Comprehensive Survey of Butterflies at the Sam D. Hamilton Noxubee National Wildlife Refuge

Jordan Gesell

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Comprehensive survey of butterflies at the Sam D. Hamilton Noxubee National Wildlife Refuge

By

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A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Science
in Agricultural Life Sciences
in the Department of Biochemistry, Molecular Biology, Entomology and Plant Pathology

Mississippi State, Mississippi

November 2020
In collaboration with the Sam D. Hamilton Noxubee National Wildlife Refuge, I collected detailed information on the butterflies (Lepidoptera: Papilionoidea Latreille, 1802) of the refuge. I produced a comprehensive checklist of butterflies and skippers numbering 60 species. In addition, I collected data on flight periods as well as local plant community associations. Butterfly abundance surveys were conducted to assess seasonal habitat use across six site classes. Special emphasis was placed on pine forest at various stages of management for the endangered red-cockaded woodpecker (Picoides borealis). An exploratory analysis of butterfly diversity and abundance was conducted using non-metric multidimensional scaling (NMDS). Using a Pearson correlation, I determined that butterfly species richness correlated positively with understory plant morphospecies richness across site classes. A correlation was not found for data solely collected from the pine sites, suggesting factors other than understory morphospecies richness govern butterfly richness within a site class.
ACKNOWLEDGEMENTS

No one achieves anything alone. This project would not have been possible without the efforts and influence of many individuals. Chief among them is Dr. JoVonn Hill, my major professor, who put me on the path to a career in entomology and who has guided my education since I arrived at Mississippi State. I also want to thank Jennifer Seltzer for instilling discipline in me and teaching me how to get things done. I thank the Sam D. Hamilton Noxubee National Wildlife Refuge for initiating and funding the project, and for providing the assistance of their summer workers during the most laborious part of my field work. In particular I want to recognize Steven Lewis, the former refuge biologist, for providing advice, perspective and for being so pleasant to work with. I am also deeply grateful to the Mississippi Entomological Museum and all who work there. The thousands of hours spent among them have enriched my life in ways I could never have predicted.
TABLE OF CONTENTS

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER

I. CHECKLIST OF BUTTERFLIES AT THE SAM D. HAMILTON NOXUBEE NATIONAL WILDLIFE REFUGE

Introduction

Methods

Results

Discussion

Staple species

Migratory species

Rare and likely species

II. SURVEY OF BUTTERFLY ABUNDANCE AT THE SAM D. HAMILTON NOXUBEE NATIONAL WILDLIFE REFUGE

Introduction

Prior Surveys

Methods

Abundance Surveys

Site Characterization

Statistical Analysis

Results

Statistical Analysis

Discussion

Trends in butterfly diversity and abundance

Plant Community Choice

Disturbance

Takeaways from vegetation analysis

Factors driving butterfly diversity at Noxubee
Conclusions ..........................................................................................................................31

REFERENCES ....................................................................................................................32

APPENDIX

A. SITE DESCRIPTIONS ........................................................................................................36

B. SPECIES PROFILES .........................................................................................................48

Family Papilionidae (Latreille) ..........................................................................................49
Family Pieridae (Swainson) ..............................................................................................53
Family Lycaenidae (Leach) ...............................................................................................57
Family Nymphalidae (Rafinesque) ..................................................................................60
Family Hesperiidae (Latreille) .........................................................................................71
Likely Species ....................................................................................................................80
LIST OF TABLES

Table 1.2  Checklist of butterfly species observed on the refuge.................6
Table 2.2  Abundance survey results by site class ........................................21
Table 2.3  Abundance survey results by transect site..................................22
LIST OF FIGURES

Figure 1.1  Map of refuge collecting localities .................................................................5
Figure 2.1  Map of abundance survey transects ...............................................................17
Figure 2.2  Butterfly Species Richness Observed by Month ..............................................23
Figure 2.3  Butterfly Abundance Observed by Month ......................................................23
Figure 2.4  Ordination of Vegetation Communities ..........................................................24
Figure 2.5  Butterfly Community Dissimilarity and Habitat Requirements .........................26
Figure 2.6  Correlation of Butterfly and Plant Diversity Metrics ......................................27
Figure A.1  Open Field 1 Starting coordinates: 33.2861°, -88.7577° ......................37
Figure A.2  Open Field 2 Starting coordinates: 33.2333°, -88.8468° ......................37
Figure A.3  Field Edge 1 Starting coordinates: 33.2482°, -88.7721° .........................38
Figure A.4  Field Edge 2 Starting coordinates: 33.2333°, -88.8484° .........................38
Figure A.5  Field Edge 3 Starting coordinates: 33.3063°, -88.8956° .........................39
Figure A.6  Pine 1 Starting coordinates: 33.2730°, -88.8025° .................................39
Figure A.7  Pine 2 Starting coordinates: 33.2747°, -88.7925° .................................40
Figure A.8  Pine 3 Starting coordinates: 33.2325°, -88.8452° .................................40
Figure A.9  Pine 4 Starting coordinates: 33.2338°, -88.8505° .................................41
Figure A.10 Pine 5 Starting coordinates: 33.3042°, -88.8876° .................................41
Figure A.11 Pine 6 Starting coordinates: 33.2207°, -88.7657° .................................42
Figure A.12 Pine 7 Starting coordinates: 33.2141°, -88.8272° .................................42
Figure A.13 Pine 8 Starting coordinates: 33.3021°, -88.8843° .................................43
Figure A.14 Pine 9 Starting coordinates: 33.2326°, -88.8729° ........................................43

Figure A.15 Bottomland Hardwood 1 Starting coordinates: 33.2861°, -88.7577° ...............44

Figure A.16 Bottomland Hardwood 2 Starting coordinates: 33.2512°, -88.8301° ...............44

Figure A.17 Bottomland Hardwood 3 Starting coordinates: 33.2954°, -88.8096° ...............45

Figure A.18 Moist Soils 1 Starting coordinates: 33.2958°, -88.8089° .............................45

Figure A.19 Moist Soils 2 Starting coordinates: 33.2711°, -88.8618° .............................46

Figure A.20 Upland Hardwood 1 Starting coordinates: 33.2508°, -88.7544° .................46

Figure A.21 Upland Hardwood 2 Starting coordinates: 33.2346°, -88.8057° .................47

Figure A.22 Upland Hardwood 3 Starting coordinates: 33.2213°, -88.9131° .................47

Figure B.1 Battus philenor (L.) - Pipevine swallowtail ........................................49

Figure B.2 Eurytides marcellus (Cramer) - Zebra swallowtail ..................................50

Figure B.3 Papilio polyxenes (Fabricius) - Black swallowtail ..................................50

Figure B.4 Papilio troilus (L.) - Spicebush swallowtail ........................................51

Figure B.5 Papilio cresphontes (Cramer) - Giant swallowtail ................................51

Figure B.6 Papilio glaucus (L.) - Eastern yellow swallowtail ................................52

Figure B.7 Anthocharis midea (Hübner) - Falcate orangetip ....................................53

Figure B.8 Eurema lisa (Boisduval & LeConte) - Little yellow ...............................53

Figure B.9 Eurema daira (Godart) - Barred yellow ..............................................54

Figure B.10 Eurema nicippe (Cramer) - Sleepy orange ..........................................54

Figure B.11 Zerene cesonia (Stoll) - Southern dogface ........................................55

Figure B.12 Colias philodice (Godart) - Clouded sulphur ........................................55

Figure B.13 Phoebis sennae (L.) - Cloudless sulphur .............................................56

Figure B.14 Feniseca tarquinius (Fabricius) - Harvester ........................................57

Figure B.15 Calycopis cecrops (Fabricius) - Red-banded hairstreak .........................57

Figure B.16 Satyrium calanus (Hübner) - Banded hairstreak ................................58
Figure B.17 *Strymon melinus* (Hübner) - Grey hairstreak ................................................................. 58

Figure B.18 *Celastrina ladon* (Cramer)/*C. neglecta* (W.H. Edwards) - Spring/summer azure .......................................................................................................................... 59

Figure B.19 *Cupido comyntas* (Godart) - Eastern tailed-blue ......................................................... 59

Figure B.20 *Asterocampa celtis* (Boisduval & LeConte) - Hackberry emperor ............................ 60

Figure B.21 *Anaea andria* (Scudder) - Goatweed leafwing ............................................................ 60

Figure B.22 *Danaus plexippus* (L.) - Monarch ................................................................................. 61

Figure B.23 *Agraulis vanillae* (L.) - Gulf fritillary ............................................................................. 61

Figure B.24 *Euptoieta claudia* (Cramer) - Variegated fritillary ......................................................... 62

Figure B.25 *Libytheana carinenta* (Cramer) - American snout ...................................................... 62

Figure B.26 *Limenitis arthemis astyanax* (Drury) - Red-spotted purple ......................................... 63

Figure B.27 *Limenitis archippus* (Cramer) - Viceroy ....................................................................... 63

Figure B.28 *Phyciodes tharos* (Drury) - Pearl crescent .................................................................... 64

Figure B.29 *Junonia coenia* (Hübner) - Common buckeye ............................................................... 64

Figure B.30 *Chlosyne nycteis* (Doubleday) - Silvery checkerspot .................................................... 65

Figure B.31 *Polygonia interrogationis* (Fabricius) - Question mark ................................................ 65

Figure B.32 *Polygonia comma* (Harris) - Eastern comma ............................................................... 66

Figure B.33 *Vanessa virginiensis* (Drury) - American lady ............................................................... 66

Figure B.34 *Vanessa atalanta* (L.) - Red admiral ............................................................................ 67

Figure B.35 *Enodia portlandia* (Fabricius) - Southern pearly-eye .................................................... 67

Figure B.36 *Enodia creola* (Skinner) - Creole pearly-eye ................................................................. 68

Figure B.37 *Satyrodes appalachia* (R. L. Chermock) - Appalachian brown .................................... 68

Figure B.38 *Hermeuptychia sosybius* (Fabricius) - Carolina satyr ............................................... 69

Figure B.39 *Megisto cymela* (Cramer) - Little wood-satyr .............................................................. 69

Figure B.40 *Cyllopsis gemma* (Hübner) - Gemmed satyr .............................................................. 70
Figure B.41 Cercyonis pegala (Fabricius) - Common wood-nymph
Figure B.42 Achalarus lyciades (Geyer) - Hoary edge
Figure B.43 Epargyreus clarus (Cramer) - Silver-spotted skipper
Figure B.44 Urbanus proteus (L.) - Long-tailed skipper
Figure B.45 Thorybes bathyllus (J. E. Smith) - Southern cloudywing
Figure B.46 Thorybes confusa (Bell) - Confused cloudywing
Figure B.47 Lerema accius (J. E. Smith) - Clouded skipper
Figure B.48 Polites vibex (Geyer) - Whirlabout
Figure B.49 Erynnis juvenalis (Fabricius) - Juvenal’s duskywing
Figure B.50 Erynnis horatius (Scudder & Burgess) - Horace’s duskywing
Figure B.51 Pyrgus communis (Grote) - Common checkered-skipper
Figure B.52 Euphyes dion (W. H. Edwards) - Dion skipper
Figure B.53 Wallengrenia egeremet (Scudder) - Northern broken-dash
Figure B.54 Amblyscirtes aesculapius (Fabricius) - Lace-winged roadside skipper
Figure B.55 Ancyloxypha numitor (Fabricius) - Least skipper
Figure B.56 Hylephila phileus (Drury) - Fiery skipper
Figure B.57 Nastra lherminier (Latreille) - Swarthy skipper
Figure B.58 Pompeius verna (W. H. Edwards) - Little glassywing
Figure B.59 Euphyes vestris (Boisduval) - Dun skipper
Figure B.60 Panoquina ocola (W. H. Edwards) - Ocola skipper
CHAPTER I
CHECKLIST OF BUTTERFLIES AT THE SAM D. HAMILTON NOXUBEE NATIONAL WILDLIFE REFUGE

Introduction

As a group, butterflies are rife with value. They have value to the public as recognizable, charismatic, and approachable organisms (Barua et al. 2012). They also possess ecological value as pollinators, herbivores, and prey for other wildlife. However, the quality with which we are most concerned is their suitability as an indicator species for habitat quality (Schultz et al. 2019). It has been argued that butterflies are potentially a poor taxon for indication of habitat quality (Fleishman & Murphy 2009). Rather, that they are often chosen for this role solely because they are charismatic. This view does have some merit, as butterflies are often chosen for this reason. However, I argue they are still a suitable indicator taxon if for no other reason than that they are a diverse insect group with a well-known taxonomy. Few other groups of organisms have such well-explored life histories and distributions (Glassberg 1999). Their host specificity alone can infer the presence of individual plant species (Fleishman et al. 2005; Toftegaard et al. 2018), and their species richness correlates with that of local plants (Mukherjee et al. 2019). Lastly, their abundance and mobility allow for ease of observation (Walker 1985). This strong combination of qualities makes them uniquely suited as a study organism for areas like the refuge in which public outreach and ecological research overlap.
The Sam D. Hamilton Noxubee National Wildlife Refuge is located in east-central Mississippi and covers roughly 19500 hectares of land. In addition to its efforts to conserve and manage wildlife, an important function of the Noxubee refuge is facilitating public exposure to nature through outreach and recreation. According to visitor surveys conducted by the Refuge in 2010 and 2011, wildlife observation accounted for 61% of visitor activity. Butterfly watching was not included as a category in the survey, but it likely makes up at least a small proportion of wildlife observation. Of the survey respondents, 41% reported engaging in birdwatching, and there is overlap between this demographic and those who specifically engage in butterfly watching (pers. comm. Schiefer).

It is evident that a link exists between human well-being and the health of natural environments. There is even evidence to support a correlation between species richness itself and mental well-being (Dallimer et al. 2012). In the interest of further engaging the public in butterfly observation and conservation efforts, the refuge commissioned a comprehensive survey of butterflies within its bounds and across the entirety of the field season.

The necessary first step of any intensive biological survey, then, is a checklist of species presence (Clench 1979; Royer et al. 1998). Such a step is especially important among highly diverse taxa such as insects. Species presence data allows for further study of abundance as well as other areas including phenology, behavior and ecological interaction.

Multiple surveys of butterfly species have been conducted in Mississippi over the past two centuries. The earliest was Weed (1894), which was a preliminary checklist of butterfly species in the northeastern portion of the state. Mather & Mather (1958) prepared a much more comprehensive list of species from all parts of the state and included flight periods in their treatment. The North American Butterfly Association (NABA) has conducted an annual count of
butterflies in early July since 1987, accumulating over 30 years of presence data for the refuge and adjacent area (Swengel 1990). However, because the survey only occurs on one day of the year in midsummer, it is unable to account for species which fly outside of that season.

Glassberg (1999) gave distributions for the butterfly fauna of the eastern United States as well as flight periods and detailed life history information. My original estimate of potential species presence on the refuge was extrapolated from the distribution maps in this treatment. Based off this information, I hypothesized that 80-100 species would be found over the course of the survey.

The most significant recent entomological survey conducted at the refuge was MacGown et al. (2012), which characterized the local ant fauna. This treatment included detailed characterizations of the various habitat types present. It then provided detailed accounts of species associations with each habitat, followed by individual species profiles with photographs. A poster was also produced for display at the refuge visitors’ center. This project was modeled after that effort and produced similar deliverables for the refuge.

**Methods**

Checklist surveying involved the development of a baseline species inventory through observation and collection of specimens. These were made across large portions of the refuge over the course of each field season, from March through October. Species presence was recorded in relation to habitat type and time of year. Phenological observations such as blooming of common flower species were also made independently of site.

Two different descriptive metrics were assigned to each species to give an impression of their prevalence on the refuge, namely “rarity” and “spread”. Species were assigned a rarity class based on their total number of recorded observations along transects during the abundance
survey portion of the project. However, the classification was also informed by observations made outside of abundance surveys. If a species was observed between one and three times, I considered it “rare”. At four to ten observations I considered it “moderately rare” and from 10-20, it was considered “moderately common”. Beyond 21 observations it was considered “common”.

The spread metric was assigned based on how many site classes a species was observed in. Site classes were the categories used to describe transect sites during abundance surveys and were listed as open field, field edge, moist soils, pine forest, bottomland hardwood, or upland hardwood. The spread metric is intended to account for species which may be highly abundant but only localized, or ones that are widespread with low abundance. Species observed in only one or two site classes were classified as “specialized”. From three to four they were considered “intermediate” and at five or greater they were considered “widespread”.

Voucher specimens representing 56 of the 60 observed species were collected from sites across the refuge as opportunities presented themselves. Collections were made from over 50 specific localities across the refuge in every major habitat type, including specialized plant communities such as baldcypress stands and canebrakes. Collection and preservation of insect specimens followed standard insect museum practices. Voucher specimens are deposited at the Mississippi Entomological Museum.

Results

My original estimate of 80 to 100 species of butterfly being present on the refuge was based on range maps (Glassberg, 1999) and data from the 4th of July Butterfly Count (pers. comm. Schiefer). By the end of the survey I had observed 60 species in total. Of all the observed species, 13 were common with over 21 observations across the study period. 16 of the observed
species were considerably rarer with only one or two observations across the study period. From October 2017 to October 2019, I produced a collection numbering 358 specimens and representing 56 of the 60 observed species.

Figure 1.1  Map of refuge collecting localities
Table 1.2 Checklist of butterfly species observed on the refuge

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Rarity</th>
<th>Spread</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Papilionidae</strong></td>
<td><strong>Swallowtails</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battus philenor</td>
<td>pipevine swallowtail</td>
<td>Common</td>
<td>Widespread</td>
</tr>
<tr>
<td>Eurytides marcellus</td>
<td>zebra swallowtail</td>
<td>Moderately common</td>
<td>Specialized</td>
</tr>
<tr>
<td>Papilio polyxenes</td>
<td>black swallowtail</td>
<td>Moderately rare</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Papilio troilus</td>
<td>spicebush swallowtail</td>
<td>Moderately rare</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Papilio cresphontes</td>
<td>giant swallowtail</td>
<td>Rare</td>
<td>Widespread</td>
</tr>
<tr>
<td>Papilio glaucus</td>
<td>eastern yellow swallowtail</td>
<td>Moderately common</td>
<td>Widespread</td>
</tr>
<tr>
<td><strong>Pieridae</strong></td>
<td><strong>Whites and Sulphurs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthocharis midea</td>
<td>falcate orangetip</td>
<td>Moderately rare</td>
<td>Specialized</td>
</tr>
<tr>
<td>Colias cesonia</td>
<td>southern dogface</td>
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<td>Colias philodice</td>
<td>clouded sulphur</td>
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<td>Eurema lisa</td>
<td>little yellow</td>
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<td>barred yellow</td>
<td>Rare</td>
<td>Unknown</td>
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<td>Eurema nicippe</td>
<td>sleepy orange</td>
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<td>Intermediate</td>
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<td>Phoebis sennae</td>
<td>cloudless sulphur</td>
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<td>Widespread</td>
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<td><strong>Hairstreaks and Blues</strong></td>
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<td>Feniseca tarquinius</td>
<td>Harvester</td>
<td>Rare</td>
<td>Specialized</td>
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<td>Calycopis cecrops</td>
<td>red-banded hairstreak</td>
<td>Common</td>
<td>Intermediate</td>
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<td>Satyrium calanus</td>
<td>banded hairstreak</td>
<td>Rare</td>
<td>Specialized</td>
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<td>Strymon melinus</td>
<td>gray hairstreak</td>
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<td>Intermediate</td>
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<td>Celastrina ladon</td>
<td>spring/summer azure</td>
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<td>Cupido comyntas</td>
<td>eastern tailed-blue</td>
<td>Common</td>
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<td>Scientific Name</td>
<td>Common Name</td>
<td>Rarity</td>
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<td>goatweed leafwing</td>
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<td>Intermediate</td>
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<td><em>Danaus plexippus</em></td>
<td>Monarch</td>
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<td>Widespread</td>
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<td><em>Agraulis vanillae</em></td>
<td>gulf fritillary</td>
<td>Moderately common</td>
<td>Intermediate</td>
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<td><em>Euptoieta claudia</em></td>
<td>variegated fritillary</td>
<td>Moderately rare</td>
<td>Specialized</td>
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<td><em>Libytheana carinenta</em></td>
<td>American snout</td>
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<td><em>Limenitis arthemis astyanax</em></td>
<td>red-spotted purple</td>
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<td>Widespread</td>
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<td><em>Limenitis archippus</em></td>
<td>Viceroy</td>
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<td><em>Phyciodes tharos</em></td>
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<td>common buckeye</td>
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<td><em>Polygonia interrogationis</em></td>
<td>question mark</td>
<td>Common</td>
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<td><em>Polygonia comma</em></td>
<td>eastern comma</td>
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<td><em>Vanessa virginiensis</em></td>
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<td>red admiral</td>
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<td>Nymphalidae, Satyrinae</td>
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<td>gemmed satyr</td>
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Table 1.2 (continued)

<table>
<thead>
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<th>Scientific Name</th>
<th>Common Name</th>
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<td>hoary edge</td>
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<td>Specialized</td>
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<td>Intermediate</td>
</tr>
<tr>
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<td>long-tailed skipper</td>
<td>Moderately rare</td>
<td>Specialized</td>
</tr>
<tr>
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<td>lace-winged roadside</td>
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<tr>
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<td>Specialized</td>
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<td>Rare</td>
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<tr>
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<tr>
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<td>Rare</td>
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<td>northern broken-dash</td>
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<td>Juvenal's duskywing common checkered-skipper</td>
<td>Common</td>
<td>Widespread</td>
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<td>Specialized</td>
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<td>dun skipper</td>
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<td>Specialized</td>
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<td>Rare</td>
<td>Specialized</td>
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</table>
Discussion

There was a notable lack of skipper diversity compared with the number of species that occur throughout Mississippi and with the NABA 4th of July Counts. 33 species have been reported on the 4th of July count since 1987, whereas this survey only recorded 19 species. I hypothesize that it is likely that their host plants, which largely consist of sedges and grasses, are highly localized and unlikely to be sampled in a broad survey. Additionally, the regular mowing of roadsides and other grassy areas likely contributes to the observed lack of diversity.

Staple species

Species were grouped into 4 different classes based primarily on the number of observations along transects. However, the frequency of sightings elsewhere on the refuge was considered in classifying species. Species were also given a “spread” rating, based on whether they were tallied in multiple site classes or only one or two. Notable “staple” species exhibiting extreme abundance and broad habitat ranges included the pearl crescent, pipevine swallowtail, red-spotted purple and cloudless sulphur.

Migratory species

Most species found on the refuge are local in nature, emerging and surviving in small areas within a given habitat range. Notable examples of these are found among the satyrs and skippers, some of which prefer highly specific and localized plant communities. Some species however are migratory, only making use of the refuge on a seasonal basis before relocating to another part of the continent. The most prominent of the migratory species on the refuge are the monarch butterfly and the cloudless sulphur, though at least eight of the observed species are
known to migrate in at least part of their range (Urquhart & Urquhart 1978; Walker 1980; Walker 2001).

**Rare and likely species**

A handful of species were observed only once or twice over the course of the study period. Most notable of these is the banded hairstreak, which was collected only once in May 2018. It exhibits a narrow habitat range and only emerges for a short period of time in mid- to late spring. The common wood-nymph is another interesting case. It was only observed once along a field edge in September 2018 though it was expected to occur more frequently. Though it is not a particularly abundant species where found, it is strongly associated with remnant prairie sites in central Mississippi (pers. comm. Hill).

The barred yellow was observed and collected on only two occasions in the fall of 2017 and 2019. Curiously its host, *Stylosanthes*, is prevalent in pine stands across the refuge which suggests it may be more abundant during the fall but is frequently misidentified in flight as the more common little yellow. Another reason for its apparent scarcity is its migratory nature. Like many local Pieridae, the barred yellow is unable to tolerate freezing temperatures and as such it must repopulate the region annually. This leaves its host, widespread though it may be, unused by the species.

The southern dogface is a species of note due to its association with prairie communities in the southeastern U.S. (Fenner et al. 2018), yet it is notably uncommon on the refuge. It was only observed three times across the study period, yet has been observed much more frequently in adjacent localities, suggesting that good quality prairie habitat is lacking on the refuge.
Several species I expected to find on the refuge were not recorded at all during the survey. Of particular note is the mourning cloak, which should be highly abundant in wetter areas with an abundance of willow trees. The Moist Soils 1 transect was established in a wet grassland that is nearly encircled by a border of willow trees. Though the site was visited numerous times across two years, the mourning cloak was never observed.

Additionally, several prominent hairstreaks including the pine elfin, juniper hairstreak and great purple hairstreak were expected but never observed. These species are highly particular about their hosts and, though locally abundant, are rarely observed without intensive long-term observation.
CHAPTER II
SURVEY OF BUTTERFLY ABUNDANCE AT THE SAM D. HAMILTON NOXUBEE NATIONAL WILDLIFE REFUGE

Introduction

As climate change and habitat destruction continue, surveys of biodiversity grow in importance as a tool to understand the nature of the ecosystems being impacted and to aid in their conservation. Comprehensive surveys of fauna in multiple taxa are a tremendous undertaking, potentially taking decades of labor and incurring enormous cost (Sharkey 2001; Scholtens & Wagner 2007). This necessitates the use of indicator taxa, which can serve as proxies for habitat quality. A survey of indicator taxa is, by comparison, low-cost and quickly completed. If the ecological context of a study organism and its local area are properly understood, surveys of indicator taxa can provide guidance for future management and conservation efforts.

The Sam D. Hamilton Noxubee National Wildlife Refuge extends into three counties in east-central Mississippi and comprises 19500 hectares of mostly undeveloped land (USFWS 2014). It measures 23.7 km from its northern to its southern extreme and 21.8 km between its eastern and western extremes. It encompasses a variety of habitats representative of conditions historically found in Mississippi and throughout the Southeastern Coastal Plain (Lowe 1913; Quarterman & Keever 1962; Cross & Wales 1974). Nearly 45% of Refuge land is pine forest, much of which dates back 80 years to plantings at the establishment of the refuge in 1940. The
remaining land comprises 31% bottomland hardwood, 10% mixed pine-hardwood, 7% upland hardwood, 3% open grassland, and 3% wetland (MacGown, 2012). It was originally established in 1940, concurrent with the founding of the U.S. Fish and Wildlife Service. At its founding, the refuge was charged with the conservation of migratory birds and other wildlife, with waterfowl singled out in particular. Since then it has codified its management goals to outline more specific priorities and generate plans for long-term management (USFWS, 2014). Currently, in addition to its mandate to manage for waterfowl the refuge has also placed emphasis on managing forest-breeding birds. Of particular focus is conservation of the endangered *Picoides borealis*, the red-cockaded woodpecker (RCW).

Management for the RCW involves the conversion of pine stands from a dense setting often mixed with hardwoods to an open, savanna-like condition with an understory dominated by forbs and grasses. This condition resembles the RCW’s preferred original habitat, which was naturally maintained through periodic exposure to fire (USFWS 1985). On the refuge, human-mediated habitat conversion is achieved using two primary tools: select removal of individual trees from the stand and a regular regime of controlled burning in the understory (Wade & Lunsford 1989; Haines et al. 2001; USFWS 2014). The whole process of generating suitable habitat takes several decades depending on the initial state, resulting in a patchwork of pine stands across the refuge of differing age classes (Craig Rudolph et al. 1996).

Waterfowl management at Noxubee is aided by regular seasonal flooding of low-lying areas throughout the refuge (Kaminski et al. 1993; Young et al. 1999). Forested stands specifically designated for inundation are classified as greentree reservoirs (GTRs). Open stands without any significant canopy cover are classified as moist soil impoundments. Both have
relevance to this study as examples of unique wetland habitats which are locally uncommon outside the refuge.

Prior Surveys

Several surveys of butterfly diversity have been conducted in the state of Mississippi over the last century. (Weed 1894) represented a preliminary effort to summarize the butterfly fauna of northeast Mississippi. (Mather & Mather 1958) attempted a much more comprehensive treatment, with observations occurring across Mississippi. (Israel 1981) was the first study in Mississippi to use a standardized sampling regime and the first to describe patterns of abundance. The author of that study used similar methods to this survey, with the exception that the established transects were longer and situated along roads. Glassberg (1999) described the butterfly fauna of the eastern U.S. including Mississippi. He gave a total of 127 species of butterflies recorded from the state. Extrapolating from the range maps given in that treatment, I initially estimated that roughly 80-100 of these species could be represented at the refuge.

Since 1987, the North American Butterfly Association (NABA) has conducted an annual count of butterflies around July 4 (Swengel 1990). The 4th of July Count makes use of a count circle 15 miles in diameter centered on the refuge in which multiple parties of observers tally the number of butterflies observed by species. However, this survey only occurs one day out of the year and does not provide observations outside of midsummer. Additionally, the count circle extends outside the boundaries of the refuge. This additional area contains black belt prairie remnants and agricultural fields, both of which contain species not found in habitat within the refuge.

Modern surveys of butterfly diversity are based largely on the Pollard walk method, first described in Pollard (1977) and considered the standard for estimating butterfly abundance.
(Royer et al. 1998). The point-count method (Henry et al. 2015) and distance-sampling method (Royle et al. 2004) have been used as well with varying degrees of accuracy. Though it is the most used option for surveying, the Pollard walk method is dependent on the detectability of individual butterflies along the transect to the surveyor. Individual detectability can be affected by various environmental and observational factors including temperature, species behavior, ground cover, whether a site is representative of the surrounding habitat and the familiarity of the surveyor with the local fauna (Pellet et al. 2012). Therefore, results derived from the Pollard Walk method should be interpreted not as the actual abundance of individual species but as the expected observable abundance.

I hypothesized that butterfly species richness would positively correlate with plant species richness in the understory. This pattern was expected to hold even within a single site class, such that pine stands in the later stages of management for RCW would exhibit greater butterfly species richness than those at earlier stages.

This hypothesis was predicated on the following assumptions:

1. As the number of plant species increases, so too does the likelihood that any one species could be used as a hostplant.
2. Sites with more open canopies would exhibit higher plant species richness than highly shaded sites.

Methods

Abundance Surveys

For this survey I used the methods outlined in (Pollard 1977). Sampling involved walking along a permanent transect path repeatedly throughout a season and tallying the number of individual butterflies observed by species. If species were unable to be identified in flight,
specimens were taken. Individuals belonging to the genera *Enodia, Polygonia, Thorybes* and *Erynnis* were marked down with the genus name only, as determination to species in flight was rare.

To ensure as much uniformity as possible, sampling only occurred within specific ranges of conditions. Transect surveys were conducted during butterflies’ window of greatest activity between 10:00 AM and 2:00 PM Central Daylight Time. Surveys were only conducted when temperatures were above 13°C in sunny conditions and 17°C in cloudier conditions. Temperatures were recorded from the nearest weather station in Louisville, MS.

Each transect path was measured out in increments using a 100-meter field tape and markers were placed every 50 meters for vegetation surveys. The transects themselves all had equal dimensions, measuring five meters in width and half a kilometer in length. Half a kilometer is the lowest allowable transect length in the method described by Pollard, but this length was necessary as the stands being surveyed would frequently measure less than a kilometer in any direction. For cases in which a stand measured no more than a kilometer in length, transects frequently needed to be oriented along the longest axis of the stand. Transects typically began firmly within a stand and every attempt was made to keep habitat composition consistent along its entire length.

Before site establishment began, the refuge provided a selection of potential stands of interest. These preselected stands represented a diverse cross-section of both representative and unique site conditions. Permanent transects were established at 22 of these sites representing six site classes. Sampled sites included open fields, field edges, pine forest, upland hardwood forest, bottomland hardwood forest and moist soil impoundments. The refuge originally requested sampling in baldcypress forest, but logistical and safety concerns caused by seasonal flooding
made this unfeasible. However, this likely had little impact on the survey as no butterfly species are known to use baldcypress as a host.

Figure 2.1 Map of abundance survey transects
Given the size of the refuge and the number of sites selected, completely random sampling of sites was logistically unfeasible. Instead I divided the refuge into three localized sectors and rotated through them on a weekly basis across the season. Four to five sites per sampling day were selected, each representing one of the six different site classes. Within a site class, sites were chosen based on the time since the last sampling event, effectively putting them in a rotation within their sector. Due to the added focus placed on pine stand management and variability, pine stands were sampled more frequently than other site classes and represented a larger share of the total number of sites. I randomized the order in which sites were sampled on a given field day. Adjacent sites such as fields and field edges were treated as pairs and sampled consecutively if they could be traveled to quickly on foot.

A typical sampling day is described herein: Before arriving at the refuge, the sites for the day were chosen and their sampling order was randomized. Arrival and sampling began shortly after 10:00 AM Central Daylight Time. At each site, the temperature was recorded from the local weather station in Louisville. At shaded sites, the temperature was revised down by one degree. The sampler walked along the marked transect path at a fixed pace, at about normal walking speed and tallied all butterflies observed crossing the transect path. Walking effort was increased in more difficult terrain to keep pace as consistent as possible. Sampling took about 15 minutes per transect. Returning to the vehicle and traveling to the next site took between 10 and 30 minutes. Sampling would occur at an average of four or five sites before 2:00 PM. Any specimens collected were placed in marked envelopes and frozen upon return to the museum.

**Site Characterization**

To garner an understanding of the factors influencing butterfly diversity and richness on the refuge, I used additional survey methods to characterize the transect survey sites. These
surveys addressed the groundcover vegetation within each stand and the trees within forested stands. Vegetation surveys were conducted in two events in the spring and fall of 2018. Forest measurements surveys were conducted in a single event in the spring of 2019.

Vegetation surveys were conducted using the quadrat method (Weaver 1918; Leis 2015), wherein a 60 cm² quadrat was placed on the ground at ten locations 50 meters apart along each transect. Each sampling point was offset one meter from the transect path to avoid trampling of vegetation during normal sampling. The offset point alternated from left to right to avoid biasing toward either side of the path. The center point of each quadrat was marked with a pin flag so it could be returned to in the second round of measurements.

At each quadrat site I measured four characteristics: number of plant morphospecies, average herbaceous height in five centimeter increments, estimated groundcover and canopy cover percentages, both in 5% increments. Canopy cover percentages were estimated from photographs taken using a smartphone camera. The camera was held at a height of approximately two meters and pointed directly upward at the canopy.

Forest measurements were taken at four points 100 meters apart along each of the 15 forested transects. A 10-factor wedge prism was used to produce an estimate of the basal area across the transect. I also recorded tree and shrub diversity at the genus level for each plot.
Statistical Analysis

All statistical analyses were conducted using the R statistical computing language, version 3.6.2 (R Core Team, 2019). I conducted a Principal Component Analysis (PCA) to determine the relative importance of plant morphospecies richness, mean groundcover percentage, mean groundcover height and mean canopy cover in the understory structure of each site class. No response variable was included in the PCA as it was only used for dimensional extraction. PCA visualizations were produced using the “factoextra” package (Kassambara and Mundt, 2020).

Analysis and graphical representations of butterfly site choice were produced using non-metric multidimensional scaling (NMDS) under the “vegan” package (Oksanen et al., 2019). All 49 species observed during transect surveys were included in the ordination, and the abundance values used were standardized by sampling frequency. Distances were computed using Bray-Curtis dissimilarity. The computation process used two dimensions and two convergent solutions were arrived at after 20 iterations. Scaling was done using centering, principal component rotation and halfchange scaling.

I analyzed the relationship between butterfly species richness and plant morphospecies richness using Pearson’s correlation coefficient for the entire set of 22 transects. Spearman’s correlation was used for a separate analysis of the pine transects only, as their values fell within a non-normal distribution. The Shapiro-Wilk test was used to check model assumptions of normality and Bartlett’s test was used to check for heteroscedasticity. Because two comparisons were made using the same dataset, I applied a Bonferroni correction and judged significance against an alpha value of 0.025.
In total, 2320 individuals representing 49 species were tallied in abundance surveys across the study period. In total, 273 transect surveys were conducted, with 140 surveys in 2018 and 133 conducted in 2019. Each site was sampled a minimum of seven times and a maximum of 21 times. The greatest number of species observed at a single site was 32 at Field Edge 3 and the lowest number was four observed at Upland Hardwood 2.

Both field seasons saw the greatest measurements of richness and abundance from late summer into fall. The greatest richness tallied on a single day was 18 species on September 18, 2018. The greatest abundance tallied on a single day was 248 individuals on September 25, 2019.

### Table 2.2 Abundance survey results by site class

<table>
<thead>
<tr>
<th>Site class</th>
<th>Richness(^1)</th>
<th>Absolute Abundance(^2)</th>
<th>Relative Abundance(^3)</th>
<th>Surveys</th>
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\(^1\)No. of species observed in site class, \(^2\)No. of individuals tallied in site class, \(^3\)Absolute abundance standardized by number of surveys conducted
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<th>Site</th>
<th>Site Richness$^1$</th>
<th>Absolute Abundance$^2$</th>
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<td>8</td>
<td>22</td>
<td>1.4</td>
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</table>

$^1$No. of species observed along transect, $^2$Total number of individuals tallied along transect,
$^3$Absolute abundance standardized by number of surveys conducted
Figure 2.2  Butterfly Species Richness Observed by Month

Figure 2.3  Butterfly Abundance Observed by Month
Statistical Analysis

The axes of the following ordination plot represent the principal components of the dataset. Principal components indicate new extracted variables which are made up of combinations of the original variables. Principal Component 1 (PC1) explains the largest proportion of the variation between understory vegetation communities (63%). PC1 is most represented (>25%) by the variables of groundcover and herbaceous height. PC2 runs along the y-axis and explains an additional 21% in variation. PC2 is most represented by the variables of morphospecies richness and canopy cover.

Figure 2.4  Ordination of Vegetation Communities

Ordination plot of vegetation survey data using PCA, arranged according to the dataset’s principal components. Each point represents a surveyed site. Color and point shape indicate site class.
Upland and bottomland hardwood forests have noticeable overlap in their understory community structure. Pine forest understory structure appears to be strongly clustered regardless of management stage. Site P4 is an obvious outlier but this is the result of an herbicide treatment in late 2018 shortly before the second vegetation survey. The strongest variation among understory communities within a single site class is evident in the field edge sites, and to a lesser degree the open field sites.

The NMDS analysis ran 20 iterations before arriving at two convergent solutions. As NMDS is primarily a tool for visualization, no p-values were produced. Instead, a stress value was computed which signifies how confidently the plot can be interpreted. The resulting stress value of 0.12682 is considered “fair” allowing for interpretation, though some distances may be misinterpreted due to weak ties.

I ran a Pearson correlation analysis to determine whether there was a statistically significant correlation between plant morphospecies richness and butterfly species richness among the transect survey sites. The analysis returned a significant correlation for both 2018 ($r(20) = 0.60, p = 0.003$) and 2019 ($r(19) = 0.63, p = 0.002$). A Pearson correlation coefficient of 0.60 or higher indicates a strong correlation.

The Spearman correlation analysis run exclusively on the pine transects returned no such significant correlation for 2018 ($r_s = 0.14, p = 0.71$) or 2019 ($r_s = 0.69, p = 0.04$). I was unable to reject the null hypothesis that any perceived correlations in pine stands were a result of random chance.
Figure 2.5  Butterfly Community Dissimilarity and Habitat Requirements

NMDS plot of community dissimilarity between all transect sites. Sites are clustered according to the species composition and relative abundance within their respective butterfly communities. This ordination plot is non-metric, so the actual cluster distances contain no information. Only relative distances are informative. Color of plot features indicates site class. Point size indicates species richness at each site. Individual species are plotted nearest the habitats where they exhibited greatest measured abundance. Darkness of species labels indicates frequency of observation.
Figure 2.6  Correlation of Butterfly and Plant Diversity Metrics

Pearson Correlation plot of mean plant morphospecies richness against 2018 and 2019 butterfly species richness measurements for all sites. Points represent values for individual transect sites.

Discussion

Trends in butterfly diversity and abundance

As might be expected, butterfly abundance and species richness rose as average temperatures increased throughout the spring and summer. Both values peaked in late summer to early fall in both 2018 and 2019, though monthly abundance in 2019 was substantially higher during this time than in 2018. The 2019 increase in abundance is especially curious as there was an extensive drought that year lasting from late August to the beginning of October.
Plant Community Choice

Butterflies exhibit a wide range of habitat requirements which are difficult to generalize, but a few key takeaways are apparent from observations made during the survey and from the ordination plots. The species exhibiting the greatest measured abundance were invariably able to take advantage of a variety of sites, though in general the habitat consisted of woodland borders or flyways in some form. Roadsides were oftentimes more attractive than more natural sites exhibiting less disturbance, as they make for ample flight corridors and are often lined with flowering Fabaceae and Asteraceae.

Fewer species than expected were found in open grassland settings, and in much smaller numbers. Open grasslands are harsher environments for butterflies than other site types due to greater sun exposure and higher probability of predation. The environment requires a high degree of specialization to thrive. As such, species exhibiting high abundance in grasslands such as the common buckeye were found almost nowhere else.

Some species appeared to be entirely habitat-agnostic and could be found with nearly equal chance at any part of the refuge. An interesting example of this was the giant swallowtail, which was infrequently seen but could be observed moving through flight corridors and open spaces regardless of plant community.

The moist soils units at Prisock Fields presented a unique assemblage of sedges and other wetland plants that could scarcely be found elsewhere on the refuge. Several species of skipper were only recorded from the moist soils units, most notably the dun skipper and the dion skipper. The latter was found with relative ease and abundance in the summer. The Ocola skipper was recorded from both moist soils transect sites but was more abundant at the Prisock Fields.
Disturbance

The refuge is actively managed throughout the year through fire, herbicide application, mowing and thinning. Due to the large number of sampling sites spread over a broad area, some effects from these disturbance events were observable in the surveys. Disturbance events which overturned the soil would often result in rapid sprouting of early colonizer plants such as *Jacquemontia tammifolia* and *Senna obtusifolia* along with other fabaceous species. Though these species tend to form monocultures early on, the rapid and simultaneous onset of blooms at these sites brought in large numbers of sulphur butterflies and skippers. In the short term, this provides apparent benefits for butterfly populations as it provides an abundant source of nutrition. The long-term effects are less certain, though it is likely that disturbance over large areas contributes to minor declines in overall diversity.

At times the management practices resulted in negative effects on butterfly populations which were readily apparent. An herbicide application at a pine site in late 2018 wiped out the herbaceous understory and resulted in a noticeable drop in butterfly abundance. Other disturbance events such as mowing and controlled burns resulted in only temporary drops in abundance.

Takeaways from vegetation analysis

The results of the principal component analysis indicate that vegetation community structure is largely consistent within the site classes used to group sampled sites. As such, we can have greater confidence in conclusions drawn from comparisons among plant communities.

The most important traits distinguishing understory plant communities of different site classes on the refuge are the height and percent coverage of groundcover in the understory. For example, bottomland hardwood forest understories are characterized by extremely sparse
groundcover, frequently 10% or lower as well as relatively low plant heights of around 20 cm when present. Elements such as canopy cover and plant morphospecies richness turned out to be relatively less important to understory community structure than initially expected. These two metrics are therefore not necessarily indicative for any particular plant community and cannot be used to distinguish them on their own.

Factors driving butterfly diversity at Noxubee

Field observations and subsequent analysis suggest that a strong correlation exists between butterfly species richness and plant morphospecies richness on the large scale. However, on smaller scales such as within a single site class, there are apparently many confounding variables. It is improbable that morphospecies richness is the only driver of butterfly diversity on the refuge, and it is likely that significant contributions are made by factors which were not controllable using this study design. Within pine stands in particular, there appear to be many competing factors driving butterfly presence. Such potential factors include the overall moisture regime within the stand as well as the stand’s size and age. Further research specific to pine stands would be necessary to separate these factors and determine their relative influence on butterfly community structure.

Based on the available data and observed patterns of diversity and abundance, I am led to the conclusion that any future management for butterflies on the refuge should focus on the following:

• Encouraging growth of diverse prairie specialist herbs and native grasses in remnant Black Belt soils
• Maintaining areas of weedy forbs along field edges and roadsides
• Allowing proliferation of sedges, grasses and other forbs over larger areas within moist soil impoundments for multiple consecutive years

• Maintaining a diverse and vigorous herbaceous understory in pine stands resembling those found within well-developed RCW clusters

Conclusions

This study lends further weight to the idea that butterflies as a group are acceptable for use as an indicator taxon due to their strong association with plant community diversity. It was able to answer several questions about the butterfly fauna of the refuge, as well as raise new questions that may provide the basis for further research. In my assessment, the most important of these is how abundance and diversity at the refuge compare to other areas of the state. Is species richness greater at Noxubee or does the refuge only host a different composition than the surrounding region?

Secondary to this are other questions: Why was the observed skipper diversity at Noxubee lower than expected? Is it due to an observational bias or does it reflect a broader pattern? What are the long-term effects of disturbance on butterfly diversity and how do they vary based on disturbance type? Finally, how might we expect climate change to alter the communities and relative abundance of butterflies in the region? It is my expectation that the results of this survey will lay the groundwork for answering these questions and others like them as the refuge continues to pursue its goals of conserving some of our most valuable and threatened resources.
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Figure A.1  **Open Field 1**  Starting coordinates: 33.2861°, -88.7577°

Moderately hilly open field at the Morgan Hill prairie restoration area. Transect crosses a gravel trail twice as it runs southward. Higher areas are dominated by grasses and lower areas between the hills feature sedges and intermittent patches of sumac. The site was burned in spring 2019.

Figure A.2  **Open Field 2**  Starting coordinates: 33.2333°, -88.8468°

Flat open field along Section Line Road dominated by tall grasses with occasional solitary pine trees halfway through the stand. Pine stands bordered the field on all sides. The site was burned in spring 2018 and mowed in fall 2018.
Figure A.3  **Field Edge 1**  Starting coordinates: 33.2482°, -88.7721°

Wooded border at the southern end of the Morgan Hill prairie restoration area. Densely wooded edge comprises pines, junipers and hardwoods such as sweetgum.

Figure A.4  **Field Edge 2**  Starting coordinates: 33.2333°, -88.8484°

Triplett’s Pasture Road, an unpaved road running along the western edge of Open Field 2. West margin of road borders sparse pine forest with understory vegetation encroaching onto the road.
Figure A.5  **Field Edge 3**  Starting coordinates: 33.3063°, -88.8956°

Narrow footpath following densely wooded border of a small field along Keaton Tower Road. Changes in direction along the curved path produce alternating stretches of sun exposure and shade. Some of the shaded areas remain moist for most of the year. The adjacent field and some of the shading vegetation along the transect were mowed in fall of 2018.

Figure A.6  **Pine 1**  Starting coordinates: 33.2730°, -88.8025°

Flat site along Bluff Lake Road dominated by mature loblolly with oak and sweetgum mixed in. Few understory trees, but abundant grasses and herbaceous plants. Site is moist for the tree composition with intermittent standing water. First half of the site is noticeably dense with more hardwoods. Latter half is sparser with more understory grasses and mostly pine overstory.
Figure A.7  Pine 2  Starting coordinates: 33.2747°, -88.7925°

Pine savanna with mixed hardwood understory at Woodpecker Trail. First half with mature/overmature loblolly managed for RCW. After crossing a road, the latter half presents with a stronger hardwood component and a downhill slope abutting a cypress slew. Mixed herbaceous plants, American beautyberry and sweetgum regeneration form an occasionally thick brush layer.

Figure A.8  Pine 3  Starting coordinates: 33.2325°, -88.8452°

Flat, dense pine forest along Section Line Road with many mature trees. Understory can be dense with brambles, greenbriar, sparse oak and hickory saplings. Midstory with occasional oak, hickory, sweetgum and Prunus spp. Some minor dips are present which are very moist or with standing water in winter and spring.
Figure A.9  **Pine 4**  Starting coordinates: 33.2338°, -88.8505°

Very gently sloping pine forest along Section Line Road, just west of Triplett’s Pasture Road. Understory alternates between dense bramble with hickory and more open areas with forbs and grasses. An herbicide application in fall 2018 wiped out the understory and vegetation was sparse in spring 2019.

Figure A.10  **Pine 5**  Starting coordinates: 33.3042°, -88.8876°

Moderately hilly mixed pine forest along Keaton Tower Road with very dense understory. Alternating stretches of deep shade and open raised areas choked with oak regeneration and Elliot’s huckleberry.
Figure A.11  Pine 6  Starting coordinates: 33.2207°, -88.7657°

A mostly gently sloping pine site with a dense undergrowth of brambles, sweetgum and sumac. Other small bushy plant species mixed in. A pond and old house site add diversity to the species present, namely buttonbush, juniper and Osage orange.

Figure A.12  Pine 7  Starting coordinates: 33.2141°, -88.8272°

Barely sloping mesic pine forest with a grass/forb-dominant understory. Occasional oak, hickory in overstory, but no midstory. Understory becomes dense with forbs, brush in spring and summer.
Figure A.13  **Pine 8**  Starting coordinates: 33.3021°, -88.8843°

Intermittently sloping mixed pine forest along Keaton Tower Road with crowded overstory and shaded understory. Understory comprises sweetgum regeneration with intermittent dense patches of brambles and muscadine vines.

Figure A.14  **Pine 9**  Starting coordinates: 33.2326°, -88.8729°

Gently sloping open pine savanna at the west end of Section Line Road with sometimes thick, brushy understory. Otherwise very open with grasses and forbs dominating. Occasional oak saplings present along with sweetgum and groundseltree.
Figure A.15  **Bottomland Hardwood 1**    Starting coordinates: 33.2861°, -88.7577°

Flat, deeply shaded bottomland site near the east end of River Road, with very little herbaceous understory. Mild seasonal flooding in winter leaves the soil continuously moist. Trees fall frequently and form obstructions along the transect while altering the canopy structure.

Figure A.16  **Bottomland Hardwood 2**    Starting coordinates: 33.2512°, -88.8301°

Mostly flat creekside bottomland site just south of Loakfoma Creek along Dummy Line Road. Understory is occasionally marked with canebrakes but is otherwise sparsely vegetated. Midstory is denser and composed of younger hardwoods and small standing deadwood.
Figure A.17  **Bottomland Hardwood 3**  Starting coordinates: 33.2954°, -88.8096°

Flat bottomland site within a greentree reservoir northwest of Bluff Lake. Large hardwoods dominate and very little understory vegetation is present, giving the site a very open feel. Occasional treefalls create obstacles along the transect and open up the canopy. Such lit areas are taken advantage of by climbing greenbriar and muscadine vines. When understory vegetation is present it typically comprises lizard’s tail, pawpaw and a few shade-tolerant grasses.

Figure A.18  **Moist Soils 1**  Starting coordinates: 33.2958°, -88.8089°

Moist soil impoundment northwest of Bluff Lake, across the dam from Bottomland Hardwood 3. Seasonal flooding submerges the site in feet of water over the winter. Vegetation is predominantly medium to tall grasses with intermittent baldcypress saplings. The site is bordered on nearly all sides by willows.
Figure A.19  **Moist Soils 2**  Starting coordinates: 33.2711°, -88.8618°

Large moist soil impoundment at Prisock Fields off west Bluff Lake Road. This site also floods during the winter season. Sedges, willow saplings and forbs were abundant during the 2018 field season. During the 2019 field season, the site remained flooded for the year and was not sampled.

Figure A.20  **Upland Hardwood 1**  Starting coordinates: 33.2508°, -88.7544°

A mesic upland hardwood site near White’s Pond with a mix of understory hardwoods and a few scattered softwoods at drier spots. Primarily oak and hickory overstory but with abundant maple, elm and sweetgum saplings and young trees. Site periodically retains water from rainstorms. Most trees present are capable of surviving some flooding.
Figure A.21  **Upland Hardwood 2**  Starting coordinates: 33.2346°, -88.8057°

Flat site dominated by mostly hardwoods, namely oak and hickory with a smattering of other genera. During rainy portions of the year, the soil remains very moist with some mild localized flooding near the margins of the stand. The forest floor is relatively bare, with little understory herbaceous vegetation. Many dead hickory and sweetgum saplings populate the understory.

Figure A.22  **Upland Hardwood 3**  Starting coordinates: 33.2213°, -88.9131°

Strongly sloping upland site off Bevil Hill Road dominated by oaks (mostly white), hickory and pine. Junipers, dogwood, maples and Elliot’s huckleberry mix in understory. Moist for an upland site with many small seeps.
APPENDIX B

SPECIES PROFILES
The following accounts summarize all the information gathered on each species recorded from the refuge. Host information is derived from (Glassberg, 1999) as well as (Opler & Malikul, 1998) and supplemented with field observations where applicable. All measurements are given in centimeters.

**Family Papilionidae (Latreille)**

![Battus philenor (L.) - Pipevine swallowtail](image)

**Figure B.1 Battus philenor (L.) - Pipevine swallowtail**

Abundant on the refuge, especially in open areas near woods or water bodies. Also abundant within woodlands but uncommon in hardwood stands. Observed flying from March through August. Hosts are *Aristolochia* spp. (pipevines). An active and abundant species, one of the most readily observed in spring and early summer. Its host is difficult to find but must be abundant on the refuge to account for such a large swallowtail population.
A somewhat restrictive species, the zebra swallowtail is most consistently found in moist woodland settings where it flies frantically between trees and along open corridors. Observed flying from March into June. Host is *Asimina triloba* (pawpaw).

The black swallowtail was not frequently observed, but appears to prefer open sites and flight corridors near wet areas. It is noticeably smaller and more agile than other “black” swallowtails in the region. It was recorded sporadically from March into September. It hosts on Apiaceae and Rutaceae.
Figure B.4  *Papilio troilus* (L.) - Spicebush swallowtail

The spicebush swallowtail is infrequently observed, though some individuals may be confused with other “black” swallowtails from a distance. It is relatively large and was most frequently observed flying in the midstory or canopy along wooded flight corridors and field edges. This survey recorded it from May into August. Hosts on *Lindera* spp. (spicebush), *Sassafras* and *Persea borbonia* (red bay).

Figure B.5  *Papilio cresphontes* (Cramer) - Giant swallowtail

A somewhat rare species on the refuge, the giant swallowtail is a large and striking butterfly. It was rarely observed landing or feeding, instead providing only short windows of observation as it passed through an area. It uses flight corridors and open spaces while searching for its hostplants, which are locally very sparse. It hosts on *Ptelea trifoliata* (hoptree), *Poncirus trifoliata* (trifoliate orange) and *Zanthoxylum clava-herculis* (Hercules’ club). Observations were made in April, July and August.
Figure B.6  *Papilio glaucus* (L.) - Eastern yellow swallowtail

Also known as the tiger swallowtail, this large butterfly is highly charismatic and comes in two color morphs. The more common of the two is the standard yellow, but some females are near black with blues and yellows like other “black” swallowtails. However they will still exhibit the same tiger-stripe pattern on the wing undersides. This species is not particularly rare to see, but never seems to be abundant. Like other large swallowtails it rests infrequently and makes use of wooded flight corridors, field edges and open spaces. Observed flying throughout the season, as well as on warm days in late winter. Hosts are *Prunus serotina* (black cherry) and *Liriodendron tulipifera* (tulip-poplar).
Family Pieridae (Swainson)

Figure B.7  *Anthocharis midea* (Hübner) - Falcate orangetip

The falcate orangetip butterfly is perhaps the most distinct harbinger of spring at the refuge. In early March, they emerge in abundance among bottomland forests and along waterways. They exhibit strong sexual dimorphism, with males exhibiting orange wingtips and females presenting in nearly all white. Due to their slow, meandering flight and bright coloration, they can be visible across long distances. They typically only fly until mid-April and disappear for the rest of the year. Hosts are cited as being *Arabis* (rock cress) and *Barbarea* (wintercress). On the refuge this species is strongly associated with *Cardamine bulbosa*, an early-blooming white-flowered mustard.

Figure B.8  *Eurema lisa* (Boisduval & LeConte) - Little yellow

The little yellow is a common and abundant butterfly, particularly in the fall. It tends to fly close to the ground along roadsides and field edges, as well as in sparse pine stands. This species migrates northward from coastal regions annually and becomes noticeable at the refuge from July until the first frost, sometimes exhibiting large local population booms. It hosts on *Chamaecrista* (partridge pea) along with various other Fabaceae.
Figure B.9  *Eurema daira* (Godart) - Barred yellow

This species was only observed twice during the survey, both times in October, flying low to the ground in pine forest. Like many sulphurs, it is a migratory species which is extirpated from the region by frost every year. As such it is never common on the refuge, even though its host is abundant in developed pine forests. Its preferred hostplant is *Stylosanthes* (pencilflower).

Figure B.10  *Eurema nicippe* (Cramer) - Sleepy orange

This medium-sized, deep orange butterfly is a common species which can be highly abundant locally. It tends to prefer field edges and open areas where Fabaceae grow in abundance. The moist soil units at Prisock Fields experienced a large flush of this species after a field was turned over and subsequently taken over by its hostplant, *Senna obtusifolia* (sicklepod). Other hosts include other *Senna* spp. as well as *Cassia* and other Fabaceae.
The southern dogface was only observed on three occasions during the survey. Once was along River Road and was likely a chance observation. The other two were along a field edge and in a sparse pine savanna. This species is strongly associated with blackbelt prairie remnants in this area of the state. It hosts on *Dalea* spp. as well as other Fabaceae. It appears to be most readily observed in July and August but was also observed in March.

The clouded sulphur was observed only once in March along a road through mesic hardwood forest, near White’s Pond. It is known to be an early spring species but never appears to be common when observed. Its likely hosts are among the Fabaceae.
Figure B.13  *Phoebis sennae* (L.) - Cloudless sulphur

Both common and abundant, the cloudless sulphur could be considered one of the “staple species” of the Noxubee refuge. It is found in multiple habitats, most prominently along field edges, roadsides, open grasslands and pine forest. At times it can exhibit extreme local abundance, especially following soil disturbance events after which monocultures of fabaceous plants take hold. It has been observed from March to October but is much more readily observed from late summer into fall. It hosts on *Cassia, Senna* and likely other Fabaceae.
Family Lycaenidae (Leach)

Figure B.14  *Feniseca tarquinius* (Fabricius) - Harvester

The harvester butterfly is well known as the only carnivorous butterfly species in North America. It was observed only twice on the refuge, both times along the same creek embankment at River Road. (Mather & Mather, 1958) gives a flight period of March through July for Mississippi. I observed it once each in March and July. It is likely that the harvester is more common than it appears but is unlikely to be encountered due to its unique life history. Caterpillars feed on Eriosomatinae (woolly aphids), which commonly host on alders or beech.

Figure B.15  *Calycopis cecrops* (Fabricius) - Red-banded hairstreak

The red-banded hairstreak is the region’s most abundant and widespread Lycaenid, flying low to the ground along roadsides, field edges, pine forest and (less preferentially) hardwood-dominant stands. It can be observed at varying abundances from March through October, with at least one apparent period of high abundance in early April. The caterpillars host in fallen leaves of *Rhus* (sumac), *Myrica cerifera* (wax myrtle), and *Quercus* spp. (oaks).
Figure B.16  *Satyrium calanus* (Hübner) - Banded hairstreak

The banded hairstreak was collected once on the refuge on May 31st 2018. It and other members of its genus are known for having restrictive habitat requirements and small windows of activity. The banded was collected in a mesic pine forest south of Section Line Road (along pine transect 7). It reportedly hosts on *Carya* (hickories) and *Quercus* (oaks).

Figure B.17  *Strymon melinus* (Hübner) - Grey hairstreak

Large for a hairstreak, and very plainly bright grey with no other colors save for a distinct orange spot on the underside of the wing. The grey hairstreak is a curiously uncommon species on the refuge. It was most frequently associated with densely brushy areas in the open as well as field/forest edges. It is cited as hosting on a broad variety of plants from many families. It was observed from August into October.
The azures represent a confusing complex of species in the southeastern United States. Their habitat requirements, flight periods, and general appearance strongly overlap making it difficult to reliably distinguish them on the wing. As such, this survey treated them as a single entity. They are sometimes confused with the related eastern tailed-blue but are larger in size and tend to prefer more wooded situations. They seem particularly preferential of small forest clearings where they will fly four to six feet above the ground. They were observed from March into August. Their hosts are cited as the flowering portions of Cornus spp. (dogwood), Prunus serotina (black cherry) and other woody plants.

The eastern tailed-blue is a mainstay of unpaved roads during the warm season. It can be easily found from March through October in a multitude of habitats such as field edges, open grasslands, developed pine forests and areas of disturbance. It tends to fly very close to the ground unlike the similar azure butterflies. Their larvae feed on the flowers and young seeds of herbaceous legumes such as Vicia (vetch), Trifolium (clover), Lespedeza (bush clover), Medicago sativa (alfalfa) and Lathyrus (peavines). Another potential host is Medicago lupulina (black medic), which is abundant across the refuge in the habitats occupied by this species.
Family Nymphalidae (Rafinesque)

Figure B.20  *Asterocampa celtis* (Boisduval & LeConte) - Hackberry emperor

The hackberry emperor is unique among the refuge butterflies in that it is extremely abundant but was never tallied once during abundance surveys. This highly localized distribution owes to the species’ exclusive association with *Celtis* spp. (hackberry), its hosts. This species was observed flying from May into August, but was sighted infrequently. It is one of a few local butterfly species with little fear of humans, readily landing on an observer to drink from their sweat.

Figure B.21  *Anaea andria* (Scudder) - Goatweed leafwing

A moderately common butterfly, the goatweed leafwing is brilliantly colored with scarlet or orange above with drab patterning underneath resembling dead leaves. This contrast causes it to appear suddenly as it takes flight and then vanish when at rest. It alternates between making swift passes near an observer and maintaining a safe distance while resting. The goatweed leafwing prefers the edges of pine woods and adjacent flight corridors, where it claims territory and defends it from other individuals. Hosts are species in the genus *Croton* (hogwort). It was observed sporadically from March until October.
Perhaps the most well-known butterfly in North America, the monarch is moderately common on the refuge. It was typically observed in open fields both in uplands and near wetlands, as well as along unpaved roadsides. It is a migratory species, likely only using the refuge as a stop on the way to a more northerly destination. Many spring individuals were observed to be pale and worn after making the months-long journey from Mexico. Its hostplants are *Asclepias* spp. (milkweed), which are scattered around the refuge. It was observed regularly at low abundances from March through August and again in October. No observations were made in September.

Vibrant, active and relatively large, the gulf fritillary is highly distinctive in the field. It is a migratory species which travels northward from the Gulf Coast annually. As a result it is most abundant from the end of summer through the fall, though it was observed at least once in March. It enjoys brushy areas in open sites as well as field edges and roadsides. Its host is *Passiflora incarnata* (passionvine).
Figure B.24  *Euptoieta claudia* (Cramer) - Variegated fritillary

Similar in lifestyle to the gulf fritillary, the variegated fritillary is much rarer. It also prefers open fields and field edges. This survey only recorded it on two occasions, both in October. It hosts on *Passiflora incarnata* (passionvine).

Figure B.25  *Libytheana carinenta* (Cramer) - American snout

The American snout is a somewhat uncommon species on the refuge. It was associated with hardwood forest edges and flyways but was sometimes observed in more open areas adjacent to grasslands. It is sporadic in occurrence, which is evident from it being recorded only during odd months in the survey. Its hosts are *Celtis* spp., where it is often found using the same space as hackberry emperors. Like the hackberry it is less afraid of humans and may land on an observer.
The red-spotted purple is a common, darkly-colored butterfly that may be confused with several dark swallowtail species from a distance. However, it lacks the tails entirely. It is another “staple species” of the refuge, having been recorded from every major habitat type on the refuge on dates from April through October. It sometimes exhibits high local abundance. It hosts on various trees, particularly *Prunus* (cherry/plum), *Populus* (poplar), and black oaks. The form which flies in Mississippi is subspecies *astyanax*, which is a variant of the white admiral.

A somewhat localized species, the viceroy prefers open spaces near bodies of water or moist soils. It is not commonly observed, but there are usually multiple individuals when it is observed. It is noticeably more abundant in the presence of its hosts, *Salix* spp. (willows). The survey recorded it in April and then again from July through October.
Figure B.28  *Phyciodes tharos* (Drury) - Pearl crescent

The most abundant and widespread butterfly on the refuge. Has been found in every major habitat type, but most prefers brushy woodland edges, roadsides and sparse pine woods. Can be found throughout the year from early spring to the end of the growing season. It hosts on various Asteraceae, with *Symphyotrichum* commonly preferred in the southeast.

Figure B.29  *Junonia coenia* (Hübner) - Common buckeye

The common buckeye is a common presence on the refuge, being found in great abundance in open fields and sunny areas. It was rarely found in any other habitat. It flies throughout the season from March through October. Huge flushes of abundance were observed in grasslands in fall. Its hosts are cited as *Linaria* (toadflax), *Agalinis* (false foxglove), *Plantago* (plantain) and *Ruellia* (wild petunia).
Figure B.30  *Chlosyne nycteis* (Doubleday) - Silvery checkerspot

The silvery checkerspot is infrequently observed unlike its smaller cousin, the pearl crescent. When it is present there are typically multiple individuals flying. It was associated with pine woods with rich understories and the edges thereof. It was observed primarily in summer, from May to September. It hosts on *Verbesina* spp. (wingstem), *Helianthus* (sunflower) and *Rudbeckia* (black-eyed Susan) among other Asteraceae.

Figure B.31  *Polygonia interrogationis* (Fabricius) - Question mark

The question mark is a common butterfly, being typically observed along the edges of hardwood forests and sunning on roads both paved and unpaved. It is probably much more abundant than this survey was able to account for, as it appears to prefer the canopies of deciduous trees over flying at ground level. Observations were made in February and March and again from May through October. I observed at least one large flush in abundance at the end of October, wherein the butterflies descended from the trees in large numbers across the whole of the refuge. Its hosts are cited as *Ulmus* (elm), *Celtis* (hackberry), *Urtica* (nettle) and *Boehmeria* (false nettle).
The eastern comma is likely much less common than its congener, the question mark. Of all the *Polygonia* collected, the comma was never among them. However, there were confirmed observations of them in the field. It is known to share a similar life history to other *Polygonia* species and prefers the same habitats of deciduous forests and woodland edges. Its hosts are cited as *Ulmus* (elm), *Celtis* (hackberry), *Urtica* (nettle) and *Boehmeria* (false nettle).

The American lady was observed very infrequently in 2018 but was much more common in 2019. It is not a highly abundant species, but multiple individuals are usually observed when it is present. It appears to prefer brushy woodland borders at the edges of pine forest as well as brushy areas along roadsides. It was observed only in April and July in 2018. In 2019 it was recorded from March into June and again in October. Its period of greatest abundance appears to be late spring. It hosts on *Gnaphalium* spp. (cudweeds).
The red admiral is a striking butterfly which is recognizable at a distance. It is somewhat uncommon but has a consistent preference for the edges of moist or bottomland forest and adjacent roadsides. It hosts on various species of Urticaceae (nettles), of which *Boehmeria cylindrica* appears to be the most common on the refuge. It was observed from March through May and again in July and August.

Larger than most other Satyrinae, the pearly-eyes are a distinct group, though they are almost never seen outside of bottomland forest. Due to their nearly identical appearances, behavior and habitat preference, this survey treated the genus as a single entity. Multiple individuals can usually be observed where their hosts, *Arundinaria* spp. (canes) are present. I observed individuals flying from May into October. When collections were made, southern pearly-eyes were obtained at a higher rate than other species.
Figure B.36  *Enodia creola* (Skinner) - Creole pearly-eye

The creole pearly-eye exhibits strong overlap with other *Enodia* spp. in regards to habitat and host preference. It prefers bottomland hardwood forests, and canebrakes in particular. It hosts on *Arundinaria* spp. (canes). The creole pearly-eye was collected at a much lower frequency than the southern pearly-eye.

Figure B.37  *Satyrodes appalachia* (R. L. Chermock) - Appalachian brown

The Appalachian brown is a delicate-looking species of satyr, found predominantly in bottomland hardwood forest but occasionally in moist pine woods. It is not commonly observed, but is also not exceedingly rare. Sites exhibiting the highest abundance of this species appear to be ones near to creeks and river bottoms. It was observed flying from April to September. It hosts on various species of Cyperaceae (sedges).
Figure B.38  *Hermeuptychia sosybius* (Fabricius) - Carolina satyr

One of a handful of extremely abundant and widespread butterflies on the refuge, the Carolina satyr is not as restrictive as other satyrines. It can be found anywhere with abundant shade, from bottomland hardwood forests to typical pine woods and dense field edges. It tends to fly low to the ground in these settings, going for short distances before coming to rest on vegetation. Observations were made from April into October, with several flushes in abundance throughout the season. Its hosts are listed as *Axonopus* (carpetgrass) and *Eremochloa ophiuroides* (centipedegrass), though it likely hosts on many species of grasses.

Figure B.39  *Megisto cymela* (Cramer) - Little wood-satyr

The little wood-satyr is a relatively uncommon satyr on the refuge. It appears to prefer dense, shady woods and the edges thereof. It was never abundant when found. Observations were made from April into June, then in August and September. It hosts on various species of grasses.
The gemmed satyr is found about as frequently as most satyr species on the refuge. Not common, but not exceedingly rare either. It appears most abundant near flowing streams and along creeksides. It was observed from March through July and then from September into October. Its host is cited as *Cynodon dactylon* (bermudagrass) but it likely makes use of various grass species.

The common wood-nymph was observed only once on the refuge, along a field edge in September 2018. It is a prairie specialist in the region, preferring edges and open sites near its host, *Tridens flavus* (purpletop tridens). It has been observed with some reliability just outside the refuge along chalky outcrops and prairie remnants, though it never appears abundant.
Family Hesperiidae (Latreille)

Figure B.42  *Achalarus lyciades* (Geyer) - Hoary edge

The hoary edge is a relatively uncommon skipper species with a similar appearance in flight to the silver-spotted skipper. This species, however, was more associated with denser and shadier habitat along woodland edges. Observations were made in May and July. It appeared particularly abundant in late July of 2019. Its hosts are *Desmodium* (ticktrefoil), *Lespedeza* (bush clover) and *Baptisia* (wild indigo).

Figure B.43  *Epargyreus clarus* (Cramer) - Silver-spotted skipper

The silver-spotted skipper can be commonly observed along open field/woodland borders among brushy vegetation. It is an active flier, appearing to search frantically along the outer edges of vegetation. It is much more abundant than the similar hoary edge and seems to prefer more open conditions. It was observed to fly from March until September. Its hosts are listed as *Robinia pseudoacacia* (black locust), *Wisteria* spp. and other Fabaceae.
Figure B.44  *Urbanus proteus* (L.) - Long-tailed skipper

The long-tailed skipper is a large, distinct, highly attractive skipper that can be found in low abundance along field edges and in open grassland. It heralds the end of summer at the refuge, flying from August until the first frost. Its hosts are cited as vining members of the Fabaceae.

Figure B.45  *Thorybes bathyllus* (J. E. Smith) - Southern cloudywing

In general, *Thorybes* (cloudywings) are highly similar in habitat preference, behavior and appearance in flight so they were treated as a single entity during abundance surveys. However, unlike other members of the genus, the southern cloudywing is often distinctly marked. Members of this genus were observed from March through October, though they appear to be most abundant in late spring through summer. They prefer field edges, brushy areas and sparse pine woodlands. Their hostplants are listed as *Desmodium* (ticktrefoil), *Lespedeza* (bush clover) and other Fabaceae.
Figure B.46  *Thorybes confusa* (Bell) - Confused cloudywing

The confused cloudywing is a difficult species to discern on the wing and exhibits strong overlap with other members of its genus. The majority of *Thorybes* collected turned out as this species. In general, *Thorybes* were observed from March through October along field edges, brushy areas and in sparse pine woods. Their hostplants are listed as *Desmodium* (ticktrefoil), *Lespedeza* (bush clover) and other Fabaceae.

Figure B.47  *Lerema accius* (J. E. Smith) - Clouded skipper

Both common and abundant, the clouded skipper is a mainstay of field edges and shady woods in late summer and fall. Its observed flight period spanned May through October, with strong abundance from August into October. It hosts on various grasses.
The whirlabout was only observed twice on the refuge, both times in open grassland settings. The first individual was observed in July of 2018 at Morgan Hill, the second in May of 2019 near Levee Road. It is likely more common than these observations suggest but is difficult to distinguish from other grass skippers in flight. Its hosts are listed as *Stenotaphrum secundatum* (St. Augustine grass) and *Cynodon dactylon* (bermudagrass), among other grasses.

Skippers in the genus *Erynnis* are a common sight on the refuge throughout spring and early summer. They are often not reliably identifiable in the field, requiring examination of the genitalia for a confident ID. For this reason, the survey treated them as a single entity. Of the species recorded on the refuge, *E. juvenalis* appeared to be the most commonly collected during the early months of the year. In late winter and early spring before the trees leaf out, *E. juvenalis* is one of the only active butterflies in woodlands. Along with the other duskywings, they generally fly low to the ground along field edges, brushy areas and unpaved roads. Their hosts are *Quercus* spp. (oaks), though they were repeatedly observed to show interest in the budding stems of *Carya* spp. (hickories).
Figure B.50  *Erynnis horatius* (Scudder & Burgess) - Horace’s duskywing

Horace’s duskywing is one of two species of *Erynnis* recorded from the refuge during the survey. As the genus was treated as a single entity during field surveying, the abundance of *E. horatius* relative to other species is not well-understood. Specimens were collected in summer and into early fall. Their host plants are *Quercus* spp. (oaks).

Figure B.51  *Pyrgus communis* (Grote) - Common checkered-skipper

This wide-ranging skipper was observed infrequently on the refuge. Whenever it was spotted however, there were always multiple individuals present, suggesting it is a highly localized species. It tends to prefer flying low to the ground in open grassy areas. Previous observation suggests it prefers lawn-like settings over natural areas. Its hosts are among the Malvaceae. On the refuge, it was observed to fly only in October.
Figure B.52  *Euphyes dion* (W. H. Edwards) - Dion skipper

The Dion skipper was only observed during a few collection events in June of 2018 at the Prisock Fields moist soil impoundment. When it was observed, however, it was somewhat abundant. Its hostplants are among the Cyperaceae (sedges), which appeared abundant and diverse at the Prisock Fields impoundments.

Figure B.53  *Wallengrenia egeremet* (Scudder) - Northern broken-dash

The northern broken-dash is only recorded from a couple of observation events in April, May and July. It hosts on various grasses, and was associated with overgrown open areas near woodland edges.
Figure B.54  *Amblyscirtes aesculapius* (Fabricius) - Lace-winged roadside skipper

This species was observed and collected only once in August along wooded trails near Douglas Bluff Road. Its hostplant is suspected to be *Arundinaria* (cane).

Figure B.55  *Ancyloxypha numitor* (Fabricius) - Least skipper

The least skipper was observed and collected twice, in April and in August. It hosts on grasses in open settings and was associated with moderately wetter areas.
This skipper was only observed twice on the refuge. It was associated with grassy open areas, often invaded with non-native grasses. Its hosts are cited as *Cynodon dactylon* (bermudagrass) and *Digitaria sanguinalis* (crabgrass), among other non-native grasses.

During late summer and into fall, there are flushes of small, tan to dark brown skippers with few discernible patterns on their wings. The swarthy skipper is the most likely candidate for the majority of these skippers. It was associated with field edges and brushy areas and flew low to the ground.
Figure B.58  *Pompeius verna* (W. H. Edwards) - Little glassywing

The little glassywing was observed once on the refuge from a collection in September of 2018. It was collected at the Morgan Hill prairie restoration site. It reportedly hosts on *Tridens flavus* (purpletop tridens).

Figure B.59  *Euphyes vestris* (Boisduval) - Dun skipper

The dun skipper was observed once at the Prisock Fields moist soil impoundments in August of 2018. It is known to be associated with wetlands and adjacent areas. Its hosts are reported as sedges.
The Ocola skipper was tallied a total of three times, all in October of 2018 along both moist soils transects. It is reported to host on various species of wetland-associated grasses.

**Likely Species**

Several Mississippi butterfly species that are likely to be on the refuge were not observed, either due to extremely low abundance or behaviors that make human observation of them rare. They are summarized here, without photographs or refuge-specific host information or flight periods.

*Atlides halesus* - Great purple hairstreak

The great purple hairstreak appears to be fairly uncommon everywhere it is observed. This is partially due to its association with *Phoradendron leucarpum* (American mistletoe). The hairstreak typically stays high in the canopy of oak trees where the mistletoe is present and is less likely to be observed near the ground.
Callophrys gryneus - Juniper hairstreak

The juniper or olive hairstreak specializes on Juniperus virginiana (eastern red cedar), which is common in the region but relegated to small patches on the refuge. Individuals have been spotted less than four miles north of Noxubee in a patch of red cedar no larger than some observed on the refuge.

Callophrys niphon - Eastern pine elfin

The eastern pine elfin is associated with the growing tips of pine trees and is therefore mostly found in the treetops or among young pine stands. It likely exists in abundance on the refuge but is difficult to observe nearer to the ground. Young pine stands were surveyed for the elfin during its flight period and a probable candidate was observed but unable to be confirmed.

Asterocampa clyton - Tawny emperor

The tawny emperor shares habitat with its congener, Asterocampa celtis (the hackberry emperor), but tends to be much less abundant. The hackberry emperor is abundant but highly localized on the refuge and it is likely that the tawny emperor is present at the same sites at a much smaller proportion.

Nymphalis antiopa - Mourning cloak

The mourning cloak is associated with Salix spp. (willows) where its caterpillars will feed in the hundreds. It was curiously absent from the refuge during the survey but given its habits and the abundance of willows in the area, it is likely present at Noxubee.

Vanessa cardui - Painted lady

The painted lady is associated with an extremely broad range of hosts but does not tolerate sub-freezing temperatures. It migrates northward from the gulf coast and Mexico annually. This trait likely contributes to its relative rarity in central Mississippi.
**Enodia anhedon** - Northern pearly-eye

The northern pearly-eye shares the same habitat and host requirements as the other Enodia species present on the refuge, and is probably detectable with more intensive sampling of canebrakes.

**Thorybes pylades** - Northern cloudywing

The northern cloudywing was not among the collected *Thorybes*, but due to its difficulty being distinguished from other members of its genus it may exist on the refuge at a lower abundance than could be picked up through sampling.

**Copaeodes minima** - Southern skipperling

The southern skipperling appears to be more strongly associated with disturbed or manicured grassy settings such as lawns. Though there are sites such as these on the refuge, they are a byproduct of human use and were not targeted with the same intensity as more natural and representative settings.

**Atalopedes campestris** - Sachem

The sachem is associated with anthropogenic grassy landscapes such as lawns and roadside borders in a similar manner to the southern skipperling. As such, it was not observed in the more representative, natural areas which comprised the majority of sampled localities.