of differences between researcher and citizen gathered data. Both datasets were also used to explore the effects of phenology on the natural variation expected within a low temporal resolution dataset such as this one. Our data suggest that, while there may be some effects of participant experience and detection consistency in data reliability, the data collected by the program are generally of quality to be used by National Park managers.

The citizen data also suggest a significant effect of growing degree day on count results, particularly total accumulated GDD from the previous year are affecting the diversity of summer count data.  Lastly, I used what I learned from the study to make generalized suggestions for ways to improve the utility of citizen science programs, as well as providing an additional chapter with suggestions specific to our case study program.

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## Introduction

Citizen science, the use of participants from outside the immediate scientific community to collect, organize, and analyze scientific data, is rapidly becoming a more popular and effective way for scientists and managers to keep up with growing needs for large temporal and spatial scale datasets (Bonney et al., 2014; Silvertown, 2009). Citizen science can be utilized in a number of ways, with an ability to produce data effective in achieving research goals such as monitoring climate change, assessing ecosystem health, and recording phenological and range shifts of species (Dickinson et al., 2012). Additionally, allowing the general public to be involved in the research that underpins local natural resource management decisions creates a more engaged society. Citizens will become more interested in conservation of the world around them and more aware of the process of creating policies to protect it, potentially increasing the capacity for large scale environmental and social change in the future (Jordan et al., 2015). When employed properly, citizen science can be, and has been used as an effective tool for making important management decisions(Silvertown, 2009). It can extend research

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budgets via volunteer assistance, compile data sets that cover areas of time and/or space much larger than would be possible without the use of large numbers of volunteers, and supply huge amounts of surveying effort. Additionally, citizen science counts often involve several surveyors counting the same area simultaneously, which may increase thelikelihood of recording rare individuals, including early detection of immigrants and species invasions (Dickinson et al., 2012).

Though citizen science has great potential to contribute to scientific literature, there are many barriers to generating formal analyses from citizen--gathered data. Data reliability, consistency of data recording, and accessibility of the data can all hinder a citizen science program's ability to generate readily analyzable and publishable results (Hyder, Townhill, Anderson, Delany, & Pinnegar, 2015). In addition, the term "citizen science" itself being relatively new, and the negative notions towards data collected by nonscientists can lead to a large underrepresentation of papers based on citizen science in the literature (Silvertown, 2009).

While scientists and managers want highly reliable detailed data, more intensive data collection protocols are not always the best solution. It may be difficult to recruit and retain volunteers in projects that utilize difficult methodologies, frequent data collections, or poorly accessible study areas (Kobori et al., 2016). Many citizen science programs also fail to define clear a research question, particularly one that all invested parties, including the participants, researchers, and policy makers or managers work together to develop for the project. Development of a hypothesis, no matter how basic, provides meaning and scope for the project, increases participant knowledge of the purpose of the research, and results in better collaboration between parties (Dickinson et al., 2012; Silvertown, 2009).

Including participants in more steps of the research process increases participant skill, independence, and motivation within the project as well as within their everyday lives as amateur conservationists (Jordan et al., 2015). Shirk et al (2012) define three general goals that a citizen science program should strive to achieve: to drive scientific results, to develop specific skills for participants, or to increase the public's interest in conservation and decision making. The best citizen science programs are ones that integrate two or even all of these goals, so that all parties may benefit.

Large, well established citizen science programs such as the National Audubon Society's Christmas Bird count are have been utilized extensively and contribute greatly to the scientific literature. They are well developed and create broad databases on species populations and distributions for use in future monitoring and analysis. While these large counts are the most well—known, there are many other programs that are less utilized and focus more on local public outreach and education, rather than collecting data to address defined research questions (Silvertown, 2009).

## Research Questions

### *Study Background*

For this project, I looked at a less studied, typical citizen science program, the North American Butterfly Association (NABA) butterfly counts. These counts take place across the United States as well as in Canada and Mexico and allow local groups to plan and carry out counts in an area of specific interest. Each count takes place within a 15 mile radius of set coordinates where volunteers walk transects, record all the butterflies seen, and send compiled data sets to NABA headquarters through an online submission form (North American Butterfly Association, 2014).

More specifically, I examined a single local count that takes place in and around Congaree National Park (CNP) in Richland County, South Carolina. Butterfly abundance and diversity data have been collected at the park sporadically since 1978, and the NABA 4th of July and Seasonal counts in began in 2010. These counts take place every summer on or around July 4th, and every fall in September. Though a large amount of data have been collected over the years, little to no formal analysis at CNP has been done as a result of the counts. Rather, it has been used primarily as an outreach and education tool for the Park, as well as a skill building, learning, and recreational opportunity for local amateur lepidopterists. The data also contribute to a large NABA database that compiles all the count data from across North America.

This count is of particular interest to managers at the National Park as butterflies can be a useful study species for a wide variety of management based research questions (Kremen, 1992). Butterflies also pose many unique obstacles to citizen scientist programs. For one, large numbers of species, many of which are similar in appearance, can make it difficult for inexperienced participants to produce accurate and consistent identifications (Kobori et al., 2016). Secondly, butterflies have complex phenology that can pose detection and analysis issues. Timing, length, and numbers of flight seasons vary among species and across years, which may result in variation in what low temporal resolution data sets record across time, but this complex phenology also makes

Lepidoptera a strong study system for climate change monitoring (Parmesan & Yohe, 2003)

The goal of this project is to explore how citizen science can be used to address research and resource management questions. I used this particular case study as a model for how researchers can examine citizen science count data and methods for verification of data quality. Additionally, I looked at how a citizen science project like this one can be optimized to address the research needs of managers and researchers in the future. I aimed to use the citizen science data from this count, along with a systematically gathered control dataset to better understand the butterfly populations at Congaree National Park, in the scope of the goals of park managers, local count organizers, and the NABA parent program. This was done in a three part project: first, by comparing the composition of the citizen science dataset to the control dataset; second, by exploring the effects of phenology on natural variation in the data; and lastly, by using what I learned from the case study to make recommendations for the optimization of similar local citizen science counts.

### *Comparison of Datasets*

The first question I attempted to answer was whether the data being collected by participants in the local citizen science counts has equal potential to estimate butterfly populations in the park as data collected by scientists. I used the systematically gathered control dataset from representative transects in the Park to act as a comparison that allowed for exploration of data quality and species composition comparisons. I asked whether or not the citizen science data were estimating the same species diversity in the park as the control data, in spite of differing sample sizes, and if so, whether or not the species compositions were similar. I also used simple data manipulations to explore potential sources of differences in the data sets to ask the question of what may be driving differences between the citizen data and control data. Though I hypothesize that in many cases the citizen science data may be of comparable quality, I expect that there will be differences between the datasets. I hypothesize that identification reliability, detection consistency, and habitat inclusion will play a large role in the diversity and species composition of the datasets.

### *Controlling for phenological variation*

Next, I aimed to quantify the effects of inter and intra-year phenology on count results. Though the 4th of July and Seasonal Counts center on the same dates each year, I hypothesize that calendar date may not be the best predictor of butterfly populations for the counts. There are many factors that can affect butterfly phenology such as precipitation, photoperiod, and overwintering stage, and it can be extremely difficult to account for all of these variables. I chose to use growing degree days (GDD), which is an expression of the degree to which butterflies can develop over a year based on maximum and minimum temperatures, as our predictor. Though this metric fails to account for all factors affecting butterfly development, it is a viable means to account for phenology in most butterflies(Cayton, et al, 2015). This will help account for variability in temperature patterns that drive phenology. I hypothesize that GDD will have a significant effect on the citizen science count results, and if so this variation must be understood if one is to use the counts occurring only twice a year for formal analysis and management decisions.

I also hypothesize that, due to there only being two counts per year, that the citizen science surveys are missing certain significant flight events within the year.

## Methods

### *Comparison of Datasets*

In order to have a reliable dataset spanning the entire year for use in analysis and program validation, I conducted field surveys at Congaree National Park at approximately seven day intervals beginning March 16 and ending on November 22, 2015. Transects were chosen that overlapped previous NABA count locations, were easily accessible by the general public, and included diverse habitats, including areas of particular concern to park managers (Toole, 2004; National Park Service, 2014) (figure 1.1).

**Figure 1.1:** Map of Congaree National Park. the transects for the control dataset included the Kingsnake, Boardwalk, Sims, and Bluff trails, the roadside between the Visitor Center and the Bluff Trail, the parking lot at the Kingsnake trailhead, and the two campgrounds. (Source: National Park Service)

Since butterflies seek shelter in cool, windy, or cloudy conditions, surveys were conducted on days which favored butterfly flight by having low winds, at least partly cloudy skies, and adequately warm conditions (Dennis & Sparks, 2006). Researchers from the University of South Carolina surveyed the transects using a modified Pollard walk (Pollard, 1977). Surveyors walked the approximately 14 miles of transects at a uniform pace, recording all butterflies seen within a 5 meter buffer of the trail. When possible, identifications were made passively, and pictures taken for verification if needed. When necessary, individuals were netted, photographed for identification, and released. Transects were broken into sections that allowed researchers to record not only the identification of the individual, but also the sector of the transect in which it was seen. Sectors were marked via waypoints on a GPS unit that was carried during surveys, and were based on habitat transitions. Habitats include upland, bottomland hardwood, pine savannah, open canopy, riparian, and various other areas of interest. Though these habitat data are not analyzed here, they will be used in future work.

In order to contrast our control dataset with NABA count data, species diversity estimates were derived using individual-based species rarefactions. This was necessary due to the large difference in the sample sizes between the two datasets. I know that it is impossible to sample all individuals of a population, therefore most surveys under-estimate the number of species. Samples of larger numbers of individuals or higher sampling effort are likely to record a disproportionately higher number of species. Individual-based rarefaction allows comparison of two samples in spite of this bias by rarefying the larger sample to the abundance level of the smaller sample. For example in our overall comparison, PAST Biodiversity software (Hammer, Harper, & Ryan, 2001) was used to take  samples of 2,145 individuals, the number of individuals from the control dataset, from the citizen science dataset.  This process was repeated 1,000 times in and these new model datasets analyzed for mean diversity.  In each comparison, the estimated diversity of the two samples in question is thought to be comparable when the experimental diversity of the smaller sample falls within the 95% confidence intervals of the expected diversity of the rarefaction of the larger sample.  If the experimental species richness fails to fall within these bounds, there are likely one or more factors aside from sample size leading to differences in diversity estimates from the datasets (Gotelli & Colwell, 2011).

Several simple data manipulations were done and additional rarefactions run in order to explore various possible drivers of differences in diversity estimations.    First, loner species, defined as any species observed only once over the course of the years of interest, were removed from the citizen science dataset (this dataset is referred to as “NABA no loners”).  Next, in an attempt to minimize the effects of habitat variation, the citizen science data were pared down to only include only the transects that overlapped the immediate areas in which the control dataset were collected (referred to as “NABA transect overlap”).  Each of these new datasets was separately compared to the control dataset.  Additionally, new datasets were created by removing all *Hesperiidae* from both the original citizen science dataset and the NABA transect overlap and compared a control dataset with *Hesperiidae* removed, since this family is likely to be a large source of misidentification in the data due to the fact that this family includes many small, similar-looking species.

Since rarefaction only estimates diversity, I also looked at how similar the datasets were in terms of the species composition. To achieve this, beta diversity analyses were run using Whitaker's beta diversity for pairwise comparisons, (Whitaker, 1960). This allowed us to quantify the similarities in the presence and absence of species across data sets to determine if datasets estimating comparable diversity also consisted of similar species compositions for the sample. Additionally, it allowed us to see if the data manipulations affected the species overlap of the datasets, or if the proportion of shared and distinct species stayed consistent. I also qualitatively looked at what species were shared between datasets and what species were distinct to each dataset, to explore possible patterns in the data.

### *Controlling for phenological variation*

In order to control for intra- and inter-year variation in count results based on phenology, growing degree day (GDD) values were calculated for each year as a substitute for calendar date. The weather data were gathered from the weather station at the National Park, and in years with large sections of data missing the data were supplemented with data from the nearest weather station. GDD values were calculated using the single-sine method (Baskerville & Emin, 1969; Roltsch, et al., 1999), and total accumulated GDD for each year was calculated independently beginning with January 1. I used the minimum and maximum thresholds of 10˚C and 30˚C, consistent with those proposed by Cayton, et al (2015) as well as being in general agreement with work done in other insects (Hodges & Braman, 2004; Nufio et al., 2010).

I calculated abundance and diversities across growing degree days for the flight season in the control dataset in order to calculate peak and minimum flight seasons in terms of GDD. The GDD up to the date of each citizen science count were calculated, and these were compared to richness across the year calculated from the control data. This is important for both understanding natural variation in the NABA data across years, but also for long term monitoring of phenology shifts in the face of climate change.

Lastly, the NABA data were compared to GDD data using multiple regression analysis to explore possible correlations between the abundance and diversity recorded in the counts and the GDD from January 1 of that year to the date of the count. I also performed regression analyses using annual GDD from the previous year as a predictor of diversity of the summer citizen science count results. Though there is likely to be variation in the data from a number of sources, this allows for a quantitative assessment of the type of variation that is to be expected in the data from weather alone.

### *Case study recommendations*

Lastly, I took what I learned from this case study to make recommendations for the optimization of the count that can be easily translated to other localized citizen science counts. I give suggestions for ways to minimize the short comings associated with citizen-gathered data and maximize the count's usability by participants, researchers, park managers, and other interest groups. I look at data recording, data storage and reporting at a local level, work towards developing concrete research questions for the count, and explore means to increase connection pathways between citizen participants, park managers, and researchers. Finally, I set the stage for future research to continue in the field of citizen science in order to meet the growing need for public participation in surveys.

## Results

### *Count Results*

From 2010 through 2015, the twelve citizen science counts at Congaree National Park recorded 7,853 individuals of 77 species within the park. Of those, only 2,154 individuals were recorded in the summer counts, and 5,699 were recorded in the fall counts. However, despite the large difference in abundance between the summer and fall totals, the number of species recorded was very similar at 64 and 66 respectively. 11 of the species recorded by the citizen science counts were only ever recorded once across the six year period. The control dataset contained 2,145 individuals from March through November. These data consisted of 54 species. Species Venn diagrams for the entire citizen science count dataset and the citizen science dataset paired down to overlapping transects, as they compare to the control dataset can be seen in figure 1.2.

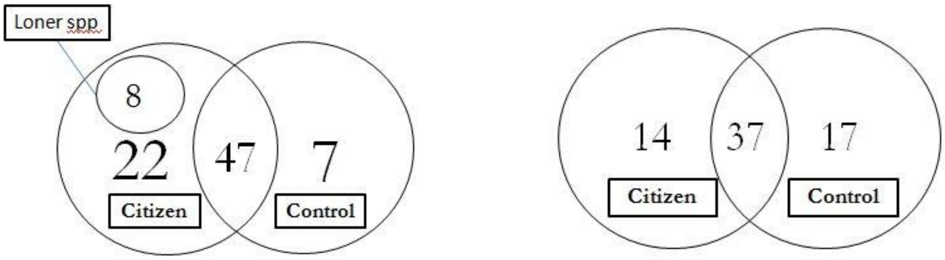

**Figure 1.2:** Species comparisons for the citizen science dataset (left) and NABA Overlap (right) dataset as compared to the control.

*Comparison of Datasets*

The individual-based rarefaction of the NABA dataset compared to the control sample resulted in a mean species richness of 62 rarefaction generated dataset. The number of species recorded in the control dataset of 54 species fell well outside of the 95% confidence intervals of the rarefaction curve of 57-67, meaning the citizen science and control datasets have significantly different diversities. The beta diversity between these two datasets was 0.282. Figure 1.3 shows the rarefaction curves for the two datasets.

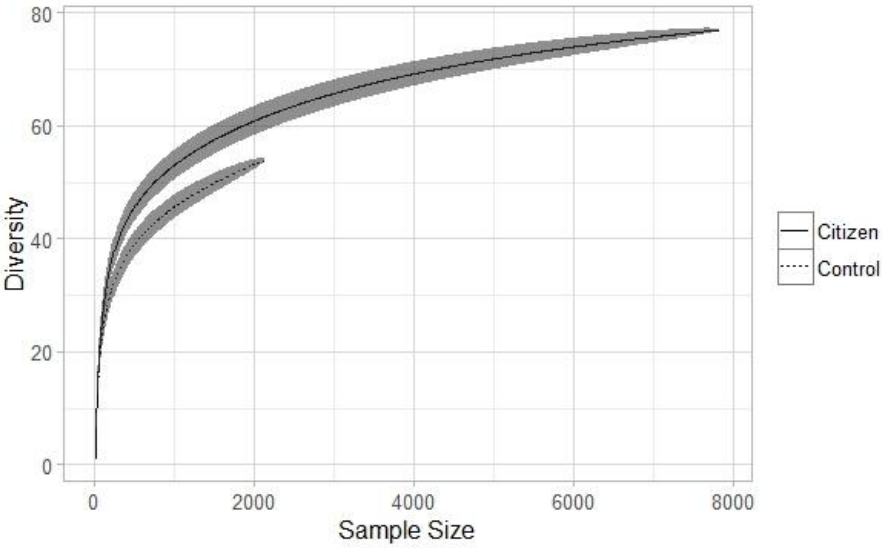

**Figure 1.3:** The individual-based species rarefaction curves for the citizen science and control datasets, with 95% confidence intervals.

Removing the loner species from the citizen science data and comparing this new dataset to the control greatly lowered estimated richness of the model to 59 species, with 95% confidence intervals of 55-63. The diversity of the control dataset of 54 fell only very slightly outside of these confidence intervals. This data manipulation also resulted in a slight reduction in beta diversity from 0.282 to 0.271.

When *Hesperiidae* were removed from the NABA no loners dataset and rarefied to the abundance level of a control dataset also in which *Hesperiidae* removed, the mean richness from the model was 39 species with the 95% confidence intervals at 36-41. The diversity of the control dataset of 41 species means that the two samples do not significantly differ in species diversity. The beta diversity was greatly reduced to 0.195. Figure 1.4 shows the individual based species rarefaction curves for the citizen science data set and the control dataset with *Hesperiidae*, and their associated 95% confidence intervals.

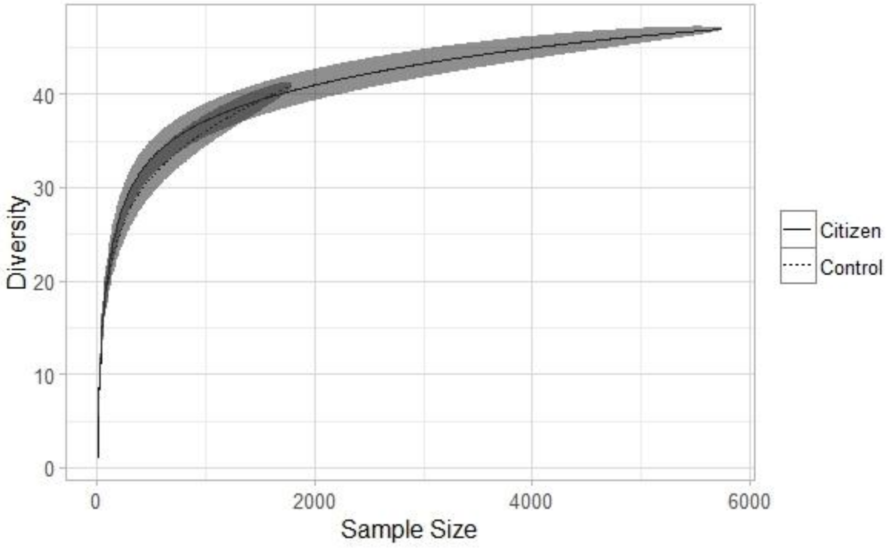

**Figure 1.4:** The individual-based species rarefaction curves for the citizen science and control datasets with *Hesperiidae* removed, with 95% confidence intervals.

The citizen science dataset pared down to only include transects that coincided with the control dataset consisted of 1,361 individuals of 51 species. In this case, the control dataset was the larger of the two comparison datasets. When rarefied to the abundance level of the NABA overlap dataset, the mean richness was 49 with 95% confidence intervals of 45-52. The 51 species of the comparison citizen science dataset fall within those bounds, and the two datasets have a beta diversity of 0.301. Removing Hesperiidae from both datasets resulted in a rarefaction derived mean richness of 36 which is the same number of species as the NABA overlap dataset. Removing Hesperiidae also reduced the beta diversity to 0.280. Figure 1.5 shows the individual-based rarefaction curves and their associated 95% confidence intervals for the NABA overlap and control datasets. Table 1.1 summarizes the rarefaction data and beta diversities.

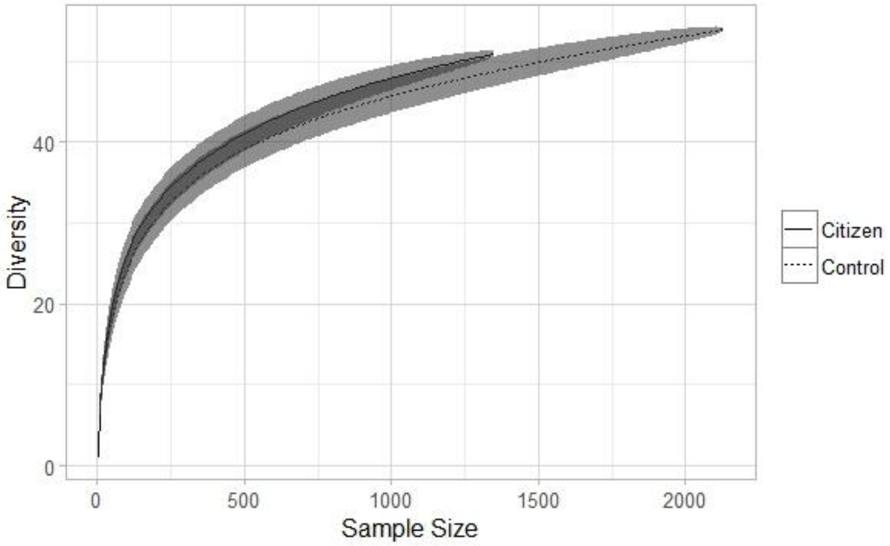

**Figure 1.5:** Individual based rarefaction curves for the NABA Overlap and control datasets, with 95% confidence intervals

**Table 1.1:** Rarefaction data and associated beta diversities for dataset comparisons

| Dataset Rarefied | Manipulations | Mean Diversity | 95% CI | Comparison Diversity | Beta Diversity |
|---|---|---|---|---|---|
| Citizen | None | 62 | 57-67 | 54 | 0.282 |
| Citizen | Loners removed | 59 | 55-63 | 54 | 0.271 |
| Citizen | Hesperiidae removed | 39 | 36-41 | 41 | 0.195 |
| Control | Overlapping transects | 49 | 45-52 | 51 | 0.301 |
| Control | Overlapping transects, Hesp. removed | 36 | 33-39 | 36 | 0.280 |

### *Controlling for phenological variation*

Over the course of the citizen science counts, there was variation across years in both the total and pattern of accumulation of growing degree days.  The year 2012 had the highest number of growing degree days with 6,266.  Conversely, the following year in 2013, the fewest growing degree days were recorded at 5,533.  The historic average total annual GDD over the years of 1948-2012 is 5,844 (Southeast Regional Climate Center, 2013). The accumulation of GDD followed a similar curve as to be expected from the literature (e.g. Cayton et al., 2015)as seen in Figure 1.6.

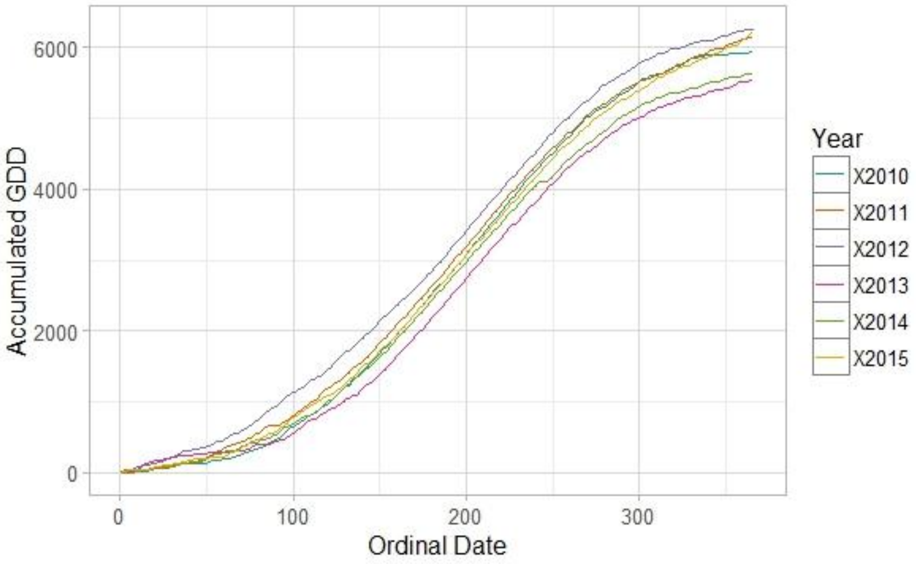

**Figure 1.6:** Accumulation of growing degree days for each year of biannual NABA counts at the Park

When the number of individuals and number of species across the field season in the control survey were graphed against GDD, there was a well defined peak in abundance at 1088 growing degree days, followed by a several week trough of low abundance. This peak was mirrored nearly identically in the diversity data, as was the timing of the substantial drop in the data following the peak. There was some fluctuation across the summer months in the data, specifically in terms of diversity, but both diversity and abundance peaked at nearly the same point in the fall. The peak abundance for a single survey of 336 individuals fell on 4,524 growing degree days. The peak diversity of 26 species fell very slightly earlier at 4,358 growing degree days. The early season peak in abundance which fell on 1,088 growing degree days was only 105, but the peak diversity for the spring, falling on 971 GDD was 17 species. This is consistent with what has been seen in the Congaree citizen science counts, which have recorded substantially higher abundance in the Seasonal Counts versus the 4th of July Counts, and much higher individual to species ratios. When the growing degree days for the dates of the citizen science counts for each year are compared to the abundance and diversity across the year from the control data, it is seen that the NABA 4th of July counts always fall directly between the large early and late season peaks. The dates for the summer counts fall during a period of consistently low abundance and highly variable diversity. The growing degree days associated with the fall counts, however, coincide very well with the period of peak abundance and diversity seen in the late season in the control dataset, as seen in figure 1.7.

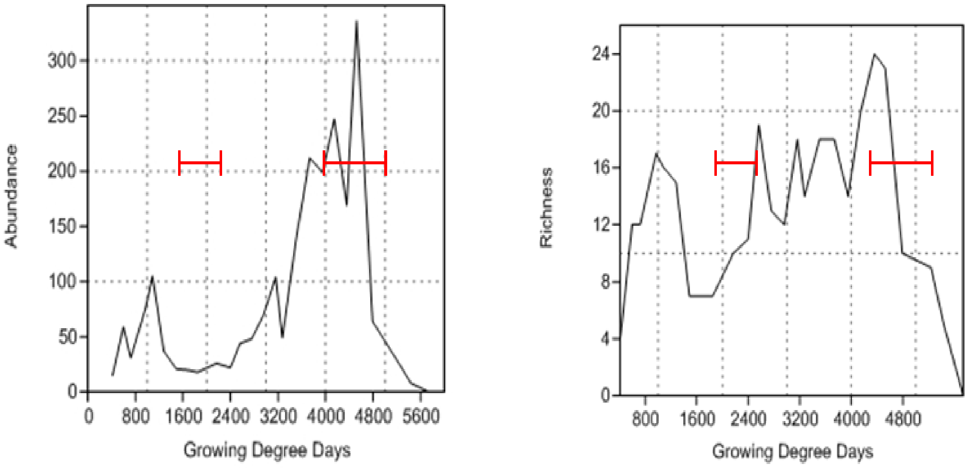

**Figure 1.7:** Abundance and richness for the control dataset across the accumulated growing degree days. Bars represent the range of accumulated growing degree days for the citizen science counts.

Citizen science data were not correlated with GDD values from the year of the corresponding count for either abundance ($R^2$=0.12, p=0.525) or diversity ($R^2$=0.04, p=0.697). However there was a marginally significant non-linear relationship between the diversity recorded in each of the 4th of July citizen science counts and the total accumulated GDD from the previous calendar year($R^2$=0.99, $F_{2,3}$=1,834.7, p=0.0005) (Figure 1.8). The relationship was chosen as a third order polynomial based on an AIC value of 48.091 as compared to the AIC of 54.813 of the second order relationship. In the model, all the predictors for previous years GDD were significant, and there was no significant interaction with GDD from the current year of the count. This relationship will require future monitoring to increase data point density, especially in the region of higher GDD values.

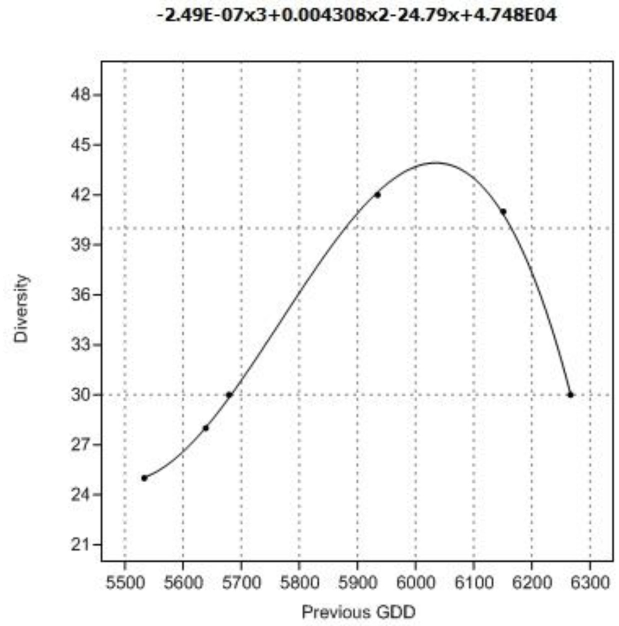

**Figure 1.8:** Diversity from the July 4th Counts graphed against total accumulated growing degree days from the previous year.

## Discussion

### *Comparrison of Datasets*

Since the individual-based rarefaction failed to fully account for the differences in the diversity estimations between the citizen science and control datasets, it can be concluded that there are more factors than simply sample size impacting the disproportionately high diversity of the citizen science dataset. Our hypothesis that both misidentifications and increased detection of rare or vagrant species may occur in the citizen science data was supported since the analysis suggests that one of the factors leading to the discrepancy in diversity between the datasets is the number of loner species in the citizen science dataset. Since removing these data lowered the beta diversity between the two datasets and greatly reduced the differences between the diversity estimated from rarefactions and the number of species in the control dataset, it is clear that loner species are at least partially driving the high diversity in the citizen science data. The loner species, consisting of both small and difficult to identify species as well as species that are more likely rare species within the Park (see appendix B), are likely a source of both misidentifications and increased detection of rare species as compared to the control. These hypotheses were further supported by the fact that in all comparisons of diversity, beta diversity values were reduced and rarefaction comparisons became more similar when *Hesperiidae* were removed from the dataset. The small, often similar-looking species of this family may be introducing a large number of misidentifications into the data, as well as inconsistent detection rates. This means that in the future, some analyses may be more robust when *Hesperiidae* are omitted from the citizen science data.

The habitat included in each transect also played a significant role in the count results. In the rarefaction analysis, the only citizen science count data that were comparable to the control data without manipulation were the data from the NABA overlap dataset. This comparison minimized differences in habitat between the datasets, and the rarefaction results were very similar. It will be important in future analysis to account for differences between years in which habitats included in the counts were different. Likewise, this shows that one cannot effectively compare datasets across transects of differing habitats within a year unless habitat is included in the analysis. On the other hand, this shows that the citizen science data are detecting differences between habitats, and can be useful in habitat monitoring at the Park. This comparison also had the highest beta diversity, which is likely a result of the low surveyor experience on this transect. Since this transect is commonly surveyed in the citizen science counts (Frank Henning, Pers. Comm.) by the most novice participants who may only be able to correctly identify common and easily distinguishable species, it may be a large source of bias in the data (Kelling et al., 2015). However, once Hesperiidae are removed, the beta diversity is reduced to nearly the same level as that between the overall datasets.

Overall, our analysis suggests that the citizen science counts at Congaree National Park are in fact collecting data that are of comparable quality to that of data generated from professional scientific surveys. The ability of the citizen counts to detect rare species and collect data at a large spatial scale, including a much wider range of habitats than possible with standard scientific methods, make the count data a potentially valuable tool for both National Park managers and researchers. There may be additional needs for control analyses by research groups to quantitatively assess effects of habitat inclusion in transects, surveying effort, and surveyor experience. Better understanding these factors may further the opportunities for analysis of the data.

### *Controlling for phenological variation*

Since the my analysis suggest that GDD is in some respects driving citizen science count results and that there are defined peaks in abundance and diversity in butterfly populations at the Park, it is clear from our analysis that taking into account phenological variation across the year is an integral part of analyzing a citizen science dataset such as this one. An analysis of the citizen science data without accounting for phenology would result in false trends. Understanding the differences in the timing of the 4th of July Counts and Seasonal Counts and how they correlate with large spikes and troughs in abundance and diversity for the year helps to explain the large discrepancy in abundances recorded between the two counts. When this is understood, one can better monitor changes across space and time. Additionally, knowing what one would expect to see based on the current flight season patterns allows for monitoring of shifts in phenological patterns.

The fact that in spite of the various biases associated with citizen gathered data, the results 4th of July counts at the park are correlated with total accumulated GDD from the previous year alone has clear climate change monitoring implications. The surveys have been successfully monitoring phenology and responses to extreme temperature years unknowingly. If this type of monitoring is possible over long time periods with the use of citizen participants, it will be extremely beneficial to researchers and managers. The non-linear relationship seen suggests that years in which the GDD crosses some given threshold, there is a negative response in butterfly diversity, which makes this a particularly important trend for continued monitoring in the face of climate change.

Though there was no correlation between the accumulated GDD within the year at each count date, it is unlikely that intra-year GDD has no effect on variation in count results. It is more likely, however, that there are interactions of other factors affecting the data along with GDD. It is important that consistent, detailed data on survey effort, surveyor experience, local weather parameters on count days, etc. be taken on count days that can be added into analyses to account for natural variation. This will allow for the most accurate analysis of true population trends coming from factors of concern to park managers.

### *Case study recommendations*

The analyses support that collection of a control dataset is a viable solution to questions related to the problems associated with citizen gathered data. The use of a systematically gathered control dataset at a smaller spatial scale, but much higher temporal scale proved to be an effective tool in helping our case study citizen science count to better address the needs of Congaree National Park. A dataset across an entire field season gathers a relatively large dataset that can be used for quality control comparisons, as well as allows for understanding of flight season changes and other phenological variations. In future studies, I hope to further analyze data on habitats of concern, flood regimes, and species invasions to narrow the scope of the project and address specific management questions.

In a citizen science count, it is important to develop research goals for the project and collect data in a way that addresses these goals. For instance, in this case study, habitat management is of particular concern to the Park (National Park Service, 2014), so it is important for citizen science count datasheets to be delineated by habitat areas. Additionally, developing a project goal, and keeping the participants involved and providing feedback on goal progress rather than simply having participants take part in the survey itself, creates more a more informed and motivated public (Jordan et al., 2015). Our analyses show an apparent difference in identification reliability between transects counted by new, inexperienced participants, and transects counted by experienced return participants. This bias may be abated by increasing the general experience level of count participants, or simply being able to have experienced, return participants accompany less experienced participants in the field to provide guidance. Many of these return participants also play an active role in the planning of the count, networking with park employees, and handling of data.

Lastly, if the count data are to be used at a local level, it is important for the data to be available quickly and easily to managers, researchers, and local interest groups. Though the North American Butterfly Association has a data submission process, I suggest making data readily available to a larger audience on an online database such as eButterfly that can then be linked to places such as park or interest group websites. This allows for access to count data by count participants interested in count results, as well as researchers, managers, and interest groups from outside of the immediate count network. Use of an online database also helps to address issues with a low temporal scale dataset. Many citizen science count participants, though not trained in a scientific field, are very well versed in the identification of the organism of interest. These amateur naturalists often also spend many more days in the field collecting survey data in addition to the formal citizen science counts, but this data may never be officially recorded. Allowing these individuals access to the database, as well as researchers who may be collecting data at the time will result in a much more robust and useful dataset for management and research purposes.

# CHAPTER 2: RECOMMENDATIONS SPECIFIC TO THE CONGAREE NATIONAL PARK BUTTERFLY COUNTS

In light of the work done in this study, here I aim to provide recommendations specific to the North American Butterfly Association butterfly counts at Congaree National Park. First and foremost, it will be important for community members, park managers, and university researchers to work together to develop objectives and testable hypotheses that can benefit the various interest groups. Since our analyses suggest that the citizen science data are of a quality to address research questions, groups may begin develop more robust hypotheses based on the data generated from the citizen science surveys. The program's current general question of species presence and absence is a strong base to grow on, and provides opportunities to expand into more specific questions. Hypotheses may be broad, and will likely be dynamic, changing with the needs of the Park across time. Likewise, data collected will be useful for a wide range of research applications even if those applications fall outside the initial hypotheses developed by the program. Examples of potential hypotheses may include the effects of flood regime; effects of invasive species, including feral hogs; monitoring of prescribed burn recovery areas; and climate change monitoring, including continuing to test the effects of growing degree days as a predictor of phenology. Once hypotheses are defined, it will be important that data are recorded in such a way as to support data analysis specific to these hypotheses. For instance, if researchers or managers are interested in habitat affinities, datasheets should be separated by habitat type so that data can be categorized accordingly. Additionally, if the data are to address robust hypotheses, detailed data from each count will need to continue to be kept on effort from each transect, weather conditions, etc. Since differences in levels of surveyor experience can have significant effects on citizen science data and methodologies have been developed to correct for this variation such as the route regression model (Geissler and Sauer 1990), when surveyors sign in to the counts, they should also be asked indicate their level of butterfly surveying and identification experience.

If data are to be utilized by interest groups and researchers outside the immediate count group, data accessibility will also need to be increased. Since currently data are submitted to NABA online and stored via spreadsheets, I suggest utilizing an online database. There are numerous online tools for citizen scientists, including eButterfly (www.e-Butterfly.org) and iNaturalist (www.inaturalist.org) that allow groups to set up pages and store data. This will allow the data to be accessed easily and widely, furthering its applicability. Using an online database will also help to mitigate some of the issues with phenological variation found in our analysis by allowing access the posting of butterfly sightings across the entire year. Giving other groups access to the database such as surveyors for the BioBlitz, or allowing certain amateur and professional surveyors access to upload data across the year will help fill in the blanks between the NABA counts. This may very well pick up species that are repeatedly missed by the current counts simply because of timing. This could especially help pick up the early season spike in diversity and abundance seen in this study’s control dataset if events or counts are taking place during this time.

Lastly, I suggest designing a program for community outreach and involvement. While participation in counts is often strong, it is often dominated by a core group of returning participants. Return participants are extremely important for successful citizen science programs, but there may also be opportunities to bridge the gap between these participants and the casual weekend visitors who occasionally participate. Increasing the casual participants' stake in the project goals and growing the number of return surveyors may lead to increases in data quality and community empowerment (Jordan et al., 2015). I suggest sending a newsletter to follow-up after each count summarizing the count results, letting participants know what was seen and what is being done with the data. A exhibit on the importance of citizen science in the Park, the various projects that take place and how people can participate could be created by a University of South Carolina student to be displayed to reach a wider crowd as well. Allowing the participants to see the large amount of data generated and the science being supported by the work they did in the surveys may increase their attachment to the work. This has the opportunity to not only create dedicated and skilled return surveyors, but also strong conservationists in general.

Ultimately, the goals of the project will vary across time and across groups. As long as communication channels between count participants and organizers, park personnel, and researchers stay open, and objectives are re-evaluated as needed, a citizen science program such as this has the potential to achieve a wide range of goals. Research studies such as this can be a successful tool for re-evaluation throughout the course of the program as needed, and scientific validation should continue to be an important step in the process. When these objectives are reached, this citizen science program will continue to be grow in its usefulness as a research and management tool long into the future.

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# APPENDIX A – CONTROL SURVEY SPECIES LIST

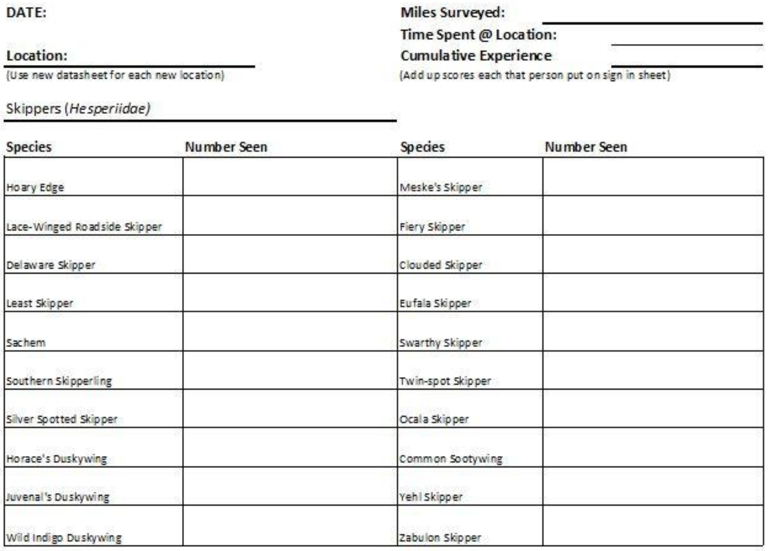
| **Family** | **Common Name** | **Genus** | **species** |
|---|---|---|---|
| Hesperiidae | Lace-Winged Roadside Skipper | *Amblyscirtes* | *aesculapius* |
| Hesperiidae | Least Skipper | *Ancyloxypha* | *numitor* |
| Hesperiidae | Silver Spotted Skipper | *Epargyreus* | *clarus* |
| Hesperiidae | Horace's Duskywing | *Erynnis* | *horatius* |
| Hesperiidae | Dun Skipper | *Euphyes* | *vestris* |
| Hesperiidae | Fiery Skipper | *Hylephila* | *phyleus* |
| Hesperiidae | Clouded Skipper | *Lerema* | *accius* |
| Hesperiidae | Zabulon Skipper | *Poanes* | *zabulon* |
| Hesperiidae | Tawny-edged Skipper | *Polites* | *themistocles* |
| Hesperiidae | Little Glassywing | *Pompeius* | *verna* |
| Hesperiidae | Southern Cloudywing | *Thorybes* | *bathyllus* |
| Hesperiidae | Long-Tailed Skipper | *Urbanus* | *proteus* |
| Hesperiidae | Southern Broken-dash | *Wallengrenia* | *otho* |
| Lycaenidae | Eastern Pine Elfin | *Callophrys* | *niphon* |
| Lycaenidae | Red-Banded Hairstreak | *Calycopis* | *cecrops* |
| Lycaenidae | Spring Azure | *Celastrina* | *ladon* |
| Lycaenidae | Summer Azure | *Celastrina* | *neglecta* |
| Lycaenidae | Eastern Tailed Blue | *Cupido* | *comyntas* |
| Lycaenidae | Harvester | *Feniseca* | *tarquinus* |
| Lycaenidae | Southern Hairstreak | *Satyrium* | *favonius* |
| Nymphalidae | Gulf Fritillary | *Agraulis* | *vanillae* |
| Nymphalidae | Hackberry Emperor | *Asterocampa* | *celtis* |
| Nymphalidae | Tawny Emperor | *Asterocampa* | *clyton* |
| Nymphalidae | Silvery Checkerspot | *Chlosyne* | *nycteis* |
| Nymphalidae | Gemmed Satyr | *Cyllopsis* | *gemma* |
| Nymphalidae | Monarch | *Danaus* | *plexxippus* |
| Nymphalidae | Creole Pearly-Eye | *Lethe* | *creola* |
| Nymphalidae | Northern Pearly-Eye | *Lethe* | *anthedon* |
| Nymphalidae | Southern Pearly-Eye | *Lethe* | *portlandia* |
| Nymphalidae | Zebra Longwing | *Heliconius* | *charithonia* |
| Nymphalidae | Carolina Satyr | *Hermeuptychia* | *sosybius* |
| Nymphalidae | Common Buckeye | *Junonia* | *coenia* |
| Nymphalidae | American Snout | *Libytheana* | *carinenta* |
| Nymphalidae | Red spotted Purple | *Limenitis* | *arthemis* |

| | | | |
|---|---|---|---|
| Nymphalidae | Little Wood Satyr | *Megisto* | *cymela* |
| Nymphalidae | Morning Cloak | *Nymphalis* | *antiopa* |
| Nymphalidae | Pearl Crescent | *Phyciodes* | *tharos* |
| Nymphalidae | Phaon Crescent | *Phyciodes* | *phaon* |
| Nymphalidae | Eastern Comma | *Polygonia* | *comma* |
| Nymphalidae | Question Mark | *Polygonia* | *interrogationis* |
| Nymphalidae | Appalachian Brown | *Satryodes* | *appalachia* |
| Nymphalidae | Painted Lady | *Vanessa* | *cardui* |
| Nymphalidae | Red Admiral | *Vanessa* | *atalanta* |
| Papilionidae | Zebra Swallowtail | *Eurytides* | *marcellus* |
| Papilionidae | Black Swallowtail | *Papilio* | *polyxenes* |
| Papilionidae | Eastern Tiger Swallowtail | *Papilio* | *glaucus* |
| Papilionidae | Palamedes Swallowtail | *Papilio* | *palamedes* |
| Papilionidae | Spicebush Swallowtail | *Papilio* | *troilus* |
| Pieridae | Falcate Orange Tip | *Anthocharis* | *midea* |
| Pieridae | Cloudless Sulphur | *Phoebis* | *sennae* |
| Pieridae | Orange Sulphur | *Colias* | *eurytheme* |
| Pieridae | Sleepy Orange | *Eurema* | *nicippe* |
| Pieridae | Cabbage White | *Pieris* | *rapae* |
| Pieridae | Checkered White | *Pontia* | *protodice* |

# APPENDIX B – LIST OF CITIZEN SCIENCE DATASET LONER SPECIES

| Family | Common Name | Genus | species |
|---|---|---|---|
| Hesperiidae | Hoary Edge | *Achalarus* | *lyciades* |
| Hesperiidae | Delaware Skipper | *Anatrytone* | *logan* |
| Hesperiidae | Meske's Skipper | *Hesperia* | *meskei* |
| Hesperiidae | Twin-spot Skipper | *Oligoria* | *maculata* |
| Hesperiidae | Tropical Checkered Skipper | *Pyrgus* | *oileus* |
| Hesperiidae | Tawny-edged Skipper | *Polites* | *themistocles* |
| Hesperiidae | Hayhurst's Scallopwing | *Staphylus* | *hayhurstii* |
| Lycaenidae | Harvester | *Feniseca* | *tarquinus* |
| Lycaenidae | Banded Hairstreak | *Satyrium* | *calanus* |
| Lycaenidae | Phaon Crescent | *Phyciodes* | *phaon* |
| Lycaenidae | Texan Crescent | *Phyciodes* | *texana* |

# APPENDIX C – RECOMMENDED DATA SHEET



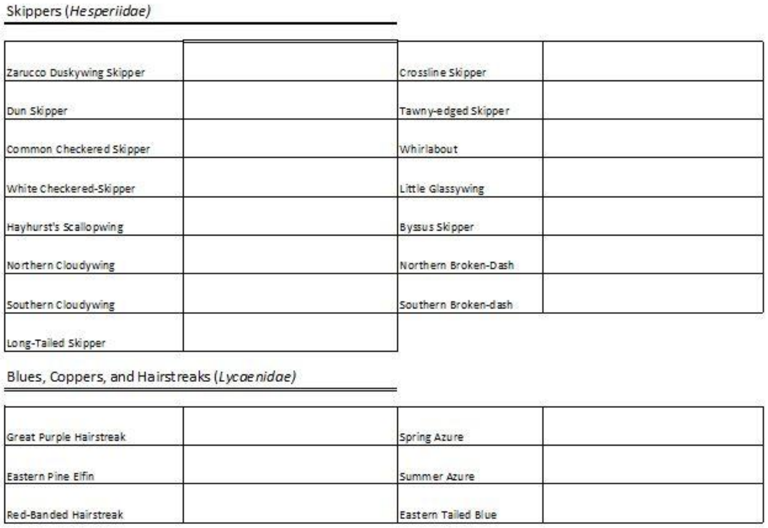
**DATE:**

**Location:**
(Use new datasheet for each new location)

**Miles Surveyed:**
**Time Spent @ Location:**
**Cumulative Experience**
(Add up scores each that person put on sign in sheet)

Skippers (*Hesperiidae)*

| Species | Number Seen | Species | Number Seen |
|---|---|---|---|
| Hoary Edge | | Meske's Skipper | |
| Lace-Winged Roadside Skipper | | Fiery Skipper | |
| Delaware Skipper | | Clouded Skipper | |
| Least Skipper | | Eufala Skipper | |
| Sachem | | Swarthy Skipper | |
| Southern Skipperling | | Twin-spot Skipper | |
| Silver Spotted Skipper | | Ocala Skipper | |
| Horace's Duskywing | | Common Sootywing | |
| Juvenal's Duskywing | | Yehl Skipper | |
| Wild Indigo Duskywing | | Zabulon Skipper | |

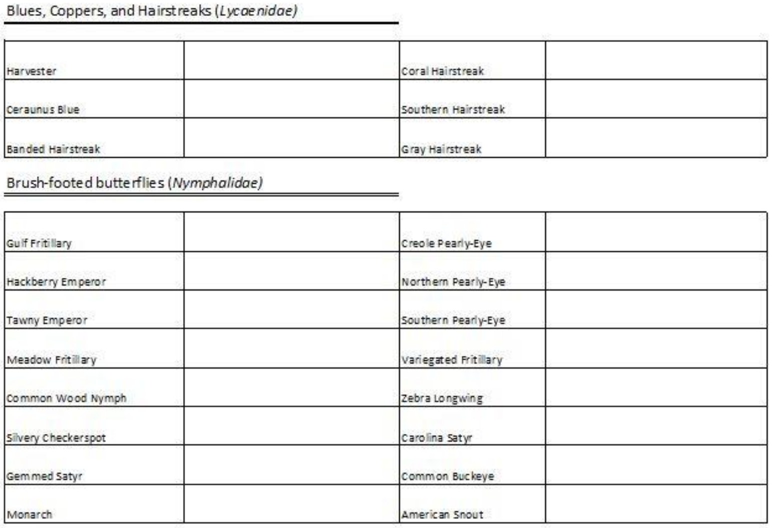


Skippers (*Hesperiidae)*

| | | | |
|---|---|---|---|
| Zarucco Duskywing Skipper | | Crossline Skipper | |
| Dun Skipper | | Tawny-edged Skipper | |
| Common Checkered Skipper | | Whirlabout | |
| White Checkered-Skipper | | Little Glassywing | |
| Hayhurst's Scallopwing | | Byssus Skipper | |
| Northern Cloudywing | | Northern Broken-Dash | |
| Southern Cloudywing | | Southern Broken-dash | |
| Long-Tailed Skipper | | | |

Blues, Coppers, and Hairstreaks (*Lycaenidae)*

| | | | |
|---|---|---|---|
| Great Purple Hairstreak | | Spring Azure | |
| Eastern Pine Elfin | | Summer Azure | |
| Red-Banded Hairstreak | | Eastern Tailed Blue | |

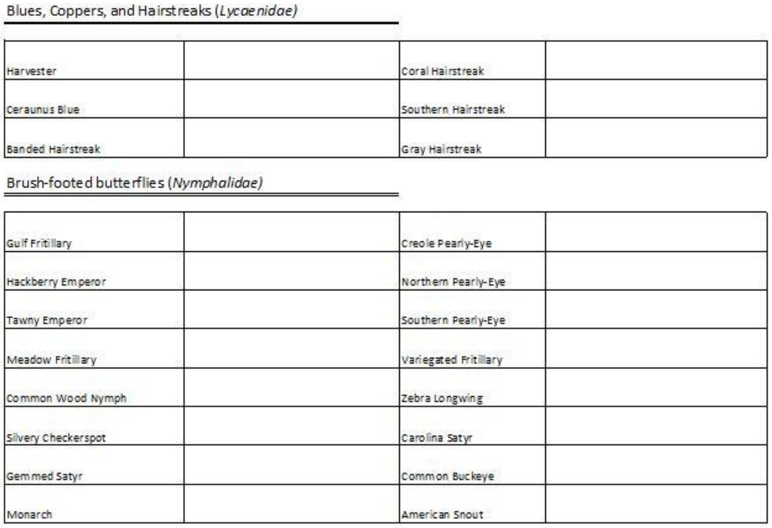


Blues, Coppers, and Hairstreaks (*Lycaenidae*)

| | | | |
|---|---|---|---|
| Harvester | | Coral Hairstreak | |
| Ceraunus Blue | | Southern Hairstreak | |
| Banded Hairstreak | | Gray Hairstreak | |

Brush-footed butterflies (*Nymphalidae*)

| | | | |
|---|---|---|---|
| Gulf Fritillary | | Creole Pearly-Eye | |
| Hackberry Emperor | | Northern Pearly-Eye | |
| Tawny Emperor | | Southern Pearly-Eye | |
| Meadow Fritillary | | Variegated Fritillary | |
| Common Wood Nymph | | Zebra Longwing | |
| Silvery Checkerspot | | Carolina Satyr | |
| Gemmed Satyr | | Common Buckeye | |
| Monarch | | American Snout | |

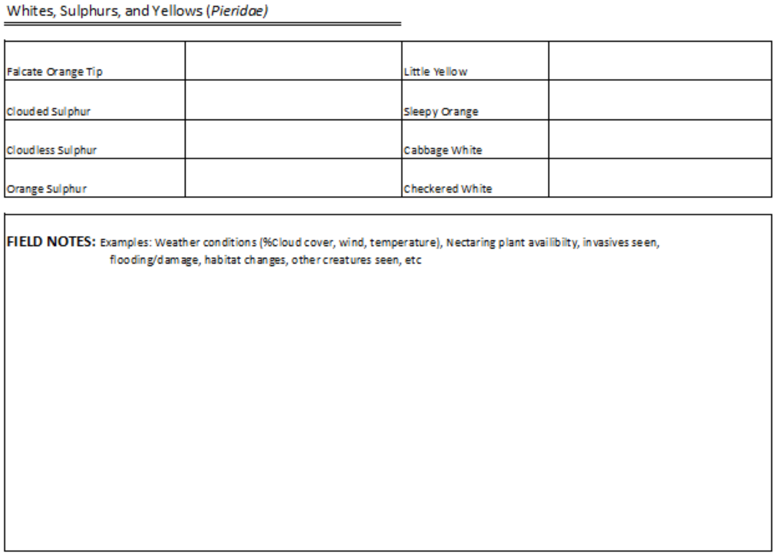


Blues, Coppers, and Hairstreaks (*Lycaenidae*)

| | | | |
|---|---|---|---|
| Harvester | | Coral Hairstreak | |
| Ceraunus Blue | | Southern Hairstreak | |
| Banded Hairstreak | | Gray Hairstreak | |

Brush-footed butterflies (*Nymphalidae*)

| | | | |
|---|---|---|---|
| Gulf Fritillary | | Creole Pearly-Eye | |
| Hackberry Emperor | | Northern Pearly-Eye | |
| Tawny Emperor | | Southern Pearly-Eye | |
| Meadow Fritillary | | Variegated Fritillary | |
| Common Wood Nymph | | Zebra Longwing | |
| Silvery Checkerspot | | Carolina Satyr | |
| Gemmed Satyr | | Common Buckeye | |
| Monarch | | American Snout | |



Whites, Sulphurs, and Yellows (*Pieridae*)

| | | | |
|---|---|---|---|
| Falcate Orange Tip | | Little Yellow | |
| Clouded Sulphur | | Sleepy Orange | |
| Cloudless Sulphur | | Cabbage White | |
| Orange Sulphur | | Checkered White | |

**FIELD NOTES:** Examples: Weather conditions (%Cloud cover, wind, temperature), Nectaring plant availibilty, invasives seen, flooding/damage, habitat changes, other creatures seen, etc

# APPENDIX D – PUBLICATION COPYRIGHT TRANSFER INFORMATION

*Ecology, Ecological Applications, Ecological Monographs*

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